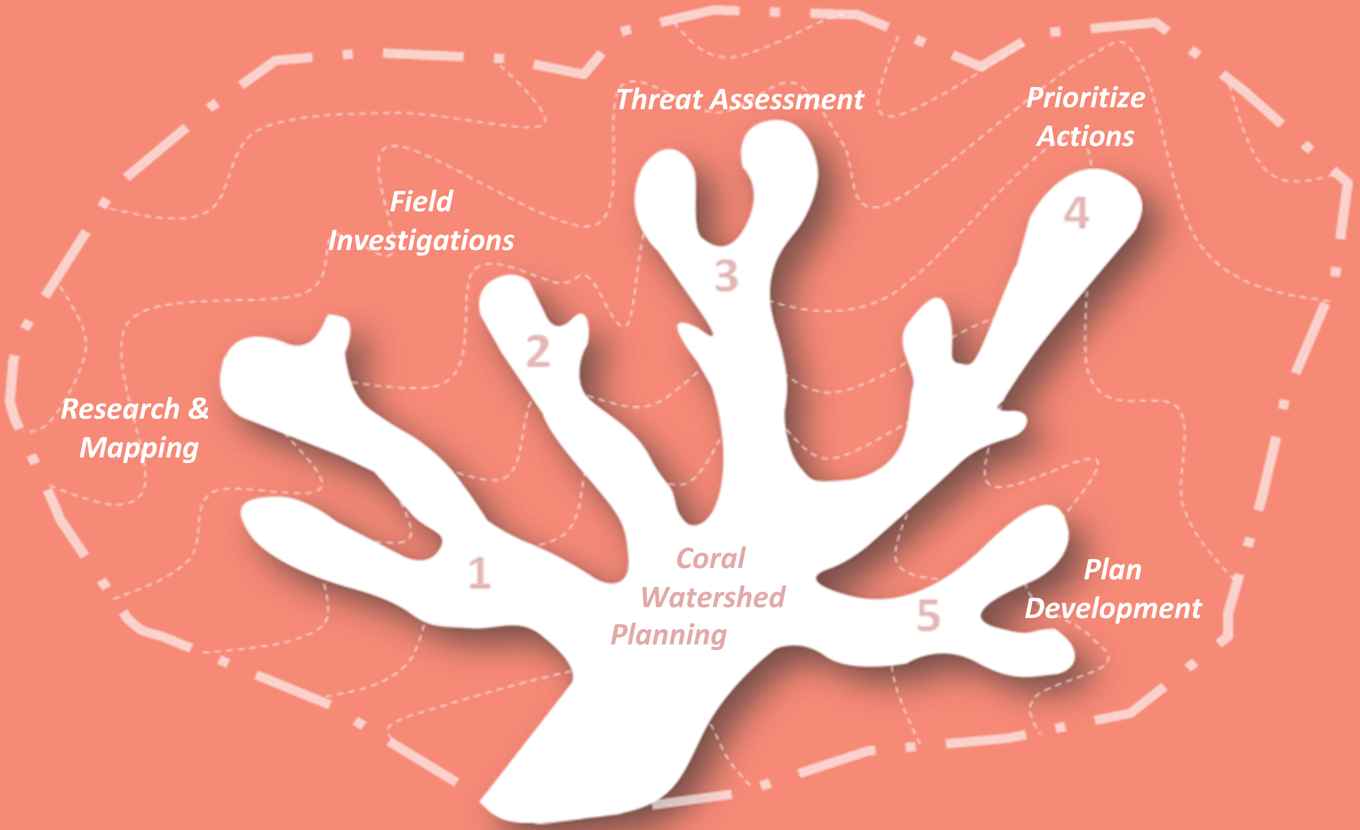
Coral Watershed Assessment Tool

Decision support for prioritizing threats and restoration actions



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Acronyms

ACOE	U.S. Army Corps of Engineers
BANCS	Bank Assessment for Nonpoint Source Consequences of Sediment
BMP	Best Management Practice
C-CAP	Coastal Change Analysis Program (NOAA)
CNMI	Commonwealth of the Northern Mariana Islands
DEM	Digital Elevation Model
EMC	Event Mean Concentration
EPA	U.S. Environmental Protection Agency
ESC	Erosion and Sediment Control
FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
HSG	Hydrologic Soil Group
IBI	Index of Biological Indicators
IC	Impervious Cover
I/E	Information/Education Program
IDDE	Illicit Discharge Detection and Elimination
LIDAR	Light Detection and Ranging (remote sensing method)
NASA	National Aeronautics and Space Administration
NCCOS	National Centers for Coastal Ocean Science (NOAA)
NCEI	National Centers for Environmental Information
NFWF	National Fish & Wildlife Foundation
NGOs	Non-Governmental Organizations
NOAA	National Oceanographic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
ORI	Outfall Reconnaissance Investigation
PS	Profile Sheet
RBP	Rapid Bioassessment Protocol
RSAT	Rapid Stream Assessment Technique
TMDL	Total Maximum Daily Load
TNC	The Nature Conservancy
NSPECT	Nonpoint Source Pollution and Erosion Comparison Tool
USCRTF	U.S. Coral Reef Task Force
USDA-NRCS	U.S. Department of Agriculture, Natural Resources Conservation Service
USGS	U.S. Geological Survey
WTM	Watershed Treatment Model

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Introduction

This tool was created to assist watershed managers to more effectively link watershed assessments and management planning with coral ecosystem restoration and conservation. Tropical watersheds are complex, as are the localized mechanisms connecting land-based stressors to the reef. For these watersheds, understanding existing conditions and the threats posed to corals by specific watershed activities is necessary to set management priorities and secure funding for future watershed interventions.

One of the key themes emerging from a survey of island watershed managers is the need for watershed planning guidance to prioritize threats, pollution sources, and management strategies. Given limitations on budgets and staff resources, it is important to know that funds and personnel are being used effectively, and that management efforts will lead to improvements in the watershed and on the reef.

This tool lays out a simple, <u>5-step flow chart</u> for conducting a watershed assessment (**Figure 1**), including data compilation and mapping, field assessments, prioritizing management options based on reef benefit, and establishing a monitoring program. This method can be as simple or complex as capacity and planning objectives dictate.

Where additional details are required, each step references a series of <u>profile sheets (PS)</u> that include detailed descriptions on how to accomplish various steps using simple or more sophisticated techniques (**Tables 1** and **2**).

Table 1. Watershed Assessment Levels

	*<u>Baseline Level</u>* Basic activities and standards needed to complete the process. Starting simple; using available off-the-shelf tools or resources
	*<u>Good Practice Level</u>* A bit more advanced to achieve a higher level of resource improvement. More customized tools, calculations, or assessments that provide a higher degree of analysis.
	*<u>Best Practice Level</u>* More sophisticated approach tied to specific outcomes that requires more inputs and/or technical expertise, but is more accurate regarding watershed impacts and reef and benefits.

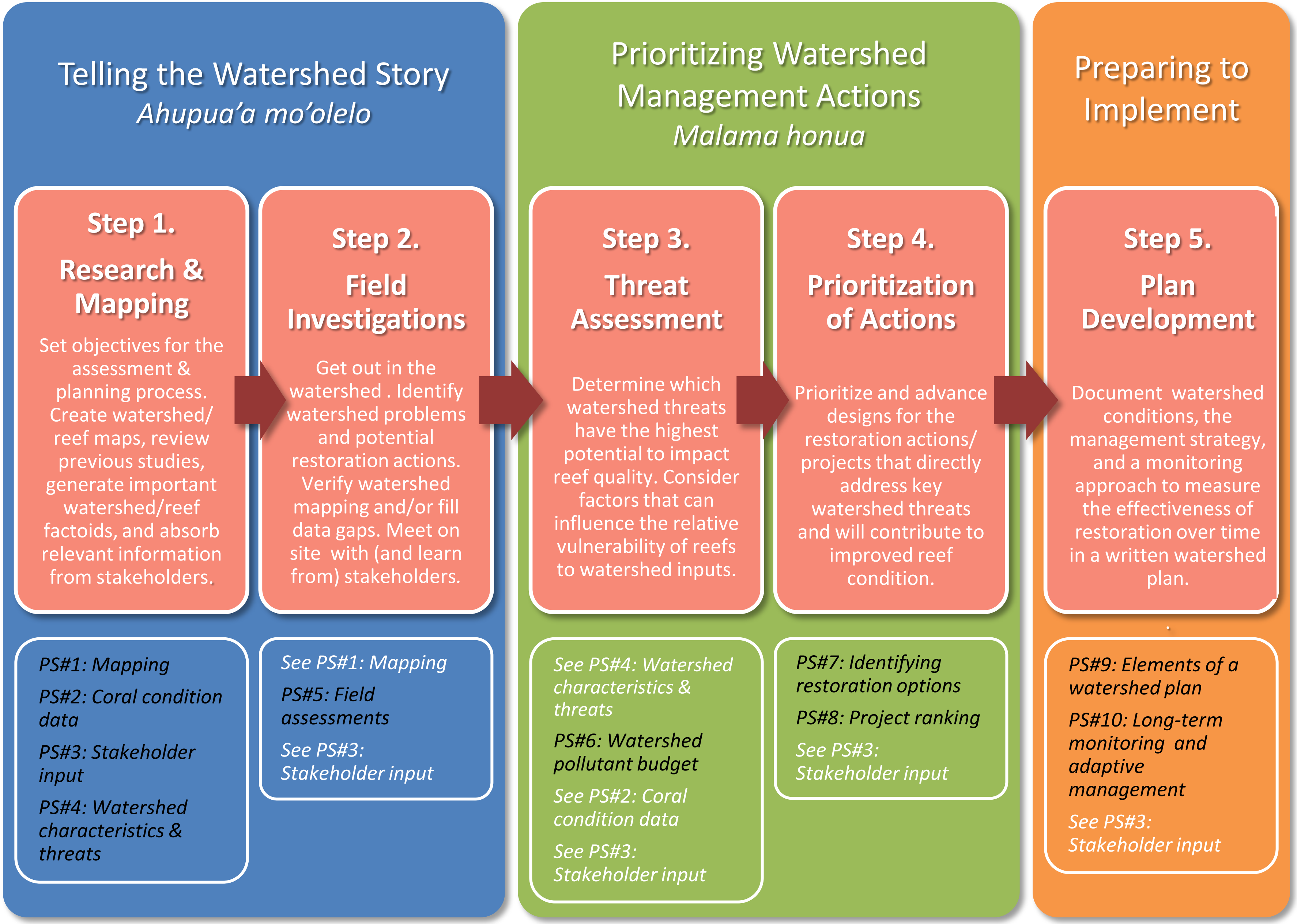
This tool is intended to provide a framework for managers, funders, and community groups to identify the types of information that need to be gathered and evaluated to develop an effective watershed plan. Instead of re-inventing the wheel, this tool references, where appropriate, existing guidance on coral indicators, assessment protocols, management techniques, and pollutant loading.

Systematic navigation of the flow chart will help users to prioritize actions for coral improvement and make informed management decisions for their watershed.

Objectives

NFWF's objective for developing this tool is to better inform funding decisions for watershed projects that are tied to coral improvement. NFWF hopes that this tool will help bring projects to the top of the list that have the best coral bang for the buck.

Figure 1. Coral Watershed Assessment Tool 5-Step Process



Telling the Watershed Story
Ahupua'a mo'olelo

Step 1.
Research & Mapping

Set objectives for the assessment & planning process. Create watershed/ reef maps, review previous studies, generate important watershed/reef factoids, and absorb relevant information from stakeholders.

PS#1: Mapping

PS#2: Coral condition data

PS#3: Stakeholder input

PS#4: Watershed characteristics & threats

Step 2.
Field Investigations

Get out in the watershed . Identify watershed problems and potential restoration actions. Verify watershed mapping and/or fill data gaps. Meet on site with (and learn from) stakeholders.

See PS#1: Mapping

PS#5: Field assessments

See PS#3: Stakeholder input

Prioritizing Watershed Management Actions
Malama honua

Step 3.
Threat Assessment

Determine which watershed threats have the highest potential to impact reef quality. Consider factors that can influence the relative vulnerability of reefs to watershed inputs.

See PS#4: Watershed characteristics & threats

PS#6: Watershed pollutant budget

See PS#2: Coral condition data

See PS#3: Stakeholder input

Step 4.
Prioritization of Actions

Prioritize and advance designs for the restoration actions/ projects that directly address key watershed threats and will contribute to improved reef condition.

PS#7: Identifying restoration options

PS#8: Project ranking

See PS#3: Stakeholder input

Preparing to Implement

Step 5.
Plan Development

Document watershed conditions, the management strategy, and a monitoring approach to measure the effectiveness of restoration over time in a written watershed plan.

PS#9: Elements of a watershed plan

PS#10: Long-term monitoring and adaptive management

See PS#3: Stakeholder input

Table 2. Profile Sheets Summary

PS#	Step	Description	Baseline Level	Good Practice	Best Practice
PS#1: Mapping	1,2	Watershed delineation tips and list of mapping layers needed	Google maps and a marker, rely on free online mapping products	Desktop GIS with some data layers available (land use, impervious cover); capacity to create shapefiles but limited analyses	GIS with extensive mapping data already available (LIDAR, utilities, etc); capacity to run analyses
PS#2: Coral condition data	1,3,5	Level of monitoring information needed and how to plan for data collection	A few available indicators that can address whether there is a water quality problem at the site of a coral ecosystem	A more complete set of indicators to help determine if water quality problems are affecting coral reef ecosystem health	Thresholds for management actions using a more robust set of indicators to analyze sources and the effects of management actions
PS#3: Stakeholder input	all	Suggestions for developing a plan to engage watershed stakeholders	Agency-driven process that includes public meetings at key times to inform and solicit feedback from stakeholders	Cast a wider stakeholder net; provide more opportunities for active participation to make group decisions on watershed priorities	Includes participation in each step of watershed planning process by broad set of stakeholders; steering committee guides technical approach
PS#4: Watershed characteristics & threats	1, 3	List of watershed factoids and stats that need to be generated; How to identify priority threats	Qualitative, simple analysis using High, Medium, Low, based on inputs from your map and some field work	Use data to develop a more quantitative system that relies on some data and professional judgment.	Watershed modeling, likely tied to GIS with monitoring and calibration. Refer to PS #6
PS#5: Field assessments	2	What to look for in the field and how to recognize opportunities	Focus on key areas; windshield survey	Use or adapt existing field protocols; more comprehensive field assessment of pollution sources	Enhanced field crew training and level of expertise

PS#	Step	Description	Baseline Level	Good Practice	Best Practice
PS#6: Watershed pollutant budget	3	Methods for quantifying pollutant loads	Simple Method that uses impervious cover as an indicator of watershed health	More quantitative approach using simple spreadsheet tools to identify pollutant concentrations, loads, and yields	More sophisticated, calibrated models to better simulate pollutant loading and threats.
PS#7: Identifying restoration options	4	Homing in on feasible restoration options, linking them to priority threats, and developing various levels of design	Confer with experts to identify tailored "tool box" of structural + non-structural options; confirm feasibility of practices at each site; develop 10% design concept for all projects and more advanced design for highest priorities	More technical assistance needed to develop site specific designs; 30% concept for candidate projects or high priority; simple quantitative methods to assess benefits and planning-level costs	High diversity of structural and non-structural practices; more developed design plans (up to 70% design) for permit/shovel ready; performance monitoring design component included
PS#8: Project ranking	4	Method for conducting and documenting project ranking	Select a handful of screening factors; use a mostly qualitative system.	Add some quantitative screening factors; calculate key benefits of candidate projects	Utilize additional screening factors and more rigorous quantification of costs and benefits
PS#9: Elements of watershed plan	5	Compiling all you've done so far into a simple or more detailed watershed plan	Packaging of completed products to meet basic EPA watershed planning criteria	More comprehensive, technical plan that documents advanced modeling efforts and monitoring protocols	Provides more detail on priority project design/development and early implementation
PS#10: Long-term monitoring & adaptive management	5	Making adjustments to coral indicators; add watershed indicators and performance monitoring	Select a few programmatic indicators to gage successful implementation of the plan	Add additional indicators, including collecting data from the watershed	Use a more robust set of indicators to analyze trends over time

To this end, the tool was designed to meet the following objectives:

- Develop a more island-friendly and less "intimidating" method for watershed assessment and planning;
- Better link priority management recommendations with coral improvement;
- Target watershed managers in islands with varying levels of technical and program capacity;
- Allow for user to conduct more sophisticated analyses where applicable; and

Tool Context

It should come as no surprise that only implementing one or two watershed restoration projects will likely be insufficient to counteract centuries of human alterations to the natural hydrology of watersheds. There are thousands of independent land use decisions made each year (if not each day) that contribute collectively to the long-term decline in water quality, habitat, and the health of coral reefs and other aquatic resources. Restoration takes time, especially if new land use decisions continue to compound existing problems.

Watershed dynamics are complex, characterized by an interplay of climate, geology, topography, land use, and other factors. Selecting AND implementing the most appropriate management or restoration strategies can be challenging. On the other hand, it is important to acknowledge that the sophistication of the watershed planning process should be dictated by existing watershed knowledge and available resources allocated to the process. Both small and large steps will lead to greater understanding and action.

> ***Restoration takes time, especially if new land use decisions continue to compound existing problems.***

Coral Reef and Tropical Watersheds

It's fair to say most, if not all, coral reefs near inhabited US watersheds have suffered from watershed impacts. Richmond et al., (2007) surmises that these stressors, when combined with episodes of natural reef disturbance, may actually prevent cycles of coral recovery that would take place in the absence of watershed inputs. The vulnerability of coral ecosystems to land based sources of pollution also depends on several factors related to the coral itself, the currents within the lagoon, and concentrations of key pollutants.

A number of researchers have studied these systems, and a quick overview of selected findings may be instructive. Note that this does not represent an exhaustive literature search, but certain studies are highlighted to illustrate particular watershed concepts.

Castillo (2010) studied a watershed in northern Venezuela, and found that slope, the amount of runoff, and agricultural land uses were the main predictors of nitrate and phosphorus across the watershed. This

While watershed inputs are critical, actual impacts will also be associated with dynamics in the marine environment.

type of research indicates that **climate, land features, and land uses** play significant roles in pollutants in a watershed.

Ramos-Scharron and MacDonald (2007) built a GIS-based model for dry catchments in St. John, USVI. Extensive monitoring led to several conclusions, including that unpaved roads can be a dominant source of sediment, increasing watershed sediment loads by 3 to 9 times compared to undisturbed conditions. Another study by the chief author also found that some relatively simple erosion control strategies for unpaved roads reduced sediment yields by 70% (Ramos-Scharron, 2012). These studies are instructive in understanding that **land and infrastructure management** can affect pollutant loads to downstream lagoons, and remedial efforts promise to be effective if **targeted to priority threats**. Presumably, the same could be true for threats associated with recreational, agricultural, wastewater, or other watershed uses, although the cost and sophistication of remedial or restoration options will vary dramatically.

Ragosta et al (2010) studies a variety of factors related to bacteria (*Enterococcus*) in a watershed on the north side of the Hawaiian island of Kauai. One the main factors identified was the extent of riparian cover, with each 1% drop in riparian cover associated with a 4.6-fold increase in *Enterococcus* levels in stream water. Reduced salinity was also associated with increased bacteria. Research such as this indicates that watersheds can have certain **resiliency factors** that, when adequately protected, can provide a level of natural protection, but, when disturbed, can increase threats in a disproportional manner. Other resiliency factors in a watershed may be wetlands, vegetation on steep slopes, and other watershed features or in-the-water lagoon conditions.

Brooks, Devine, and colleagues (2007) studied the evolution of sediment in Coral Bay on St. John, and other embayments on St. Croix and St. Thomas. They identified a dramatic increase in sediment since the 1950s, likely associated with land development and erodibility factors of the landscape. Interestingly, the two main factors that led to human-induced sediment in Coral Bay were: (1) proximity to heavily-developed areas, and (2) the presence of sheltered or low-energy conditions in the Bay. As would be expected, higher-energy lagoon environments will not have as much sediment accumulation. This means that, while watershed inputs are critical, actual impacts will also be associated with **dynamics in the marine environment**.

Micronesian reef studies in Guam, Pohnpei, and Palau by Richmond, Hamnett, Wolanski, and others led to some striking conclusions related to reefs and watersheds:

1. Watershed discharges have a substantial effect on coral community composition, structure, and function with effects observed in at least **six chemically-mediated stages** of coral spawning, development, settlement/ recruitment, and zooxanthellae acquisition (Downs et al., 2005).
2. Statistically significant declines in **coral species diversity and coverage** were

observed over time and in closer proximity to watershed discharge points (Rongo, 2005).

3. Re-suspension due to wave action accounted for 50% of suspended sediment. Negative correlations were found between **herbivorous fish** abundance and turbidity, which adds to the problem.
4. Watershed sediment contributes to formation of “**marine snow**”—bacterial and microfaunal aggregations on sediment particles (Wolanski, 2003).
5. **Mangroves** (even at relatively small percentages of watershed area) can trap up to 30% of riverine sediment (Victor et al, 2004).
6. Sediment yields from a cleared and farmed watershed were 10-19% higher compared to a more pristine watershed (Victor et al, 2004). Annual riverine **sediment input** can exceed in-lagoon sediment flushing by a factor of two. In some cases, 75-98% of watershed sediment can be trapped within lagoons (Wolanski et al. 2004).

Richmond et al., (2007) conclude that without the proper management of watershed land use, successful management of adjacent reefs may not be possible. In other words, it takes a watershed to save a reef. This is a worthy challenge, and a really good time to find your Malama Honua.

Watershed planning is not new, and there are many excellent guidance documents that already exist outlining protocols for watershed assessment and planning (EPA, 2008; Schueler and Kitchell, 2005; Wilkinson and Brodie, 2011). This tool pulls key information from these sources in order to customize the process for tropical systems. In doing so, the guidance has been trimmed to bare bones, hopefully referring you to places where more detail can be easily found when needed.

> **“The successful management of fringing coral reefs adjacent to high islands may not be possible without proper land use management in the surrounding watersheds.” Richmond et al. (2007)**

Tool Applicability

Ideally, users of this tool should generally agree to (or at least be aware of) the following applicability standards:

- ☑ The primary objective is to minimize watershed impacts on corals. While other objectives are important (e.g., human health), this tool is designed to help users prioritize watershed actions from a coral-centric perspective.
- ☑ There is a coral reef to protect or restore downstream.
- ☑ The watershed size is ideally 5 square miles or less. If larger, then try to divide into smaller subwatersheds to start.
- ☑ The user must have access to GIS (or Google Earth at a minimum) to create watershed maps.
- ☑ There is an expectation for implementation. Someone is (or will be) designated to oversee actions identified in the watershed plan.
- ☑ There is an expectation that the plan will meet EPA’s planning criteria.

Before Getting Started

To ensure minimal capacity to undertake coral-driven watershed planning efforts, and to determine if a simple of more sophisticated approach will be used, we recommend the following prerequisites prior to using this tool:

- ☑ Capacity to complete the planning process, so the scale and scope of watershed assessment and planning efforts must be appropriate for your staffing, budgetary, and technological resources.
- ☑ Information, even if qualitative or anecdotal, that supports the notion that the reef is being negatively impacted by what is running off the watershed.
- ☑ Confirmation that your target watershed is a priority, is worth focusing resources and investments on, and should be the focus of your planning effort. In some cases, several watersheds may be impacting the reef system and can be aggregated for the planning effort.
- ☑ Clear articulation of the goals of the watershed assessment and planning process so you can set realistic expectations that can be communicated to staff and stakeholders.

Using the Tool

The tool is designed as a sequential, five-step flow chart that spans three phases of the watershed assessment and planning process (see **Figure 1**). Each step includes a series of yes/no questions to be answered in the affirmative before moving on to the next set of questions. The user is encouraged to go through each of the five steps and to "check off" elements within a step as they are completed. There are ten profile sheets at the end of the tool that are referenced throughout the planning process. Where more detail is needed to answer a question in the flow chart, or to better understand what switching from a "no" to "yes" might actually entail, specific Profile Sheets (attached to this tool) are referenced in the flow chart.

<u>Phase I</u>—Tell the watershed story through research, mapping, and stakeholder discussions, as well as through observations made in the field to verify conditions and identify restoration needs and opportunities. Attempt to understand the historic, current, and projected conditions of the watershed and reef, to determine, what (if anything) should be done to intervene. The story of every watershed is unique, and ultimately, you should be able to share it with others in a compelling way. There are two steps in the planning process under this phase:

Step 1: Goals, Research, and Mapping

This step identifies a several key milestones needed to generate enough information on watershed and reef conditions. Through mapping, research, and talking with knowledgeable stakeholders, this initial step can generally be completed from the comfort of your desk.

Step 2: Field Investigations

You can't know your watershed without getting out in it, especially when it is raining! (but also during dry conditions). This step adds to the watershed story through field investigations to identify watershed problems, verify existing conditions, identify potential locations for restoration actions, and fill in any remaining gaps in watershed mapping.

Phase II—Prioritize management actions based on potential restoration opportunities and the priority watershed threats to the coral community. In the past, this step was often completed informally and with little support data, or even deferred to the future in favor of early implementation. However, the two steps in this phase are intended to provide more structure to the ranking process:

Step 3: Reef Threat Assessment

This step includes developing a planning-level threats matrix for watershed conditions. You will need a sense of how vulnerable the coral ecosystem is to land-based threats. Note: Even if a coral ecosystem has a low vulnerability, there still may be good reasons to pursue watershed management activities.

Step 4: Prioritize Watershed Actions

Identify, prioritize, and verify restoration opportunities that can address priority threats and known coral ecosystem deficiencies. This may include structural projects (e.g., stormwater or wastewater improvements, erosion control, or stream restoration) and also non-structural activities (e.g., regulations and watershed education). Cast a wide net at first, and then systematically refine the priority actions. Depending on your technical capacity, the identification of potential opportunities can be done under Step 2.

Phase III—Prepare for implementation by documenting the management strategy and implementation approach to secure funds and partner support. Outline how benefits of implemented activities will be measured over time (using qualitative or quantitative techniques). This requires documentation of all the planning efforts, addressing the basic elements of a comprehensive watershed management plan.

Step 5: Watershed Plan Development

If you've made it this far, you have everything you need to compile an EPA-approved and NFWF-ready watershed management plan. Whether the plan is a compilation of tables or a series of written report(s), this step leads you through the required steps needed to document watershed conditions, the management strategy, and an approach to monitor/measure implementation success.

Profile Sheets

Each step in the process references one or several profile sheets. The profile sheets go more in-depth on various subjects and provide resources for users to find more information. There are ten profile sheets, as outlined in **Table 2.**

Each profile sheet describes three levels of program or technical sophistication, as denoted by the following graphics:

Baseline

Good

Best

These levels provide options based on staffing, technical resources, and funding. Some users may want to start with the Baseline Level to “get their feet wet,” and then move to higher levels. Others may have already achieved a baseline level of implementation and are looking to advance to the Good or Best level of practice. The distinctions between the levels are somewhat arbitrary, so users can also mix and match resources or approaches from all three levels.

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Flow Charts

Goal: Set your planning goals and objectives. Create watershed/ reef maps, review previous studies, generate important watershed/reef factoids, and absorb relevant information from stakeholders.

Step 1. Research and Mapping

☑	Milestone		Action	Comment
☐	**1.** Do you have clear planning objectives, a good watershed map (i.e., drainage boundaries, clear aerials, topography, hydrology, property lines, basic infrastructure, reef and marine resources)?	No	Write down what you want to accomplish with your planning project. Use Table 2 to identify the level of effort you expect. Create a watershed map. If you don't have GIS, use Google Earth for aerials and hand draw in watershed boundaries, label roads, and streams/outlets. *See PS#1: Mapping*	Start with your planning goals and make sure your work plan will get you there. You will need a watershed map for field assessments, to locate problem areas and proposed projects, to show stakeholders where they live, and to conduct basic land use analyses. Most places don't have LIDAR, infrastructure mapping, impervious cover, or unpaved vs. paved road GIS. This information is useful for modeling, generating watershed metrics, and project design and ranking.
	Yes			
☐	**2.** Have you reviewed existing studies and reports? Do you know anything about the condition of the coral reefs or watershed function? Have indicators of reef quality, or monitoring data identified "red-flags" for watershed inputs?	No	Confer with experts and agencies that have this type of information, including past watershed plans, monitoring reports, resource assessments, or generalized data for regional reef health. If there are no indicators of watershed/reef issues, then it may not be the highest priority watershed for restoration (maybe for conservation…). *See PS#2: Coral condition data*	There are likely to be past plans, or other studies that can provide insights into different watershed functions You need to have something, even if qualitative or anecdotal, that supports the notion that the reef is being negatively impacted by what is running off the watershed.
	Yes			
☐	**3.** Has local knowledge been solicited and documented on coral condition, sources of watershed pollution, specific problem areas, geology/soils, currents, etc.?	No	Meet with local residents, businesses, agency, and resource users (fishermen, surfers, beach goers) to get a sense of watershed history, changes in drainage, water quality, etc. ; and establish a plan for identifying and engaging key watershed stakeholders. *See PS#3: Stakeholder input*	Identify key property owners and implementation partners. Meetings should be short, advertised through churches, include food, and linked to community events. Residents and users are tied to the resource and are invaluable sources of watershed information. Documenting this generates goodwill and buy-in. Have them draw on maps.
	Yes			
☐	**4.** Have you generated watershed and reef stats (e.g., land use breakdown, watershed or reef resiliency factors)? If possible, identify factors that increase or decrease coral vulnerability. These can include the shape and energy of the lagoon, watershed slope, geology, streams, and climate	No	Quantify watershed stats (e.g., % impervious, % land use, % sewered, miles dirt roads, #piggeries, existing stormwater pipes, rate of change of significant new land uses). Include any information on existing BMPs, wetlands, buffers or other factors that provide treatment, as well as coral vulnerability factors (flushing rates, circulation patterns). *See PS#4: Watershed characteristics and threats*	Watershed characteristics can tell you a lot about the health of a given watershed and can point you to the likely sources of watershed pollutants and save time in the watershed planning process. A lot of scientific research has been conducted over the last few decades establishing watershed indicators. You may want to pay particular attention to watershed uses that have changed rapidly in recent times or that are likely to change dramatically in the future. Can you identify watershed areas where the focus may be protection of existing resources, restoration, or a combination?
	Yes			
	Proceed to Step 2.			

Step 1 Deliverables: *Watershed planning goals/objectives; maps; baseline report of existing information and watershed stats; and stakeholder engagement plan.*

Step 2. Field Investigations

Goal: Identify watershed problems and potential restoration actions, verify watershed mapping and/or fill data gaps, meet on site with stakeholders.

☑	Milestone		Action	Comment
☐	1. Have you pre-identified locations to visit based on what you know about the watershed, accessibility, and level of effort you can dedicate to the field? Yes	No	Develop a field plan that identifies teams and schedules, locations to visit, and who should join you on-site to provide more information or access. *See PS#1: Mapping*	Island watersheds can have steep, inhospitable terrain; no public easements on stream corridors; impassible roads; aggressive feral cats; and places were you could get into trouble. Know your limitations, call ahead, don't go alone, respect private property, and take a phone and a first aid kit. Take along experts who are knowledgeable about restoration opportunities & feasibility.
☐	**2.** Have you observed both wet and dry weather conditions at key coastal discharge locations? How about on the reef? Yes	No	Conduct informal or more systematic surveys at discharge points. Put on some fins, swim out to check out conditions on reef (not during a storm!!!). *See PS#5: Field Assessments*	
☐	**3.** Have you explored streams/guts/wetlands? Yes	No	Streams and wetlands are watershed resiliency features. Walk the stream network where feasible. Evidence of problems in stream can be followed uphill to potential sources. *See PS#5: Field Assessments*	You could burn all your field effort on stream walks. Consider popping in and out at strategic locations and reserving sweaty hikes to known problem locations. Key things to look for include overall habitat quality, culverts, pipes, erosion, trash, and buffer quality. Consider measuring channel cross-sections for modeling purposes. For ponds and wetlands, get a sense of depth and habitat quality.
☐	4. Have you driven or walked upland areas (outside of the immediate stream corridor)? Yes	No	Explore. Get sense of pollution sources, land use hotspots and upland drainage patterns (along roads, piped network, etc) to each key discharge locations *See PS#5: Field Assessments*	When driving around, look for things that could be problematic when it rains. Hotels, farms, auto repair, dumps, piggeries, quarries, very large impervious areas, disturbed/unstable soils, etc. Check out residential areas for maintenance practices and evidence of organized community groups that can influence behaviors.
☐	**5.** Have you updated watershed mapping and communicated field findings Yes	No	Transfer field findings to maps. Let stakeholders know what you saw. *See PS#3: Stakeholder input*	Update maps to show problem locations, existing infrastructure, flow paths, etc. Post for easy viewing, Google web maps, etc.

Proceed to Step 3.

Step 2 Deliverables: *Field findings report with updated maps, locations and descriptions of problems and potential opportunities; good photos of watershed condition; stakeholder report outs; verification /update of watershed characteristics.*

Step 3. Threat Assessment

Goal: Determine which watershed threats have the highest potential to impact reef quality. Consider factors that can influence the relative vulnerability of reefs to watershed inputs.

☑	Milestone	Action	Comment
☐	**1**. Do you know which watershed issues are the biggest threat to the reef? Yes	No Summarize and rank the watershed threats/sources of watershed using watershed info derived earlier. Account for watershed resiliency and coral vulnerability factors (e.g., the shape and energy of the lagoon, wetlands, coral adaptation capacity, and existing treatment practices). *See PS#4: Watershed characteristics & threats*	Major threats (e.g., wastewater, erosion) have been identified, so now it is time to prioritize threats. Wherever possible, the matrix should be tied to identified benchmarks and red flags. Part of this step is to understand how vulnerable the coral ecosystem is to activities that take place on the land. Note that even if relative vulnerability is low, there may be compelling reasons to undertake projects (i.e., human health). This can be done with a quantitative or qualitative approach.
☐	**2.** Have you quantified watershed pollutant loads (and do you need to refine the priority threats list)? Yes	No Use land use coefficients, monitoring results, or other data to establish a pollutant load budget from various land uses or activities. This may require simple spreadsheet calcs or more complicated modeling methods. *See PS#6: Watershed pollutant budget*	This can seem intimidating, but if you have already established watershed factoids, estimating loads can be relatively easy and meaningful.
☐	**3**. Is there existing coral and water quality monitoring data that could be used to verify watershed threats? Yes	No Meet with other agencies and researchers to exhaust all data avenues. If no data is available, adopt data assumptions from neighboring areas. Craft a monitoring plan as part of this effort. *See PS#2: Coral condition data*	Coral indicators are vital to tracking coral health conditions through time. Existing resources provide some guidance on benchmarks and red flags for a wide range of indicators. These can be used to better understand the impacts of local, land-based threats versus more global or regional threats.
☐	**4.** Has the threats matrix been verified? Yes	No Meet with stakeholders. Review the steps above to help refine, revise, and verify the threats matrix. The matrix is likely a living document that can be modified as new information, data, and insights become available. *See PS#3: Stakeholder input*	Verification involves conferring with stakeholders and ensuring that small but significant sources have not been overlooked. The outcome should be a verified threats matrix that clearly ranks and prioritizes threats and sources of pollution so that the most appropriate restoration opportunities can be identified in subsequent steps..

Proceed to Step 4.

Step 3 Deliverables: *identification of priority watershed threats; pollutant load estimates; vetting with stakeholders and actual observations.*

Step 4. Prioritize Watershed Actions

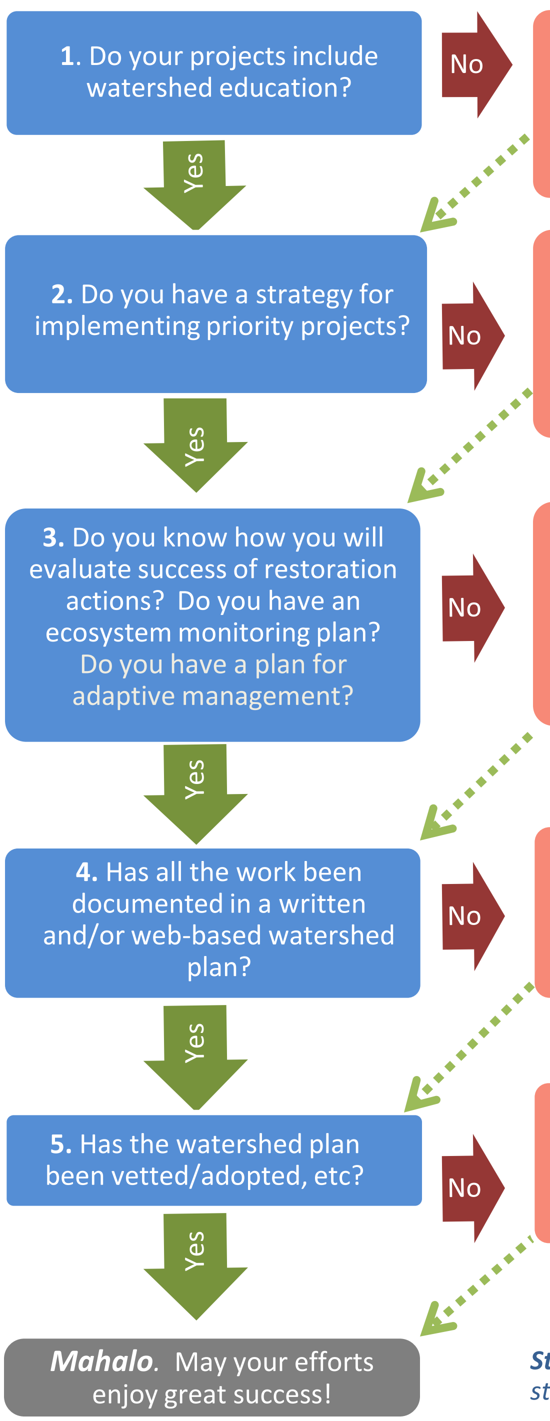
Goal: Prioritize and advance designs for the restoration actions/ projects that directly address key watershed threats and will contribute to improved reef condition.

☑	Milestone	Action	Comment
☐	**1.** Have you identified restoration options to address watershed threats?	No Review and update your observations from Step 2 about protection & restoration opportunities. Link the opportunities with specific threats that will be addressed. Make sure you develop concept sketches/brief description for potential structural & non-structural options. *See PS#7: Identifying restoration options*	Use simple or more complex methods to link priority threats with applicable protection and/or restoration strategies. For identified practices, you will need enough of a concept to communicate the activity, determine feasibility, and be able to rank it. These can range from stormwater retrofits to wetland restoration to educational programs.
	Yes		
☐	**2.** Do you know which projects are a priority? Have prioritization factors been identified and a ranking system developed? Prioritize projects/actions based on threats matrix for improving coral conditions	No Identify factors that are most relevant to the watershed (e.g., feasibility, cost/benefit, community support, public involvement, long-term maintenance issues, available funding, and other factors). You can also assign scores and weights to the factors to help with prioritization. *See PS#8: Project ranking*	These factors provide a systematic way to compare projects across types (e.g., structural practice vs. community education). Planning-level costs, pollutant reductions, or coral improvement scores (or other ways to measure benefits) will have to be developed for some of the factors. This can usually be done with literature values or looking at local/regional examples. The scoring system can be something that everyone can quickly understand, such as a 100-point scale.
	Yes		
☐	**3.** Has your project ranking been fully vetted with stakeholders ?	No Generate an initial priority list. Assemble a group of stakeholders to look through the list. Do the priority projects meet the “gut check” and “best professional judgment?” Are there hidden project killers or lower-ranked projects that should be elevated due to opportunities? *See PS#3: Stakeholder input*	People with knowledge of the watershed, administrative and political systems, restoration funding sources, and on-the-ground knowledge can help with verification/vetting the priority projects. Document all projects in a watershed plan in case situation changes down the road.
	Yes		
☐	**4.** Do you have refined design plans/strategies for priority projects?	No Spend time refining your top projects so you better understand constraints, costs, and feasibility. You’ll need to do this in order to plan for implementation. You may need to bring outside experts on board to help with technical designs. *See PS#7: Identifying restoration options*	Don’t make the mistake in thinking that advanced project designs are for structural projects only. If non-structural actions make the list (e.g., regulatory changes or hiring of erosion control inspectors), advanced design can mean writing regulations or identifying what agency and budget mechanisms are needed to hire personnel.
	Yes		
	Proceed to Step 5. If you can begin to implement, go ahead and get started.		

Step 4 Deliverables: *Narrative and concept sketches for project opportunities; project ranking matrix; advanced designs for priority projects; stakeholder buy-in.*

Goal: Document watershed conditions, the management strategy, and a monitoring approach to measure the effectiveness of restoration over time in a written watershed plan.

Step 5. Watershed Plan Development



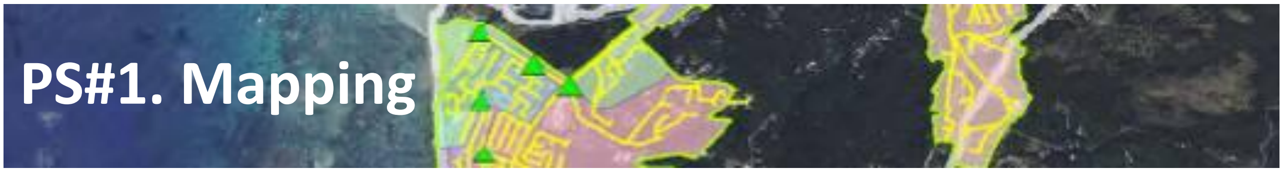
☑	Milestone		Action	Comment
☐	**1.** Do your projects include watershed education?	No	Look through your list of issues and opportunities. ID target messages, audiences, and specific watershed education and outreach actions. *See PS#9: Elements of a watershed plan*	The watershed plan will need a communication, education, and outreach component for successful implementation. These can be simple and informal, or more comprehensive.
☐	**2.** Do you have a strategy for implementing priority projects?	No	Identify who, what, when, where, and how much it is going to cost over the next 5-10 years to implement your priority projects. *See PS#9: Elements of a watershed plan*	These are components of a basic implementation strategy. One trick is to ensure that the plan is realistic, so may require phasing or other strategies to sync implementation with available funding, resources, timing of capital improvements, etc.
☐	**3.** Do you know how you will evaluate success of restoration actions? Do you have an ecosystem monitoring plan? Do you have a plan for adaptive management?	No	Develop a monitoring plan for both programmatic milestones and trends in watershed and coral indicators, water quality, or other ecosystem functions. *See PS#10: Long-term monitoring*	Looking forward, this is how you will know whether your plan is successful, and, importantly, how to make necessary adjustments as projects are implemented based on lessons learned (adaptive management). Luckily, many templates and indicator methods are available.
☐	**4.** Has all the work been documented in a written and/or web-based watershed plan?	No	Document your efforts by assembling the work completed in Steps 1 through 5 into a written watershed plan. *See PS#9: Elements of a watershed plan*	There are options for how simple or complex to make the plan, and it is important to match this level of sophistication with program capabilities and how the plan will be used for actual implementation.
☐	**5.** Has the watershed plan been vetted/adopted, etc?	No	Make sure to close loop with stakeholders and give them a chance to comment, sign up, volunteer, etc. *See PS#3: Stakeholder input*	The process outlined in this tool identifies several key milestones for stakeholder input. If this is followed, then there will be the necessary buy-in when you reach this step in the process, but your stakeholders are also key players to ensure implementation.

Mahalo. May your efforts enjoy great success!

Step 5 Deliverables: *Targeted education plan, monitoring plan, and implementation strategy; written watershed management plan; pig roast!*

Profile Sheets

PS#1. Mapping



What Is It?

Watershed Assessment Levels

	Baseline Level Google maps and a marker, rely on free online mapping products
	Good Practice Desktop GIS with some data layers available (land use, impervious cover); capacity to create shapefiles but limited analyses
	Best Practice GIS with extensive mapping data already available (LIDAR, utilities, etc.) capacity to run analyses

A good map goes a long way in helping to unlock the mysteries of your watershed. In fact, you can approximate problems areas, estimate how much time field assessments will take, and identify potential restoration options just by looking at an aerial image of your watershed.

Why Is It Important?

Watershed maps are critical to every step of the watershed planning process. Without a proper map, you can't estimate the size of your drainage area, land use acres, or length of streams. You can't show the locations or interconnections between key watershed features (e.g., outfall pipes and high quality benthic habitats), and you won't be able to utilize many modeling programs. But more importantly, imagine trying to communicate your management vision to others when they can't see where their house or favorite beach sits in the watershed.

Getting Started

1. Make an honest assessment of your mapping capacity. Who is going to do your mapping and what tools are you going to use (e.g., in-house GIS capabilities, get NOAA to do it for you, or piece together your map from free online mapping tools like Google Earth)? Are you able to make your own maps easily, calculate areas, and do basic analyses?

2. Check your watershed size. Most watersheds have already been mapped (usually based on surface topography; a few may include groundwater flows). The smaller your watershed, the easier it is to figure out what's going on, how to fix it, and how to measure the impact of your efforts. Ideally, your watershed is 5 square miles or less. If it is larger than that, you will find benefit in subdividing it into smaller units.

3. Reach out to agencies and utilities for available mapping data. A list of key watershed mapping data you may want is provided in **Table PS1-1**. There is much publicly-available data, even for the islands, and, yes, even for those of us that don't have access to desktop GIS.

4. Determine what data gaps need to be filled and how you plan to fill them. In your research, you may decide that there is some mapping information that you want to create as part of your watershed planning process (e.g., unpaved road, eroded shorelines, or septic system mapping). You may be able to derive this information from GIS analysis of existing data or you will need to create new mapping data based on input from agencies, stakeholders, and field observations.

5. Determine what methods will be most appropriate for updating maps and for sharing map information with others. Consider quality control measures that will be taken if your data will become part of the GIS universe, including appropriate metadata (information on what the data is, when it was collected, etc).

The following levels of practice summarize general data needs and level of GIS-savvy that should be planned for during the watershed planning process. **Table PS1-1** outlines these three levels of practice for a recommended set of mapping features.

Baseline Practice

At this level of mapping capacity, you may be relying on a combination of free (or low cost) online mapping products and geo explorers to create the basemaps that you need (see ESRI online and open source alternatives). Most of the federal and state/territorial agency GIS repositories have an online mapping system that allows you to view available data layers and to print maps you have created. You can generate watershed factoids, mark up hard copy maps with pen and ink and use Google Earth to create new features for sharing and to make simple calculations (e.g., area, length, etc).

Good Practice

With desktop GIS capacity, you can edit, create, and geoprocess mapping layers (e.g., creating impervious cover polygon from CCAP raster file, delineating drainage areas to outfalls, and calculating impervious acres in each outfall contributing area). As you create new data, you will want to consider mobile data collection technologies that maximize post-processing efficiency. At this level, you should be sharing your watershed maps online (e.g., Google maps) that give the public access to key locations, data, and photos in the watershed (watershed boundaries, restoration sites, etc).

Best Practice

At this level, you have access to a tremendous amount of recent, high quality GIS data that will allow you to conduct some fairly sophisticated analyses, including integrating with pollutant or hydrologic models. Better data means you can spend more time identifying solutions to problems because you already have the backbone information on your watershed (e.g., pipe network already mapped, so you can spend time prioritizing outfalls or calculating the percent of your watershed that is being treated by BMPs). You may choose to conduct interactive watershed mapping exercises with stakeholders (similar to coastal use surveys) and to build an attractive geomapper of your watershed (e.g., ESRI story maps: https://storymaps.arcgis.com/en/).

Table PS1-1. Watershed Mapping Data and Analyses

Mapping Data	Baseline	Good	Best
Watershed boundaries*	Watershed and subwatershed units defined from center of headlands on either side of a bay or lagoon; rely on boundaries already developed by others (USGS or state agency)	Subwatershed units delineated from major stream inlets, with small areas of direct drainage to bay	Consider groundwater movement; subwatershed or catchment boundaries delineated for each drainage point (e.g., stream or stormwater outfall) into the bay.
Aerial Images	Google Earth ®	Better resolution images, without clouds; historic images for comparative purposes	Even more recent, higher resolution
Elevations	USGS quad sheets, online topographic basemaps	10 feet or better contours in GIS	2 ft contours; LIDAR, DEMs; plus bathymetry
Hydrology and coastal dynamics	USGS streams or state agency hydrology and wetlands	Better local data that includes smaller or dry channels, canals, better classification of wetland types	Stream condition information (eroded areas, piped, channelized); wetland quality; coastal dynamics (circulation patterns)
Geology	USDA-NRCS soils maps, look at HSG soil group (A, B, C, or D); know if you have limestone or volcanic geology	Groundwater information; critical recharge areas	Erosion potential
Cadastral	Municipal or village boundaries; public lands; online tax assessor records	Parcels boundaries with ownership and land use codes	
Land use/Land cover	Land use polygons created by looking at the aerials (urban vs vegetated blocks)	Official land use and land cover data layers; NOAA CCAP land use change; zoning	Tracking vegetation and revegetation efforts; Future buildout and master planning for modeling purposes
Impervious cover	Estimate from land use coefficients, eyeballing aerials (see Profile Sheet #6)	Derive from NOAA CCAP data (requires a little GIS work with rasters) or calculate based on buildings, parking lots, roads polygons	Direct measure IC using most up to date aerial imagery
Infrastructure	Outfalls, existing stormwater BMP facilities; sanitary sewer service area	Drain, sewer, and water line utility maps, wellheads; delineate drainage areas to all outfalls	Area treated by stormwater BMPs, maintenance tracking systems
Marine habitats	Benthic cover; NOAA Biomapper	Habitat quality, anthropogenic impacts	High resolution mapping; comparison over time
Monitoring stations	303(d) assessment units and water quality monitoring stations; stream gauges	Coral and benthic monitoring sites (NCCOS)	Displays showing comparative level of quality
Climate Adaptation	Shoreline erosion; FEMA flood hazard maps	Sea level rise estimates; shoreline change	Identify high risk infrastructure and land uses; social vulnerability

* If you are in Florida, your watershed boundaries may be influenced primarily by inlets, canals, and control structures

References & Resources

There are a number of places where you can obtain GIS data for your watershed area. **Table PS1-2** provides a short (but certainly not exhaustive) list of recommended places to start looking for GIS data:

Table PS1-2. Useful Sources of Watershed Mapping Data

Source	Weblink	Description
NOAA Digital Coast	https://coast.noaa.gov/digitalcoast/	Repository of land cover, LIDAR, benthic habitat, sea level change, aerials, and more for coastal states and territories.
NOAA National Center for Environmental Information (NCEI)	https://data.nodc.noaa.gov/geoportal/catalog/search/search.page	Search by location, primarily coral and marine ecosystem data; more than GIS and a little tricky to navigate.
NOAA National Centers for Coastal Ocean Science (NCCOS)	https://coastalscience.noaa.gov/products/maps	Maps and geographical explorers such as Biomapper, for habitat and ecological datasets in the islands.
USGS	https://water.usgs.gov/maps.html or for Caribbean data go to: https://pr.water.usgs.gov/infodata/	Watershed boundaries, hydrology, stream gauges, USGS maps, and more.
State and Territorial data portals	• CNMI http://becq1-dcrm.opendata.arcgis.com/ • Guam http://north.hydroguam.net/gis_download.php; http://maps.guam.gov/ • American Samoa http://doc.as.gov/resource-management/ascmp/gis/ • USVI https://usvi.mapgeo.io (online parcel mapping) • Puerto Rico http://www2.pr.gov/agencias/gis/ • Hawaii http://planning.hawaii.gov/gis/ • NOAA CRCP CORIS https://www.coris.noaa.gov/portals/ • Delineations of inlet contributing areas for SEFL have been developed by for NOAA CRCP (contact Horsley Witten Group)	

PS#2. Coral Condition Data

What Is It?

Coral condition data are collected over the long-term to establish baseline conditions, compare conditions over time, and identify “red flags” when certain conditions enter the danger zone for declining coral ecosystem health. Often the parameters measured are referred to as **indicators**, which can include chemical, physical, biological, and social factors. Monitoring for indicators can happen at various scales: from the entire island, specific embayment or watershed, or down to the site level (the last two being most relevant for watershed planning objectives addressed in this profile sheet).

Watershed Assessment Levels

	Baseline Level A few available indicators that can address whether there is a water quality problem at the site of a coral ecosystem.
	Good Practice A more complete set of indicators to help determine if water quality problems are affecting coral reef ecosystem health.
	Best Practice A more robust set of indicators to analyze sources and the effects of management actions.

Why Is It Important?

Collecting and analyzing coral condition data is the only way to evaluate the current condition of coral ecosystems, how changes on the land may be influencing these ecosystems, and how effective certain watershed interventions may be in improving ecosystem conditions. Teasing out a direct connection between coral condition and watershed-derived stressors is not straightforward. Regardless, a fundamental understanding of the quality of the coral community is paramount to being able to prioritize management actions across a myriad of potential threats (e.g., loss of herbivorous fishes due to overfishing, invasive biota, thermal impacts, disease, physical impacts due to vessels, etc., as compared to watershed factors, such as sediment or nutrient loading).

Getting Started

- Review your available coral and watershed information.
- Confer with local coral monitoring staff, NOAA and EPA contacts, and others who may be familiar with coral condition monitoring efforts in your study area. Ask these experts what they think the functional relationship is between available coral data and the watershed you are studying, as well as adjacent or similar watersheds on the island. It may be that your watershed is part of the puzzle about certain coral ecosystem issues. It may also be that, due to geography, geology, currents, and other factors, your watershed is not a big player in terms of influencing the studied coral ecosystems (in which case, new monitoring stations that are closer to your watershed outlet may be called for).

- Try to determine whether there are specific pollutants of concern for the coral that should become the focus of watershed interventions. This will allow you to prioritize data collection efforts.
- As time allows, avail yourself of the excellent guidance available on coral indicators, such as:
    - *U.S. Coral Reef Task Force, Watershed Partnership Initiative, Priority Ecosystem Indicators* (USCRTFa, USCRTFb); https://www.coris.noaa.gov/activities/uscrtf_watershed_tools/Priority_Ecosystem_Indicators_Final%202_18_16.pdf)
    - *Healthy Reefs for Healthy People* (McField and Kramer, 2007); http://www.healthyreefs.org/cms/publications/.

  These publications will broaden your understanding of how to select the most appropriate indicators for your watershed. Some of the methods discussed in these publications are used at the island or jurisdiction-scale, which can be used to design consistent approaches at the smaller site (or watershed/lagoon) scale. Use in-house resources, colleges and universities, interns, or other capacity to expand your coral condition monitoring program.
- Develop a written plan that can be modified and updated as the program evolves.
- Use an adaptive management approach to periodically evaluate and modify your indicators and monitoring strategy.

Tiered Approach for Tying Monitoring to Management Actions

Different levels of program sophistication can be selected deliberately based on staff availability and expertise, funding, site conditions, and other resources. Relating coral condition to a particular watershed adds a layer of complexity to a monitoring program. Some practitioners have begun to conceptualize how different tiers of coral condition monitoring may be understood, particularly as monitoring relates to possible management actions.

Table PS2-1 identifies a series of questions to ask in a tiered approach, beginning with basic questions and building on knowledge as more monitoring is conducted**.** In this regard, the levels of sophistication presented in this profile sheet may be more of a sequential process than selecting a particular level.

Another valuable resource that gages a monitoring program based on the types of management questions that can and cannot be answered is in *Healthy Reefs for Healthy People, Chapter 9, Tables 9.b and 9.c* (McField and Kramer, 2007). Due to their length, these tables are not reproduced in this profile sheet, but the publication is easily accessible on the internet: http://www.healthyreefs.org/cms/publications/. Flower et. al., (2017) provides a comprehensive approach to linking monitoring indicators with stressors, such as sedimentation and water quality, to guide management planning (see reference at the end of this profile sheet).

Table PS2-1. Tiered Series of Questions Relating Monitoring to Management Actions[1]

Question	Guidance
Q1: Is the reef healthy?	There needs to be some evidence that the reef is unhealthy in order to move forward with watershed planning efforts.
Q2: Is there a water quality problem?	There may be other stressors impacting the reef, but for watershed planning, we primarily care about water quality impacts. Use inexpensive, low-resolution techniques such as remote sensing (e.g., ocean color) to determine whether there is, comparatively, a turbidity/nutrient enrichment problem at a particular site. If the answer appears to be yes, go to the next question. Flower et.al, (2017) offers suggestions on how to identify stressors based on monitoring indicators.
Q3: Is water quality affecting coral health at the site?	To move on to this question, you need to have some sort of baseline. When you don't have a historic baseline, look at things like dive or fishing records. If you have historic water quality information (or ocean color products), you can establish trends in coral health over time. You can also use this information to quickly determine likely coral health based on existing water quality.
Q4. How is the watershed contributing to water quality problems?	If there appears to be a water quality effect on coral health, then you can begin to analyze the source of the problem, the extent of the effect, etc. to better understand the management needs.
Q5. How can we measure watershed impacts over time?	

[1] *From: Water Quality Management Workshop, Summary of Breakout: Defining Thresholds for Management Action (supplied by Lisa Vandiver, Ph.D., Marine Habitat Restoration Specialist, NOAA Restoration Center)*

Baseline Level

The baseline level would include relatively simple, low-cost techniques to answer Question #2: *Is there a water quality problem at my site?* Since the intent of this profile sheet is to integrate coral condition monitoring with a watershed plan, the "site" in question would be the lagoon or receiving waterbody that is influenced by the watershed in question. Note that lagoon currents and dynamics may influence which land-based watersheds are influencing a particular coral ecosystem, and that is a good question to ask your local and regional coral experts.

Table PS2-2 outlines several techniques and resources that may qualify for this baseline level. **Table PS2-3** provides more guidance on use of the Secchi Disk, as noted in **Table PS2-2**.

Table PS2-2. Baseline Level Coral Condition Monitoring Indicators and Approaches

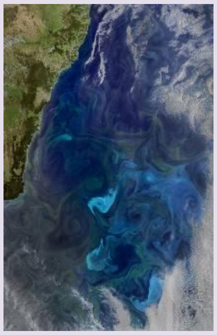
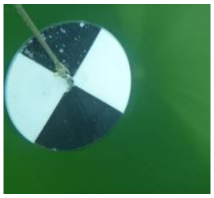
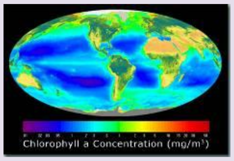
Indicator	Description	Method Guidance
Ocean Color 	• Analysis of satellite images through time, including historic data to note any changes. • May want to also include "reference" areas (e.g., similar lagoon conditions but where the watershed inputs are relatively undisturbed).	Consult your local GIS and mapping staff, as well as NOAA and NASA representatives and resources. For instance, see: https://oceancolor.gsfc.nasa.gov/ https://neo.sci.gsfc.nasa.gov/view.php?datasetId=MY1DMM_CHLORA Healthy Reefs for Healthy People: A Guide to Indicators of Reef Health and Social Well-being in the Mesoamerican Reef Region (McField & Kramer, 2007), Indicator Profile S9 – Ocean Color, pp. 32-33). http://www.healthyreefs.org/cms/publications/
Secchi Disk measurements 	• A relatively simple way to measure the transparency of water, which can be related indirectly to turbidity. • The disk can be used at several fixed stations and also reference sites to keep a record through time. • A year is likely the minimum time to start analyzing baseline conditions and trends. • The Secchi Disk can be used from a boat for vertical readings or in the water by divers for horizontal measurements.	Healthy Reefs for Healthy People (McField & Kramer, 2007), Indicator Profile S8 -- Water Quality: Temperature Salinity, Transparency, pp. 30-31). http://www.healthyreefs.org/cms/publications/ Wider Caribbean Region Global Coral Reef Monitoring Network http://www.cep.unep.org/global-coral-reef-monitoring-network-workshop-report (see Appendix D, section 6, water quality – Secchi disk excerpt below in **Table PS2-3**) Informal evidence indicates that a good Secchi disk range for healthy coral is 0.2 to 0.6 meters (Sturm, personal communication).
Chlorophyll a 	• Measure of the biomass of phytoplankton in the water. • Requires collecting water samples and sending to a certified laboratory for analysis (drinking water treatment labs may be able to do this), so may also be appropriate at the Good Practice Level. • While a bit more sophisticated, this analysis can corroborate the two techniques listed above and can provide insight on nutrient conditions.	U.S. Coral Reef Task Force, Watershed Partnership Initiative, Priority Ecosystem Indicators, Section 3 (p. 22) and Appendix L.

Table PS2-3. Guidance for Use of Secchi Disk in Tropical Waters (Source: *Wider Caribbean Region Global Coral Reef Monitoring Network, Appendix D,* http://www.icriforum.org/sites/default/files/Annex_D_-_Proposed_data_methods.pdf, ICRI*)*

The Global Coral Reef Monitoring Network (GCRMN) highly recommended method for estimating water quality is to deploy regularly a Secchi disk at sites around the study region.

The Secchi disk is a black-and-white disk (20 cm in diameter, for the purpose of GCRMN) that is attached to a measured and marked pole, rope, or chain. The disk is lowered into the water from a boat or a diver at the surface until the disk disappears from sight; at this point the measurement on the pole, rope, or chain is recorded. The disk is lowered a bit more, then pulled back up toward the surface slowly. When the disk is visible again, the measurement on the pole, rope, or chain is again recorded. The average of these two measurements is recorded as the best estimate of the distance at which the Secchi disk is visible through the water.

Note that at many tropical locations, the depth of the forereef site will be less than the vertical Secchi depth (e.g., in cases where one can see the reef from the water's surface). In these cases, horizontal Secchi distances can be substituted. The Secchi disk will be placed or held at one location, along with the end of a transect tape. An in-water observer will swim away from the disk, pulling the transect tape and will record the distance at which the Secchi disk is no longer visible.

It is *highly recommended* to collect information on water quality at weekly intervals at standardized sites (1-8 total) that are ideally co-located with the benthic sampling sites. It is *recommended* to collect information on water quality at monthly intervals with a comparable spatial distribution. Notably, the frequency of sampling for water quality is much more frequent than the benthic sampling. As such, it is important to consider complementary on-water efforts (e.g., law enforcement and monitoring, partners in recreational dive industry) to support water sampling. Given the relatively low amount of training needed to collect water quality data reliably, there are a broad set of partners that can be engaged to help gather this information consistently.

Good Practice

If a water quality problem exists, the next question is whether poor water quality is affecting coral health at the site (e.g., watershed outlet) in question. Answering this question will require more robust monitoring and analysis using additional indicators. Establishing a Good Practice Level will require some strategic thinking about the appropriate indicators and how to measure them based on staff, financial, and technical resources. Any program like this will require not only the resources to collect data, but to organize and analyze the data and use it for adaptive management purposes.

The USCRTF *Watershed Partnership Initiative Priority Ecosystem Indicators* report (USCRTFa) identifies several priority water quality indicators that may be appropriate at this stage (see **Table PS2-4**). These recommendations stress that monitoring at site/watershed scales should strive to be consistent in terms of parameters and methods with broader-scale monitoring efforts (such as at the jurisdiction or region level). The priority indicators are intended to help with this alignment.

Another key purpose of tracking priority indicators is to eventually identify certain "red flags," "tipping points," or "thresholds" that represent danger zones for coral ecosystems. It would be important to know if certain ecosystem are approaching this type of tipping point before these levels are exceeded. This level of analysis would likely require monitoring at various sites in collaboration with partners in jurisdictional and federal agencies and universities.

Table PS2-4. Priority Water Quality Indicators for Site-Scale Coral Reef Ecosystem Monitoring, from USCRTF Watershed Partnership Initiative, Priority Ecosystem Indicators (Section 3)[1]

Priority Indicator		Reference in Report to Methods
Water Quality	Total Nitrogen	Appendix L
	Total Phosphorus	
	Chlorophyll a	
	Dissolved Oxygen	Appendix M
	Turbidity	Appendix N
Coral Community[1]	Benthic cover, Coral recruitment, Coral colony size structure, Coral taxonomic richness, Herbivorous fish biomass	Appendices B -- G
Sediment Quality[1]	Sediment constituent accumulation, Sediment toxicity testing	Appendix H

[1] *Note that the report identified a more comprehensive set of coral ecosystem indicators that go beyond water quality to address coral community and sediment quality.* www.coris.noaa.gov/activities/uscrtf_watershed_tools/Priority_Ecosystem_Indicators_Final%202_18_16.pdf*)*

Another resource for identifying a broader set of priority indicators is the *Healthy Reefs for Healthy People* report (McField & Kramer, 2007). The report describes 58 indicators, but no single set of indicators is ideal for every situation. **Table PS2-5** lists the priority ecosystem indicators recommended by the authors to establish a good baseline as well as other indicators of social change and well-being. The scope of this type of monitoring program may go well beyond a focused watershed plan or study – the authors intend a much broader coral reef scientific and social initiative. However, each indicator is well documented, with reference to benchmarks, targets, and red flags.

Table PS2-5. Priority Indicators from *Healthy Reefs for Healthy People – A Guide to Indicators of Reef Health and Social Well-being in the Mesoamerican Reef Region* (McField & Kramer, 2007, Table 9.a)

Ecosystem Structure	Drivers of Change
S3 Focal Species Abundance	D1 Coastal Development Index
S4 Coral Cover	D2 Tourism Development Index
S6 Fish Abundance	D7 Contaminant Accumulation
S8 Water Quality	D10 Conch Abundance
S12 Mangrove Extent	D14 Coral Bleaching Index
Ecosystem Function	**Social Well-being**
F1 Coral Recruitment	SW2 Safe Water and Sanitation
F5 Coral Mortality	SW4 Poverty
F11 Herbivorous Fish	SW5 Economic Contribution of Marine Related Activities
F12 *Diadema* Abundance	SW11 Environmental Perceptions
F13 Fleshy Macroalgal Index	SW14 MPA Effectiveness

Note: The letters/numbers in front of each indicator refers to the reference to that indicator in the report. http://www.healthyreefs.org/cms/publications/.

Best Practice

The Best Practice Level delves into the sources of identified problems, trends in the data, and the effect of implementing management practices. This is of course a longer-term prospect with more commitment of resources through time.

Both reports noted above for the Good Practice Level contain flow charts and decision trees that assist managers in identifying key problems and the best indicators to address those problems (Section 4 in the USCRTF report, and Section 9 in the *Healthy Reefs* report). Those wishing to explore a more robust, long-term program may want to start with these decision trees and also a collaborative approach involving jurisdictional and federal agencies, universities, and watershed stakeholders.

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PS#3. Stakeholder Input

What Is It?

Community engagement is a prerequisite for watershed efforts, especially where the ahupua'a approach and the traditional village structure are a formal part of how island communities are organized. A stakeholder is any individual, agency, or organization affected by decisions made in the watershed plan. You will need a plan for how to communicate with key stakeholders, what participation opportunities will be offered, and how you will use the input that you receive.

Watershed Assessment Levels

	Baseline Level Agency-driven process that includes public meetings at key times to inform and solicit feedback from stakeholders
	Good Practice Cast wider stakeholder net; provide more opportunities for active participation to make group decisions on watershed priorities
	Best Practice Includes full participation in each step of watershed planning process by broad set of stakeholders; steering committee guides technical approach

Why Is It Important?

Watershed planning is about managing people. People generally don't like to be managed, especially if they have had no hand in crafting the management approach. Therefore, keeping watershed stakeholders informed early and often, as well as providing real opportunities for input and participation in the planning process is important. A good stakeholder process can provide you with better watershed information, improve local support for proposed management actions, and engage future implementation partners.

Getting Started

To begin crafting your stakeholder input strategy, the following steps should be completed:

1. Identify your watershed stakeholders. If you are on a small island, you might know many of the watershed stakeholders that you will be trying to engage in the planning process. Stakeholders are not equal; many come to the table with varying degrees of watershed awareness, concern, expertise, and capacity to participate actively. **Table PS3-1** summarizes the broad universe of stakeholders to consider. From this, you will need to narrow down to a smaller list of key stakeholders. EPA (2008) and NOAA (2105) provide a stakeholder worksheet that can help you organize key stakeholders by those that will be directly affected, have decision-making authority, offer useful resources or needed skills, be implementing actions, or be active supporters or opponents to the process.

2. Determine where your planning process fits on the stakeholder involvement continuum (**Table PS3-2**). On one side of the continuum, it is assumed that an agency (or technical consultant) is responsible for the watershed planning process. On the other side, the

watershed planning process is driven completely by community stakeholders. Generally, the most effective watershed plan involves a stakeholder engagement process that falls somewhere in the middle of this spectrum. If there are a number of active stakeholders with the ability to contribute significantly to watershed decisions and implementation, then consider a high level of stakeholder engagement. If expectations are for limited input or support, then a lower level of stakeholder participation may be sufficient.

3. Develop a strategy for stakeholder participation that includes a communication plan, effective participatory mechanisms, and follow-up provisions. **Table PS3-3** summarizes various levels of stakeholder engagement during each step of the watershed planning process. The following levels of practice summarize varying levels of stakeholder engagement to consider in developing your stakeholder strategy:

Baseline Level

At a minimum, stakeholders should be kept informed and given an opportunity to provide feedback at key times during the planning process. Communication with stakeholders may include scheduled public meetings and one-on-one meetings with key agency staff or researchers. Traditional media (e.g., newspaper, radio, local news broadcast) is used to announce watershed planning activities and progress. Public meetings are provided to educate stakeholders on key watershed issues and project milestones, as well as to solicit input on known problem areas and proposed watershed priorities. All stakeholder meetings should include refreshments (regardless of your funding restrictions), as well as some sort of interactive part of the agenda. A smaller group of key implementation stakeholders remain involved once the watershed plan is completed.

Good Practice

Going beyond the baseline level, involves more active participation from stakeholders to help drive the decision-making process. This may involve having additional on-site meetings in the field with key stakeholders, as well as facilitating workshops where stakeholders help generate watershed goals and prioritize threats and projects. Your meetings should be structured for interaction and consensus building through group exercises, participatory mapping, live polling, etc. Since you are putting folks to work, you better step up the food and beverages. Communication tools should be expanded to reach a wider audience more frequently through social media and online project websites to provide access to maps and findings.

Best Practice

At this level, you better be prepared to roast a pig or host a watershed happy hour. In addition to the stakeholder engagement already described, consider establishing a planning advisory group or steering committee of key stakeholders to participate throughout the entire process. Not only should members of this committee provide guidance, but they should be tasked with developing implementation strategies, targeted educational plans, and technical monitoring plans.

Table PS3-1. Broad Groups of Watershed Stakeholders

Agency	Public	Partner	Funders
Primarily responsible for restoration activities, budgets, coordination, and enforcement	*Large group distinguished by level of watershed awareness, activeness, and proximity to problems and solutions*	*Non-government stakeholders that are expected to provide many services*	*Public and private investors in watershed restoration*
• Federal agencies (NOAA, USDA, USGS, EPA, ACOE) • State or territorial environmental agencies (Dept. of Planning, Environmental Protection) • Public utilities • Land owning (Dept of Ed, Public Works, Parks Dept) • Local agents and elected officials (Village Mayors)	• General public (watershed residents and businesses) • Schools, churches, community groups • Key property owners • Homeowners associations • Recreational clubs and resource users	• Universities and research institute scientists • Businesses, industry representatives • Chamber of Commerce • Developers • NGO's (watershed groups, land trusts) • Local media	• Foundations • Corporate sponsors • Individual donations • Federal or state/territorial agency (grants)

Table PS3-2. Watershed Stakeholder Engagement Spectrum (adapted from NOAA, 2015)

Scale	Low 1	2	3	4 High
Type	Agency-driven process for watersheds with few non-agency stakeholders. Decisions are made by watershed planning (agency) lead and other stakeholders are informed of decisions.	Watersheds with diverse interests, but few active stakeholder groups. Agency gathers input from stakeholders before deciding.	Ideal for watersheds with active, informed stakeholders. Stakeholders decide and recommend actions for agency to take.	Community-driven effort, with little to no agency support or political interest. Stakeholders decide to act and then implement.
Pros	• Minimal cost stakeholder process, quicker planning phase • High potential to implement since actions are self-selected to be within agency's purview	• Effective means of integrating local knowledge • Low cost/time stakeholder process • Results in broad array of restoration options	• Broader public support • High likelihood of implementation of diverse actions • Increased funding potential	• High level of community support • Early implementation of community projects
Cons	• Actions often limited to public sector projects • Greater potential for public opposition • Funding may be limited to internal agency funds	• Input often not used • Requires follow-up with stakeholders • Scientist and agencies may override stakeholder interests	• Time consuming stakeholder process • Scientists and sponsor agency might not agree with watershed priorities	• Generally less sophisticated plan • Agencies may not support watershed priorities • Funding could be challenging

Table PS3-3. Soliciting Stakeholder Input

Steps in Planning Process	Baseline	Good	Best
Step 1. Goals, Research and Mapping	• Public meeting to discuss project and solicit input on issues, goals, and perceived solutions • Meet separately with agency and utility staff to get reports and mapping data	• Set up website or social media for project • Solicit additional input on issues and watershed vision via online surveys	• Set up planning advisory group or steering committee • Hold formal watershed goal setting and visioning process
Step 2. Field Investigations	• Public meeting or web/social media; get folks to mark up maps and identify problem areas • Get permission to access properties	• Set up on-site visits with owners and managers to identify problems and opportunities • Post maps showing locations of problem areas and potential opportunities	• Include key stakeholders on field assessment teams, especially community leaders and agency staff • Post photos and field information
Step 3. Threat Assessment	• Public meeting or web/social media to share and solicit feedback on threat assessment ranking	• Organize field trip to reef/watershed to observe conditions • Workshop to get stakeholders to identify priority threats	• Have reef scientists meet with advisory group and present at public meeting
Step 4. Prioritize Actions	• Public meeting or web/social media to share and solicit feedback on project ranking • Solicit feedback on watershed education and outreach methods	• Workshop to get stakeholders to establish ranking criteria and agree on priority projects • Feedback from key implementers on advanced designs and costs	• Advisory group to refine prioritization and other workshop results • Begin identifying implementation strategy for priority projects
Step 5. Develop the Plan	• Meeting to present draft plan and solicit feedback • Final public meeting/celebration to present final plan	• Workshop to develop implementation plan • Provide hands-on early action/outreach project	• Subcommittee to develop education plan • Subcommittee to develop monitoring plan

References

There are several good references that offer details on stakeholder messaging, various participation techniques, and suggestions for conflict resolution and facilitating consensus across diverse interests. In addition to general guidance on watershed stakeholder engagement, lessons from marine protected area planning may provide good insights into how to best engage local stakeholders in coral reef watersheds.

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PS#4. Watershed Characteristics & Threats

What Is It?

Once you have done some mapping, reviewed existing reports and studies, and perhaps some field work (see **Profile Sheet #5**), you may have a reasonable idea of which watershed land uses or threats may be the priorities for your watershed. However, it is important to derive these conclusions (at least in a preliminary sense) from a structured quantitative or qualitative process that allows for various stakeholders to participate (**Profile Sheet #3**).

Watershed Assessment Levels

	Baseline Level *Qualitative, simple analysis using High, Medium, Low, based on inputs from your map and some field work.*
	Good Practice *Use data to develop a more quantitative system that relies on some data and also professional judgment.*
	Best Practice *Watershed modeling, likely tied to GIS with monitoring and calibration.*

Why Is It Important?

Much of the process of watershed planning involves prioritizing among various threats and restoration options. Without prioritization, it is difficult to know where to focus resources or achieve the most cost-effective solutions. This step is one of several to prioritize the various threats and stressors in the watershed.

Getting Started

- Some basic mapping analysis and field work will help generate watershed information that you will use to characterize the watershed. **Table PS4-1** summarizes some of the common features (sometimes referred to as “metrics”), but you may have others that are more specific to your watershed.
- Several steps in this process will require professional judgment to assign either qualitative or quantitative values for various threats. This is best done with a group, although not one that is too large and difficult to manage. Think about a core group that you’d like to have involved and the methods of communication (e.g., email, a couple of group meetings; see also **Profile Sheet #3).**
- Review the options in this profile sheet: Baseline, Good, or Best level and select the level that is most appropriate for your watershed effort.
- Note that this profile sheet is linked closely with **Profile Sheet #6: Watershed Pollutant Budget.** Land use/cover will be a common theme between the two profile sheets, as different land uses represent varying levels of threat and different fractions of the overall watershed pollutant budget. It may be best to consider your process by consulting these two profile sheets together.

Table PS4-1. Common Watershed Features, Statistics, or "Metrics" to Generate

- Watershed and subwatershed area
- % land use/land cover type
- % impervious cover or urban land
- % forested
- % adequate riparian buffer
- Miles of streams/guts/canals
- # of road/stream crossings
- # of culverts, dams, or other structures
- Miles of shoreline
- Wetland acres (by type)
- Miles of paved/unpaved roads
- % HSG soils
- % or area of highly erodible soils
- % area managed by BMPs
- # of outfalls
- % area sewered vs. onsite systems
- Area or length of impaired segments
- Number of monitoring stations
- # of wellheads
- # of jurisdictions

Baseline Level

The baseline level of watershed threat assessment is a qualitative approach; assigning High, Medium, or Low scores based on various input information from your mapping and field work. After completing Steps 1 and 2 of the Tool, you probably have some sense of what the threats are in your watershed, even if they cannot be quantified fully. It is entirely appropriate at this stage to use a qualitative approach to prioritizing threats. This may be a precursor to a more sophisticated, quantitative approach, or simply as far as you can get at this point in time with available resources. In either case, it is a worthwhile exercise.

Table PS4-2 provides a hypothetical example of a qualitative threat assessment based primarily on land use and land cover categories. In many watersheds, land use/cover will be the primary driver for relative pollutant contributions, as different land uses generate different typical pollutant loads per unit of area (see **Profile Sheet #6**). The number and identification of land use/cover categories can be customized to particular watersheds, and this should become apparent in Step 1 of the Tool. In general, the table provides a systematic way to look at:

- The proportional acreage of each land use in the watershed, largely derived from Step 1 or other mapping or GIS.
- The "Intensity" of each land use, which basically describes to extent to which the land use creates land clearing and grading, changes in watershed hydrology (e.g., soil compaction, impervious surfaces, removal of vegetated areas and buffers, etc.), density, and other related factors. This is going to be a judgment call based on the range of land uses in the watershed.
- Other factors that may inform the threat assessment, such as the rate of change of the land use category. For instance, a certain agricultural or tourist enterprise may have experienced a high rate of change over the course of a decade or two, and this trend is likely to continue. This category may be a higher overall threat than other land uses that are relatively stable. Another factor could be topography, as certain land uses are generally located on steep and more erodible land, increasing the threat level. These factors are important to document in whatever threats matrix you decide to use.

Table PS4-2. Example of a Simple Land Use/Cover Threat Assessment (customize to each watershed)

Land Use/Cover[1]	% of Watershed[2]	Intensity[3] (H, M, L)	Other Factors (e.g., rate of change, climate or topography factors)	Threat (H, M, L)[4]
Agriculture Type: grazing (or customized category)	7%	M	Some on steep slopes with high rainfall in upland areas.	M
Agriculture Type: coffee (or customized category)	1%	H	Not a lot of land area, but generally in the uplands and on slopes with high rainfall, intensively managed land.	M
Agriculture Type: piggeries (or customized category)	3%	H	Same as above.	M
Developed: residential	25%	M	Most near shoreline, but beginning to encroach onto steeper slopes.	H
Developed: commercial	15%	M	A few big box stores with large parking lots, but generally smaller, dispersed sites closer to shoreline along major roads.	
Developed: industrial	10%	H	Several mining sites that may have disproportionate impacts.	
Bare Land or active construction	3%	M	Seems to be growing in area and moving onto steeper, upland sites.	M
Recreation: golf courses, parks, etc.	10%	H	1 medium-sized golf course with high fertilizer & pesticide inputs. Also, several diving sites, parking, staging areas in parks along shoreline.	H
Scrub land	5%	L	Mostly on steep slopes, but stable.	L
Open or Forest	15%	L	Same as above.	L
Shoreline	6%	L	Stable	L

[1] These categories were approximated from existing studies, but the number and labeling of categories can be customized to each watershed, depending on available GIS layers and other information.

[2] Derived from the equation: (Area of Land Use Category/Total Watershed Area) x 100. This figure can be measured using GIS or approximated from land use maps or aerial photos.

[3] Intensity describes the density or intensity of use of the particular land use. For instance, a residential use may be dispersed, single-family structures (low intensity) or apartments or higher density structures (high intensity). Agricultural uses can be small, "family" type operations (low) or larger, commercial-scale uses (high). Intensity can be an important factor in deciding whether a use is a priority pollutant source.

[4] "Threat" in this table is a qualitative or professional judgment assessment based on information in the columns to the left. It is advisable that watershed managers specify the main pollutants of concern for the given watershed and those pollutants should be the focus of assigning H, M, and L values. Many watershed assessments include: nutrients (nitrogen and phosphorus), sediment, and bacterial (E. coli or *Enterococcus*). Some may include heavy metals, toxics, temperature, or other pollutants.

In some watersheds, there may be other activities that are important threats or pollution sources, but not necessarily associated with a particular land use category. These other threats may include unpaved roads, discharges from wastewater systems, recreation and tourism, burning/badlands, erosion along streams and guts, and other activities. **Table PS4-3** shows another example of how these sources can be assessed in a simple, qualitative way.

Table PS4-3. Example of a Simple Threats Assessment of Other Sources (customize to each watershed)

Other Watershed Threats	Factors (documented problems, rate of change, description of problems, etc.)	Watershed Threat (H, M, L)
Wastewater – septic systems, cesspools	Most residential development on central wastewater system; a few documented cases of failing septic systems further from the main developed areas.	L
Wastewater – treatment plants	Wastewater plant is in adjacent watershed and has been subject to recent consent orders.	M
Recreation/tourism	Growing industry in this watershed in past decade. Some sites have frequent bus traffic and some erosion from foot traffic in shoreline areas. Several fuel spills from tour buses have been documented.	H
Burning, badlands, ungulates	A few isolated spots, generally small parcels.	L
Landslides	Only a few instances; on steep land, but isolated.	L
Solid waste	Noticeably more illegal and informal dumping spots in tourist and commercial areas. Some seem to be growing in size.	M
Unpaved roads	These are mostly in residential areas in the uplands, on steeper slopes. Erosion seems to be getting worse, and maintenance is infrequent.	M -- H
Streams & guts : inadequate buffers, erosion, etc.	Most are "dry" (intermittent flow after larger storms) and on steeper land. Almost all area heavily vegetated and have at least some buffer area. A couple are exhibiting fairly severe erosion.	M

Tables PS4-2 and **PS4-3** should be customized and used in combination as part of the threats and pollutant prioritization process. The purpose of prioritization is to gain insight on how to allocate available funds, staff resources, compliance activities, code changes, etc. In some cases, this step will naturally lead to the conclusion that a more quantitative approach is advisable, and these are addressed in the sections below.

Good Practice

At this level, the threat assessment procedure is a combination of qualitative and quantitative assessment with additional consideration for watershed resiliency and coral ecosystem vulnerability factors. You will be doing a bit more analysis and scoring, as illustrated in **Table PS4-4** and described below:

- The example in **Table PS4-4** is a more sophisticated Threats Matrix that includes benchmarks for assigning H, M, and L values, and some quantification on a scale of 1 to

10. The example addresses both land use and other watershed threats, and combines the level of threat with rate of change (e.g., how rapidly are tourist facilities expanding?). The idea is to use the benchmarks in the table to assign an appropriate score in each category. All of this can be customized to different watersheds.

- Watershed Resiliency factors are included. These factors help a watershed maintain some level of resiliency in the face of land use or other changes. Resiliency factors can include the extent of vegetative cover on steep slope and in riparian zones, the extent and quality of wetlands in the watershed and mangrove ecosystems at the shoreline, and even the degree to which watershed stewardship is adopted by citizens and businesses. The table includes rows to add other resiliency factors that may be applicable to your watershed.
- Coral Vulnerability factors are used to express the degree to which activities on the land or in the watershed actually impact the coral ecosystem. This can be a complex relationship, and it may be difficult to know how one watershed's input may affect coral. It may be necessary to consult coral experts to get some insight on this question. Relevant information may include the shape of the shoreline, currents, wind, and wave energy in the lagoon, the type of coral, and other factors. Pollutant from the watershed may be flushed away relatively quickly, or may sit in a quiescent lagoon for long periods of time. In addition, your watershed may be one of several that are potentially impacting coral health. This information is critical if you want to take a hard, honest look at relative threats associated with the watershed in relation to other "non-watershed" threats, such as over-fishing, boat damage, water temperature, etc. However, if your primary objective is to improve conditions in the watershed and downstream waters, then the question may be less relevant.

The scoring exercise in **Table PS4-4** results in a tabulation of 1 through 10 scores in various categories. What does it all mean, and how can you pull it together into something that is meaningful for the rest of your watershed planning effort? It may be that going through the exercise with a selected group of experts and stakeholders will be instructive and informative in and of itself. However, you can also pull all the information together into a master score calculated in a simple spreadsheet (**Table PS4-5).** This may be useful if you are comparing different subwatersheds or watersheds as part of the assessment.

There are a few things to note about this type of scoring system. A score of 10 represents the lowest and 1 represents the highest threat. This is important when you get to total scoring because a high score will always be "good" or less threat, and a low score will be "bad" or more threat. Weighting of certain factors is completely optional, but allows for some professional judgment in the scoring**.** The example shown in **Table PS4-5** has a total maximum score of 170 by adding scores for threats, resiliency, and vulnerability. You should customize this by using a simple spreadsheet or more sophisticated method, depending on your needs.

Table PS4-4. Watershed Threats, Resiliency, and Coral Vulnerability Matrix. *Review the benchmarks in each category and circle the relevant number (1 – 10) based on available data and professional judgment. Add additional categories or customized for your watershed, as appropriate. A score of 10 represents the **lowest** and 1 represents the **highest** threat.*

	Low = L			Medium = M			High = H			
Watershed Threats:								**Subtotal**		______
% Developed Land (DL)	10	9	8	7	6	5	4	3	2	1
	DL < 15% of watershed area. Most in small patches and not large, connected parking lots, multi-lane roadways, large commercial rooftops etc. If impervious cover can be measured, it is < 10% of watershed area. If increasing, rate of change is slow or moderate.			DL = 16-25% of watershed area. Several areas where development is more concentrated, with larger multi-lane roadways, parking lots, etc. Impervious cover generally < 20% of watershed area. If increasing, rate of change is moderate to somewhat rapid.			DL >25% of watershed area. Much of it is in large parking lots, large commercial or industrial buildings, multi-lane roadways, multi-family complexes, etc. Impervious cover generally > 20% of watershed area. If increasing, rate of change is high compared to historic.			
% Agricultural Land (AL)	10	9	8	7	6	5	4	3	2	1
	AL < 15% of watershed area. Most are relatively small operations without a lot of land clearing, confined animals, waste lagoons, altered drainage, etc. If increasing, rate of change is slow or moderate.			AL = 16-30% of watershed area. Many small operations, but also some larger, cleared and cultivated areas, extensive unpaved roads, confined animals, drainage diversions, etc. If increasing, rate of change is slow or moderate.			AL > 30% of watershed. Some larger-scale operations, high animal density, confirmed areas of erosion, many unpaved roads; some confirmed water quality problems at high end of scale. If increasing, rate of change is high compared to historic rates.			
% Recreational Uses (RU)	10	9	8	7	6	5	4	3	2	1
	RU < 15% of watershed area. Most are low-intensity parks with lots of green space. If increasing, rate of change is slow or moderate.			RU = 16-30% of watershed area. Parks and green space plus a few smaller-scale golf courses, dive areas, etc. If increasing, rate of change is slow or moderate.			RU > 30% of watershed OR includes highly-managed golf courses with fert. & pesticide inputs, dive sites with large parking lots, frequent bus traffic, etc. If increasing, high rate of change.			
% Bare Land (BL)	10	9	8	7	6	5	4	3	2	1
	BL < 5% of watershed area. A few active construction sites, but little evidence of badlands, active landslides, etc.			BL = 6-10% of watershed area. More widespread active construction, badlands, and/or landslides on steeper land.			BL > 10% of watershed area OR exposed, bare land is quite evident and active erosion is visible in some of the areas, much of it on steep land.			
% Unpaved Roads (UP)	10	9	8	7	6	5	4	3	2	1
	UP < 1% of watershed area. Few to no unpaved roads. These tend to be on flatter terrain and are generally maintained.			UP = 2-5% of watershed area. Some on steeper land and maintenance may be more infrequent. Some, not widespread, erosion of road surface and/or ditch lines and outfalls is evident. Miles of unpaved road may be increasing at moderate rate.			UP > 5% of watershed area. Poorly-maintained and discharging directly to waterbodies. Sediment plumes and active erosion are visible and somewhat prevalent. Miles of unpaved roads may be increasing at a moderate to high rate.			
Wastewater (WW)	10	9	8	7	6	5	4	3	2	1
	Most of watershed development has central sewage collection and plant is functioning properly; few or no consent orders or enforcement actions with regard to treatment plant, pump stations, collection system overflows, etc.; no groundwater injection			Watershed has a combination of central sewer system and dispersed septic systems. Some issues have been reported. Dry weather field screening reveals occasional indications of sewage in surface water, but generally not continuous or large volumes.			Sewer plant and collection system has numerous problems and possible consent orders. Some areas have partially-functioning septic system or cesspools. Dry weather field screening reveals more frequent indications of sewage in surface water, with some sources appearing to be chronic.			
Solid Waste (SW)	10	9	8	7	6	5	4	3	2	1
	Very infrequent and small illegal dumping or trash problems. Landfills and waste collection is well-managed.			Some occurrence of dump sites and litter along roadsides, some near waterbodies. Landfills and waste collection may have some compliance issues.			Dump sites and litter are fairly widespread and many are close to waterbodies. Landfills and waste collection generate frequent complaints and/or compliance issues.			

	Low = L			Medium = M			High = H			
Streams & Guts (SG)	10	9	8	7	6	5	4	3	2	1
	Most streams or channels are stable; bank erosion is infrequent. > 50% have riparian vegetation along both banks. Beach berm at outlet.			Some streams have significant erosion issues. 30-50% have at least some riparian vegetation. Some have been channelized or modified.			Many have visible erosion during storms and it seems to be getting worse. < 30% has riparian vegetation. Many have been piped or channelized during development. Open outlet.			
Watershed Resiliency:								**Subtotal**		______
Wetlands, Salt Ponds (WT)	10	9	8	7	6	5	4	3	2	1
	WT > 10% of watershed area. Wetlands and/or salt ponds are prevalent and are generally in good condition (e.g., healthy vegetation, little dumping, not filled with sediment).			WT = 5-9% of watershed area. Wetlands and/or salt ponds are infrequent; existing ones are in moderate to poor condition based on disturbances, filling, dumping, erosion, etc.			WT < 5% of watershed area. Wetlands and/or salt ponds tend to be poor or degraded condition or under threat from expanding development.			
Forest & Scrub (FS)	10	9	8	7	6	5	4	3	2	1
	FS> 65% of watershed area, comprising large contiguous areas. Land is generally in good condition with little erosion, and includes vegetated land along streams and guts as well as on steep slopes.			FS = 40-64% of watershed area. Forest/scrub land may be in smaller patches or fragmented by roads and development. Approximately 50% of riparian and steep slope areas have good vegetative cover that is in moderate to good condition.			FS < 40% of watershed area. Majority of riparian and steep slope areas do not have adequate vegetative cover. Existing forest and scrub land is in poor to moderate condition with some erosion, diseases, infestations, etc.			
Watershed Stewardship (WS)	10	9	8	7	6	5	4	3	2	1
	Active community group with ed. programs. Jurisdiction has inspection and enforcement program for environmental regulations. Citizens have knowledge of actions that protect waterways and coral.			Some community activities and education. Jurisdiction inspections and enforcement is somewhat spotty. Citizens may not understand actions that protect waterways.			Generally poor stewardship levels. Jurisdiction inspection and enforcement program is lacking.			
Coral Ecosystem Vulnerability:							**Subtotal**			______
Watershed to Reef Transport	10	9	8	7	6	5	4	3	2	1
	Shoreline/path to reef is long pathway; embayment not enclosed; high flushing rate from tides/wind. Lagoon does not stay turbid after storms. Shoreline mangroves may intercept a portion of watershed sediment.			Shoreline/path to reef is medium pathway; embayment partially enclosed by reef structure; some flushing from tides/wind. Lagoon becomes turbid after storms but clears up in short amount of time.			Shoreline/path to reef is short and direct; embayment is closed and quiescent; flushing is limited. Lagoon stay turbid for relatively long periods after storms.			
Watershed Size	10	9	8	7	6	5	4	3	2	1
	Watershed is < 2 square miles.			Watershed is 2-5 square miles			Watershed is > 5 square miles			
Geology & Slope of Watershed	10	9	8	7	6	5	4	3	2	1
	Watershed generally not steep, and/or is characterized by limestone with few surface water features and reduced runoff.			Watershed has some moderately steep land, and/or has a mix of limestone, volcanic, or other geology resulting in moderate runoff volume.			Watershed has significant steep terrain, and/or is mostly volcanic or another geologic parent material that results in high levels of runoff.			
Climate	10	9	8	7	6	5	4	3	2	1
	Average annual rainfall < 30 inches (especially in steep slope areas); Dry to moderately dry conditions.			Average annual rainfall = 30 -- 60 inches (especially in steep slope areas); Moderate rainfall intensities.			Average annual rainfall > 60 inches, with significant rainfall intensities during wet season (especially in higher elevation, steep slope areas).			
Other:	10	9	8	7	6	5	4	3	2	1
Watershed Threats Matrix:									**Total Score**	______

Table PS4-5. Example of Master Scoring for Threats, Resiliency, and Coral Vulnerability using results from **Table PS4-4;** this can be done using a simple spreadsheet.

	Maximum Score: 1-10	Weight[1]	Weighted Score
Watershed Threats			
Developed Land (DL)	10	2	20
Agricultural Land (AL)	10	1	10
Recreational Uses (RU)	10	1	10
Bare Land (BL)	10	1	10
Unpaved Roads (UP)	10	2	20
Wastewater (WW)	10	1	10
Solid Waste (SW)	10	1	10
Streams & Guts (SG)	10	1	10
Other			
TOTAL THREATS			***100***
Watershed Resiliency			
Wetlands (WT)	10	1	10
Forest & Scrub (FS)	10	1	10
Watershed Stewardship (WS)	10	1	10
Other			
TOTAL RESILIENCY			***30***
Coral Ecosystem Vulnerability			
Watershed to Reef Transport	10	1	10
Watershed Size	10	1	10
Geology & Slope	10	1	10
Climate	10	1	10
Other			
TOTAL VULNERABILITY			***40***
TOTAL MAXIMUM SCORE			**170**

[1] It is optional to assign weights; it allows the watershed team to make value judgments that some factors are more important than others. In this example, developed land and unpaved roads are weighted higher, and this could be determined in Steps 1 and 2.

Best Practice

At this level, you will likely get into some more sophisticated modeling of threats, perhaps using a GIS-based model that also includes some monitoring and calibration. In this situation, the information in **Profile Sheet #6: Watershed Pollutant Budget** may be more relevant to your efforts.

PS#5. Field Assessments

What Is It?

Mapping and GIS are wonderful tools, but cannot substitute for actually seeing the watershed conditions during wet and dry weather. Field assessments are structured, organized ways to get out in the field, collect consistent information, and record and catalogue this information so that it can help with other aspects of the watershed plan, such as the threats assessment (see **Profile Sheet #4**).

Watershed Assessment Levels

	Baseline Level *Focus on key areas; windshield survey.*
	Good Practice *Use or adapt existing field protocols; more comprehensive field assessment of pollution sources.*
	Best Practice *Enhanced field crew training and level of expertise.*

Why Is It Important?

In some ways, field assessments are used to verify information derived from mapping and GIS. However, these assessments almost always generate new information that ends up being vitally important to understanding the priority threats or issues in a watershed.

Getting Started

1. Develop a strategy to make the best use of your field time. Generally, people look forward to going out into the field. However, field work can be time-consuming and expensive. Think about the following:
   - What are the goals and objectives of field assessment work in the overall context of your watershed planning effort? Review the steps of the flowchart and think about how field assessments can complement and support the other steps in the process. List out and prioritize the “watershed places” that should be included: outfalls (places where streams, guts, storm pipes enter the lagoon), streams/guts, wetlands and ponds, badland areas, large commercial/impervious areas, neighborhoods, farms, etc. Your watershed map will be a huge help with this. If you can quantify your target field assessment areas (e.g., # of outfalls, linear miles of stream, acres of developed area, etc.), it will help you figure out the resources needed to conduct the work. Mark all your field target areas on the map.
   - Based on the analysis above, what is the needed level of effort in terms of person-days? Is this available with in-house resources, or do you need to recruit allied agency personnel, a consultant team, interns?

   - What season(s) may be best to conduct field work? There may be advantages to seeing certain areas during the wet season, when sediment plumes or erosion may be more evident (see **Figure PS5-2**). If you are looking for illicit discharges, such as sewage leaks, you will want to go during dry weather.
2. Based on your answers to the above, develop a field plan that lists schedules, personnel, equipment needed, and, importantly a data processing plan – in other words, what will be done with all the information that is generated, which can include field sheets, digital photos, measurements, etc. You will be more satisfied down the road if this process if well organized.
3. Now comes the hard question: do you have the resources to pull it off? Be deliberate about picking a Baseline, Good, or Best practice level, as described below. It is unlikely that personnel can dedicate 100% of their time to the effort, so it may be necessary to break tasks into chunks that can be performed in half-day increments. The field work can also be phased as resources become available.

Baseline Level

Baseline field assessments rely on watershed maps to identify and focus on areas of concern. Conduct a windshield tour, hopefully during both dry and wet weather. Pop out of the car to look at selected outfalls, stream/gut crossings, commercial areas, etc. Take lots of digital photos. Mark observations on a copy of your watershed map (or "field" maps that focus in on smaller areas). You may also want to create some simple sketches of particular areas or possible restoration ideas. Depending on the skill level of the staff, use some of the field sheets noted in the Good Practice Level section. Maintain a field tracking sheet (or digital version on your phone or tablet) to record dates, personnel making observations, notes on observations, and photo numbers.

Good Practice

At the Good Practice Level, additional investigations can be added to the field assessments. Use or adapt available field forms for outfalls, stream corridors, or land use assessments. **Figure PS5-1** illustrates various watershed investigations you might engage in and the pollution sources they are likely to turn up. **Table PS5-1** provides a list of available "off-the-shelf" field protocols and field sheets. Many protocols are developed for non-island conditions, so some customization is advisable. The best protocols prompt the observer to not only identify problem areas, but also to score the severity of problems and suggest restoration options. If not already done, include dry AND wet weather observations.

Table PS5-2 provides a quick look-up table for linking dry and wet weather observations of water conditions with probable sources or places to look in the watershed. **Table PS5-3** lists typical equipment to take along on your field reconnaissance.

Best Practice

This level will include a broader set of assessments, with more focus on identifying and collecting field data for restoration options. This will involve more extensive training for field personnel and likely require onsite meetings with facility managers, property owners, and other knowledgeable stakeholders. Another feature of this level is the customization of the field protocols and forms to adapt to your watershed conditions.

Figure PS5-1. Examples of Various Watershed Field Investigations

Evaluate condition of unpaved roads and potential for sediment delivery to bay or lagoon.

Map, inspect, and evaluate existing stormwater BMPs; is there potential to improve performance or add an amenity? Share data with the responsible agency.

Map, verify, and inspect piped drainage network. Smell for sewage. Check outfalls. Share data with Public Works Department.

Look for failing septic systems or evidence of sanitary sewer overflows (toilet paper and fecal material). Report to proper agency.

Walk streams and map channel alterations, buffer impacts, trash dumping, outfalls, habitat and water quality conditions.

Evaluate badlands, landslides, wetlands, or other natural areas for restoration or conservation opportunities.

Look for washwater, dumpster juice, automotive products, or other discharges entering the drainage system from residential and commercial areas during dry weather. Identify what the behaviors are that need to be targeted for education to reduce these sources of pollution.

Evaluate construction sites, quarries, or other areas where erosion control measures should be used to prevent offsite turbid discharges.

During wet weather, you may observe tremendous sediment plumes from areas with inadequate vegetation or construction activities.

Look at all road crossings/culverts for infrastructure maintenance and repair needs. Share data with Public Works Department.

Evaluate coastal shoreline erosion and infrastructure vulnerability. Where does it make sense to stabilize or retreat?

Explore ways to retrofit (insert stormwater treatment) at large parking lots or other expanses of impervious cover.

Investigate potential stormwater retrofit sites during storms to see drainage patterns and problems.

Check out agricultural areas for erosion issues, nutrient load potential, aquatic buffers, farm pond sedimentation, and other issues and opportunities.

Investigate issues with confined animal feeding operations.

Collect a water sample from a storm sewer manhole to test for pollutants during an illicit discharge detection and elimination (IDDE) investigation.

Use portable ammonia meters to test samples; ammonia may indicate sewage contamination.

Evaluate dry weather flows at outfalls should for sewage or other non-stormwater flow.

Check for vegetated buffer encroachment, bank erosion, wash water or septic system discharges, and other common residential stream impairments.

Look for retrofit options at large areas of unmanaged impervious cover.

Assess wetlands and ponds that provide watershed resiliency functions; what is their quality and sediment depositional history?

Table PS5-1. Available Protocols & Field Forms for Various Watershed Issues

Watershed Issue	Available Field Protocols & Forms
Outfalls, illicit discharges, dry weather discharge -- sewage, oils, detergents	Outfall Reconnaissance Inventory (ORI), Illicit Discharge Detection & Elimination (Brown et al., 2004) http://www.cwp.org/illicit-discharge-detection-and-elimination/
Streams & Guts: erosion, blockages, riparian conditions, trash, habitat, etc.	• Unified Stream Assessment (Kitchell and Schueler, 2005) http://owl.cwp.org/?s=unified+stream+assessment • Various methods outlined in (EPA, 2008, Section 6.5): physical, habitat, geomorphic, biological/habitat, etc. https://www.epa.gov/nps/handbook-developing-watershed-plans-restore-and-protect-our-waters • Stream repair Investigation form (CWP, 2004) http://owl.cwp.org/mdocs-posts/sri_field_form/
Unpaved roads: erosion, poor management	• Maine Gravel Road Score sheet www.maine.gov/dep/land/watershed/camp/road/ • *Soil and Water Road Condition Index – Field Guide to dirt road assessment* http://www.fs.fed.us/eng/php/library_card.php?p_num=0877%201806P • PASER Visual Survey https://www.ctt.mtu.edu/sites/default/files/resources/paser/gravelpaser.pdf • PSU Dirty Dozen Criteria www.dirtandgravel.psu.edu/sites/default/files/.../Assessment_DirtyDozen.pdf • GIS-based Unpaved Road Assessment http://mtri.org/unpaved/
Upland areas: impervious cover, uncontrolled stormwater, pollution hotspots, retrofits, source control	• Unified Subwatershed and Site Reconnaissance (Wright et al., 2005) http://owl.cwp.org/mdocs-posts/urban-subwatershed-restoration-manual-series-manual-11/ • Manual3: Urban Stormwater Retrofit Practices Manual (Schueler et al., 2007) http://owl.cwp.org/mdocs-posts/urban-subwatershed-restoration-manual-series-manual-3/ • Retrofit inventory for Volunteers (CWP, 2010) http://owl.cwp.org/mdocs-posts/cwp_2010_modified_rri_form/ • Municipal Pollution Prevention and Good Housekeeping (Novotney and Winer, 2008) http://owl.cwp.org/mdocs-posts/urban-subwatershed-restoration-manual-series-manual-9/
Wetlands, reservoirs: sedimentation, quality of vegetation	• CNMI Rapid Watershed Assessment (2015) www.cnmilaw.org/images/Wiki-Images/rapidA.pdf • http://www.usace.army.mil/Portals/2/docs/civilworks/regulatory/reg_supp/HPI_Peer_Rev.pdf. • Wetland assessment for Australian Wetlands www.wetlandcare.com.au/index.php/download_file/view/962/369/ • Wetlands at risk protection tool (WARTP) simple method field form http://www.wetlandprotection.org/images/stories/PDFs/WARPT_Simple_Method_Field_Form_060111.pdf
Agricultural areas: land clearing, erosion, certain pollutants	• See NRCS for local inventory and conservation BMP assessments. https://www.nrcs.usda.gov/wps/portal/nrcs/site/pia/home/ or https://www.nrcs.usda.gov/wps/portal/nrcs/site/pr/home/ • Your Farm and Water Quality https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid...ext=pdf

Table PS5-2. Potential Pollution Sources for Various Wet & Dry Weather Observations of Waterways

Field -- WET	Field -- DRY	Potential Source	What else to look for?
Turbid/brown, red/muddy, or possibly greyish	Turbid for days after storm, then clearer as things settle	Active construction; stormwater from urban land; stormwater from industrial operations, such as quarries; stormwater from agriculture	Dirt/sediment accumulated or dirt stains in storm drains, on parking lots, in guts and channels or in stockpiles. Agricultural fields that are cleared or grazed with exposed soil. Poorly-managed unpaved roads.
Sewage odor, especially turbid water	Sewage odor, milky, whitish color and/or scummy stains; higher flows than expected	Sewage discharges from straight pipes; failing septic systems, wastewater treatment facilities, pump stations, animal waste lagoons; sanitary sewer overflows	Active utility work, residential or commercial districts with old systems, small package wastewater treatment plants, sewer manholes near streams or storm pipes, concentrations of animals, animal waste lagoons that may not have adequate capacity
Milky white color that permeates throughout the water; no sewage odor		Paint, lime; swimming pool filter backwash; concrete wash-out; stone cutting	Commercial or industrial sites, outdoor activities or materials storage that is exposed to rainfall, concrete trucks washing out on roadways or into storm drains, commercial swimming pool maintenance
	Suds (persistent, bright colored); sweet, fruity, detergent, or chlorine smells	Washing activities that include detergents	Car washes, car dealerships and rental companies, fire stations, fleet maintenance areas, and parking lots with mobile car washes. If there is a chlorine odor, but no suds (water is clear), source could be draining of swimming pools or water line breaks
Some oily sheen or slight oil or petroleum smell	Thick or swirling oily sheen; oil or petroleum smell; fluorescent green	Petroleum leaks or spills, leaking cars/trucks (fluorescent green = antifreeze), fuel storage or pumping at industrial or agricultural operations	Vehicle maintenance or fueling areas, petroleum storage tanks that may be leaking. Greasy or oil discharge may also indicate improper management of restaurant grease traps.
Brown or green plumes after rainfall	Chlorine or fertilizer smell; algae growth in path of water	Fertilizer runoff, runoff from landscape maintenance areas, fertilized yards, agricultural fields	Bright green lawns, landscape maintenance areas, irrigated golf courses, fertilized agricultural fields, or other irrigated areas
Debris, trash washing down guts, streams, channels	Debris, trash, chemical or oil containers piling up in guts, streams, channels	Dumping, poor solid waste management	Dump sites, poorly-managed or uncovered dumpsters, construction debris discarded from construction, industrial, or agricultural operations
Red, purple, blue, black; chemical or solvent smell, sharp, pungent		Hazardous waste or chemicals	Commercial, industrial, or intensive agricultural sites, poorly-managed waste areas, recent accidents or spills

Table PS5-3. Equipment to Take for Typical Field Investigations

Safety

- Cell phone w/emergency contact #s
- Safety vest
- Steel-toe boots if pulling manholes or other heavy objects
- Safety cones if working around traffic
- First-aid kit
- Sun block
- Flashlight (can also be used to look into manholes)

Maps & Forms

- Watershed map (extra field copies)
- GIS data on phone or hand-held device, if available
- GPS if available and road map
- Field forms
- Authorization letters to enter private property
- Photo IDs and business card
- Clipboards, pencils, sharpies

Equipment

- Manhole puller
- 100-foot tape measure
- Pocket rod and hand level
- Digital camera
- Soil probe or auger
- If taking water samples (e.g., illicit discharge investigations):
    - Disposable gloves
    - Safety goggles
    - Clean sample bottles
    - Labels and sharpies
    - Hand sanitizer
    - Cooler and cold packs if samples must be preserved
    - Rubber boots

Note: *Not all of this equipment may be necessary for every field exercise, as it depends on the types of activities being conducted.*

References & Resources

See Table PS5-1.

Brown, E., Caraco, D., and B. Pitt. 2004. Illicit Discharge Detection and Elimination: A Guidance Manual for Program Development and Technical Assessments. Center for Watershed Protection (CWP) and University of Alabama.

EPA. 2008. Handbook for Developing Watershed Plans to Restore and Protect Our Waters. Prepared by Tetra Tech. EPA 841-B-08-002.

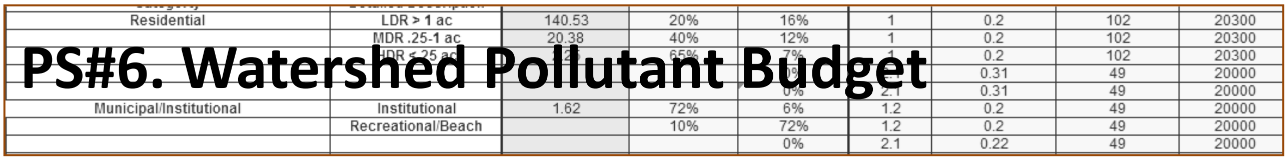
Kitchell and Schueler, 2005. Manual 10:Unified Stream Assessment: A User’s Manual. Urban Subwatershed Restoration Manual Series. CWP, Ellicott City, MD.

Novotney, M., Winer,R. 2008. Manual 9: Municipal Pollution Prevention/Good Housekeeping Practices. Urban Subwatershed Restoration Manual Series. CWP, Ellicott City, MD.

Schueler, T., Hirschman, D., Novotney, M., Zielinski,J. 2007. Manual 3: Urban Stormwater Retrofit Practices Manual. Urban Subwatershed Restoration Manual Series. CWP, Ellicott City, MD.

Wright, T., Swann, C., Cappiella, K., Schueler, T. 2005. Manual 11: Unified Subwatershed and Site Reconnaissance. Urban Subwatershed Restoration Manual Series. CWP, Ellicott City, MD.

PS#6. Watershed Pollutant Budget



Residential	LDR > 1 ac	140.53	20%	16%	1	0.2	102	20300
	MDR .25-1 ac	20.38	40%	12%	1	0.2	102	20300
	[illegible]	[illegible]	65%	7%	1	0.2	102	20300
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.31	49	20000
	[illegible]	[illegible]	[illegible]	0%	2.1	0.31	49	20000
Municipal/Institutional	Institutional	1.62	72%	6%	1.2	0.2	49	20000
	Recreational/Beach		10%	72%	1.2	0.2	49	20000
				0%	2.1	0.22	49	20000

What Is It?

This refers to a method to estimate watershed pollutant loads using available watershed information (e.g. annual rainfall, land use acres, etc). This analysis is part of EPA a-i watershed planning criteria, but can be performed using simple or complicated methods.

Why Is It Important?

A watershed pollutant budget can be used to: (1) identify potential contributors to watershed pollutant loads; (2) compare the relative contributions of sources or subwatersheds; (3) establish baseline loads and reduction targets; and (4) track changes through time. This analysis can help managers prioritize the most promising restoration strategies.

Watershed Assessment Levels

	Baseline Level *Simple Method that uses impervious cover as an indicator of watershed health*
	Good Practice *More quantitative approach using simple spreadsheet tools to identify pollutant concentrations, loads, and yields.*
	Best Practice *More sophisticated, calibrated models to better simulate pollutant loading and threats.*

Getting Started

1. Confer with your partners to determine how complex of a watershed model you want to produce. This decision should be based on the extent and quality of available input data, your ability to get better data, in house capacity to run a model, and how accurate the output information really needs to be. For most watershed planning projects, relative comparisons rather than absolute loads may be sufficient.
2. You should already have the land use area breakdowns and a completed watershed threats matrix (**Profile Sheet #4**). You'll need to know the annual rainfall and select pollutants of concern of most interest for your watershed. If previous models have been done in the watershed or a nearby watershed, consider using consistent input information.

Understanding Pollutant Load Calculation Methods

Before launching into descriptions of each level of practice, it is important to review some basic steps in the pollutant load calculation method:

1. Identify land use/cover categories: It will be necessary to calculate (or at least approximate) total acres of each land use for your watershed, preferably accompanied by polygons on a map, such as would be derived through GIS (see **Profile Sheet #1**).

2. Select one or more "target pollutants": These will be the pollutants of most concern for your watershed AND for which data are generally available. For most coral watersheds, these will likely be nutrients (nitrogen and phosphorus), sediment, and perhaps bacteria (E. coli or *Enterococcus*), although data may be more difficult to obtain for the latter.

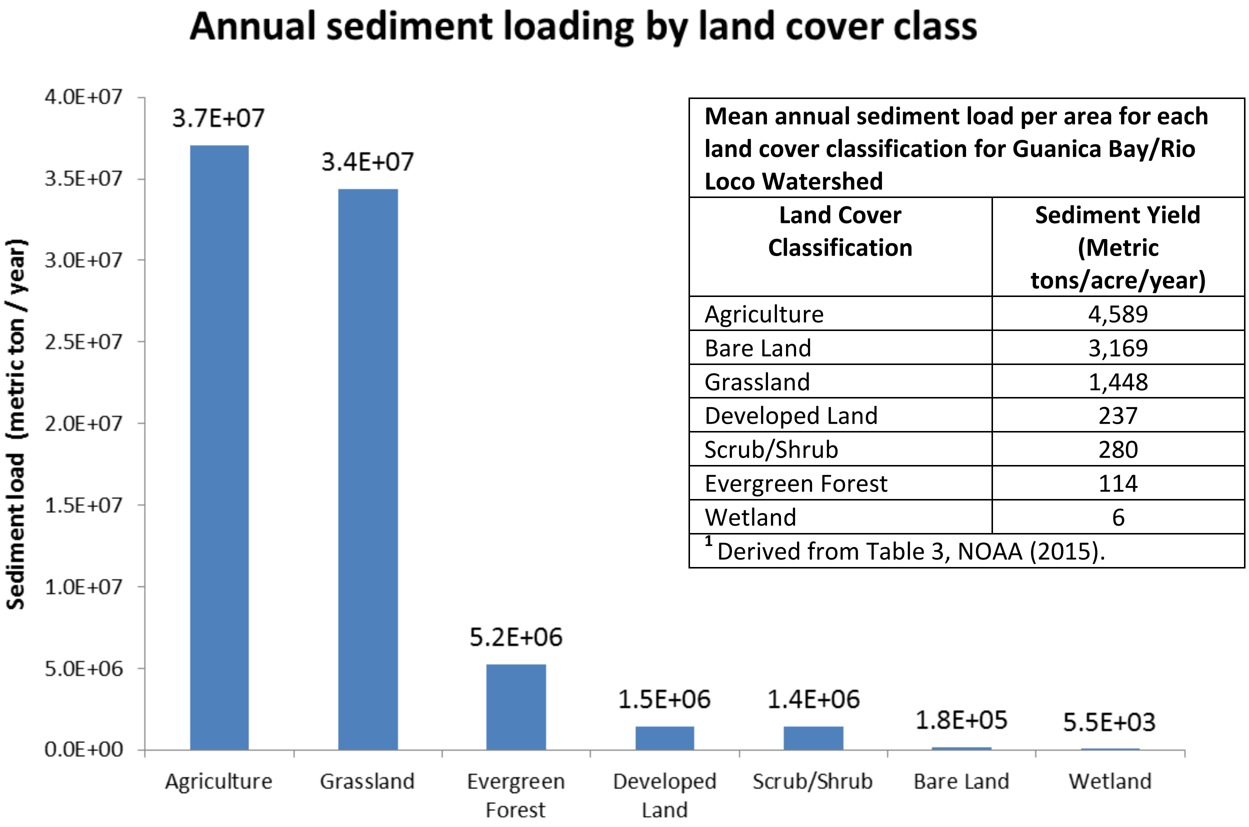
3. Assign representative concentrations, loads, and/or yields for each land use category for the target pollutant(s). Here it is necessary to make several important distinctions. Data may be available for various land use categories for the following:

   - Event Mean Concentrations (EMCs): EMCs represent the average pollutant concentration over the course of many storm events. EMCs are usually expressed as milligrams/liter (mg/L), or, for bacteria, most probable number (MPN/100 ml) or similar.
   - Pollutant Loading: The load of a particular pollutant is the total amount that is produced by the watershed, usually on an annual basis. As such, the load is calculated as: concentration x volume. Load can be expressed in pounds or metric tons. Most spreadsheet tools automate the process of calculating loads using land cover, annual rainfall, and sometimes factors that describe how efficiently water and pollutants are conveyed in the watershed.
   - Pollutant Yield: The pollutant yield is simply taking load values and standardizing them per acre. As such yields may be expressed as pounds/acre/year or metric tons/acre/year. Understanding yields can help prioritize watershed threats, as some land covers may have a lot of acreage in the watershed, but a relatively low yield. Alternately, some covers may not have high acreage numbers, but each acre is contributing a disproportionate load of pollutants. As an example, **Figure PS6-1** illustrates how different priorities can be derived from examining pollutant loads and yields.

Baseline Level

As luck would have it, there is a "Simple Method," although there is still some basic math involved. At this level, you can quantify planning-level pollutant loads, but this can be done using straight-forward look-up values and the Simple Method equation. The Simple Method was developed based on consistent findings about the link between impervious cover and the health of receiving waterbodies. This relationship has been investigated and confirmed by various researchers (Schueler et al., 2009). The Simple Method uses impervious cover, annual rainfall, and typical pollutant concentrations in urban stormwater to calculate pollutant loads for relatively small watersheds (2 – 20 square miles).

Figure PS6-1. The graph show total load in metrics tons/year for each land cover category. From the graph, it appears that agriculture and grassland are the top priorities. However, when the loads are converted to yields (metric tons/acre/year), as shown in the table to the right, bare land rises as a priority because its yield is more than double that of grassland (NOAA, 2015, Figure 2 and Table 3, using OpenNSPECT model).


Annual sediment loading by land cover class

Mean annual sediment load per area for each land cover classification for Guanica Bay/Rio Loco Watershed	
Land Cover Classification	**Sediment Yield (Metric tons/acre/year)**
Agriculture	4,589
Bare Land	3,169
Grassland	1,448
Developed Land	237
Scrub/Shrub	280
Evergreen Forest	114
Wetland	6

[1] Derived from Table 3, NOAA (2015).

Table PS6-1 outlines the equation and factors for the Simple Method, and provides references for some of the input data (some of which is particular to island locations). The best way to proceed with the Simple Method is as follows:

1. Determine the land use categories and the land area in each category (you should have done this is Step 1 of the Tool already; see **Profile Sheet #1**).
2. Determine your target pollutants. The Simple Method is best to use with Total Phosphorus (TP), Total Nitrogen (TN), and Total Suspended Solids (TSS). A more complex equation is used for bacteria.
3. If you have access to GIS that can measure impervious cover directly, that is the most accurate method. However, you can also approximate impervious cover by selecting from the range of values in **Table PS6-2** for various land uses (Note that impervious cover may not be the best pollutant load measure for watersheds that are dominated by agricultural or more rural land uses or even some industrial watersheds where one or two high intensity sites -- e.g., mines, fueling and maintenance operations -- may contribute disproportionate loads. It is most relevant for developed or developing watersheds).

4. Use local data or look up values for average annual rainfall (P) and Event Mean Concentrations (C) for your target pollutants. **Table PS6-3** shows default ranges of EMCs that can be used for various land use/cover categories. These values have been derived from studies in several island and coral watersheds. The National Stormwater Quality Database can be a good general reference, however, for regional EMC values (Maestra et al., 2005).
5. Build a simple spreadsheet that allows you to enter your input data and calculate the resulting pollutant loads. See **Table PS6-4** for an example spreadsheet output for a theoretical small watershed (1 square mile) using four land use categories. Note that the calculation is completed separately for each category, and then the loads are added together. The table shows the calculation for TN, but a similar method can be applied to TP and TSS.

Table PS6-1: Pollutant Load Export Equation (adapted from Schueler et al., 2007)

Equation & Factors	Explanation & References
Simple Method Equation L = [(P)(Pj)(Rv)/(12)](C)(A)(2.72)	Solve for each land use category in your watershed and then add the results for total load for the selected pollutants.
L = Average annual pollutant load (pounds)	This is the value you are solving for using the Simple Method. As stated above, you can solve for each land use category.
P = Average annual rainfall depth (inches)	Use local (jurisdiction) data or use the charts in the following reference for U.S. jurisdictions and several other islands: *Stormwater Management in Pacific and Caribbean Islands: A Practitioner's Guide to Implementing LID, Appendix A: Precipitation Data Reference Guide* (Horsley Witten Group & CWP, 2013) https://www.coris.noaa.gov/activities/stormwater_lid/
P_j = Fraction of rainfall events that produce runoff	This accounts for small storms where the water is stored in depressions, evaporates, or soaks into the ground. In the U.S. Mid-Atlantic, a value of 0.9 is used (Schueler et al., 2007). In tropical climates with higher evaporation rates, select a value of 0.8 to 0.9.
R_v = Runoff coefficient, which expresses the fraction of rainfall that is converted into runoff $R_v = 0.05 + 0.009(I)$	I = amount of impervious cover, expressed as a whole number. For instance, if the watershed has an impervious cover of 25%, I = 25. See **Table PS6-2** for typical impervious cover percentages of various land use categories. For your watershed, select an appropriate value from the range, based on the "intensity" of the land use (e.g., commercial "big box" stores with large parking lots would be at the upper end of the commercial land use range, and small-scale, dispersed commercial sites with intervening green space would be at the low end).
C = Event mean concentration of the pollutant in urban runoff (mg/l)	**Table PS6-3** provides EMCs for TP, TN, and TSS for a variety of land uses, largely derived from island environments. These are presented in ranges of values; select an appropriate number from the range or simply use the mean value in the range.
A = Area of the contributing drainage or land use type (acres)	This is the area of each land use category in your watershed.

Note: 12 and 2.72 are unit conversion factors

Caveats with the Simple Method Approach

It is important to be aware that, at this Baseline Level, the Simple Method is not like more sophisticated models that account for characteristics such as slope, watershed conveyances, very specific land covers, and other watershed dynamics.

Another caveat is to use caution when simply relying on land cover to prioritize the most important pollution sources. Sometimes a land use can represent a very small proportion of the watershed, but have a disproportionate contribution to pollutant loads. Available data may not be able to reveal these "outliers," but they are certainly important to identify when setting priorities. These uses may include poorly-managed unpaved roads, inadequate wastewater treatment, illicit discharges, excessive recreational use, and other uses or sources. For instance, some researchers have indicated that unpaved roads may contribute 90% or more of sediment loading and over 60% of total watershed discharge for small storms while only comprising a small percentage of the land surface (1% or less) (Ramos-Scharron and Thomaz, 2016; Ramos-Scharron and LaFevor, 2015).

That said, land cover, including impervious cover, is a primary and widely-used watershed indicator for pollutant loading and is generally easy to measure. Especially at this Baseline Level, it can be considered a solid approach for many applications. However, if your watershed conditions and/or modelling capacity demand a more sophisticated approach, refer to the Good and Best Practice level descriptions below in this profile sheet.

Good Practice Level

This is a somewhat more sophisticated approach that still uses a spreadsheet-based tool to derive all the land use-based pollutant loads. One such tool that has been applied to island watersheds is the ***Watershed Treatment Model (WTM)*** (Caraco, 2013; http://owl.cwp.org/mdocs-posts/watershed-treatment-model-wtm-2013/).

The WTM allows the user to start with just land use sources, and then add on additional sources as more watershed information becomes available (e.g. wastewater discharges, stream erosion, boat discharges, livestock). The WTM also allows for the estimation of future land use conditions, accounting of existing BMPs, and testing of load reduction potential under restoration options. The WTM (**Figure PS6-2**) can calculate watershed loads for TN, TP, TSS, and, in some applications, fecal coliform bacteria. It also can be used to estimate annual runoff volumes.

Another resource in addition to the WTM is NOAA's *Digital Coast, How to Use Land Cover Data as a Water Quality Indicator:* https://coast.noaa.gov/digitalcoast/training/water-quality-indicator.html. This resource outlines a six-step process and links to several data sources, tools, and other resources that can help with the analysis. One such data source is the *Coastal Change Analysis Program* (C-CAP). You should check with NOAA representatives to ensure that the scale of these data are appropriate to use for your watershed.

Table PS6-2. Impervious Cover (IC) Look-Up Values for Various Land Use Type; use to compute R_v in **Table PS6-1**

Typical Land Use Category	IC Coefficient Ranges in Finney et al. (2008)	IC Coefficient in WTM (2013) Default	Example coefficients used recently in British Virgin Islands loading models by Horsley Witten Group
Roads	50-100%	80%	100% paved, 90% unpaved
Commercial	35-85%	72%	72%
Industrial	-	53%	None in watershed
Institutional	-	-	72%
High density residential	35-65%	33% (44% multifamily)	65%
Med density residential	20-38%	21%	40%
Low density residential	5-20%	12%	20%
Agricultural land	2-7%	0%	None in watershed
Recreational	-	-	10%
Open lands	3%	-	None in watershed
Forested land*	0-7%	-	0% for vacant land

Table PS6-3. Event Mean Concentrations (EMCs) for Various Land Use Categories[1]

Land Use[2]	Total Nitrogen EMC (mg/L)	Total Phosphorus EMC (mg/L)	Total Suspended Solids EMC (mg/L)	Fecal Coliform (MPN/100ml)
Low Intensity Residential	1.00 – 1.77	0.18 – 0.22	19	3,220 -- 20,300
Med Intensity Res., Com., Ind.	1.87 – 2.29	0.22 -- 0.30	27	
High Intensity Res., Com., Ind.	2.10 – 2.22	0.47 -- 0.50	56 -- 102	
Construction, Bare Land	1.00	0.12 – 0.2	70 -- 680	
Pasture/Hay	2.48 -- 3.30	0.48 -- 0.62	55	39
Row Crops, Cultivated Land	2.46 – 2.68	0.42 -- 0.49	107	
Institutional	1.2 -- 1.51	0.18 – 0.22	49	20,000
Recreation -- Golf Courses	1.87	0.30		20,000
Recreation -- Parks, etc.	1.2 -- 1.51	0.18 – 0.22	49	
Roads -- Paved	1.2 -- 1.37	0.16 -- 0.17	36	13,700
Roads -- Unpaved	1.2 – 1.37	0.24	2,895	13,700
Mining	1.18	0.15		
Scrub/Shrub	1.16 – 1.25	0.05 -- 0.10	11	
Open	1.05 – 1.25	0.05 – 0.06	11	
Wetland (various types)	1.10 -- 1.50	0.10 – 0.20	11	
Unconsolidated Shore, Beach	0.97 – 1.2	0.12 – 0.22	49 -- 70	20,000
Upland Woods, Mixed Forest	1.00 – 1.25	0.03 – 0.05	11	

[1] EMCs from various sources applied to island/coral environments (note that some source data were derived from national data): (1) NSQD (from Maestra et al., 2005); (2) Coral Bay, St. John (CBCC,2014) using Watershed Treatment Model (WTM); (3) Applied Ecology, Spatial Watershed Iterative Loading (SWIL) Model Methodology Report (2015), TMDL Model for FL; and (4) OpenNSPECT default values for Wai'anae region of Oahu, Hawaii (NOAA, 2014). For application, the lower range may apply to areas with lower rainfall, shallower slopes, good soils for infiltration, and/or other conditions that would lead to lower loading rates. Higher range may apply to areas with higher rainfall, steeper slopes, poor soils, and/or other conditions that would lead to higher loading rates.

[2] Land use categories are an amalgamation of the sources listed above. Each source uses somewhat different land use or land cover categories; users interested in replicating a certain method should consult the appropriate reference. Not all categories from each reference are included in this table.

Table PF6-4. Example Simple Method Calculation Chart; a spreadsheet can be used to compute these values

Land Use	Impervious (%)[a]	Rv[b]	C (mg/L)[c]	A (acres)	TN Load (lbs/year)[d]
Low Intensity Residential	15	0.19	1.40	150	225
Medium Intensity Commercial	60	0.59	2.08	75	532
Pasture	4	0.09	2.90	300	432
Golf Course	10	0.14	1.87	115	174
TOTAL				640	1363

Constants from Simple Method (assumed values for this example):

P = Average Annual Rainfall = 30 inches

P_j = Fraction of rainfall events that produce runoff = 0.85; Constants = 12 and 2.72

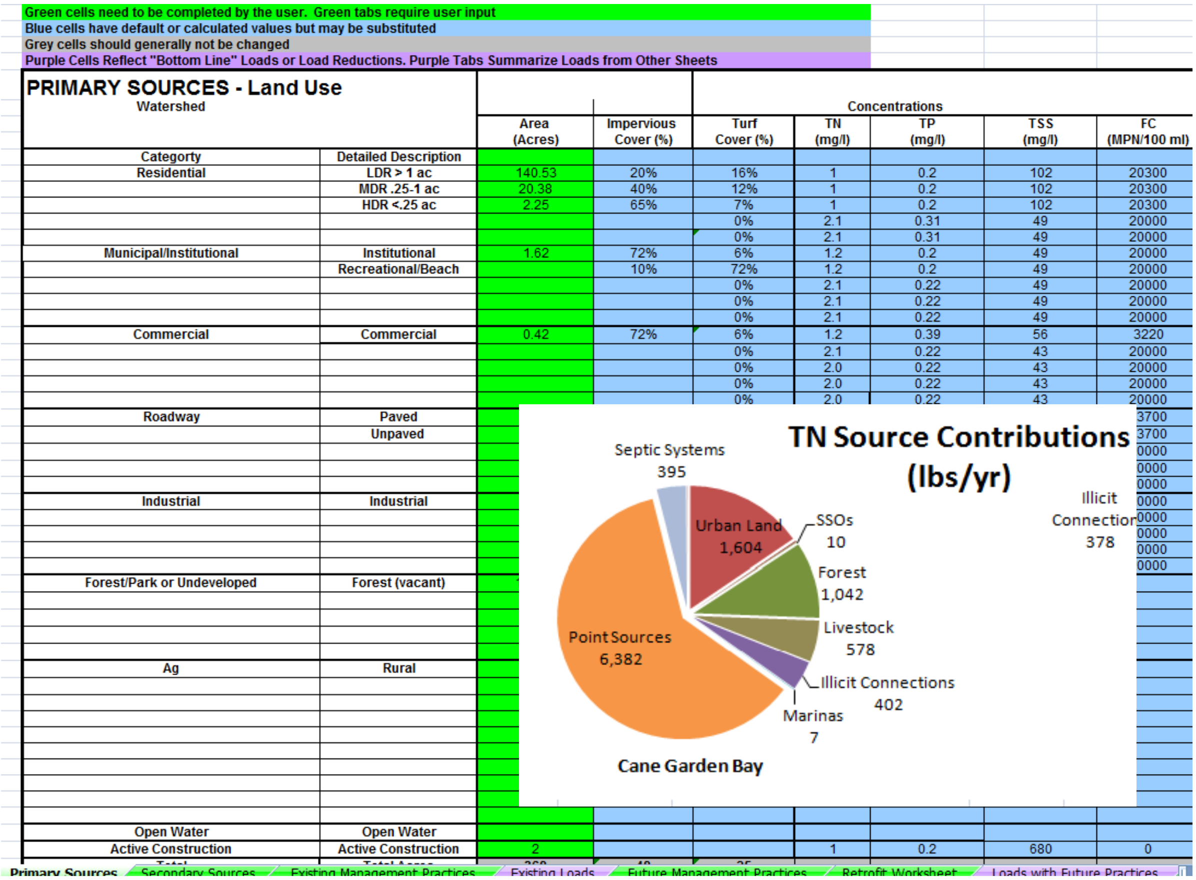
[a] Average impervious cover values derived from **Table PF6-2.**

[b] Rv = 0.05 + 0.009(I), where I = percent impervious cover as a whole number.

[c] Event Mean Concentration (C) values derived from **Table PF6-4.**

[d] Load = [(P)(Pj)(Rv)/(12)](C)(A)(2.72)

Figure PF6-2. The WTM is a simple spreadsheet watershed pollutant loading model.



Green cells need to be completed by the user. Green tabs require user input

Blue cells have default or calculated values but may be substituted

Grey cells should generally not be changed

Purple Cells Reflect "Bottom Line" Loads or Load Reductions. Purple Tabs Summarize Loads from Other Sheets

PRIMARY SOURCES - Land Use

Watershed

				Concentrations				
		Area (Acres)	Impervious Cover (%)	Turf Cover (%)	TN (mg/l)	TP (mg/l)	TSS (mg/l)	FC (MPN/100 ml)
Categorty	Detailed Description							
Residential	LDR > 1 ac	140.53	20%	16%	1	0.2	102	20300
	MDR .25-1 ac	20.38	40%	12%	1	0.2	102	20300
	HDR <.25 ac	2.25	65%	7%	1	0.2	102	20300
				0%	2.1	0.31	49	20000
				0%	2.1	0.31	49	20000
Municipal/Institutional	Institutional	1.62	72%	6%	1.2	0.2	49	20000
	Recreational/Beach		10%	72%	1.2	0.2	49	20000
				0%	2.1	0.22	49	20000
				0%	2.1	0.22	49	20000
				0%	2.1	0.22	49	20000
Commercial	Commercial	0.42	72%	6%	1.2	0.39	56	3220
				0%	2.1	0.22	43	20000
				0%	2.0	0.22	43	20000
				0%	2.0	0.22	43	20000
				0%	2.0	0.22	43	20000
Roadway	Paved							3700
	Unpaved							3700
								0000
								0000
								0000
Industrial	Industrial							0000
								0000
								0000
								0000
								0000
Forest/Park or Undeveloped	Forest (vacant)							
Ag	Rural							
Open Water	Open Water							
Active Construction	Active Construction	2			1	0.2	680	0

Best Practice

In some cases, a more complex approach is desired involving use of more data-intensive models calibrated to measured loads, integrated with GIS, and used to optimize restoration scenarios. Various watershed models are available for watersheds that have the requisite data inputs and know-how to run the models. It is beyond the scope of this profile sheet to describe all the available models. There are many that have been used, some through academic institutions, government agencies, and/or Total Maximum Daily Load (TMDL) studies. Some models approximate the average load of pollutants on an annual basis; and others simulate flows and pollutants from particular storm events. In general, these models require a high level of data and technical expertise, and would be applicable for watersheds that have adequate funding to undertake such an effort. **Table PF6-5** provides a sampling of models that have been developed in tropical or coral locations. The table is in no way exhaustive, but will give you a sense of available methods.

Table PF6-5. Sampling of Available Models Used in Tropical Watersheds

Practice level	Model	Reference	Pollutants of Concern	Comment on Model Selection
🪸 ⭐	Watershed Treatment Model (WTM)	Caraco, 2013	TN, TP, TSS, bacteria	Not spatially-based and doesn't account for slope; free, relatively user-friendly excel spreadsheet; can update input parameters. Also described in Good Practice Level section. http://owl.cwp.org; search for Watershed Treatment Model
⭐	Nonpoint Source Pollution and Erosion Comparison Tool (Open NSPECT)	NOAA, Coastal Services Center, 2014	Sediment, TN, TP, lead, zinc	Appropriate for planning level estimates; doesn't model time or sophisticated flow (e.g. groundwater) https://coast.noaa.gov/digitalcoast/tools/opennspect.html
🐟	Hydrology, Oceanography, Meteorology, Ecology (HOME)	Richmond *et al.*, 2004	Sediment	Links to coral health based on watershed inputs, hydrology, mangroves, wave energy, etc. Applied to watersheds in Guam and Palau. https://cfpub.epa.gov/ncer_abstracts/index.cfm/fuseaction/display.abstractDetail/abstract/587/report/F
	STJ-EROS: GIS-based sediment budget model (St. John, USVI)	Ramos-Scharron & MacDonald. 2006.	TSS	High data input needs
	Spatial Watershed Iterative Loading (SWIL) (Brevard County, FL)	Applied Ecology. 2015.	TP, TN	Does not seem to have widespread application for coral watersheds outside of FLA
	Soil and Water Assessment Tool (SWAT Model) (Jamaica)	Grey, et al. 2014.	Streamflow, runoff	GIS interface. Described in paper at http://swat.tamu.edu/
	Annualized Non-Point Source Pollution Model (AnnAGNPS) (Island of Kauai, HI)	Polyakov, et al. 2007.	Sediment, TN, TP, organic carbon, pesticides	Described in paper and on website. www.nrcs.usda.gov/wps/portal/nrcs/detailfull/null/?cid=stelprdb1042468

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PS#7. Identifying Restoration Options

Watershed Assessment Levels

	Baseline Level Confer with experts to identify tailored “tool box” of structural + non-structural options; confirm feasibility of practices at each site; develop 10% design for all projects and more advanced design for highest priorities.
	Good Practice More technical assistance needed to develop site specific designs; 30% design for candidate projects or high priority; simple quantitative methods to assess benefits and planning-level costs.
	Best Practice High diversity of structural and non-structural practices; more developed design plans (up to 70% design) for permit/shovel ready; performance monitoring design component included.

What Is It?

You may already have started identifying potential restoration opportunities during initial field assessments (see **Profile Sheet #5**). From a wide range of structural and non-structural options, how do you decide which solutions work best to address a specific watershed issue? Selection of restoration options will require more group discussion, additional site visits, and some technical expertise to conceptualize feasible designs and plan for implementation.

Why Is It Important?

The meat of the watershed plan is identifying real and feasible restoration projects/actions. The good news, is that there is no right or wrong answer to restoration, but some alternatives will be better than others based on your watershed threats and restoration goals. While it helps to have a general sense of what the common approaches are to reducing sediment or other loads from various watershed land uses, this is the time when creative, out-of-the-box thinking can pay off. You don’t have to be an engineer to envision restoration options, but you do need to have some level of experience to differentiate between the feasible and the impractical, and to know who to call for needed technical support.

Getting Started

1. Review the threats assessment from Step 3 (and **Profile Sheet #4**) to determine key pollutants of concern and list the types of restoration options to address issues seen in the field during Step 2 (**Profile Sheet #5**). Compile any restoration recommendations that came from your initial field investigations. Table **PS7-2** offers some suggested actions to address common watershed issues.
2. Based on the anticipated list of restoration options, evaluate the level of expertise needed to work with planning partners to advance the design.

3. Determine what level of project identification and design development your planning effort can provide in house versus hiring consultants or looking to other partners for support. At a minimum, develop concept sketches and narrative description for all restoration projects.
4. Revisit appropriate field assessment methodologies listed in **Profile Sheet #5** for key observations that need to be made on site when identifying restoration options.
5. Look at other restoration projects or model BMPs that have been implemented in nearby areas to get a sense of what is feasible, what conditions and constraints to look for at your candidate site, and existing design plans and cost estimates that can be shared.

Design Levels

This profile sheet refers to concept or design levels (10%, 30%, 70%). This is terminology used by design professionals to explain the level of detail provided. However, there are not hard and fast rules about what exact details should be provided at each level. To help clarify in the context of this profile sheet, **Table PS7-1** provides recommendations for what should be included at each level, as described below for the Baseline, Good, and Best categories.

Table PS7-1. Descriptions of Typical Design Levels

Design/Concept Level	Recommended Content
Baseline: 10%	• Field sketches: could include basic dimensions (length/width) or area to be treated/restored • Identify locations on map/GIS • Basic narrative descriptions of practice(s) • Qualitative measures of cost, benefit, and other factors (e.g., H, M, L)
Good: 30%	• Field sketches + more detailed illustrations (e.g., plan view, profile) composed in the office, showing dimensions, drainage areas, existing conditions (e.g., utilities, trees), proposed materials • Identify on map/GIS • 1-2 page narrative description; preliminary cost estimates and pollutant reductions; next steps to complete design and implement (e.g., permitting, field survey, complete design, etc.) • Small, simple projects can be constructed from design documents
Best: 70-100%	• Enough detail for permitting, plan review; usually an engineered plan, but can be simpler for smaller projects • More detailed estimates of cost and pollutant reduction

Baseline Level

Develop a tailored “tool box” of structural and non-structural actions to apply at specific sites in the watershed. Confer with experts on generic designs and practice descriptions. For structural projects, go to each identified site and confirm the feasibility of selected practices. Create a site sketch on an aerial map showing the proposed practice footprint, available area, area managed (or serviced) by the practice, and any notable constraints (e.g., conflicting uses, utilities, mature trees). This would be considered the 10%

design level, which is primarily to provide enough of a description and illustration to communicate the concept to stakeholders. Assign a High, Medium, or Low cost/benefit that can be used for subsequent prioritization, or use average cost/load reduction benefits derived from the literature (further guidance in **Profile Sheet #8**). None of these projects would be considered “shovel-ready,” as more work will need to go into the design, implementation planning, and permitting. Priority projects can be advanced to a more detailed level, as needed.

Good Practice

Seek more technical assistance to develop restoration concepts to the 30% design level, at least for the high priority opportunities. For structural projects, this may mean using GIS and AutoCAD rather than a marker and an aerial photo to size projects based on real design criteria, estimate material quantities and planning level costs, and estimate load reduction benefits. At this 30% design stage, simple projects, such as rain gardens, cisterns, or other non-engineering intensive activities could be considered “shovel-ready” since little additional effort will be needed to get to implementation. For the highest priority projects, consider developing renderings for illustrative purposes, or taking them to a 70% “permit-ready” design, as needed.

Best Practice

At this level, you should expect to sink a significant amount of effort to bring a diversity of structural and non-structural projects to the “shovel-ready” state (70% design). Many of the more feasible and less complicated projects/actions that have been permitted (or don’t require permitting) could be taken to construction documents (100% design). The bigger projects requiring many implementation partners, permitting steps, or significant funding may be on a slower trajectory. Performance monitoring and evaluation should be part of the project design.

The art of watershed restoration is being able to conceptualize specific projects and actions needed to address the watershed issues you have discovered during the assessment work. **Table PS7-2** provides a very basic list of the types of actions to consider relative to watershed issues and suggested sources for more information. Each topic could be a manual in of itself.

References & Resources

See links to references listed in **Table PS7-2.**

Table PS7-2. Linking issues with potential projects/actions

Watershed Issue	Potential Restoration Actions	Comments and Suggested Resources
Stormwater runoff (water quality or flooding)	• Stormwater retrofitting to improve performance of existing facilities or siting of new BMPs • Disconnection or reduction of impervious cover • Demonstrate new or preferred BMP technologies • Rainwater harvesting and reuse to reduce runoff volume	• Anyone can envision stormwater retrofits; may need engineer for design • Simple, small retrofits -- rain gardens, cisterns, or disconnection -- at residential scale can be designed by most people with some basic guidance • Larger more complex projects that are subject to local stormwater design standards or permitting may require support of engineer or other experienced persons • Add water quality design goals to capital infrastructure improvement with help from public works or utility • See *Stormwater Management in Pacific and Caribbean Islands: A Practitioner's Guide to Implementing LID,* (Horsley Witten Group & CWP, 2013) www.coris.noaa.gov/activities/stormwater_lid/ • Refer to your state/territorial stormwater design manual
Wastewater contamination	• Septic system maintenance, upgrades, or sewer hookup • Upgrade wastewater treatment plants • Conduct illicit discharge investigations and eliminate discharges (IDDE) • Separate combined sewers	• Sewer or centralized wastewater will be within jurisdiction of Wastewater Utility, Department of Health, or other government agency. • Use a wastewater engineer or similar to conceptualize decentralized package systems or to provide septic system upgrade solutions • If centralized wastewater treatment is inadequate or failing, technical support will be needed to recommend upgrades (UV, membranes, wetland polishing, etc) • Recognize that these can be expensive, large-scale projects that will require implementation planning and partner support • Illicit discharge detection & elimination guidance, see Brown et al., 2004 www.cwp.org/illicit-discharge-detection-and-elimination/ • See EPA. 2002. Onsite Wastewater Treatment and Disposal Manual and website with resources for homeowners and small package plant systems www.epa.gov/septic/onsite-wastewater-treatment-and-disposal-systems • Florida DEP wastewater guides and manuals www.dep.state.fl.us/water/wastewater/
Solid waste management	• Landfill management (recycling, waste to energy, leachate collection, etc) • Trash collection centers • Clean ups & dumping prevention • Marine debris removal	• Simple trash cleanups and collection center siting and design are easy; you'll need more experience and Waste Management Authority support for other recommendations • For overview of island-specific issues and opportunities see CLEANER PACIFIC 2025: Pacific Regional Waste and Pollution Management Strategy 2016–2025 https://sustainabledevelopment.un.org/content/documents/commitments/1326_7636_commitment_cleaner-pacific-strategy-2025.pdf
Erosion and sedimentation	• Stabilization of dirt roads • Erosion and sediment control at construction sites • Badlands revegetation	• Erosion & sediment control (ESC) measures and dirt road stabilization alternatives are fairly straightforward and can be identified by anyone with a base level of experience • See NRCS and local agencies for support in planning revegetation projects, particularly since there are native

Watershed Issue	Potential Restoration Actions	Comments and Suggested Resources
	• Erosion and sediment control at quarries • Landslide prevention and stabilization	species preferences • Geotechnical engineers should be consulted for landslide and some mining operations • See Penn State University Dirt Road Field Guide www.dirtandgravel.psu.edu/general-resources/esm-field-guide • See local stormwater manuals and ESC field guides • See Unpaved road design and maintenance program standards (NOAA CRCP, in press)
Rural and agricultural/ livestock issues	• Conservation practices to reduce erosion & nutrients (e.g., fertilizer mgmt.) • Manure management • Dry compost piggeries • Riparian buffer planting and livestock exclusion	• See NRCS Conservation Practice (Pacific) www.nrcs.usda.gov/wps/portal/nrcs/site/pia/home/ or (Caribbean) www.nrcs.usda.gov/wps/portal/nrcs/site/pr/home/ • See Chapter 2 Management Measures for Agricultural Resources in EPA (1993). www.epa.gov/sites/production/files/2015-09/documents/czara_chapter2_agriculture.pdf
Specific tourism & recreation industry impacts	• Hotel and resort sustainable design and green business practices • Golf course best practices • ATV and dirt bike course management • "Clean" marinas/blue flag beach program • Marine sports/tourism green practices • Coral safe sunscreen ed.	• Global Sustainable Tourism Criteria (www.gstcouncil.org/gstc-criteria/) • West Hawaii Standards for Marine Tourism http://coral.org/west_hawaii_standards/ • Low Impact Design & Development—An Overview for the Accommodations Industry in Hawai'i 2015 http://coral.org/lid/ • Hawai'i Hotel Reef Stewardship Guide 2014 http://coral.org/hotelstewardship/ • Recycled Water for Reefs A Guide for West Maui's Resort and Condominium Properties 2013 http://coral.org/hawaiiwater/
Degraded habitat or loss of natural watershed resiliency factors	• Shoreline & stream restoration • Wetland restoration/ pond dredging • Land conservation • Buffer enhancement • Build resiliency for climate change	• You will likely need technical assistance for shoreline stabilization with "hard" or "soft" engineering techniques, hydrologic assessments, etc. • Wetland and shoreline work will require permitting so contact local permitting agency and federal agencies for planning support (e.g., NOAA Restoration Center, Fish and Wildlife, Army Corp of Engineers, and NRCS). • The Nature Conservancy (TNC) has broad network in Pacific and Caribbean for land conservation methods
Weak human stewardship and oversight	• Watershed education and outreach projects • Update or adoption of new environmental and development regulations, programs, and permitting • Better enforcement of existing regulations • Infrastructure maintenance • Municipal source control and good housekeeping	• The non-structural projects can make a significant impact on water quality and are an important part of the suite of restoration options • Many of these do not require technical skills, but a good understanding of regulations and government programs related to development activities, natural resource protection, and infrastructure management • Tap stakeholder and agency partners for assistance in identifying non-structural opportunities

PS#8. Project Ranking & Prioritization

What Is It?

Project ranking and prioritization refers to a process to score, rank, and prioritize candidate projects based on several pre-selected “screening factors.” It is a way to start prioritizing your projects in a consistent, structured manner.

Watershed Assessment Levels

	<u>Baseline Level</u> *Select a handful of screening factors; use a mostly qualitative system.*
	<u>Good Practice</u> *Add some quantitative screening factors; calculate some key benefits of candidate projects.*
	<u>Best Practice</u> *Utilize additional screening factors and more rigorous quantification of costs and benefits.*

Why Is It Important?

Through the watershed planning process, you will be surrounded with promising ideas and restoration opportunities, but also realize that you cannot implement all of them. How, then, do you decide which projects should be prioritized? Can this be done in a relatively subjective manner so that personal preferences, politics, or other factors do not have undue influence? These are the chief issues behind having a structured ranking and prioritization process. The process may not be 100% objective, but it allows all candidate projects to be ranked based on a consistent set of screening factors.

Getting Started

1. The most important aspects of project ranking and prioritization are to have a collaborative process to select the most appropriate screening factors and a system to score your candidate projects that is within the means of your watershed planning effort. This profile sheet will assist you in being deliberate about selecting a Baseline, Good, or Best level to frame the task.
2. It will be helpful to review a few watershed plans and how they handle ranking and prioritization. If possible, select some plans from your island or a neighboring jurisdiction. Consult your local coral and coastal management agencies for suggestions.

Understanding Screening Factors

The term “screening factor” is used here as a criterion that can be used to score, rank, and help prioritize a list of candidate projects. There are many different options for selecting screening factors, and it is best if this process if collaborative with some stakeholder involvement.

Table PS8-1 lists and describes several common screening factors used as part of watershed planning. It is certainly not anticipated that ALL of these factors will be used for each plan, as the selected screening factors will depend on the sophistication of the effort (Baseline, Good, Best) and how relevant each factor is to the goals and objectives of the watershed plan. At this point, it is recommended to review the available factors in the table, perhaps add to or modify the list based on your particular needs, and then recommend several to be used for the watershed plan.

Table PS8-1. Basic Screening Factors for Project Prioritization (Adapted from: CWP, 2005)

Screening Factor	Description & Guidance
Planning-Level Cost	Cost is an essential screening factor, but presented as specific cost estimate, relative cost, or range depending on the level of design. It can be measured in a variety of ways: • <u>Total Construction Cost</u>: construction costs can be estimated from similar projects in the jurisdiction or from other islands, or from general literature values. • <u>Total Lifecycle Cost</u>: Life-Cycle cost includes not only construction, but items such as land acquisition, design, permitting, project management, and long-term operation and maintenance. The trade-off is that it is a more useful cost figure, but also much more difficult to quantify with any degree of accuracy.
Cost Per Unit of Benefit (Cost Effectiveness)	Total cost (construction or life cycle) is a good factor, but may not reveal the most cost-effective projects (e.g., large projects will usually have higher total costs, but may be more cost-effective compared to small projects). “Cost per unit of benefit” attempts to capture cost-effectiveness. This screening factor can vary based on the type of restoration project: • Cost per treated acre or impervious acre (e.g., stormwater retrofit) • Cost per acre (e.g., revegetation, habitat restoration, agricultural projects) • Cost per linear foot (e.g., stream or shoreline restoration) • Cost per pound of pollutant reduced (e.g., wastewater or stormwater treatment) • Cost related to potential coral reef ecosystem benefit (qualitative) The key to this screening factor is the ability to calculate or approximate both the cost and benefit side of the equation. General literature values exist and may suffice for initial screening and ranking.
Compatibility With Goals	Candidate projects will likely have multiple benefits, but how compatible are these potential benefits with the actual goals of the watershed planning process? At this step, it is important to take a clear-eyed look at your list of potential restoration opportunities and provide best professional judgment as to how relevant they are to your planning goals and objectives. If the objective is to protect coral ecosystem, you can judge the extent to which projects will benefit the coral.
Long-Term Maintenance	A project will likely succeed or fail based on whether it is properly maintained. Some practices may require fairly rigorous maintenance, such as periodic sediment removal or management of vegetation, while others may have lighter maintenance burdens. Another factor for long-term maintenance is whether a responsible party is identified and can reasonably take on the tasks assigned.

Screening Factor	Description & Guidance
Landowner Willingness	Most projects will need a willing public or private landowner. Some programs focus primarily on public lands due to this issue. However, public projects may also encounter obstacles because the practice(s) may not be compatible with the operational goals of the landholding agency. Programs that depend on cooperation from private landowners will likely require an extensive outreach and educational campaign.
Design & Permitting	Candidate projects will also vary with regard to the level of effort needed for design and permitting. It is important to assess at early stages whether extensive (and perhaps costly) design and permitting may be involved. Projects that involve wetlands, streams, shorelines, potential historic areas, etc. will likely undergo a permitting process. Does the program or assigned agency have the capabilities to undertake the design and permitting task?
Opportunities for Outreach, Education, and Public Visibility	A major consideration for some programs is whether a project can be used as part of education and outreach programs. This type of project may be a park, school, municipal building, museum, dive or other tourist area, or other location where the public will interact with the project. A location where signage can be installed is another consideration. This factor can also consider the extent to which a project may even be visible to the public or perhaps is in an area with more limited access and/or visibility (visibility can also be split out as its own screening factor if it is a major concern for the plan).
Community Benefits	The public is more likely to accept and support a project where there are multiple benefits. Projects that will clean-up degraded areas, provide landscape, open space, or habitat amenities, provide recreational opportunities, provide “green” jobs for installation and maintenance, reduce flood or storm risks, aid the local economy, or provide other such benefits will be more likely to garner community support. Some projects may be controversial or not have support from the surrounding neighborhood or community, so this also needs to be considered.
Streamlining & Coordination	A streamlined project can be coordinated with other ongoing efforts, such as capital improvement programs, renovation of a park or school, ongoing road maintenance activities, another (already-funded) restoration project, or similar. The point here is that a project is more likely to be successful when some of the implementation steps can “ride” on efforts that are already funded or in the implementation pipeline. A streamlined project may also build on existing partnerships and/or resources from allied agencies.

Baseline Level

A baseline level of ranking and prioritization may have four to five screening factors, doesn’t require too much quantification (e.g., avoid having to calculate actual pollutant removals or costs—for now), and uses a qualitative scoring system (e.g., High, Medium, Low). **Table PS8-2** provides an example of how a baseline ranking can work, with Low (L), Medium (M), and High (H) ratings corresponding to numerical scores of 1, 2, and 3, respectively. The screening factors and scores in the table are for illustrative purposes only, and users should select factors and a scoring system that fit their project. If such a system is used, it is important to at least document the rationale behind assigning L, M, or H ratings to a project. This does not have to be a highly analytical procedure, but at least should outline the thought process so that these assignments can be revisited and are transparent to stakeholders.

One thing that can be ascertained from the table is that distinct types of projects can be compared to each other (e.g., a structural stormwater retrofit vs. an educational campaign). This type of comparison is perhaps one of the most challenging aspects of a ranking system, as it may seem like comparing apples and oranges (or coconuts and mangos). Some may decide it is best to score types of projects separately, such as scoring only the stormwater retrofit projects against each other. This is a legitimate way to handle the challenge, and should be decided with the program partners.

Table PS8-2. Example of Simple Ranking Based on Four Screening Factors & High, Medium, Low Scale [1]

Candidate Project	Cost-Effectiveness	Outreach & Education	Community Benefits	Design & Permitting	Score
Stormwater retrofit of dive area parking lot	L (1)	M (2)	M (2)	H (3)	**8**
Reforestation of badland area	M (2)	M (2)	H (3)	M (2)	**9**
Plant riparian buffer along Stinky Gut at elementary school	H (3)	H (3)	H (3)	M (2)	**11**
Train erosion control inspectors	L (1)	M (2)	L (1)	L (1)	**5**
Education campaign to reduce illegal dumping	M (2)	H (3)	M (2)	L (1)	**8**

[1] In this table, **L = 1; M = 2; H = 3**

[2] Make sure scoring for L, M, H "runs in the same direction" for all screening factors. For instance, an "H" for outreach/education and community benefits means the project has more of these good qualities. An "H" should always be a good quality; therefore, for Design & Permitting, an "H" means that design and permitting is easy and straight-forward, while an "L" means that is complicated and costly.

Good Practice

At the Good Practice Level, you should expect to use a mix of five to seven quantitative and qualitative screening factors. Quantitative factors, such as cost and cost-effectiveness (e.g., cost per pound of sediment reduced) assume some type of data analysis or calculation. Qualitative factors such as education benefits, community benefits, and level of effort rely largely on professional judgment, preferably assigned using a collaborative process. Consider optional weighting of screening factors that are deemed more important than others. **Tables PS8-3** and **PS8-4** provide further theoretical examples of how this system can work; these examples use five screening factors to score and rank eight different projects.

Table PS8-3 illustrates the scoring system based on a 100-point scale, which is readily understood by most stakeholders. Care must be taken to ensure that the scores "run in the right direction." For instance, a High (H) rating for Outreach and Education is a good quality (thus receiving the top score of 20). Alternately, an H rating for Design and Permitting burden means extra bureaucratic hurdles, so is not a good quality; as shown in the table, an H in this case gets a low score of 0 and the L rating gets the high of 10. The main point here is to make sure your scoring system, however you construct it, is consistent in that you assign high scores for "good" project qualities.

Table PS8-4 applies this system to eight theoretical projects. The table tries to make all the computations transparent; however, it is much better to do this type of analysis using a spreadsheet. Your list of candidate projects may run into the dozens or hundreds, so the spreadsheet helps keep all the data organized. This is not the only way to score and rank projects based on quantitative screening factors; it is simply an example of one possible method. Also, it can be challenging to develop consistent costs for different types of projects (e.g., stormwater retrofits vs. education programs), so, again, there is some justification for having separate scoring for each category.

Table PS8-3. Example Scoring System for 100-Point Scale Using Five Screening Factors

Screening Factor	Type	Maximum Score	Definition of Range
Planning-Level Cost ($); just construction cost for structural projects	quantitative	30	Calculate cost for each project; divide all values into quartiles: • 1st quartile = 30 • 2nd quartile = 20 • 3rd quartile = 10 • 4th quartile = 0
Cost-Effectiveness ($ per pounds of sediment removed)	quantitative	30	Calculate cost and sediment removal for each project; divide all values into quartiles: • 1st quartile = 30 • 2nd quartile = 20 • 3rd quartile = 10 • 4th quartile = 0
Outreach & Education	qualitative	20	L = 0 M = 10 H = 20
Community Benefits for Green Jobs and Neighborhood Revitalization	qualitative	10	L = 0 M = 5 H = 10
Design & Permitting	qualitative	10	L = 10 M = 5 H = 0
TOTAL		**100**	

Table PS8-4. Example Scoring & Ranking Using Screening Factors from **Table PS8-3.** The analysis in this table is best done using a spreadsheet.

Candidate Project	Planning-Level Cost ($)[1]	Cost Effectiveness ($/lb of sediment)[2]	Outreach & Education	Community Benefits	Design & Permitting	Total
	Max = 30	*Max = 30*	*Max = 20*	*Max = 10*	*Max = 10*	*Max = 100*
1. Stormwater retrofit of dive area parking lot	$80K Score = 0	Pounds = 40 $2000/lb Score = 10	M = 10	M = 5	H = 0	**25**
2. Stormwater retrofit at municipal building	$50K Score = 10	Pounds = 15 $3333/lb Score = 0	H = 20	M = 5	M = 5	**40**
3. Reforestation of badland area #1	$40K Score = 10	Pounds = 80 $500/lb Score = 30	M = 10	H = 10	M = 5	**65**
4. Reforestation of badland area #2	$25K Score = 20	Pounds = 40 $625/lb Score = 20	L = 0	H = 10	L = 10	**60**
5. Plant riparian buffer along Stinky Gut at elementary school	$15K Score = 30	Pounds = 10 $1500/lb Score = 10	H = 20	M = 5	L = 10	**75**
6. Restore wetlands at town pond	$60K Score = 0	Pounds = 100 $600/lb Score = 20	H = 20	H = 10	H = 0	**50**
7. Train erosion control inspectors	$20K Score = 30	Pounds = 200 $100/lb Score = 30	M = 10	L = 0	M = 5	**75**
8. Education campaign to reduce illegal dumping	$30K Score = 20	Pounds = 15 $2000/lb Score = 10	H = 20	M = 5	L = 10	**65**

[1] The scoring is based on the quartile method from **Table PS8-3.** This involves splitting the values into 4 groups. In this example, there are 8 candidate projects with scores of $15K, 20K, 25K, 30K, 40K, 50K, 60K, 80K (ranked in order). A simple spreadsheet analysis can divide these values into 4 groups (or quartiles), with 2 projects in each group. This results in the following scoring for planning-level cost:

- $0 – 24K = 30 points
- $25 – 35K = 20 points
- $36 – 53K = 10 points
- $54 – 80K = 0 points

[2] Cost Effectiveness screening factor scoring is based on quartiles, using the same method as above:

- $0 – 575/pound = 30 points
- $576 – 1063/pound = 20 points
- $1064 – 2000/pound = 10 points
- $2001 – 3333/pound = 0 points

A few observations about **Tables PS8-3** and **PS8-4** may help users understand some of the nuances of applying this type of scoring system:

Mix of Quantitative & Qualitative Factors

Table PS8-3 has two quantitative and three qualitative screening factors. You can adapt this to change the mix, but it is good to have both types of factors in your scoring system. The quantitative factors usually take more work to research and calculate the scores.

Weighting of Factors

It is apparent from the scoring system in **Table PS8-3** that not all the screening factors are weighted equally. Cost and Cost-Effectiveness together comprise 60 out of the total 100 points that are possible. This is a deliberate way to "weight" certain screening factors that are most targeted or relevant to the watershed planning goals. For instance, if demonstration projects and community education are the primary drivers of the plan, then Education & Outreach and Community Benefits could be weighted higher.

Data Needed For Quantitative Factors

The two quantitative factors (cost and cost-effectiveness) cannot be used without supporting data. The reason the factors use the term "planning-level" is that it is not expected that enough data will be available at this stage to fully vet what actual costs will be prior to any design work being conducted. The main data that will be required are the cost of various types of projects and the pollutant removal benefits. There are various national or regional-level sources for this type of data for different topics, such as stormwater management (CWP, 2013; WERF, 2009). It is ideal to blend this general or broader-scale data with regional or jurisdiction information from your location, if such are available. Researching the available data is a great project for an intern or graduate student, and outside expertise may also be needed.

Putting Different Types of Projects on the Same Ranking Scale?

Also, for the quantitative screening factors, the data may have much more veracity for structural or constructed practices versus other types of programs, such as education, training, outreach, etc. Some models, such as the Watershed Treatment Model (Caraco, 2013), attempt to provide data for a broad set of practices. However, depending on your watershed context, it may make some sense to separate out your analysis by scoring and ranking structural practices separately from non-structural, with the latter having fewer quantitative factors. In **Table PS8-4**, training erosion control inspectors ranks highly, but it must be acknowledged that the pollutant removal benefits are speculative (it may, however, be an excellent option to add to the watershed plan in combination with other practices).

Link to the Threats Assessment

It appears from **Table PS8-4** that structural practices, such as stormwater retrofits, are not as cost-effective or do not score as highly as other types of practices, such a reforestation or riparian restoration. In general, urban stormwater practices will be more expensive than other types of practices. However, it may not be wise to discard the urban practices, especially if urban stormwater is a major threat in your watershed. This is where Step 3 of the Tool (and **Profile Sheet #4**) is critical. The results of Step 3 may lead your effort in the direction of focusing primarily on, for example, stormwater issues. In this case, most of your candidate projects will be stormwater-focused. This also illustrates the importance of selecting the most appropriate screening factors for your watershed.

Numbers Are Good, But Still Need Professional Judgment

The numerical total scores in this process (the last column in **Table PS8-4**) result in a list of ranked project. However, it is important to understand that this ranking should be considered preliminary, and the ranked list is an excellent step in the process to seek input and feedback from stakeholders (**Profile Sheet #3**). There may be compelling technical, administrative, or social reasons why some projects should be elevated in importance, while others removed from the list of high priority projects. In this regard, the scoring and ranking is a valuable tool that can assist with community decision-making.

Best Practice

The Best Practice Level will, in many regards, be similar in mechanics to the Good Practice Level, but may include even more screening factors, as well as a more rigorous process for assigning values to the quantitative screening factors. For cost, this may mean more research on likely costs for the candidate projects based on concept plans, with cost estimating being based on approximate sizing, materials, permitting, land acquisition, etc. For pollutant removal, the enhancement can involve using various models to simulate load reductions.

It is beyond the scope of this profile sheet to describe all the means for this more advanced level. **Table PS8-5** at the end of the profile sheet does provide an example, modified from an actual project. Schueler and Kitchell (2005) and EPA (2008) provide more detailed guidance for project ranking and prioritization.

References & Resources

Caraco, 2013. Watershed Treatment Model. Updated spreadsheet model. Watershed Treatment Model, version 3.1 (2002). Center for Watershed Protection. www.cwp.org

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Table PS8-5. Example of a More Sophisticated Scoring & Ranking Table (from a project in Virginia)

Site ID	Site Description	Proposed Practice	Drainage Area (acre)	Impervious Cover (acre)	Target WQv (cf)	Available Practice Width (ft)	Available Practice Length (ft)	% Water Quality Volume[1]	TP Removal (lb/yr)	TN Removal (lb/yr)	TSS Removal (lb/yr)	Cost $	Cost Effectiveness ($/lb TP removed)	Scoring						Rank
														Cost Effectiveness	Phosphorus Removal	Maintenance Burden	Potential Utility or Site Constraints	Aesthetics / Safety	Total Score	
H42	Median on Route 33	Regenerative Stormwater Conveyance	88.50	57.4	222,780.36	20	1,000	11	17.55	179.9	13,751	$1,076,220	$61,309	14	35	15	10	2.5	76	1
H11	R.S. Park	Enhancement	0.64	0.54	1,942.05	3	72	11	0.18	2.02	436.47	$775	$4,234	35	7	7.5	10	2.5	62	2
H47	Londa Lane Extended	Enhancement	10.25	3.67	17,910.78	113	113	99	0.86	12.81	1,483.18	$63,503	$73,472	2	35	7.5	10	5	60	3
H10-D	R.S. Park @ b'ball courts	Bioretention	4.09	0.45	4,458.73	25	45	33	1.50	25.57	439.10	$35,701	$23,776	35	3	7.5	5	5	55	4
H29-A	Questar Elementary School	Bioretention	0.60	0.53	1,883.61	10	70	38	0.38	3.58	330.73	$17,330	$45,174	18	1	15	10	5	49	5
H-10A	L.C. Basin	Enhancement	20.16	5.73	31,283.70	-	-	19	0.76	12.10	1,157.85	$21,540	$28,344	5	31	7.5	5	0	49	6

[1] This refers to the percent of the Water Quality Volume (WQV) captured by the practice. For this application, the WQV is defined as the runoff generated by 1" of rainfall in the drainage area, which is the Virginia standard in the Runoff Reduction Method. Since these are retrofit projects, they do not have a regulatory obligation to meet 100% of the WQV, but it is a good metric by which to compare projects.

PS#9. Elements of a Watershed Plan

What Is It?

Many of us dread the thought of preparing a written watershed plan, particularly one that meets the infamous “a-i criteria.” Fortunately, by the time you’ve gotten this far in the planning process, the plan could almost write itself. Whether your approach is to simply compile materials produced under each step of the planning process, or to craft a more polished, detailed narrative, there are some fundamental elements of a watershed plan that should be included in the package.

Watershed Assessment Levels

	Baseline Level Packaging of completed products to meet basic EPA watershed planning criteria
	Good Practice More comprehensive, technical plan that documents modeling efforts and monitoring protocols
	Best Practice Provides more detail on priority project design/development and early implementation

Why Is It Important?

The primary purpose of the watershed plan is to: (1) provide a roadmap for the implementation of proposed management strategies, and (2) to document findings of the planning effort. A watershed plan needs to describe watershed conditions in a way that clearly identifies problems and specific solutions. It should provide a thoughtful approach to implementing those solutions, and describe a mechanism for determining if those actions are working.

Documenting the findings from your watershed research, field assessments, and decision-making efforts is the best way to keep the watershed story alive after you have moved on and to take advantage of unexpected implementation or funding opportunities. While existing condition reports and implementation priorities reflect a single moment in time, the written plan provides a framework that can be updated and modified as the watershed (and its stakeholders) evolve over time.

EPA outlined nine criteria that a watershed plan must meet to be eligible for implementation funding through their 319 grant program (**Table PS9-1**). Even if you are indifferent about that, it is worth noting that these criteria are just the fundamental elements of a good management plan.

Getting Started

1. Review what you have accomplished to date in your planning process. What products and materials have you already delivered that can be integrated into your watershed plan? Use **Table PS9-2** as a checklist to see if you have all the elements needed for a watershed plan. Decide how you want to package the watershed plan and how much effort you are willing to put into it. Consider the following:

- Keep your management plan short. As much as you may not want to write it, most folks don't want to read it. The implementation strategy may ultimately be the focal point of your plan, so think "executive summary" and present support information as technical appendices or in supplemental reports.
- Who is the audience? Determine if the plan will be directed at funders, implementation agencies, or the community. Each audience may be looking for different information to be most prominent.
- Showcase your best watershed photos – both good and bad. Images of watershed degradation -- sediment plumes, dead reefs, leaking discharge pipes, sewage filled channels, etc. -- leave a long-lasting impression, especially when juxtaposed with images showing how important these resources are for the life and economy of the island: kids swimming in the lagoon, beautiful water scenes, water-dependent businesses, healthy reefs.

2. Create a **targeted education plan**. If watershed education and public involvement opportunities were <u>not</u> identified or did not make the priority cut, here is your chance to remedy the situation. EPA is not prescriptive on what the education plan should contain, although the *Getting in Step* program guidance documents are great resources for developing your education and outreach program. In general, the following approach is recommended:
   - Revisit field notes and watershed threat matrix (**Profile Sheet #4**) to identify the watershed behaviors that contribute to significant watershed pollutants or resource issues.
   - Craft messages that address how specific behaviors impact the watershed/reef and what alternative behavior is preferred. For example, if failing septic systems are contributing to excess nutrients and algal growth, then the message should be to residents encouraging them to inspect systems regularly or hook up to sewer if available.
   - Tailor watershed messages to different audiences (e.g., residents, businesses, agencies, etc). For example, if stormwater runoff is an issue, explain to homeowners how a rain garden may help reduce driveway runoff, explain to businesses how parking lot landscape features can serve dual purposes, and encourage agencies to update stormwater regulations to require water quality treatment or volume reduction.
   - Determine the best mechanism for distributing watershed messages (e.g., radio, bill inserts, signage, and event booths). Identify opportunities to coordinate watershed messages with existing educational programs or events hosted by others (e.g., agencies, utilities, schools, churches). Identify highly visible locations for watershed signage and public outreach events.

- From your list of educational options, set annual priorities and provide an annual budget for the next 5 years. This should information will ultimately go into the implementation strategy.

3. Develop a **monitoring plan** that allows you to evaluate the effectiveness of the watershed management plan programmatically as well as at the resource. To this end, EPA calls for establishment of interim milestones and measureable criteria to evaluate progress as part of an overall monitoring program. See **Profile Sheet #10** for more detail on setting up a monitoring program. An estimate annual budget for monitoring should be included in the overall implementation strategy.

4. Develop an **implementation schedule** for the watershed management plan that clearly identifies responsible parties, schedule, and costs over a given planning horizon. Providing a realistic assessment of how long it takes to accomplish actions requires accounting for the "hidden" cost/time to design, permit, and construct capital projects; raise funds and align agency budgets; hire staff; establish non-profit organizations; or allow for legal review of new regulations; etc. There is no set protocol for developing an implementation strategy, even though it is arguably the most important part of the watershed plan. The EPA Handbook (2013) provides a good primer on developing implementation schedules and includes a template in Appendix B (Worksheet 12-1), as well as some examples. How the schedule will be used to approach funders and organize implementation partners will dictate the format and level of detail that goes into its development. Consider the following:
    - For each proposed management action, define the "who, what, when, where, and how" it will be accomplished; include planning-level costs if possible. A tabular format seems to work well for comparing the suite of projects and actions to determine how they best fit together over a 5 (short term) and 10-year (long-term) horizon.
    - For each year, sum the total estimated cost of each proposed item. Some schedule readjustment may be required at this point, and typically, the least expensive and easiest to implement actions are front-loaded, while the more complex and expensive items are back-loaded.
    - Use key stakeholders, implementation partners, or steering committee (if you have one) to help establish or refine the strategy, particularly where coordination with existing programs or activities can provide cost savings or speed up implementation.
    - Include interim milestones for progress evaluation in your schedule.

The following levels of practice offer suggestions for packaging the watershed plan in the context of meeting EPA's nine planning criteria. The existing materials generated to date will dictate what information can be packaged in the plan. Fortunately, there is no right or wrong approach to organizing your watershed plan. **Table PS9-2** illustrates simple to more complex options for what the plan might look like.

Baseline Practice

At this level, the watershed plan may be a simple document organized into the following sections: watershed conditions and threats, management goals and potential actions, an education plan, monitoring plan, and implementation schedule. Relevant watershed maps, threats matrix, and tabular summaries of watershed characteristics and potential projects should be included. Consider attaching rough pollutant loading estimates, concept sketches, and project ranking matrices as technical appendices to the watershed plan. This plan should meet EPA's minimum watershed planning criteria, without being overly complicated for watershed managers to produce.

Good Practice

At this level, there is potentially more to include in the watershed plan, at least a more sophisticated modeling and monitoring approach, advanced design plans, and more backup information on how priorities were selected. The watershed plan may be supported by supplemental reports (e.g., baseline or watershed characterization report, technical modeling memorandums, field reports, and map library) or special studies (e.g., stakeholder surveys, wetland evaluations, climate impact studies, or flood inundation modeling). At this level, it is easy for the implementation schedule to get lost in a sea of technical information; therefore, it is important to structure your report in a way that elevates the implementation strategy.

Best Practice

At this level, the watershed plan will likely need to reference advanced design plans, more sophisticated modeling, and more comprehensive monitoring and educations plans. It is quite possible that the watershed plan itself becomes a "glorified" executive summary, followed by separate volumes or companion reports that will contain the specific information needed to implement management actions and measure and evaluate success.

References

EPA. 2008. Handbook for Developing Watershed Plans to Restore and Protect Our Waters. Prepared by Tetra Tech. www.epa.gov/nps/handbook-developing-watershed-plans-restore-and-protect-our-waters

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EPA. 2008. Appendix B. Worksheet 12-1. Template for Preparing Implementation Plan Matrix, in Handbook For Developing Watershed Plans to Restore and Protect Our Waters. www.epa.gov/sites/production/files/2015-11/documents/2008_04_18_nps_watershed_handbook_app_b.pdf

Wilkinson, C., Brodie, J. (2011). Catchment Management and Coral Reef Conservation: a practical guide for coastal resource managers to reduce damage from catchment areas based on best practice case studies. Global Coral Reef Monitoring Network and Reef and Rainforest Research Centre Townsville, Australia, 120 pp https://repository.library.noaa.gov/view/noaa/655

Table PS9-1. EPA's Nine Watershed Planning Criteria (adapted from EPA, 2013)

	Criteria	Coral Watershed Planning Tool	
		Step in Tool + Profile Sheets (PS)	Products you have
a	An **identification of the causes and pollution sources** that need to be controlled to reduce watershed loads, and an estimate of the extent to which sources are present in the watershed (e.g., X number of dairy cattle feedlots needing upgrading; Y acres of row crops needing improved nutrient management or sediment control; or Z linear miles of eroded stream bank needing remediation).	Steps 1, 2, and 3 • PS#1 Mapping • PS#4 Watershed characteristics and threats	• Watershed stats • Threats matrix
b	An **estimate of watershed pollutant loads and expected reductions** for the management measures (recognizing the natural variability and the difficulty in precisely predicting the performance of management measures over time). Estimates should be itemized as in (a) above (e.g., the total load reduction expected for dairy cattle feedlots; row crops; or eroded stream banks).	Step 3 • PS#6 Land use loading budget • PS#8 Project Ranking	• Pollutant load budget • Cost/benefit estimates for projects (ranking)
c	A **description of the NPS management measures** that will need to be implemented to achieve estimated load reductions (as well as to achieve other watershed goals), and the location of where those measures will be taken.	Steps 2 and 4 • PS#5 Field assessments • PS#7 Identifying restoration projects	• Maps with project locations • concept or advanced project designs
d	An **estimate of the amounts of technical and financial assistance needed**, associated costs, and/or the sources and authorities that will be relied upon, to implement this plan. Consider Section 319 programs, State Revolving Funds, USDA's EQIP and CRP, local CIP, and other relevant public and private funds.	Steps 4 and 5 • PS#7 Identifying restoration projects • PS#8 Project ranking • PS#9 Elements of a watershed plan	• Advanced project designs • Cost/benefit estimates for projects (ranking) • Implementation strategy
e	An **information/education component** that will be used to enhance public watershed awareness and encourage their early and continued participation in selecting, designing, and implementing management measures	Steps 4 and 5 • PS#1 Stakeholder input • PS#7 Identifying projects • PS#9 Elements of a watershed plan	• Stakeholder engagement • Advanced project designs • Targeted education plan
f	A **schedule for implementing** the management measures identified in this plan that is reasonably expeditious.	Step 5 • PS#2 coral condition • PS#9 Elements of a watershed plan • PS#10 Monitoring	• Watershed goals • Implementation strategy • Monitoring plan
g	A **description of interim, measurable milestones** for determining whether management measures or other control actions are being implemented.		
h	A set of **criteria that can be used to determine whether loading reductions are being achieved over time** and progress is being made towards meeting goals		
i	A **monitoring component** to evaluate the effectiveness of the implementation efforts over time, measured against the established criteria.		

Table PS9-2. Watershed Plan Packaging

Elements	Baseline	Good	Best
Watershed Problems (EPA criteria a)	Watershed maps and narrative description of existing conditions and problems; tabular summary of watershed statistics; include baseline threats matrix	Separate baseline or watershed characterization report that provides summary of existing data; serves as a technical supplement	Watershed conditions report combined with field assessment findings; links problems with solutions
Solutions (EPA criteria c)	Map and corresponding tabular summary of potential and priority project locations	Separate field findings report or appendix that includes concept sketches of all projects; project ranking matrix and description of selection process	Advanced designs for priority projects and activities; include backup information on all projects in appendix or technical report (field forms, low priority project concepts, etc)
Modeling (EPA criteria b)	Include tabular results of basic land use load and load reduction spreadsheets	Estimate load reduction benefits for each individual project/activity; include backup information in technical memo or appendix	Advanced modeling of existing conditions and potential load reductions; potentially tied to reef conditions
Implementation Strategy (EPA criteria d,f)	Schedule matrix for short and long-term implementation of priority actions, with loosely estimated annual budgets; potential funding options; interim milestones; stakeholder feedback requested	More refined annual and project-specific budget details based on stakeholder input; capital projects broken out by engineering, permitting, and construction phases; load reduction benchmarks based on annual implementation	Crafted by implementation partners or steering committee; includes short, mid, and long term schedule, detailed funding strategy; clear alignment with existing programs; includes implementation of early action projects; include monitoring benchmarks
Targeted Education Plan (EPA criteria e)	Contains watershed awareness messaging on significant issues at least once a year	Messaging targeted to priority threats and tailored to multiple audiences; at least one public outreach/ involvement activity; watershed signage	Messaging multiple times a year; using more than one delivery mechanism; integrated with existing education programs/activities by others; several opportunities for public involvement
Monitoring Plan (EPA criteria g,h,i)	Select a few programmatic indicators to gage successful implementation of the plan.	Add additional indicators, including collecting data from the watershed	Comprehensive monitoring program with oversight committee coordination; use a more robust set of indicators to analyze trends over time in watershed and on reef

PS#10. Long Term Monitoring & Adaptive Management

Watershed Assessment Levels

	Baseline Level Select a few programmatic indicators to gage successful implementation of the plan.
	Good Practice Add additional indicators, including collecting data from the watershed.
	Best Practice Use a more robust set of indicators to analyze trends over time.

What Is It?

Once plan implementation is underway, long-term monitoring and adaptive management will help gage the success of implementation activities. This success can be based on *programmatic* measures, such as hiring a staff person, securing a grant, or constructing projects, and/or on *environmental/ ecosystem* measures, such as improvements in water quality or coral condition. This is also a crucial step in EPA's watershed planning procedure (see **Profile Sheet #9**), as described below:

> *Once you've started to implement your watershed plan, you need to monitor both water quality and land treatment to ensure smooth implementation and to measure progress toward meeting goals. The adaptive management approach is not linear but circular, to allow you to integrate results back into your program. You need to create decision points at which you'll review information and then decide whether to make changes in your program or stay the course. As part of your evaluation efforts, you'll periodically review the activities included in your work plan and the monitoring results to determine whether you're making progress toward achieving your goals.*
> [From: Handbook for Developing Watershed Plans to Restore and Protect Our Waters (U.S. EPA, 2008), Section 13.6, p. 13-6.]

Figure PS10-1 illustrates an example monitoring and adaptive management flowchart from the EPA publication.

Why Is It Important?

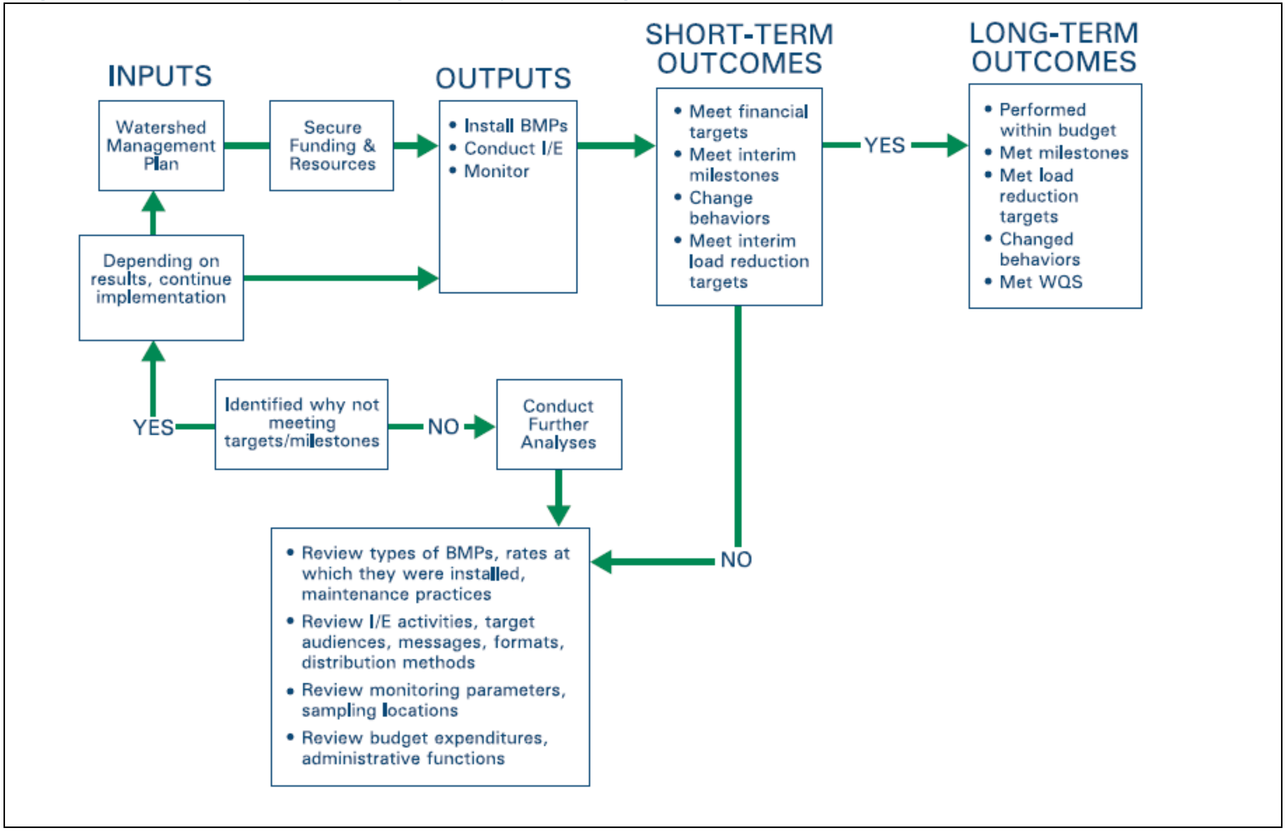
Long-term monitoring is the only way to determine if implementation actions are effective and mid-course corrections are needed (adaptive management). This is critically important, as staff and financial resources will be spent to implement the plan, and stakeholders will want to know that the actions are achieving their stated purposes.

Getting Started

1. Long-term monitoring and adaptive management are not strategies that are developed AFTER the plan is already written and adopted: they need to be part of the original written plan (see **Step 5** in the Tool & **Profile Sheet #9**). Therefore, the best way to "get started" is to include a long-term monitoring and adaptive management strategy in the original plan.

2. As with all planning steps presented in these profile sheets, the approach can be simple or complex. The sophistication of your strategy should be based on available resources, personnel, and funding. The plan may envision more extensive monitoring as the program evolves and more resources become available. Look through the Baseline, Good Practice, and Best Practice levels in this profile sheet; begin with some Baseline steps and plan to advance to more sophisticated levels in the future.
3. Be sure to check with funding agencies (e.g., National Fish & Wildlife Foundation) from which you have secured grants. Most will require the identification of “metrics” that must be tracked as part of the funded program. These metrics will likely also serve as items for your long-term monitoring effort.
4. It will be important to synchronize your long-term monitoring program with existing and ongoing monitoring and evaluation efforts. Confer with the appropriate jurisdictional, regional, and national agencies that are already conducting some type of monitoring (e.g., coral condition monitoring, as presented in **Profile Sheet #2**).

Figure PS10-1. Example monitoring and adaptive management flow chart (from EPA, 2008).



5. **Profile Sheet #6** addresses watershed pollutant and threat assessment. Depending on the sophistication level, this may involve some type of modeling. Whatever modeling is employed, it will help streamline your efforts if the model can also incorporate long-term

program and ecosystem monitoring data, so that you can use also use the model as an evaluation tool.

6. As with many watershed planning steps, this step may be an excellent way to collaborate with colleges, universities, and natural resource agencies. Interns can also be employed to conduct some of the monitoring.

Baseline Level

EPA's watershed planning guidance provides a succinct description of what may be considered a baseline level of long-term monitoring. Much of this focuses on the *programmatic* aspects of watershed plan implementation:

> *As part of developing your implementation plan, you devised a method for tracking progress. Using that tracking system, you should review the implementation activities outlined in your work plan, compare results with your interim milestones, provide feedback to stakeholders, and determine whether you want to make any corrections. These reviews should address several key areas:*
>
> - *The process being used to implement your program. This process includes the administrative and technical procedures used to secure agreements with landowners, develop specifications, engage contractors, and the like.*
> - *Progress on your work plan. Check off items in your annual work plan that have been completed.*
> - *Implementation results. Report on where and when practices have been installed and have become operational.*
> - *Feedback from landowners and other stakeholders. Review information on the stakeholders' experience with the implementation process and with operation and maintenance of the practices.*
>
> [From: Handbook for Developing Watershed Plans to Restore and Protect Our Waters (U.S. EPA, 2008), Section 13.6.1, p. 13-8.]

As stated above, funding agencies will likely require the identification of "metrics" that can be tracked as the program or project is implemented. **Table PS10-1** provides some example programmatic metrics that may be requested by funding agencies and that are also in line with EPA's recommendations.

Obviously, monitoring programmatic activities is important, but does not get at the question of whether the watershed or ecosystem is actually benefiting from the activities. Incorporating this type of monitoring is important as the program evolves to the Good Practice Level.

Table PS10-1. Examples of Program Metrics That Can Be Tracked (Adapted from: NFWF, 2016)

Project Activity	Recommended Metric
Building institutional capacity	# of organizations contributing to goals
Outreach, education, technical assistance	# and type of people targeted by programs and # actually reached; types of stakeholders & feedback received
Volunteer participation	# of volunteers participating in projects
Improved management practices	# of practices implemented; # of acres under improved management or treated by practices; linear feet of streams/guts/shoreline restored or cleaned up, etc.
Management and governance	Identification of responsible parties and schedules for watershed plan activities; # of administrative and technical procedures developed; # of plan activities implemented

Good Practice Level

The type of monitoring conducted at the Good Practice level is highly dependent on the nature of the watershed and the planning effort. In addition to the programmatic elements noted under the Baseline Level, the long-term monitoring will involve the selection of a limited number of indicators that can be tracked over time to gage changes in the natural system. Some measurement techniques are quite simple and others require trained personnel and/or specialized equipment. **Table PS10-2** lists several possible indicators; it is not expected that each program will utilize all of these indicators, but that several strategic indicators can be used based on the specific goals and objectives of the watershed plan. It should be noted that the indicators in the table are appropriate to track conditions in the watershed, such as streams, guts, riparian areas, developed areas, etc. **PS #2** addresses water quality and other indicators more appropriate for the actual coral location out in the lagoon.

There are a variety of methods to measure each type of indicators. In some cases, the table notes several specific methods, but it is beyond the scope of this profile sheet to identify all available methods. Natural resource agencies and universities may be able to help identify the most appropriate methods for your watershed conditions. The table does identify the general level of training or equipment required for each indicator.

Best Practice Level

The Best Practice Level involves consulting detailed resources and customizing the long-term monitoring and adaptive management strategies (e.g., indicators, metrics, protocols) to be used for a specific application. While the list of available resources is quite broad, **Table PS10-3** lists several that are specific to watershed planning. These resources may point to others that may be beneficial for particular users.

Table PS10-2. Examples of Different Types of Indicators to Track Progress Towards Watershed Plan Goals (Adapted From: CWP, 2005, Tables 32 and 33)

Indicator	Level of Expertise/Training or Equipment Required (High, Medium, Low)
Coral Condition Indicators (See **Profile Sheet #2)**	
Water Quality Indicators in the Watershed (streams, guts, ponds, etc.)	
• Pathogens (E. Coli, enterococci) • Ammonia • Total Nitrogen • Total Phosphorus • Chlorophyll a • Dissolved Oxygen • Sediment, Turbidity, and/or Secchi Disk (the latter for ponds, lakes, lagoons) • Heavy Metals	L – M There are low-cost “volunteer monitoring” kits or meters available for some of these parameters. Some analyses may be able to be conducted at the local wastewater plant or government laboratory.
Biological Indicators (Streams/Guts)	
• Fish diversity (Fish Index of Biological Indicators) • Aquatic insect diversity (Benthic IBI) • Single indicator species for local watershed (e.g., benthic diatoms as indicators of eutrophication) • Riparian vegetation cover and diversity • Pesticide levels in fish tissue	M – H These methods generally require trained professionals. Some, such as fish tissue sampling, required specialized equipment for sampling and laboratory analysis.
Physical and Hydrologic Indicators	
• Rainfall • Stream habitat index (e.g., Rapid Bioassessment Protocol – RBP, Rapid Stream Assessment Technique – RSAT) • Streambank stability (e.g., bank pins, Bank Assessment for Non-point Source Consequences of Sediment – BANCS) • Stream temperature, average baseflow	M Most of these methods are based on visual assessments or simple field methods, but DO require adequate training to obtain consistent results.
Community Indicators	
• Trash collected during clean-up events • Recreational use levels, attitudes (e.g., Creel surveys) • Public access points • Citizen attitudes towards natural resources (e.g., before and after surveys for educational events)	L – M Design and oversight may require a professional, but the methods can generally be applied by interns or community volunteers. Before and after surveys should be designed carefully to be unbiased and to obtain the desired information.
Restoration Practice Performance	
• Physical condition and performance of stormwater practices (e.g., CWP, 2009) • Stormwater sampling upstream and downstream of practices (e.g., CWP, 2008) • Water quality monitoring upstream and downstream of wastewater or industrial sites • Structural integrity of stream/shoreline restoration practices • Survival and coverage of vegetation used for restoration practices • Native vs. invasive species at restoration sites	M – H An inspector-type position can handle assessments of physical condition and performance. At the higher end, water quality monitoring design and analysis is sophisticated, but samples can be collected by interns or similar.

Table PS10-3. Several Detailed Resources on Indicators & Metrics for Monitoring and Assessment

Resource	Description & Link (where available)
Metrics and Protocols for Progress Assessment in Chesapeake Bay Stewardship Fund Grants (Sellner et al., 2011), prepared for the National Fish & Wildlife Foundation	An extensive description of indicators, metrics, and protocols for watershed restoration activities in the following categories: agriculture, stormwater, forestry, habitat restoration, tidal and non-tidal wetlands, stream restoration, organizational planning, and social marketing www.nfwf.org/chesapeake/Documents/Metrics%20and%20Protocol%20Report.pdf
Methods to Develop Restoration Plans for Small Urban Watersheds (CWP, 2005)	Chapter 8, Methods to Measure Improvements Over Time, provides guidance and fact sheets on project tracking, sentinel monitoring (fixed stations to measure trends over time), performance monitoring, and ongoing management structures. http://owl.cwp.org/mdocs-posts/urban-subwatershed-restoration-manual-series-manual-2/
Monitoring to Demonstrate Environmental Results: Guidance to Develop Local Stormwater Monitoring Studies Using Six Example Study Designs (CWP, 2008), prepared for EPA	Detailed study guidance and designs for monitoring: stormwater quality at outfalls, pollution source areas, performance of stormwater practices, implementation and longevity of stormwater practices, public education to improve water quality, and cumulative effect of treatment at the catchment scale. http://owl.cwp.org/mdocs-posts/monitoring-guidance-for-ms4s-six-example-study-designs/
Local watershed planning initiatives; examples and lessons learned	There are many local and regional examples of watershed and estuary programs that have included extensive monitoring and modelling. One example is the Tampa Bay Estuary Program. www.tbeptech.org/; see also Guanica & Culebra Watershed Plans (Puerto Rico) and other island jurisdictions' plans at this NOAA link: www.coris.noaa.gov/activities/projects/watershed/
Chapter 8 Monitoring and Tracking Techniques for Management Measures EPA (1993).	*Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters* reference manual from EPA provides special guidance on setting up monitoring protocols for various management measures. www.epa.gov/sites/production/files/2015-09/documents/czara_chapter8_monitoring.pdf

References & Resources

Center for Watershed Protection. 2009. Stormwater BMPs in Virginia's James River Basin: An Assessment of Field Conditions & Programs.

Center for Watershed Protection. 2008. Monitoring to Demonstrate Environmental Results: Guidance to Develop Local Stormwater Monitoring Studies Using Six Example Study Designs.

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Schueler and Kitchell. 2005.. Methods to Develop Restoration Plans for Small Urban Watersheds, Version 2.0. Urban Subwatershed Restoration Manual Series: Manual 2. CWP, Ellicott City, MD.

Sellner, K.G. M. Palmer, L. Wainger, A.P. Davis, B. Benham, E.J. Ling, and G. Yagow. 2011. Metrics and protocols for progress assessment in Chesapeake Bay Stewardship Fund Grants. A report to the National Fish and Wildlife Foundation. CRC Publ. No. 11-173, Edgewater, MD.

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