9 Monitoring Costs

By S.A. Dressing and D.W. Meals

9.1 Introduction

Monitoring plans must be designed to help achieve watershed project or program goals. This could be a relatively simple task with an unlimited budget, but perhaps the most frequently cited problems for those who design and carry out water quality monitoring programs are the limitations and unpredictability of funding. Although cost should not be the defining factor in the design of monitoring plans, it must be considered from the start. Both "cheap" monitoring programs that are inadequate to achieve project objectives or great monitoring programs that are discontinued because funding disappears are worse than no monitoring at all because much or all the money spent is essentially wasted.

While funding can almost never be guaranteed over the course of a multi-year monitoring effort, careful cost analysis at the beginning can help design a monitoring plan that will meet objectives and fit within a cost range that can be sustained until the project ends. In some cases, project budgets might be insufficient to carry out meaningful monitoring; in such cases, monitoring should not be done. In all other cases, project staff must seek a balance that provides the ability to achieve monitoring objectives that are supportive of project or program goals at an affordable cost.

Although an exact monitoring budget will be highly specific to the setting of a particular project, monitoring costs can be estimated reasonably well as part of project planning. Even a very good cost estimate, however, will miss the mark on category specific costs. For example, sampling trips may take more or less time than anticipated, equipment costs can change drastically if equipment is washed away or needed equipment suddenly becomes available from a discontinued monitoring effort, or data analysis and reporting requirements change under new management or because of unexpected findings or additional requests for information. While the total budget allotted to a monitoring project may not change, projects should maintain flexibility to shift resources within a budget to ensure that project objectives are met with maximum cost efficiency.

In this chapter, potential monitoring costs for the types of monitoring described in this guidance document are illustrated using a spreadsheet tool that has been developed to estimate monitoring costs for nonpoint source watershed projects (Dressing 2012, 2014). Two user-editable versions of the spreadsheet can be downloaded at this site: (https://www.epa.gov/polluted-runoff-nonpoint-source-pollution/monitoring-and-evaluating-nonpoint-source-watershed). The master spreadsheet allows users to determine every detail in their cost estimation, whereas the simplified spreadsheet includes default assumptions for monitoring designs, sampling types, and parameters, as well as basic algorithms to allow users to generate cost estimates with as little input as possible. See Appendix 9-1 for additional details on the cost estimation spreadsheets.

9.2 Monitoring Cost Items and Categories

A complete accounting of monitoring costs begins with watershed characterization and development of a QAPP (see chapter 9) and ends with data analysis (see chapter 8) and reporting. Costs incurred by monitoring efforts can include monitoring site selection, construction of monitoring stations, installation and setup of monitoring equipment, sample collection, laboratory analysis, and the ultimate removal of monitoring sheds at the conclusion of the project (see chapters 2 and 3 for details on monitoring designs). Some monitoring efforts include the cost of contracts or grants for monitoring support.

Specific cost items can be grouped and summarized in many (and often overlapping) ways, including the categories shown in Table 9-1. These categories are basically people and things, whereas the categories shown in Table 9-2 are organized by project phases and key project elements. Some costs are incurred once during a project (e.g., site establishment) while others are recurring (e.g., sampling site visits), so annual costs often vary, particularly for the first and last years of a project.

Table 9-1. Costs grouped by type of item or activity

Cost Category	Items Included In Category
Labor	All labor costs (inclusion of fringe benefits optional).
Installed Structures	Materials and labor costs.
Other Site Establishment Costs	One-time fee, electricity connection, setup, etc.
Purchased Equipment	All purchased monitoring equipment.
Rental Equipment	All rented monitoring equipment.
Monitoring Supplies	All startup and annual monitoring supplies.
Office Equipment	All purchased office equipment.
Office Supplies	All startup and annual office supplies.
Travel/Vehicles	All use of vehicles for travel, construction, sample pickup, etc.
Laboratory Analysis	Annual laboratory analysis.
Data Purchases	Maps, data, satellite & aerial photography.
Printing/Media	Printing and other report output media (e.g., CD, web).
Electricity/Fuel	All fuel and power costs for operating sites.
Site Service and Repair	All service, repair, and replacements of sites and equipment.
Annual Site Fees	All annual fees for site access. Does not include initial fee.
Contracts	All non-itemized contracts costs.
Grants	All non-itemized grants costs.

Table 9-2. Costs grouped by project phase or element

Cost Category	Items Included in Category
One-Time Costs	
Proposal and QAPP	Cost for development of proposal and QAPP or equivalent document (added to Year 1 cost).
Watershed Characterization	Cost for characterization of watershed to aid monitoring design (added to Year 1 cost). Includes windshield surveys and analysis of existing data and maps.
Site Establishment	Includes one-time costs for setting up station, including purchase of equipment that remains at site. Site selection, preparation, and excavation costs are all included.
Portable Sampling Equipment and Startup Supplies Costs	Includes one-time costs for all portable sampling equipment or instruments that are taken to the site for use and then taken away for use at another site or time. Equipment includes such items as kick nets, pH meters, etc. Also includes one-time cost for initial purchase of supplies such as pipettes, vials, and bottles.

Cost Category	Items Included in Category
One-Time Office Equipment and Startup Supplies Costs	Includes computer hardware and software and related items.
Station Demolition and Site Restoration	Includes all costs associated with tearing down the station and restoring the site at the end of the project.
First-Year Report	This is the cost for data analysis and writing, printing, and distribution of the first-year report. Data analysis and reporting can be combined or kept separate.
Final Report	This is the cost for data analysis and writing, printing, and distribution of the final report. Data analysis and reporting can be combined or kept separate.
Annual Costs	
Access Fees	Any fees paid to landowners for allowing access to the site.
Sampling Trips to Sites	Includes labor, vehicle use, and other equipment (e.g., boat) costs for site visits.
Volunteer Training	Annual cost to train volunteers or others collecting data for the project.
Sample Analysis	Cost for laboratory analysis of samples. Includes travel to and from laboratory if done in addition to sampling trip travel. Can include costs for shipping samples to laboratories as “Other” cost.
Annual Data Analysis and Reports	This is the cost for annual analysis of project data and annual or more frequent reporting in years other than the first and last year. Includes labor and materials. Data analysis and reporting can be combined or kept separate.
Site Operation and Maintenance	Includes service/repair/replacement of equipment and structures, electric and fuel bills (e.g., for heating), and annual cost to establish and update stage/discharge relationship.
Supplies and Rental Equipment	This cost is primarily for consumable supplies (e.g., sample preservative), but can include sample bottles and other items. Also includes rental equipment and office supplies.
Land Use Tracking	Labor, travel, and services (e.g., aerial photography or data purchase) needed to track land use and land treatment.
Total Cost of Monitoring	Total cost of monitoring for the entire project period.

9.3 Cost Estimation Examples

The cost spreadsheets have been used to estimate costs for a wide variety of monitoring designs and applications. The cost estimates highlighted here were developed for three different purposes. First, the master spreadsheet was used to provide a range of estimates for a diverse set of monitoring options, with estimated costs generated for eight different monitoring scenarios covering a wide range of timeframes (see section 9.3.1). The ten cost estimates summarized in section 9.3.2 cover various monitoring approaches relevant to assessing the watershed-scale water quality impacts of programs such as USDA’s National Water Quality Initiative (NWQI). Finally, the simplified spreadsheet was used to estimate costs for 60 basic, 5-year monitoring scenarios that are summarized in section 9.3.3. It is important to note that assumptions regarding the need and cost for labor, equipment, monitoring parameters, sampling frequency, and sampling duration are all important determinants of the final cost estimates, so costs are presented in this section more for a comparative analysis than as accurate estimates for any specific monitoring type or effort. The examples are particularly useful to contemplate trade-offs among cost categories and to evaluate where cost-effectiveness can be improved, e.g., offsetting high labor costs with the purchase of automated equipment.

9.3.1 Cost Estimates for a Diverse Range of Monitoring Options

Cost estimates for the following eight monitoring scenarios are presented in this section.

1. Synoptic Survey
2. TMDL – Water Quality Standards
3. TMDL – Loads
4. Paired-Watershed - Loads
5. Long-term Single Station - Biomonitoring
6. Above/Below BMP Effectiveness - Biomonitoring
7. Input/Output Urban Low Impact Development (LID) Effectiveness
8. Photo-Point Monitoring

These eight scenarios were chosen to represent a wide range of monitoring approaches, addressing both problem assessment and project evaluation, using chemical, physical, and biological (Barbour et al. 1999) monitoring methods. With the exception of 1-year synoptic surveys (Scenario 1), costs are estimated for 1, 2, 5, and 8 years. A more detailed comparison of Scenarios 2-8 is based on five-year cost estimates. See Appendix 9-2 for additional details on these eight scenarios.

9.3.1.1 Discussion

Table 9-3 summarizes the total costs for each scenario for 1, 2, 5, and 8 years. Cost totals are taken from the base scenarios in which all equipment is purchased and all monitoring is stand-alone; that is, there are no cost savings assumed for monitoring activities that may be combined with other activities (e.g., another monitoring effort in the same area) to save on travel or labor. It should be no surprise that biological (Scenarios 5 and 6) and photo-point (Scenario 8) monitoring are the least expensive monitoring approaches in this analysis. Sampling frequency (2x/year) for biological and photo-point monitoring is far less than is assumed for water quality monitoring and load estimation, and laboratory and equipment costs are generally lower as well.

While total cost provides the best measure for comparing the costs for alternative monitoring designs, the breakout of costs by category gives a better picture of where cost savings can be found within each monitoring design. For example, labor accounted for the greatest share of total costs in all five-year scenarios, ranging from 68 percent for Scenario 7 (urban LID) to 90 percent for quantitative photo-point monitoring (Figure 9-1). Labor accounted for only 45 percent of the total cost for the 1-year synoptic survey.

Equipment costs ranged from 2 percent for Scenario 2 (TMDL water quality standards) to 12 percent of total 5-year costs for qualitative photo-point monitoring. About 45 percent of the 1-year budget for synoptic surveys was devoted to equipment. Laboratory analysis costs accounted for 16 percent of total 5-year costs for Scenario 7 (urban LID), 9 percent of the 1-year cost for a synoptic survey, and 5 percent of the 5-year cost for Scenario 2 (TMDL water quality standards), but were responsible for less than 1 percent of costs for all other scenarios.

Vehicle (mileage) costs ranged from 1 percent for Scenario 1 and quantitative photo-point monitoring to 10 percent of total 5-year costs for Scenario 2. Both Scenario 3 and Scenario 7 had 5-year budgets in which vehicle costs accounted for 9 percent of the total cost.

It is important to ensure that whatever monitoring approach is used will provide the type, quality, and quantity of information necessary to meet project monitoring objectives. Despite its lower cost, photo-point monitoring will usually not be appropriate as a stand-alone monitoring approach for tracking progress in achieving a TMDL. Likewise, biological monitoring cannot be used to estimate pollutant loads. On the other hand, weekly grab sampling for water chemistry may be wasteful if monitoring is intended to track attainment of aquatic life support, and photo-point monitoring could be appropriate for a trash TMDL such as that established for the Anacostia River (MDOE and DDOE 2010).

Table 9-3. Summary of scenario costs for diverse range of monitoring options

Scenario	Total Cost ($1,000)			
	1 Year	2 Years	5 Years	8 Years
1. Synoptic Survey	30	n/a	n/a	n/a
2. TMDL WQS	47	90	215	339
3. TMDL Loads	62	107	238	368
4. Paired-Watershed Load	93	158	348	537
5. Long-Term Biological	16	26	53	80
6. Above/Below BMP Effectiveness - Biological	17	28	58	88
7. Input/Output Urban LID Effectiveness	68	115	252	388
8. Photo-Point Monitoring – Qualitative Analysis	8	11	19	26
8. Photo-Point Monitoring – Quantitative Analysis	25	39	75	111

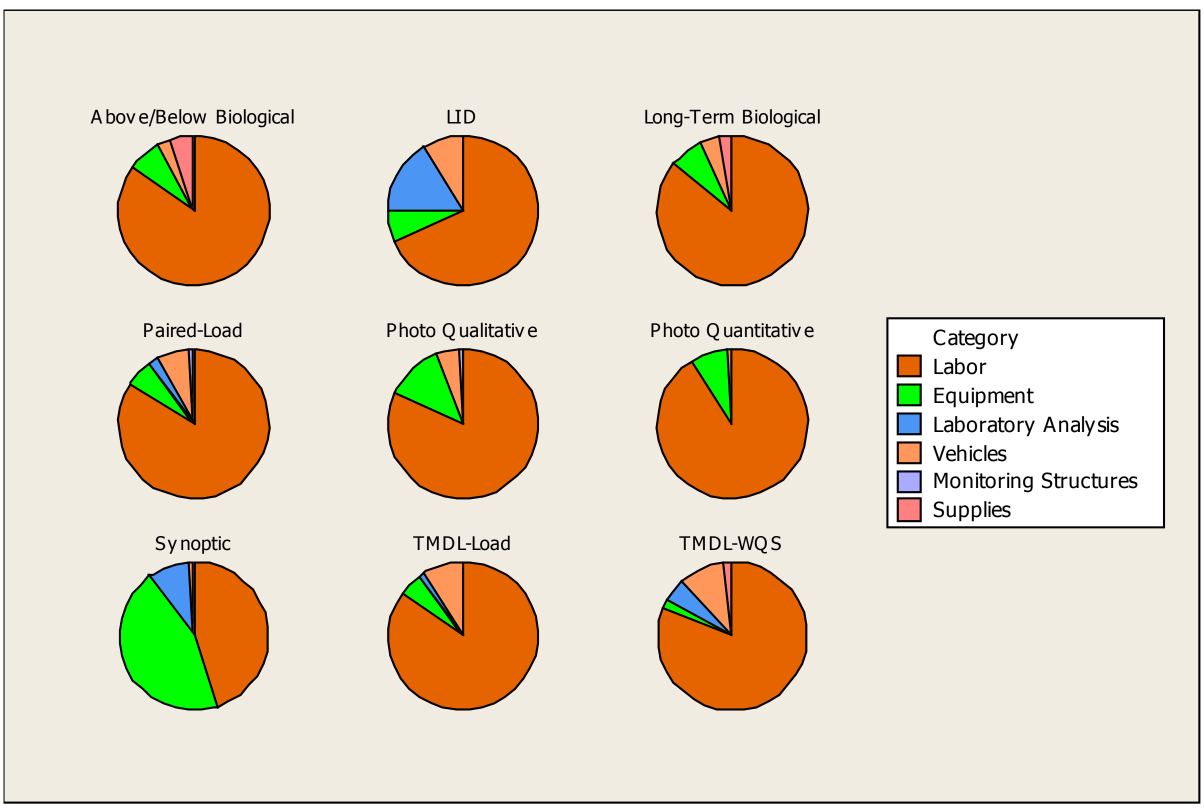


Figure 9-1. Breakout of costs for diverse range of monitoring options

9.3.2 Cost Estimates for Watershed-Scale Evaluation of Agricultural BMP Implementation

This cost analysis was performed to explore different options for planning and assessing the water quality impacts of watershed-scale implementation of agricultural BMPs. The setting assumed for the cost scenarios is a 12-digit HUC watershed covering 10,117 ha (25,000 ac), primarily in agricultural use. Monitoring is performed in perennial streams with the exception of the paired-watershed scenario that assumes intermittent flow.

Cost estimates were generated for a total of 84 scenarios, including synoptic surveys, compliance monitoring, soil testing, multiple-watershed monitoring, and paired-watershed, trend, and above/below monitoring. Cost estimates were developed for three different driving distances to the watershed to illustrate how that factor influences costs, particularly the labor share of total costs. Three timeframes were considered (three, five, and seven years) for all but synoptic surveys which were assumed to be completed within one year.

For simplicity, all labor was assumed to be performed by contractors, but this may not be affordable in many situations. Pay rates assumed (including fringe and overhead) and basic job functions are summarized in Table 9-4. Rates for government or university employees and volunteers would clearly differ, and contractor rates would vary depending on location.

Additional assumptions about number of sampling sites, monitoring frequency, monitoring variables, and various other aspects of the monitoring designs are documented in Appendix 9-3.

Table 9-4. Labor costs assumed for watershed-scale evaluation scenarios

Pay Level	Rate ($/hr)[1]	Job Functions
4	130	Monitoring design, statistical analysis, oversight, etc.
3	80	Lead field person for monitoring, data collection, bulk of writing
2	56	Field technician, lab tech, etc.
1	34	Secretarial and support staff

[1]Includes fringe and overhead.

9.3.2.1 Discussion

Results for 5-year monitoring efforts are summarized in Figure 9-2. Not shown in this figure are 1-year synoptic surveys which had the lowest cost, ranging from $12,000 to $18,000 depending on distance traveled to the watershed. The low cost of synoptic surveys compared to the cost of other scenarios indicates that they can be a very good investment for generating additional information to support final decisions on both the land treatment plan and long-term monitoring design.

Compliance monitoring is also relatively inexpensive as defined in these scenarios, ranging from $21,000 to $55,000 for 5-year efforts depending on distance traveled. The cost for a soil testing program ranges from $32,000 to $50,000 for five years with a far smaller influence of distance traveled on total cost compared to compliance monitoring. This is because soil testing requires a large amount of time collecting samples at the site, whereas sampling for compliance monitoring is relatively quick once the site is reached.

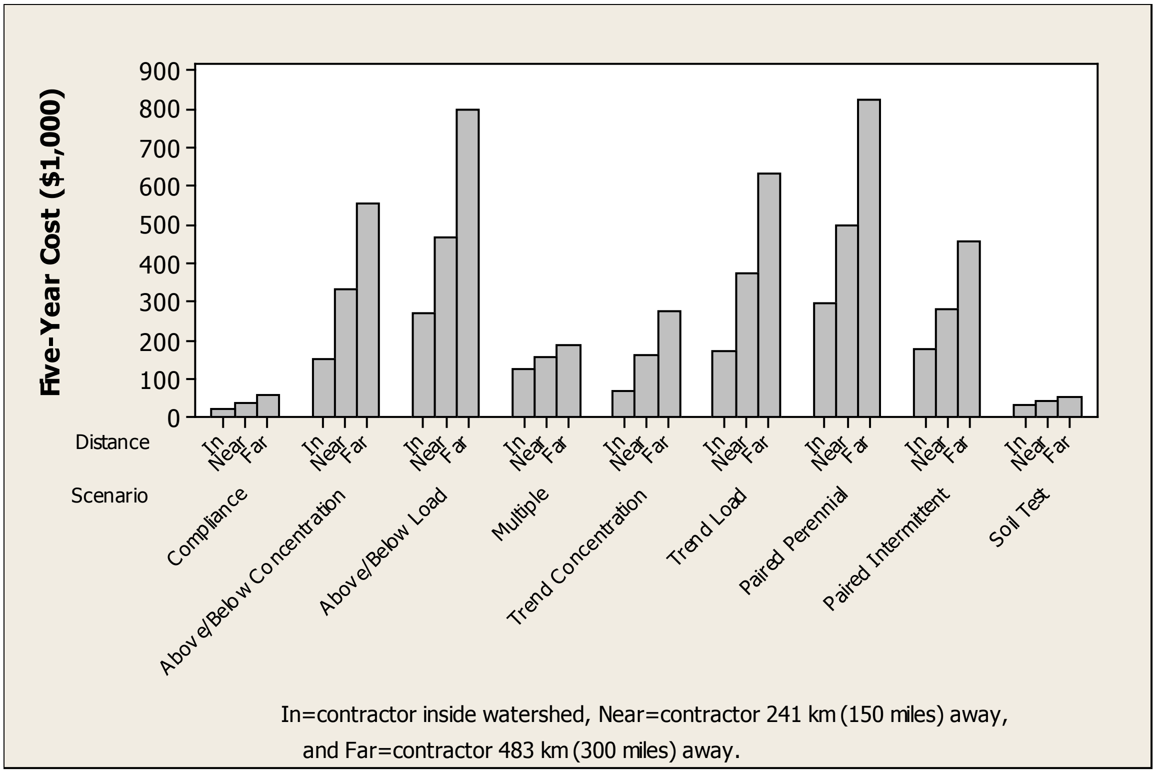


Figure 9-2. Cost estimates for watershed-scale assessment of agricultural BMP projects

Trend monitoring costs can range from $68,000 to $275,000 for a 5-year effort with grab sampling to a range of $172,000 to $630,000 for a 5-year effort with automated sampling and pollutant load estimation. Although not shown in Figure 9-3, this analysis presents an interesting choice between a 7-year grab sampling effort ($92,000-$382,000) and a 3-year load estimation effort ($112,000-$391,000) for trend analysis. This cost information coupled with an MDC analysis (see section 9.4) could lead to cost-effective solutions to monitoring needs.

The cost of above/below monitoring ranges from $152,000 to $553,000 for a 5-year grab sampling effort to $268,000 to $799,000 for a 5-year load estimation effort. Costs for above/below monitoring designs are roughly twice the cost of the parallel trend monitoring designs for grab sampling, but can be much less than double the cost for load estimation. For example, comparing 5-year costs for above/below with trend concentration monitoring shows that the “near” cost for above/below ($329,000) is about twice the “near” cost for the trend design ($159,000). However, the 5-year cost for above/below load monitoring ($466,000) is far less than double the cost for trend load monitoring ($371,000). The different patterns are largely explained by the costs for site establishment and automated sampling equipment for load estimation.

Paired-watershed monitoring (loads) are found to be similar to above/below monitoring in this analysis. Costs ranged from $176,000 to $455,000 for a 5-year effort on an intermittent stream to $294,000 to $824,000 for 5 years on a perennial stream. The major difference between paired-watershed and above/below monitoring costs is the travel between watersheds and larger area involved in land use/treatment tracking for paired-watershed monitoring.

The cost of monitoring 20 subwatersheds in a multiple-watershed design is estimated to range from $125,000 to $185,000 for a 5-year effort. Grab sampling is assumed for multiple-watershed monitoring scenarios in this analysis.

For scenarios assuming 5 years of monitoring and the "near" distance (monitoring team 241 km from watershed), labor consumes 72 to 86 percent of total cost estimates. The proportion of total costs devoted to labor often changes with project duration, however, as illustrated in Figure 9-3. In this comparison, the labor share of cost decreases with increasing monitoring duration for soil testing (assuming 20 sites), but increases for a paired study measuring loads on a perennial stream. The different trends result primarily from differences in first-year costs. The paired design assumes significant labor and equipment (~equal) costs for site establishment and purchased equipment, while the soil testing design assumes substantial labor cost to select sites via desktop analysis. It should be noted that for both scenarios total labor costs increase over time, whereas equipment, site selection, and site establishment costs are incurred in the first year only.

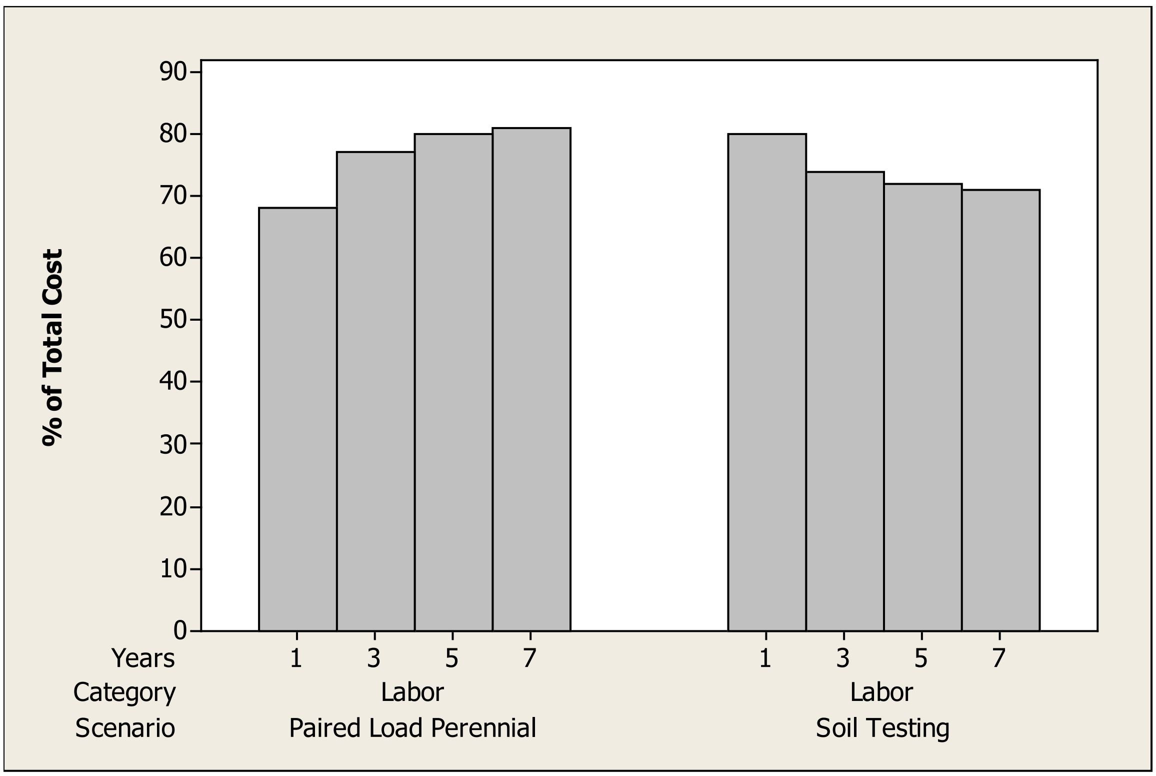


Figure 9-3. Comparison of labor cost category percentage over time

9.3.3 Cost Estimates for Five-Year Trend and Above/Below Monitoring

Cost estimates were generated for 160 scenarios that address two different designs (trend and above/below); four different monitoring variable sets (nutrient and sediment grab samples – [NSC], nutrient and sediment loads – [NSL], biological/habitat with kick net – [BioK], and sondes for nutrients and turbidity – [SNT]); four watershed sizes (202, 2023, 10117, and 20234 ha)[1]; and five different

[1] 500; 5,000; 25,000; and 50,000 acres

distances to the watershed (0, 40, 80, 121, and 161 km)[2]. All scenarios assume 5 years of monitoring, while it was assumed that sampling frequency was 2 and 26 times per year for biological and all other monitoring, respectively. In addition to sample collection and analysis, total monitoring costs also include watershed characterization, site establishment, land use/treatment tracking, data analysis, and reporting. This cost analysis was designed to test application of the simplified spreadsheet to the designs most commonly used by NPS watershed projects. See Appendix 9-4 for additional details.

Additional scenarios using all combinations of the following conditions were run to illustrate how assumptions on salary and equipment affect total cost estimates:

- Labor cost of $0 and salary adjustment of factors of 0.5, 0.7, and 1 (baseline).
- Purchase of all equipment (baseline) and equipment cost of $0.

These scenarios were run for a 2,023-ha (5,000 ac) watershed where the monitoring team was 80 km (50 mi) from the watershed, parameters that best represent the median total costs for each design and variables set.

9.3.3.1 Discussion

Figure 9-4 summarizes the results from this analysis. The box plots on the top show clearly that load estimation (NSL) is the most expensive approach when compared to concentration monitoring with grab samples (NSC) and the use of sondes for nutrients and turbidity (SNT). Biological monitoring (BioK) is the cheapest option overall, but sampling is only done twice per year versus the assumed 26 times per year for the other three options. Above/below monitoring is more expensive than trend monitoring for all variable sets because there are twice as many stations. The cost, however, is less than double because of efficiencies in labor, travel, analysis and other cost categories. It should be noted that paired designs would have costs similar to those for the above/below design.

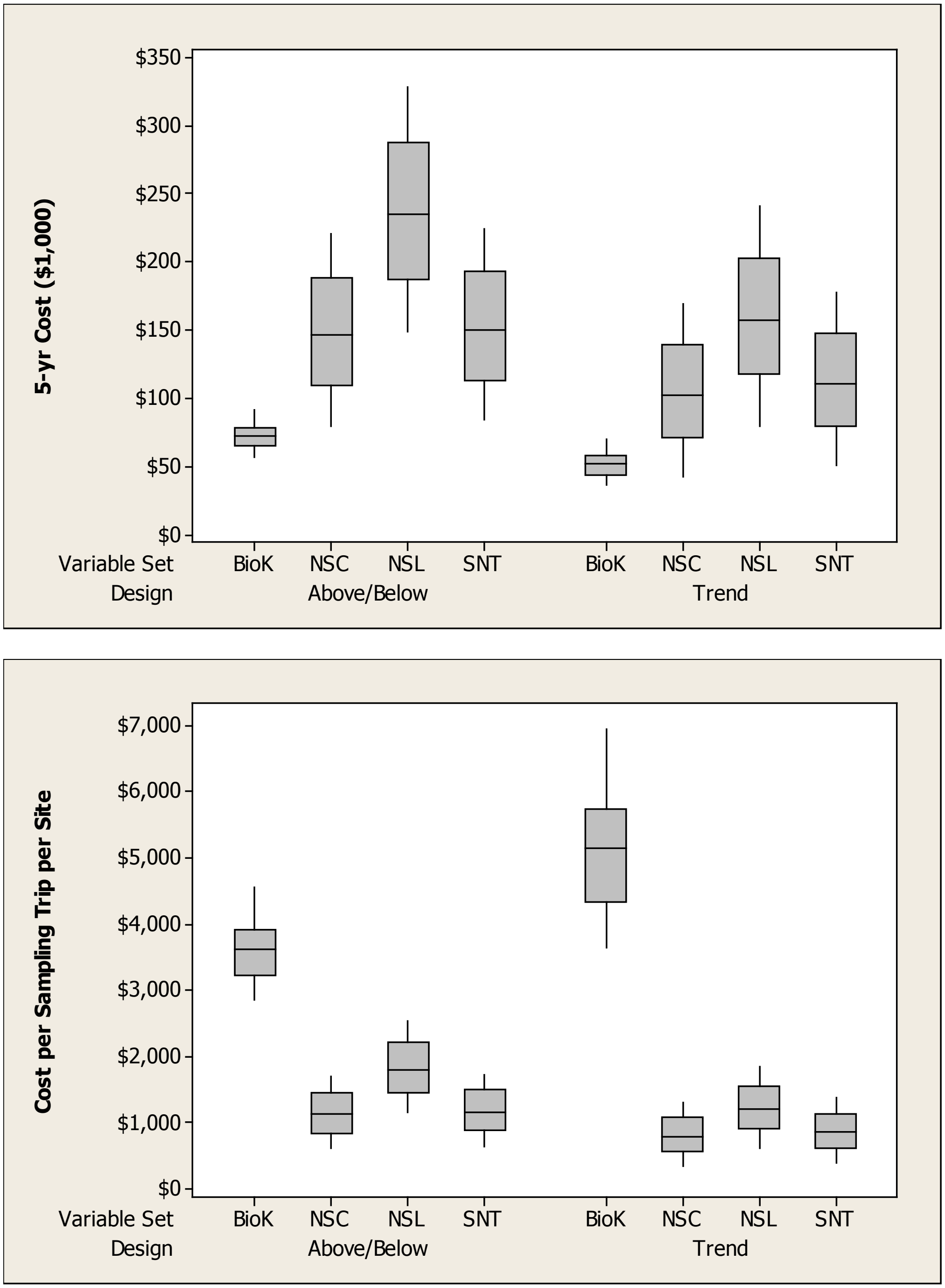
When costs are reduced to cost per sampling trip to each monitoring site (bottom of Figure 9-4), biological monitoring is by far the most expensive approach of the scenarios considered. This is due primarily to the fact that only 2 samples are collected each year versus 26 samples per year for the other scenarios. Load monitoring is more expensive than both concentration and sonde monitoring. This figure also points out the cost efficiency of above/below versus trend monitoring when using a biological approach; the extra site is relatively inexpensive. Readers should keep in mind that, as described above, total costs include more than just sample collection and analysis.

In all cases examined here, labor accounted for the largest share of costs, ranging from 63% to 84 percent of total cost (66 percent to 85 percent if labor for analysis of biological samples is included). Competitive contractor rates were assumed for labor, but the importance of labor costs can vary greatly because monitoring efforts may use far less expensive staff (e.g., volunteers) or assume that labor is not an additional cost because in-house staff are used.

Labor generally accounted for a larger share of total costs for scenarios that required less equipment, ranging from 63 percent to 74 percent for biological (74-85 percent including analysis of biological samples) and 74 percent to 84 percent for nutrient/sediment concentration monitoring. A slightly lesser share of total cost was devoted to labor in cases where sondes were assumed (66-82 percent) or loads were estimated with continuous flow measurement and automatic sampling (67-81 percent). Despite the

[2] 0, 25, 50, 75, and 100 miles

greater importance of labor in costs for biological monitoring, Figure 9-5 illustrates that the dollar amount is still far less than for other monitoring options, whether labor for analysis of biological samples is included (BioK-A) or not (BioK).



BioK=Biological monitoring with kick net; NSC=Nutrient and sediment concentration; NSL=Nutrient and sediment load: SNT=sondes for nutrients and turbidity

Figure 9-4. Box plots summarizing cost estimates for five-year monitoring efforts

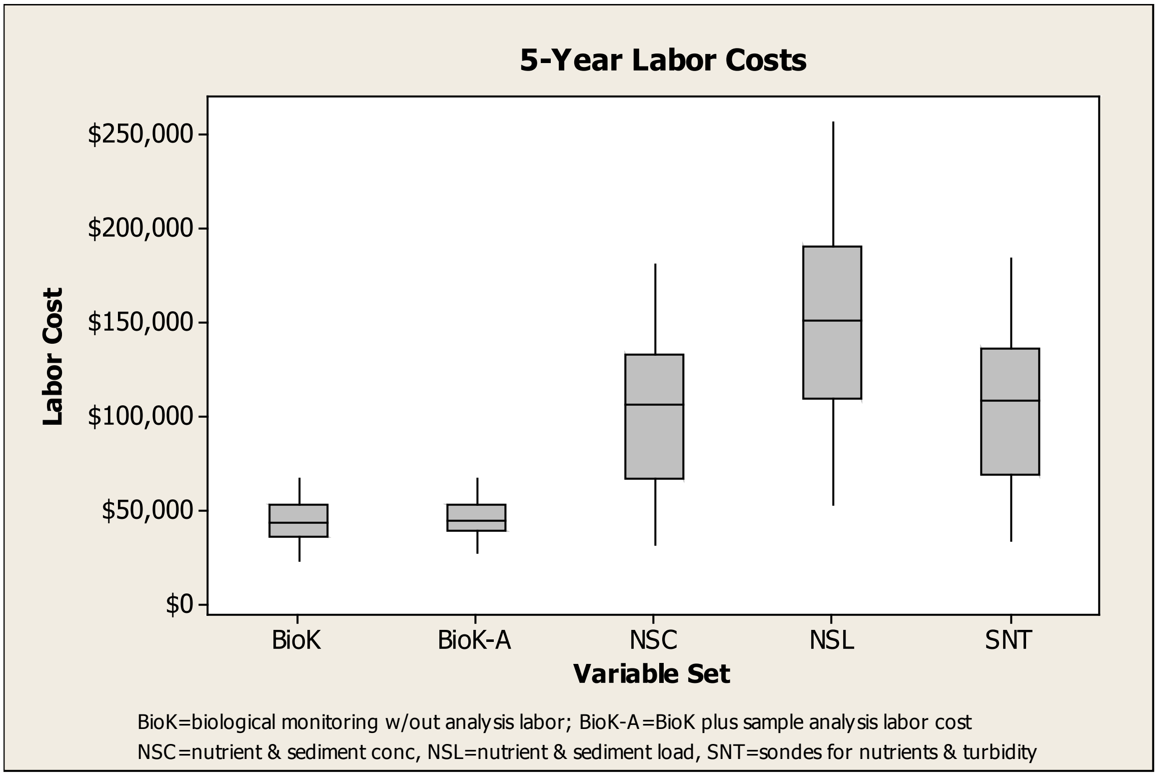


Figure 9-5. Box plots summarizing five-year labor costs

Equipment and supplies accounted for 6-27 percent of total costs for BioK, NSL, and SNT, but only a maximum of 2 percent for NSC. The large difference in importance of this cost category for biological monitoring versus grab sampling for nutrients and sediments (NSC) hinges largely on the vast differences in sampling frequencies (2x/yr vs. 26x/yr) and thus labor costs. The difference between NSC and NSL and SNT is due to the far larger reliance on purchased equipment for monitoring with sondes and measurement of loads. Sample analysis generally accounted for 2-25 percent of total costs for all scenarios.

Vehicle costs were typically well under 10% of total costs for these scenarios, and per diem costs were zero except in cases where watersheds were very large (10,117 or 20,234 ha) and monitoring teams were remote (121 or 61 km from the watershed). Overnight stays were associated with watershed characterization and land use/treatment tracking, not water quality monitoring. Each cost scenario assumes that the watershed will be characterized in the first year of monitoring, and that land use/treatment will be tracked twice per year every year.

Assumptions regarding salary and equipment costs have a substantial impact on total cost estimates as illustrated in Table 9-5. If pay rates are reduced to 70 percent of the default values, the total cost is reduced by 23-25 percent for all 64 scenarios[3] included in this analysis versus the baseline scenario of full pay rates (see Table 9-5) and purchase of all equipment. A reduction to 50 percent of default pay rates reduces the total cost by 38-42 percent. If labor costs are zeroed out, total costs are reduced by 68-84 percent. If pay rates are maintained at the default values and all equipment is assumed to be in hand with no purchases required, costs are reduced by 1-20 percent versus the baseline scenario. If equipment

[3] Two designs, 4 variable sets, 4 salary levels, 2 equipment cost levels (2x4x4x2=64).

purchases are assumed to not be needed and labor costs are reduced to 70 percent of the default values, total costs are reduced by 25-43 percent. If neither labor nor equipment costs are included, total cost is reduced by 81-98 percent of baseline cost, clearly illustrating the importance of assumptions on pay rates and equipment needs when estimating total monitoring program costs.

Table 9-5. Cost reductions due to lowering of labor and equipment costs

Salary Assumption	Equipment and Supplies	Cost Reduction vs. Base Scenario[1]	
		Range	Median
Full Cost	Purchase All	0[2]	0[2]
Reduced to 70%	Purchase All	23-25	24
Reduced to 50%	Purchase All	38-42	39
No cost for Labor	Purchase All	68-84	77
Full Cost	Zero cost	1-20	12
Reduced to 70%	Zero cost	25-43	35
Reduced to 50%	Zero cost	41-59	51
No cost for Labor	Zero cost	81-98	88

[1]Base scenario assumes full contractor salary levels and purchase of all equipment and supplies. All scenarios assume 5-yr monitoring in a 2,023-ha watershed 80 km from monitoring team.
[2]Base scenario of full pay rates (Table 9-4) and purchase of all equipment.

9.3.4 Major Conclusions from Cost Estimation Scenarios

The cost estimates provided in this section are intended to illustrate the importance of estimating the costs for *all* elements of monitoring for both the short- and long-term as part of establishing an effective and sustainable monitoring program that will meet watershed project monitoring objectives. Those who use either spreadsheet will find that they can tailor assumptions and add localized cost information to improve their estimation capabilities. With increasing experience, including making adjustments based on comparison of estimated versus actual costs, users should be able to improve the accuracy of their cost estimates over time. In all cases, but especially where budgets for monitoring are limited, accurate cost estimation is essential to assessing the potential for conducting a monitoring effort that will satisfy project objectives. Anything short of that is likely to be a waste of resources.

Because labor is such an important cost factor for all monitoring designs considered here, it provides the greatest opportunity for cost savings. These savings can be generated a number of ways, including:

- Using volunteers whenever possible. (Training costs may be incurred, however, and practical and legal limitations apply.)
- Using in-house labor. (This is not free and may involve diversion of labor from other projects or programs.)
- Negotiating contracts to ensure greater use of lower cost staff wherever appropriate.
- Using labor sources based within or near the watershed. (This will also reduce vehicle and lodging costs, but may limit options.)
- Piggybacking sampling trips with other duties to maximize benefits of travel time.

- Strategic use of in-house, volunteer, and contractor/grant labor to more efficiently match functions with capabilities and needs.
- Substituting higher initial cost equipment for some labor in long-term projects (e.g., telecommunications/data logging to reduce data collection trips).

In many cases the addition of non-instrumented monitoring sites to a watershed project can be relatively inexpensive because of the labor already invested in getting to the watershed for sampling events, as well as the labor needed to characterize the watershed, track land use and land treatment, analyze data, and develop reports. The incremental cost of adding monitoring stations should always be assessed in light of how they could contribute to achieving project monitoring objectives. For example, paired-watershed and above/below monitoring designs are inherently more powerful than single-station trend designs for evaluating the effectiveness of BMP implementation on a localized or watershed scale. The incremental cost of sampling two stations instead of one may support a stronger monitoring design that could yield results in a shorter time period, perhaps reducing overall costs in the end. In addition, findings may be more conclusive and the risk of failure reduced.

Equipment is never cheap, but the relatively low cost for equipment in most cost estimates developed here suggests that it may be cost-effective to use sophisticated equipment and instruments if they can offset higher personnel costs. Conversely, substituting labor for equipment (e.g., sending staff out to collect frequent observations vs. using a data logger) is not likely to be cost-effective. Finally, it is very important that equipment is maintained and operated in accordance with manufacturer recommendations to both obtain good data and to ensure that equipment is operable over its expected lifespan.

While this chapter did not focus on how total cost is affected by the selection of monitoring variables, it is clear that analysis of constituents such as pesticides and metals, as well as advanced methods such as microbial source tracking will cost more than *in situ* measurement of temperature or laboratory analysis of basic variables such as suspended sediment. Planners can use the spreadsheets to assess tradeoffs between adding more or different variables versus increasing sampling frequency or duration, or adding monitoring sites. Careful consideration of these and other design options should lead to better decisions regarding the makeup of a monitoring plan while both achieving monitoring objectives and staying within the budget.

9.4 Using Minimum Detectable Change to Guide Monitoring Decisions

As noted earlier, cost should not be the defining factor in the design of monitoring programs. Program designers must seek a balance that provides the ability to achieve monitoring objectives that are supportive of watershed project goals at an affordable cost. Monitoring design, for example, should be guided by the results of MDC analysis (see section 3.4.2) whenever possible. To illustrate this approach, cost estimates were developed for options considered in Example 1 (*A linear trend with autocorrelation and covariates or explanatory variables; Y values log-transformed*) of a technical note on MDC (Spooner et al. 2011). In the first scenario, weekly samples are collected for five years, resulting in an MDC of 15 percent, or an average of 3 percent change per year. By extending the monitoring period to 10 years, the MDC is increased to 20 percent, but with a lower average change of 2 percent per year required. Assuming that total P is the monitoring parameter of interest ($20 per sample analysis) the total cost (including a QAPP, reports, travel, etc.) for five years is estimated at $190,000, with 83 percent devoted to labor. A 10-year effort would cost $377,000. So, an additional $187,000 is needed to reduce the average annual change needed from 3 percent to 2 percent. This type of analysis would provide project managers with the cost information needed to determine whether they would prefer to enhance implementation of BMPs to achieve a faster rate of change or commit to a longer monitoring period to measure a slower rate of change.

The cost-benefit of adding explanatory variables can also be assessed through a combination of MDC analysis and cost estimation. For example, Spooner et al. (1987) demonstrated that adding salinity as a covariate in the Tillamook Bay, Oregon watershed study decreases the MDC for fecal coliform (yearly geometric concentration means) over an 11-year period of time (20 samples/yr; 14 sites) from 42 percent to 36 percent. For this same study, the MDC for fecal coliform decreases from 55 percent to 42 percent when doubling sampling frequency from 10 to 20 times per year over an 11-year study.

To estimate costs for the Tillamook Bay scenarios, it is assumed that there are 14 monitoring sites and fecal coliform is measured from one grab sample per site ($20/sample). Salinity is measured using a hand-held meter ($765). Sample size is increased by 10 percent for QA/QC. Sampling trips are assumed to involve 2 people for 8 hours each, including a 322-km (200 mi) round-trip to cover all 14 sites. The cost for a QAPP is assumed to be $1,400 and data analysis and reporting costs are $2,268 for the first and last years and $622 for the other nine years. The costs for watershed characterization, site establishment, and land use/treatment tracking are assumed to be zero.

These scenarios are summarized in Table 9-6. Adding salinity to the base scenario increases the 11-year cost by only $800 ($75/year) while improving the MDC by 8 percent from 55 percent (5 percent per year) to 47 percent (4.3% per year). Increasing sampling frequency nearly doubles the total 11-year cost while improving the MDC by 13 percent, from 55 percent to 42 percent (3.8 percent per year). Adding salinity measurement to the increased sampling frequency adds just $800 to the total 11-year cost, but reduces the overall MDC by an additional 6 percent to 36 percent (3.3 percent per year). Clearly, with or without an increase in sampling frequency, the additional $800 cost for salinity, while almost negligible, buys substantial additional sensitivity to detect a change in fecal coliform counts.

Table 9-6. Illustration of costs and MDC in response to changes in sampling program in Tillamook Bay, Oregon (Spooner et al. 1987)

Scenario	Sampling Program	Cost (11 years)	Cost Change[1]	MDC	MDC Change[1]
Base	10x/yr, FC	$182,600	--	55%	--
Add salinity	10x/yr, FC, salinity	$183,400	$800	47%	8%
Double frequency	20x/yr, FC	$347,400	$164,800	42%	13%
Double frequency, add salinity	20x/yr, FC, salinity	$348,200	$165,600	36%	19%

[1]Change versus Base scenario.

9.5 References

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. *Rapid Bioassessment Protocols for Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish*. 2nd ed. EPA/841-D-99-002. U.S. Environmental Protection Agency, Office of Water, Washington, DC. Accessed February 9, 2016. http://water.epa.gov/scitech/monitoring/rsl/bioassessment/index.cfm.

Dressing, S.A. 2012. *Monitoring Cost Estimation Spreadsheet – Master Version*. Tetra Tech, Inc., Fairfax, VA. Accessed April 29, 2016. https://www.epa.gov/polluted-runoff-nonpoint-source-pollution/monitoring-and-evaluating-nonpoint-source-watershed.

Dressing, S.A. 2014. *Monitoring Cost Estimation Spreadsheet – Simplified Version*. Tetra Tech, Inc., Fairfax, VA. Accessed April 29, 2016. https://www.epa.gov/polluted-runoff-nonpoint-source-pollution/monitoring-and-evaluating-nonpoint-source-watershed.

MDOE (Maryland Department of the Environment) and DDOE (District of Columbia Department of the Environment). 2010. *Total Maximum Daily Loads of Trash for the Anacostia River Watershed, Montgomery and Prince George's Counties, Maryland and the District of Columbia-Final*. Maryland Department of the Environment and District Department of the Environment-Natural Resources Administration. Accessed April 6, 2016.

NEMI (National Environmental Methods Index). 2006. *National Environmental Methods Index*. National Water Quality Monitoring Council. Accessed February 5, 2016. www.nemi.gov.

Spooner, J., R.P. Maas, M.D. Smolen, and C.A. Jamieson. 1987. Increasing the Sensitivity of Nonpoint Source Control Monitoring Programs. In *Symposium On Monitoring, Modeling, and Mediating Water Quality*, American Water Resources Association, Bethesda, Maryland, pp. 243-257.

Spooner, J., S.A. Dressing, and D.W. Meals. 2011. *Minimum detectable change analysis.* Tech Notes #7. Prepared for U.S. Environmental Protection Agency, by Tetra Tech, Inc., Fairfax, VA. Accessed March 24, 2016. https://www.epa.gov/polluted-runoff-nonpoint-source-pollution/nonpoint-source-monitoring-technical-notes.

Appendix 9-1. Overview of Cost Estimation Spreadsheets

Both the master and simplified spreadsheets support cost estimation covering all items shown in Table 9A1-1 and Table 9A1-2. Various options exist for users to change spreadsheet costs (e.g., for labor or laboratory analysis) based on local information or experience, as well as assumptions regarding labor, equipment, and other requirements for monitoring designs of interest to the user. The master spreadsheet provides total flexibility in changing cost assumptions, whereas the simplified spreadsheet is designed to provide a set of default assumptions that facilitates development of cost estimates with minimal data entry. The master spreadsheet supports costing of virtually any monitoring design, while the simplified spreadsheet supports cost estimation for only above/below, paired, and trend monitoring designs.

Data entry requirements for the simplified worksheet are:

- Beginning year for monitoring (for inflation estimates).
- Monitoring design (above/below, paired, or trend – results in 1 or 2 sites).
- Watershed size and size of second watershed for paired design.
- Distance monitoring team is from watershed.
- Extra distance to drop samples off at laboratory.
- Average speed limit for drive to watershed.
- Average speed limit within watershed.
- Mileage rate paid for vehicles.
- Per diem rate (food and non-lodging expenses).
- Lodging rate (including taxes).
- Type of sampling (biological/habitat, grab, sondes, loads).
- Variable set (2 or 3 options per sampling type).
- Sampling frequency (same at each site).
- Duration of monitoring effort.

The simplified spreadsheet provides the sample type and variable set options shown in Table 9A1-1 (Note: codes are used in Appendix 9.4). Variable sets for these options are shown in Table 9A1-2 through Table 9A1-5. The number of units needed is calculated for each cost item based on the number of monitoring sites, sampling frequency, and monitoring plan duration. Note that inclusion of specific vendor products does not indicate EPA endorsement.

Table 9A1-1. Sample type and variable set options for simplified spreadsheet

Sample Type	Grab		Load		Biological/Habitat		Sondes	
	Variables	Code	Variables	Code	Variables	Code	Variables	Code
Variable Set Options	Nutrients, Sediment	NSC	Nutrients, Sediment	NSL	Biological Monitoring with Kick Net	BioK	Nutrients, Turbidity	SNT
	Bacteria, Nutrients, Sediment	BNSC	Bacteria, Nutrients, Sediment	BNSL	Biological Monitoring with D-Frame Dip Net	BioD	Nutrients, Turbidity, Metals	SNTM
	Metals, Sediment	MSC	Metals, Sediment	MSL				

Table 9A1-2. Grab sampling variable sets

Variable Set	Cost Items	
	Equipment and Supplies	Laboratory Analysis
Nutrients and Sediment (NSC)	Style A Staff Gage (13.5 ft), T-style post, and post driver	Total N using EPA Method 351.4
	Rain Gage (plastic)	Total P using EPA Method 365.4
	Cooler (54-quart) and ice for cooler	Suspended Sediment Concentration (USGS Method)
	Bottles-1000 ml wide mouth (HDPE, Box of 24)	
	Sulfuric Acid (10 N) Liter	
Bacteria, Nutrients, and Sediment (BNSC)	Same as above	Total N using EPA Method 351.4
		Total P using EPA Method 365.4
		Suspended Sediment Concentration (USGS Method)
		E. coli and total coliform via Micrology Labs Coliscan Easygel
Metals (Total and Dissolved) and Sediment (MSC)	Above items, *minus* sulfuric acid and *plus* the items below:	Suspended Sediment Concentration (USGS Method)
	Geopump Series 1 Peristaltic Pump AC/DC	Hardness EPA Method 130.2 - Titrimetry using EDTA
	Silicone Tubing, Size 24, 25'L (for use with peristaltic pumps)	Metals Scan (5 metals) using EPA Method 200.7 ($12/metal)
	12V Battery and Charger (for peristaltic pumps)	
	Solinst Model 860 Disposable Filters (0.45 µm) 1 filter	
	1:1 Nitric acid 500ml	

As shown below, the simplified spreadsheet allows users to apply labor adjustment factors (0 to 1.5 times default assumptions) to better simulate local labor costs. Inflation can also be factored into cost estimates. The base year assumed for inflation is 2012 because most costs in the spreadsheet are from that year. Users can also change default assumptions in the simplified spreadsheet to tailor them to local costs, but this requires a level of effort that mimics what is required for the master spreadsheet.

Salary Adjustment Factor:	1	
Inflation Rate (vs. 2012)	0.0	%

The simplified spreadsheet generates simple pie charts to show costs by category (see Figure 9A1-1). Total cost is also broken down as in Table 9A1-6. Total costs are given with and without inflation estimates. Annual costs are also generated by the simplified spreadsheet as shown in Table 9A1-7. The effect of inflation is illustrated by the change in costs between the years 2017 through 2021 which would all be the same without inflation.

Table 9A1-3. Load monitoring variable sets

	Cost Items	
Variable Set	Equipment and Supplies	Laboratory Analysis
Nutrients and Sediment (NSL)	USGS portable steel gage house (2'x3'x5' tall), connection to power grid, and surge protector	Total N using EPA Method 351.4
	Style A Staff Gage (13.5 ft), T-style post, and post driver	Total P using EPA Method 365.4
	Isco Model 6712FR Fiberglass Refrigerated Sampler, 2-bottle kit (7.5-liter polyethylene), 2 extra 7.5-liter polyethylene bottles for each site, intake line with strainer, battery-backed power pack, and Flowlink Software	Suspended Sediment Concentration (USGS Method)
	Isco 730 Bubbler Flow Module	
	Isco 581 RTD (rapid transfer device) for field retrieval of Model 6712FR data	
	Pygmy-type Current Meter w/ AquaCount data logger	
	Tipping Bucket Rain Gauge	
	HOBO Event Rainfall Logger (for tipping bucket rain gauge) and Boxcar Software	
	Cooler (54-quart) and ice for cooler	
	Sulfuric Acid (10 N) Liter	
Bacteria, Nutrients, and Sediment (BNSL)	Same as above	Total N using EPA Method 351.4
		Total P using EPA Method 365.4
		Suspended Sediment Concentration (USGS Method)
		E. coli and total coliform via Micrology Labs Coliscan Easygel ($18.50 for 10 tests)
Metals (Total and Dissolved) and Sediment (MSL)	Above items, *minus* sulfuric acid and *plus* the items below:	Suspended Sediment Concentration (USGS Method)
	Bottles-1000 ml wide mouth (HDPE, Box of 24)	Hardness EPA Method 130.2 - Titrimetry using EDTA
	Geopump Series 1 Peristaltic Pump AC/DC	Metals Scan (5 metals) using EPA Method 200.7 ($12/metal)
	Silicone Tubing, Size 24, 25'L (for use with peristaltic pumps)	
	12V Battery and Charger (for peristaltic pumps)	
	Solinst Model 860 Disposable Filters (0.45 μm) 1 filter	
	1:1 Nitric acid 500ml	

Table 9A1-4. Biological monitoring variable sets

Variable Set	Cost Items
Kick Net Option (BioK)	Style A Staff Gage (13.5 ft), T-style post, and post driver
	YSI 556 D.O., pH, conductivity, temperature meter with pH kit
	pH buffer, conductivity, and ORP calibration solutions for YSI 556
	Hach Model 2100Q Portable Turbidimeter with USB+Power Module for 2100Q (for data transfer to PC) and Gelex Secondary Standards Kit
	Silicone oil and portable turbidimeter sample cells for Hach Turbidimeter
	Pentax Option W30 waterproof digital camera
	Garmin eTrex 30 GPS
	Current meter outfit (Pygmy-type). Meter, headphones, and rod.
	Bottom kick net (500 µm mesh)
	Forceps (straight fine point)
	Sieve bucket
	First aid kit, 119-piece, economy
	STEARNS neoprene chest waders and fluorescent orange PVC gloves
	Bottles-1000 ml wide mouth (HDPE, Box of 24)
	Low plastic specimen jars and black molded caps
	Ice (cooler full)
	95% Ethanol (3.8 L)
D-Frame Dip Net Option (BioD)	Above items, *minus* bottom kick net and *plus* item below
	D-Frame dip net (500 µm mesh)

Table 9A1-5. Sondes monitoring variable sets

Variable Set	Cost Items	
	Equipment and Supplies	Laboratory Analysis
Nutrients and Turbidity Set (SNT)	Style A Staff Gage (13.5 ft), T-style post, and post driver	Total P using EPA Method 365.4
	Rain Gage (plastic)	
	Hydrolab DataSonde 5 - DS5 w/ built-in data logger, temperature sensor, and connecting cable (takes 10 sensors, measures up to 15 parameters simultaneously)	
	pH, polarographic DO, temperature (comes with unit), nitrate, self-cleaning turbidity, ammonia, chlorophyll a, and conductivity sensors for DS5	
	5-meter communication cable and battery pack for DS5	
	Bottles-1000 ml wide mouth (HDPE, Box of 24)	
	Cooler (54-quart) and ice for cooler	
	1:1 Nitric acid 500ml	
	Sulfuric Acid (10 N) Liter	

Variable Set	Cost Items	
	Equipment and Supplies	**Laboratory Analysis**
Nutrients, Turbidity, and Metals (Total and Dissolved) Set (SNTM)	Above items *plus* the items below:	Total P using EPA Method 365.4
	Geopump Series 1 Peristaltic Pump AC/DC	Hardness EPA Method 130.2 - Titrimetry using EDTA
	Silicone Tubing , Size 24, 25'L (for use with peristaltic pumps)	Metals Scan (5 metals) using EPA Method 200.7 ($12/metal)
	12V Battery and Charger (for peristaltic pumps)	
	Solinst Model 860 Disposable Filters (0.45 µm) 1 filter	

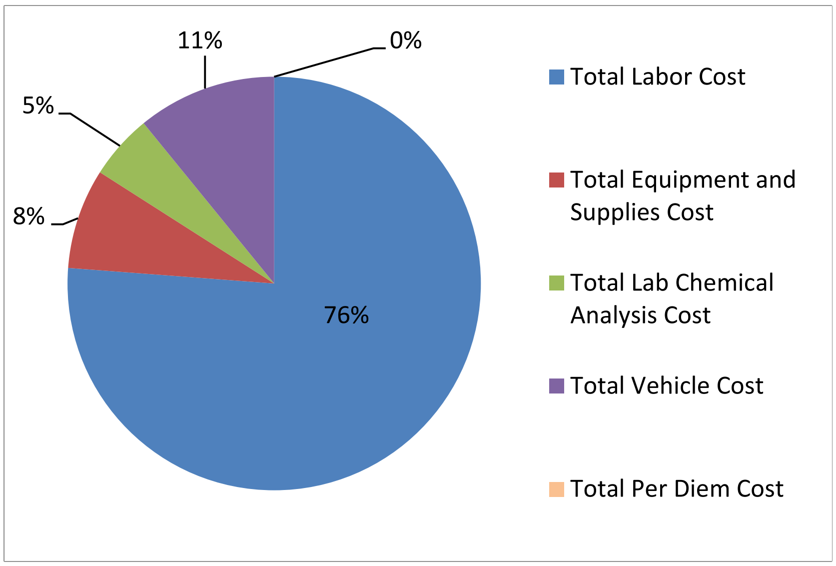


Figure 9A1-1. Pie chart from simplified spreadsheet

Table 9A1-6. Tabular output from simplified spreadsheet

Cost Category	Total Cost	% of Total
Labor	$205,167	72
Equipment and Supplies	$2,158	1
Sampling Analysis	$53,654	19
Vehicles	$22,921	8
Per Diem	$0	0
TOTAL COST	**$283,900**	**100**
Average Annual Cost	$40,557	
Total Cost with Inflation	*$325,887*	
Average Annual Cost with Inflation	*$46,555*	

Table 9A1-7. Annual costs from simplified spreadsheet

Inflation Rate: 2%			
Begin: 2016			
End: 2022			
Year	**Inflation Factor Applied**	**Annual Cost without Inflation**	**Annual Inflation-Adjusted Cost**
2016	1.08	$47,349	$51,253
2017	1.10	$39,279	$43,367
2018	1.13	$39,279	$44,234
2019	1.15	$39,279	$45,119
2020	1.17	$39,279	$46,021
2021	1.20	$39,279	$46,942
2022	1.22	$40,157	$48,951
	TOTAL	$283,900	$325,887

Appendix 9-2. Cost Estimates for a Diverse Range of Monitoring Options

As described in Appendix 9-1, a large number of assumptions must be made to estimate costs for various monitoring scenarios. Thus, while these cost estimates are intended to be informative, they are more or less relevant to any particular monitoring effort based on how well the assumptions match the realities of that specific situation. Cost estimates given here are more likely to be high than low because it is always assumed that contractors perform the monitoring (i.e., no use of in-house labor that was hired to do monitoring) and all monitoring equipment must either be leased or purchased.

Cost Scenarios and Assumptions

Cost estimates for the following eight monitoring scenarios are presented in this section.

1. Synoptic Survey
2. TMDL – Water Quality Standards
3. TMDL – Loads
4. Paired-Watershed – Loads
5. Long-term Single Station – Biomonitoring
6. Above/Below BMP Effectiveness – Biomonitoring
7. Input/Output Urban LID Effectiveness
8. Photo-Point Monitoring

These eight scenarios address both problem assessment and project evaluation, using chemical, physical, and biological (Barbour et al. 1999) monitoring methods. Five-year total costs are used for comparing Scenarios 2-8, but costs are also provided for 1, 2, and 8 years. The synoptic survey is considered a one-year effort.

The Watershed

The setting assumed for the cost scenarios is a 3,035 ha (7,500 ac) watershed, primarily in agricultural use with some urban influence. Monitoring is performed in perennial streams.

For the synoptic survey (Scenario 1) it is assumed that the nature and extent of water quality problems in the watershed are totally unknown. Thus, water chemistry sampling includes a wide range of variables. For Scenarios 2-7, the problems are assumed to be associated with sediment, nutrients, aquatic life use support, and cadmium toxicity. Stream channel restoration is the focus of Scenario 8.

Labor Costs

All monitoring is assumed to be performed by contractors; different pay rates would apply to government and university employees, and volunteers would work for free. Pay rates assumed (including fringe and overhead) and basic job functions are summarized in Table 9A2-1.

Table 9A2-1. Labor costs assumed for scenarios

Pay Level	Rate ($/hr)[1]	Job Functions
4	130	Monitoring design, statistical analysis, oversight, etc.
3	80	Lead field person for monitoring, data collection, bulk of writing
2	56	Field technician, lab tech, etc.
1	34	Secretarial and support staff

[1]Includes fringe and overhead.

Other Cost Assumptions

Monitoring proposals are assumed to be QAPPs (Quality Assurance Project Plans) prepared in 16 hours by a team that includes an expert and support staff at a cost of $1,400 for each scenario.

Transportation costs (vehicle and labor) include driving to and from the watershed, driving to monitoring sites within the watershed, and delivering samples to a laboratory for analysis. It is assumed that the watershed is 160 km (100 mi) from the base of those performing the monitoring. The sample analysis laboratory is assumed to be "on the way," so no additional mileage is added for delivering samples to the laboratory.

Watershed characterization (windshield survey) costs are included only in Scenario 1. Monitoring site selection and establishment (as needed) costs are included in all scenarios. While it is a very important part of most NPS monitoring designs and is addressed by the spreadsheet, costs for meteorological monitoring were not included in these scenarios.

Analytical methods for water quality variables were obtained from various sources such as NEMI (http://www.nemi.gov/). Constraints associated with these methods (e.g., cooling samples to 4˚C for suspended sediment, and pre-acidification for hardness) are reflected in the cost estimates through, for example, the purchase of refrigerated samplers or the use of both pre-acidified and non-acidified sample containers.

For safety reasons, all sampling is assumed to be performed by teams of at least two people. In some cases, one or two additional people are added for a limited number of sampling trips. Larger teams are assumed necessary for QA/QC checks, stage-discharge calibration during a regularly scheduled sampling event, and scenarios where both intensive water chemistry and biological monitoring are performed. In all cases where continuous flow is measured, additional labor is assumed for stage-discharge calibration.

Scenario Description and Results

Scenario 1: Synoptic Survey

Under this scenario, a windshield survey is performed to characterize the watershed and select monitoring sites. It is assumed that the survey covers 512 km (320 mi) within an 8-hour day. Water quality monitoring at six sites (1.6 km [1 mi] apart from each other) is performed on two separate sampling dates to cover both high-flow and low-flow conditions. Each sampling run is assumed to require 400 km (250 mi) and a 12-hour day (1 hour per site, plus driving time) for a team of three in a single vehicle.

Equipment and sampling assumptions for this scenario are:

- Equipment: sample bottles and jars, water quality sonde with 6 sensors (D.O., pH, temperature, conductivity, turbidity, and chlorophyll a), pygmy-type meter with data logger, kick net
- Sampling for all 6 sites: B.O.D., hardness, SSC, TP, TKN, NO_2+NO_3 –N, *E. coli* and total coliforms, biological monitoring, flow
- Sampling for 3 sites (targeted locations to keep costs down): grab sample for pesticides scan and metals scan (5 metals)

As shown in Table 9A2-2, the total cost for this one-year effort is estimated at $30,000. Equipment and labor each account for 45% of the total cost. Assuming that the contractor already has the basic monitoring equipment, however, the one-year total cost is reduced to just over $17,000.

Scenario 2: TMDL – Water Quality Standards

Scenario 2 envisions a TMDL under which water quality monitoring is performed at a single site to both track dissolved cadmium concentration (weekly grab samples) and assess aquatic life use support through biological monitoring.

Equipment and sampling assumptions for this scenario are:

- Equipment: sample bottles, multi-probe water quality meter for *in situ* D.O., pH, conductivity, and temperature measurements, kick net
- Sampling: cadmium and hardness, biological monitoring (2x/yr)

As shown in Table 9A2-2, the total cost for five years is about $214,900. Costs for one year, 2 years, and 8 years are estimated at $47,100, $90,300, and $339,400, respectively. Nearly 83% of the total cost is associated with sampling trips, with another 7% for analysis of samples for cadmium and hardness. Labor accounts for 81% of the total budget, and equipment account for only 2% of the total 5-year budget.

Scenario 3: TMDL – Pollutant Load

Under this scenario, weekly flow-weighted composite samples are taken for suspended sediment load estimation at a single site. Continuous discharge is measured with a bubbler water level sensor and a pygmy-type current meter is used for calibration.

Equipment and sampling assumptions for this scenario are:

- Equipment: sample shed, refrigerated automatic sampler (with bubble flow module, battery backup, 2-bottle kit), data transfer device and software, surge protector, pygmy-type current meter and data logger
- Sampling: discharge and suspended sediment concentration

As shown in Table 9A2-2, the total five-year cost for this scenario is estimated at $237,500. Total costs for 1, 2, and 8 years are $61,800, $106,500, and $368,400, respectively. Sampling trips and labor account for 87% and 84% of the total cost, respectively.

Scenario 4: Paired-Watershed Loads

This scenario is in many ways a doubling of Scenario 3, but shared equipment (e.g., pygmy-type current meter) is not duplicated and incremental costs for analyzing and reporting on data from the second monitoring station are assumed to be half the cost for the first monitoring station. The watersheds are assumed to be 12.8 km (8 mi) apart. Weekly flow-weighted composite samples are taken for suspended sediment load estimation at each site using an automatic sampler. Continuous discharge is measured with a bubbler water level sensor and a pygmy-type current meter is used for calibration. Unlike for Scenario 3, tracking of land use and land treatment is included in the analysis, with the cost essentially twice that for Scenario 5.

Equipment and sampling assumptions for this scenario are:

- Equipment: 2 sample sheds, 2 refrigerated automatic samplers (with bubble flow module, battery backup, 2-bottle kit), data transfer device and software, 2 surge protectors, pygmy-type current meter and data logger
- Sampling: discharge and suspended sediment concentration

As shown in Table 9A2-2, this is the most expensive scenario considered here with a total five-year cost estimated at $347,800. Total costs for 1, 2, and 8 years are $93,400, $158,100, and $537,400, respectively. Sampling trips account for about three-quarters of the total cost. Site establishment cost is significant under this scenario, accounting for nearly 7% of the total cost, while sample analysis represents about 2% of the total cost. Labor is the largest cost category at 84% of the total cost.

Scenario 5: Long-Term Trend Monitoring-Biological

This scenario assumes long-term biological monitoring (2x/yr) at a single site. Stage is measured as a covariate, but discharge is not estimated. Land use and BMP implementation are tracked via two whole-watershed surveys per year.

Equipment and sampling assumptions for this scenario are:

- Equipment: multi-probe water quality meter for *in situ* D.O., pH, conductivity, and temperature measurements, staff gage, kick net, sample bags
- Sampling: biological monitoring (2x/yr)

The total cost for five years is estimated at $52,800, while the total costs for 1, 2, and 8 years are estimated at $16,100, $25,800, and $79,800, respectively. As shown in Table 9A2-2, land use tracking accounts for about 28% of the total five-year cost, while annual sampling trips consume 26% of the five-year budget. An additional 20% is used for data analysis and reporting. The largest cost category is labor at 85% of the total cost.

Scenario 6: Above/Below BMP Effectiveness Monitoring-Biological

This scenario assumes long-term biological monitoring (2x/yr) at two monitoring sites in an above/below design to evaluate individual BMP effectiveness. Stage at the time of sampling is measured as a covariate, but discharge is not estimated. Land use and BMP implementation are tracked via two partial-watershed surveys per year.

Equipment and sampling assumptions for this scenario are:

- Equipment: multi-probe water quality meter for *in situ* D.O., pH, conductivity, and temperature measurements, 2 staff gages, kick net, sample bags
- Sampling: biological monitoring (2x/yr)

As shown in Table 9A2-2, the five-year total cost is estimated at $58,000. One-year, two-year, and eight-year total costs are estimated at $17,200, $28,000, and $88,000, respectively. The total cost for this scenario nearly matches that for Scenario 5. Despite having two sites instead of one, annual sampling trips for Scenario 6 ($15,720) cost only slightly more than for Scenario 5 ($13,860). The time spent tracking land use/land treatment is substantially greater for Scenario 5 because the entire watershed is tracked versus only a portion of the watershed under the Scenario 6 above/below study. This difference explains the greater amount and percentage of the Scenario 5 budget devoted to land use tracking ($14,640, 28%) versus that for Scenario 6 ($11,800, 20%). Labor accounts for 85% of the five-year budget.

Scenario 7: Input/Output Urban LID Effectiveness

The analysis of inflow-outflow monitoring of urban LID practices assumes two monitoring stations, one storm event sampled per week at each station, discharge measurement, and analysis of both suspended sediment and five metals.

Equipment and sampling assumptions for this scenario are:

- Equipment: 2 small sample sheds, 2 refrigerated automatic samplers (with 2-bottle kit), data transfer device and software, 2 submersible pressure transducers with data logger, 2 V-notch weir boxes, 2 surge protectors
- Sampling: discharge, suspended sediment concentration, metals scan (5 metals)

As shown in Table 9A2-2, the five-year total cost for this scenario is estimated at $251,400, while estimated total costs for 1, 2, and 8 years are $68,000, $114,900, and $387,800. Costs for monitoring site establishment and equipment contribute to the high first-year cost of this study design. After five and eight years, however, the average annual costs drop to about $50,300 and $48,500, respectively. Annual sampling trips account for nearly 71% of the total five-year budget, while annual sample analysis accounts for 16%, and equipment and site establishment combine for just over 8%. Labor is the largest cost category at 68% of the total five-year budget.

Scenario 8: Photo-Point Monitoring

This scenario assumes repeat photography of a riparian zone restoration project using two photo points (see chapter 5). Each photo point has a single camera point. Cost estimates were developed for both qualitative and quantitative approaches, with digital image analysis assumed for the quantitative approach.

Equipment assumptions for qualitative photo-point monitoring are:

- 2 meter boards, digital camera with tripod, GPS unit, field computer, compass, level, sledge hammer, measuring tape, rebar, shovel, whiteboard, metric staff gage

As shown in Table 9A2-2, the five-year cost for qualitative photo-point monitoring is estimated to be about $18,600, with 81% of the cost devoted to labor. If it is assumed that the contractor already has the major equipment, the total cost for five years is reduced to about $16,300. Total costs for 1, 2, and 8 years are estimated at $8,100, $11,100, and $26,000, respectively. Annual sampling trips account for about 48% of the total five-year budget, while site establishment, portable sampling equipment, and startup supplies consume a combined 22% of the budget. Labor is the largest cost category at 81% of the total.

When considering photo-point as an add-on monitoring activity (e.g., the same individuals who perform biological monitoring or collect water chemistry samples also take the photos), the five-year cost is reduced to $8,500 due primarily to savings in labor and vehicle costs. Coupled with the assumption that the contractor already has the major equipment the 5-year cost drops to about $6,200.

Quantitative photo-point analysis requires image processing software, and labor requirements for data analysis are increased substantially. Because quantitative photo-point analysis has not been used to any measurable extent in watershed projects, the cost estimates provided here are highly uncertain. The total cost for five years is estimated at $74,900 with 90% of the cost for labor. Assuming the contractor has all major equipment and software, the 5-year cost is reduced to about $68,700. If quantitative photo-point monitoring is added to a water chemistry or biological monitoring program, the cost is estimated at just over $53,000 for five years. Coupled with the assumption that the contractor already has the major equipment and software the 5-year cost drops to $46,800.

Table 9A2-2. Total costs for eight diverse scenarios

	Scenario								
	1	2	3	4	5	6	7	8 Qualita-tive	8 Quantita-tive
Cost Phase or Element	1 Year	5 Years	5 Years	5 Years	5 Years	5 Years	5 Years	5 Years	5 Years
Proposal and QAPP	$1,400	$1,400	$1,400	$1,400	$1,400	$1,400	$1,400	$1,400	$2,440
Watershed Characterization	$1,858	$0	$0	$0	$0	$0	$0	$0	$0
Site Establishment	$0	$0	$11,409	$22,829	$2,110	$2,234	$17,598	$1,860	$1,860
Portable Sampling Equipment and Startup Supplies Costs	$13,332	$4,210	$4,803	$4,803	$3,595	$3,595	$3,056	$2,260	$6,241
One-Time Office Equipment and Startup Supplies Costs	$0	$0	$0	$0	$0	$0	$0	$0	$0
Station Demolition and Site Restoration	$0	$0	$808	$1,616	$0	$0	$136	$114	$114
First-Year Report	$3,610	$1,952	$1,692	$2,448	$1,952	$1,952	$2,250	$720	$11,676
Final Report	$0	$3,608	$2,976	$4,422	$2,656	$2,656	$3,336	$1,224	$10,980
Annual Access Fees	$0	$0	$0	$0	$0	$0	$0	$0	$0
Annual Sampling Trips to Sites	$6,008	$177,660	$205,660	$266,539	$13,860	$15,720	$177,840	$8,820	$13,960
Annual Volunteer Training	$0	$0	$0	$0	$0	$0	$0	$0	$0
Annual Sample Analysis	$3,774	$15,880	$2,860	$5,720	$4,960	$9,920	$40,040	$0	$0
Annual Data Analysis	$0	$2,268	$2,268	$3,402	$2,268	$2,268	$2,412	$342	$17,280
Annual Reports	$0	$3,588	$3,588	$5,316	$3,588	$3,588	$3,288	$1,818	$10,368
Annual Site Operation and Maintenance	$0	$0	$0	$0	$0	$0	$0	$0	$0
Annual Supplies and Rental Equipment	$59	$4,313	$0	$0	$1,795	$2,855	$0	$0	$0
Annual Land Use Tracking	$0	$0	$0	$29,280	$14,640	$11,800	$0	$0	$0
TOTAL	**$30,040**	**$214,879**	**$237,464**	**$347,775**	**$52,824**	**$57,988**	**$251,356**	**$18,558**	**$74,919**

Appendix 9-3. Cost Estimates for Watershed-Scale Evaluation of Agricultural BMP Implementation

As described in Appendix 9-1, a large number of assumptions must be made to estimate costs for various monitoring scenarios. Thus, while these cost estimates are intended to be informative, they are more or less relevant to any particular monitoring effort based on how well the assumptions match the realities of that specific situation. Cost estimates given here are more likely to be high than low because it is always assumed that contractors perform the monitoring (i.e., no use of in-house labor that was hired to do monitoring) and all monitoring equipment must either be leased or purchased.

Cost Scenarios

Cost estimates for the following seven monitoring scenarios are described in this section. Results of the cost analysis are summarized in Figure 9-2. One year is assumed for the synoptic survey, and costs for other scenarios are estimated for 3, 5, and 7 years.

1. Preliminary Synoptic Survey
2. Compliance Monitoring
3. Above/Below Monitoring (sub-scenarios for concentration and load: 3C, 3L)
4. Multiple-Watershed Monitoring
5. Trend Monitoring (sub-scenarios for concentration and load: 5C, 5L)
6. Paired-Watershed Monitoring (sub-scenarios for perennial and intermittent flows: 6P, 6I)
7. Soil Testing

The Watershed

The setting assumed for these cost scenarios is a 12-digit HUC watershed covering 10,117 ha (25,000 ac), primarily in agricultural use. Monitoring is performed in perennial streams with the exception of Scenario 6I which assumes intermittent flow. Scenario 1 assumes that the nature and extent of water quality problems in the watershed are totally unknown, so a wider range of monitoring variables is included. For Scenarios 2-7, the problems are assumed to be associated with nutrients from agricultural sources.

Labor Costs

Labor cost assumptions are the same as described in Appendix 9-2 (Table 9A2-1).

Driving Distances and Sampling Times

Transportation costs include driving to and from the watershed, driving to monitoring sites within the watershed, and delivering samples to a laboratory for analysis. To bracket a wide range of possibilities for transportation costs and sampling times, three one-way distances and associated drive times are assumed:

- "In" - Monitoring staff are within the watershed: distance and travel time are zero.
- "Near" - Monitoring staff are based 240 km (150 mi) from the watershed, with a one-way drive time of 2 hour and 45 minutes.
- "Far" - Monitoring staff are based 480 km (300 mi) from the watershed, with a one-way drive time of 5.5 hours.

Drive distances and times for sampling runs *within* (i.e., in addition to travel distance and times *to* the watershed) the watershed are assumed to be:

- Zero miles and time for trend monitoring (1 station)
- 25 km (16 mi) and 0.5 hours R/T for compliance and above/below monitoring (2 stations)
- 48 km (30 mi) and 0.75 hours R/T for paired-watershed monitoring (2 stations, 1 in nearby watershed 24 km [15 mi] away)
- 96 km (60 mi) and 2.5 hour R/T for multiple-watershed study (20 sub-watershed stations all within same watershed)
- 80 km (50 mi) and 2 hours R/T for a soil testing study (20 fields within the same watershed)

For all scenarios in which driving to the watershed is required, it is assumed that collected samples are dropped off at the laboratory in transit with no additional driving mileage. For scenarios in which the contractor is based in the watershed, 80 km (50 mi) is added for delivery of the samples to the nearest laboratory, except for Scenario 7 for which soil samples are assumed mailed to the laboratory.

It is assumed that contractors within the watershed will not incur lodging fees, while lodging is (generally) assumed for others when work days exceed 12 hours. Efforts were made to combine activities (e.g., site establishment and discharge observation) to reduce the need for overnight stays.

For safety reasons, all sampling is assumed to be performed by teams of at least two people. Two-person teams are assumed for grab sampling and 3 people are assumed necessary for runs including discharge observations. Periodic trips for QA/QC (e.g., 4 times per year for weekly sampling) by a QA/QC expert are also included.

The time required for grab sampling is assumed to be 0.5 hours per site, whereas sampling at sites with automatic sampling and discharge measurements is assumed to require 1.5 hours per site. Scenario 7 incorporates an assumption that 45 minutes is required to collect a composite soil sample for each 4-ha (10-acre) field that is monitored.

The cost of establishing a stage-discharge relationship is included for Scenarios 3L, 5L, 6P, and 6I. It is assumed that all monitoring is performed on wadeable streams, so time assumed for a discharge observation is set at 1.5 hours. Requirements for discharge observations on larger streams would be more expensive. Costs assume eight discharge observations per year, with 6 of these as separate trips and 2 as additional time during normal sampling runs. The driving distances and hours assumed necessary for discharge observations made within each study area as separate trips are summarized in Table 9A3-1.

Table 9A3-1. Driving and labor assumptions for discharge observations as stand-alone trips

Scenario	Discharge Observation		
	Number of Stations	Total Drive Distance Within Watershed[1]	Total Hours Within Watershed[1]
3L. Above/Below	2	25 km (16 mi)	3.50
5L. Trend (Load only)	1	0 km (0 mi)	1.50
6P. Paired	2	48 km (30 mi)	3.75
6I. Paired	2	48 km (30 mi)	3.75

[1]Does not include driving distance and time to arrive at watershed.

Table 9A3-2 summarizes assumptions regarding driving distances and time spent within (and between for paired-watershed design) each watershed for sampling runs. This does not include round-trip (R/T) travel to or from the watershed, nor does it include add-ons such as discharge observations.

Table 9A3-2. Sampling distances and times within watersheds

Scenario	No. of Sites	Travel Within Watershed		Travel Between Watersheds		Time at Each Site	Total PER Site	
		km	Hours	km	Hours	Hours	km	Hours
1. Synoptic	8	32	0.75	0	0	0.5	4	0.6
2. Compliance	2	25	0.5	0	0	0.5	12.5	0.75
3C. Above/Below (Conc.)	2	25	0.5	0	0	0.5	12.5	0.75
3L. Above/Below (Load)	2	25	0.5	0	0	1.5	12.5	1.75
4. Multiple	20	96	2.5	0	0	0.5	4.8	0.625
5C. Trend (Conc.)	1	0	0	0	0	0.5	0	0.5
5L. Trend (Load)	1	0	0	0	0	1.5	0	1.5
6P. Paired (Perennial)	2	0	0	48	1	1.5	24	2
6I. Paired (Intermittent)	2	0	0	48	1	1.5	24	2
7. Soil Test	20	80	2	0	0	0.75	4	0.85

Quality Assurance Project Plans (QAPPs)

Monitoring proposals are assumed to be QAPPs prepared in 16 hours by a team that includes an expert and support staff at a cost of $1,400 for each scenario.

Watershed characterization

Watershed characterization costs apply only to Scenario 1, including a windshield survey (240 km, 8 hours) and a review of available data and maps. For all other scenarios it is assumed that the watershed has been suitably characterized for development of the monitoring program.

9.5.1.1 Site selection and establishment

For Scenarios 1 and 2 (synoptic and compliance) site selection is assumed to be a desktop exercise, requiring two staff for four hours each. It is assumed that site selection for Scenario 7 involves more time because information must be gathered to find 20 fields via a random selection process. Two staff for 20 hours each is assumed for this effort, with any additional labor provided by cooperators within the watershed. For Scenarios 3-6 it is assumed that three staff each devote 2 hours of paper investigation to each monitoring site prior to traveling to the watersheds for field investigation.

Field costs for site selection include travel (to and within the watersheds) and labor. Costs assumed for field work under Scenarios 3-6 are summarized in Table 9A3-3. It is assumed that an additional person is needed for site selection that involves installation of a sampling shed and for Scenario 4 because 20 subwatersheds must be selected.

Monitoring site establishment (as needed) costs are included in Scenarios 3 through 6, with greater cost for sites with continuous discharge measurement and automated samplers. Major materials and equipment assumed for stations at which continuous flow is measured are summarized in Table 9A3-4. A tipping rain gauge, data logger, and software are purchased for Scenarios 3L, 5L, 6P, and 6I. Plastic rain gauges are purchased for Scenario 3C and 5C, while available local precipitation records are used for all other scenarios.

Table 9A3-3. Field work costs for site selection

Scenario [# stations]	1-Way Distance from Base	Travel and Site Investigation and Selection		Number of Staff / Number of Vehicles	Number of Overnight Stays[1]
	km/vehicle	km/vehicle	Hours/person		
3C. Above/Below (conc.) [2]	0	50	5	2/1	0
	240	530	10.5	2/1	0
	480	1,010	16	2/1	1
3L. Above/Below (load) [2]	0	50	5	3/1	0
	240	530	10.5	3/1	0
	480	1,010	16	3/1	1
4. Multiple Watershed [20]	0	322	48	3/1	3
	241	804	53.5	3/1	4
	483	1,287	59	3/1	4
5C. Trend (conc.) [1]	0	10	2.5	2/1	0
	240	490	8	2/1	0
	480	970	13.5	2/1	1
5L. Trend (load) [1]	0	10	2.5	3/1	0
	240	490	8	3/1	0
	480	970	13.5	3/1	1
6P. Paired (perennial) [2]	0	40	5	3/1	0
	240	520	10.5	3/1	0
	480	1,000	16	3/1	1
6I. Paired (intermittent) [2]	0	40	5	3/1	0
	240	520	10.5	3/1	0
	480	1,000	16	3/1	1

[1]Except where the contractor is based within the watershed, overnight lodging was assumed as needed to keep the length of work days reasonable (generally 12 hours or less).

Table 9A3-4. Major equipment and materials costs for stations measuring continuous discharge

Cost Item	Unit Cost
Build sampling shed (labor and materials)	$2,000
Connection to power grid	$800
Staff gage, post, and post driver	$154
Automatic sampler with bubble flow module, battery backup, 2-bottle kit, data transfer device, and software	$10,530
Pygmy-type current meter w/data logger	$2,015

Six hours is added per station (18 person-hours) in cases where a monitoring shed is installed for automatic sampling equipment. Table 9A3-5 summarizes travel and labor assumptions for site establishment field work for Scenarios 3 and 6.

Table 9A3-5. Site establishment costs for sites designed for load estimation

	2-Way Travel to Site[1]		Shed Construction and Setup		Total Without Discharge Observation	Hours Added for Discharge Observation[2]	Total	
Scenario [# stations]	km / Vehicle	Hours / Person	Hours / Person	# Staff / # Vehicles	Hours / Person	Hours / Person	Hours / Person	# Nights
3L. Above / Below [2]	0	0	12	3/1	12	0	12	0
	480	5.5	12	3/1	17.5	3	20.5	1
	960	11	12	3/1	23	3	26	2
5L. Trend [1]	0	0	6	3/1	6	0	6	0
	480	5.5	6	3/1	11.5	1.5	13	0
	960	11	6	3/1	17	1.5	18.5	1
6P. Paired [2]	48	1	12	3/1	13	0	13	0
	528	6.5	12	3/1	18.5	3	21.5	1
	1,008	12	12	3/1	24	3	27	2
6I. Paired [2]	48	1	12	3/1	13	0	13	0
	528	6.5	12	3/1	18.5	3	21.5	1
	1,008	12	12	3/1	24	3	27	2

[1]Paired watersheds are assumed to be 24 km apart. Above/below sites are assumed to be less than 1 km apart.
[2]Hours were added to perform a discharge observation at each site where long-distance travel was involved and pollutant load estimation is planned.

Site Demolition and Restoration

Site demolition and restoration is only required for sites with sampling sheds. It is assumed that 3 people are needed for this activity, each working 3 hours at each monitoring station. Assumptions are summarized in Table 9A3-6.

Table 9A3-6. Site demolition and restoration costs

Scenario [# stations]	2-Way Travel to Site[1]		Site Demolition and Restoration	# Staff / # Vehicles	Total	# Nights
	km / Vehicle	Hours / Person	Hours / Person		Hours / Person	
3L. Above / Below [2]	0	0	6	3/1	6	0
	480	5.5	6	3/1	11.5	0
	960	11	6	3/1	17	1
5L. Trend [1]	0	0	3	3/1	3	0
	480	5.5	3	3/1	8.5	0
	960	11	3	3/1	14	1
6P. Paired [2]	48	1	6	3/1	7	0
	528	6	6	3/1	12	0
	1,008	11.5	6	3/1	17.5	1
6I. Paired [2]	48	1	6	3/1	7	0
	528	6	6	3/1	12	0
	1,008	11.5	6	3/1	17.5	1

[1]Paired watersheds are assumed to be 24 km apart. Above/below sites are assumed to be less than 1 km apart.

Sample Analysis

Analytical methods for water quality variables included in the spreadsheet were obtained from various sources such as NEMI (2006). Constraints associated with these methods (e.g., cooling samples to 4˚C for suspended sediment, and pre-acidification for hardness) are reflected in the cost estimates through, for example, the purchase of refrigerated samplers and sample preservatives.

Sample analysis for total P assumes EPA Method 365.4 (NEMI 2006) at a cost of $21 per sample. Soil samples under Scenario 7 are analyzed for soil P (Mehlich 3), textural class, and organic matter, at a total cost of $26 per sample. Soil samples are assumed to be sent by ground shipment to the laboratory.

The number of samples analyzed is increased by 10% for QA/QC.

Land Use/Treatment Tracking

Tracking of BMP implementation is assumed to occur twice per year under Scenarios 3, 5, and 6. The baseline assumption for tracking effort within a 12-digit HUC is 240 km (150 mi) driving and 8 hours R/T each time, with variations across scenarios due to differing monitoring scales and specifics. Travel distances and times to the watershed are added as appropriate.

For Scenario 4 it is assumed that a cooperator (e.g., NRCS) provides the data for the 20 subwatersheds on an annual basis; additional observations can be made during the 30-minute visits for grab sampling in each of the 405-ha (1,000-acre) subwatersheds. Under Scenario 7, annual data on organic and inorganic nutrient application rates and crop yields per field are assumed to be provided by a cooperator. The resulting assumptions are summarized in Table 9A3-7.

Table 9A3-7. Driving and labor assumptions for land use/treatment tracking

Scenario	Land Use/Treatment Tracking			Comments
	Drive Distance Within Watershed[1]	Hours Including Drive Time	Frequency (#/Yr)	
1. Synoptic	n/a	n/a	n/a	Not done.
2. Compliance	n/a	n/a	n/a	Not done.
3. Above/Below	128 km (80 mi)	6	2	Only part of watershed is tracked.
4. Multiple	n/a	n/a	n/a	Not done. Data provided by a cooperating agency.
5. Trend	240 km (150 mi)	8	2	Baseline assumption.
6. Paired	290 km (180 mi)	9	2	Tracking intensity varies by source and location.
7. Soil Test	n/a	n/a	n/a	Not done. Data provided by a cooperating agency.

[1]Does not include driving distance and time to arrive at watershed.

Supplies

Cost estimates include the purchase of ice for each sampling event and annual purchases of 1-liter HDPE bottles and sample preservative.

Data Analysis and Reports

Data analysis and reporting costs are set higher for the first and last years compared to the "middle" years. For example, involvement of higher paid staff is greater in the first and final years because of the challenges faced in developing data management and analysis procedures and rules. It is assumed that lower level staff can play a greater role in the middle years with oversight from senior staff.

The cost for analysis and reporting is greater for projects estimating pollutant loads versus those simply collecting concentration data. Synoptic surveys (Scenario 1) and compliance (Scenario 2) monitoring efforts are assumed to require less time than other scenarios because of greater simplicity. Data analysis and reporting for multiple-watershed studies (Scenario 4) is assumed to be the most time consuming despite less frequent sampling than found in Scenarios 3 and 6 because information is obtained from 20 subwatersheds. More hours are assumed for data analysis than for reporting in all cases for Scenario 7 because reports are assumed to be short and more straight-forward. Table 9A3-8 summarizes assumptions for data analysis and reporting.

Table 9A3-8. Labor assumptions for data analysis and reporting

Scenario	First-Year Report		Middle-Year Reports		Final-Year Report	
	Data Analysis (Hours)	Report Preparation (Hours)	Data Analysis (Hours)	Report Preparation (Hours)	Data Analysis (Hours)	Report Preparation (Hours)
1. Synoptic	12	18	n/a	n/a	n/a	n/a
2. Compliance	10	12	7	8	10	12
3C. Above/Below	15	22	12	12	17	22
3L. Above/Below	20	28	14	14	22	26
4. Multiple	36	34	26	24	38	32

Scenario	First-Year Report		Middle-Year Reports		Final-Year Report	
	Data Analysis (Hours)	Report Preparation (Hours)	Data Analysis (Hours)	Report Preparation (Hours)	Data Analysis (Hours)	Report Preparation (Hours)
5C. Trend	14	18	11	9	19	18
5L. Trend	16	26	13	12	20	23
6P. Paired	20	28	14	14	22	26
6I. Paired	20	28	14	14	22	26
7. Soil Test	16	12	13	10	20	11

Scenario Summaries

Scenario 1: Preliminary Synoptic Survey

Under this scenario, grab sampling is performed at 8 sites on two trips (low and high flow conditions). A team of 3 people conducts a windshield survey to characterize the watershed, but subsequent land use/land treatment tracking is not performed. Meteorological and flow data are assumed to be obtained as part of the desktop analysis of the watershed.

Equipment and sampling assumptions for this scenario are:

- Equipment: sample bottles and cooler
- Sampling: TP, SSC, B.O.D., *E. coli*, total coliform, discharge, and suspended sediment concentration

Scenario 2: Compliance Monitoring

Under this scenario, grab sampling (4x/yr) is performed at 2 sites. Land use/land treatment tracking is not performed.

Equipment and sampling assumptions for this scenario are:

- Equipment: sample bottles and cooler
- Sampling: TP

Scenario 3: Above/Below Monitoring

This scenario has two options. Land use/land treatment tracking (e.g., type and number of practices, acres treated) is performed 2x/yr for both options via windshield survey and collection of data from cooperators (e.g., USDA, Soil and Water Conservation District); emphasis is placed on the area between the above and below stations.

3C. Concentration Option: Weekly grab samples are collected at 2 sites.

Equipment and sampling assumptions for this scenario are:

- Equipment: sample bottles and cooler, 2 plastic rain gages, 2 staff gages
- Sampling: TP, stage

3L. Load Option: Weekly flow-proportional composite samples are collected at 2 sites.

Equipment and sampling assumptions for this scenario are:

- Equipment: sample bottles and cooler, 2 sample sheds, 2 tipping bucket rain gages and data logger, 2 staff gages, 2 refrigerated automatic samplers (with bubble flow module, battery backup, 2-bottle kit), data transfer device and software, 2 surge protectors, pygmy-type current meter and data logger
- Sampling: TP, continuous flow

Scenario 4: Multiple-Watershed Monitoring

Under this scenario there are 10 small watersheds each (n=20) with/without BMPs. Water quality sampling occurs six times per year. It is assumed that land use/land treatment tracking is performed 2x/yr by a cooperator, with additional observations made during water quality sampling runs.

Equipment and sampling assumptions for this scenario are:

- Equipment: sample bottles and cooler, 20 staff gages
- Sampling: TP, stage

Scenario 5: Trend Monitoring

This scenario has one monitoring site and two options. Land use/land treatment tracking is performed 2x/yr for both options via windshield survey and collection of data from cooperators (e.g., USDA, Soil and Water Conservation District). Data are collected on the nature, extent, and timing of BMP implementation – as well as operation and maintenance after implementation.

5C. Concentration Option: Twice-monthly grab samples.

Equipment and sampling assumptions for this scenario are:

- Equipment: sample bottles and cooler, plastic rain gage, staff gage
- Sampling: TP, stage, precipitation

5L. Load Option: Weekly flow-proportional composite samples.

Equipment and sampling assumptions for this scenario are:

- Equipment: sample bottles and cooler, sample shed, tipping bucket rain gage and data logger, staff gage, refrigerated automatic sampler (with bubble flow module, battery backup, 2-bottle kit), data transfer device and software, surge protector, pygmy-type current meter and data logger
- Sampling: TP, continuous flow, precipitation

Scenario 6: Paired-Watershed Monitoring

This scenario has two monitoring sites (treated and untreated) and two options that address load estimation for a perennial and intermittent stream setting. For continuously flowing streams, a single weekly composite sample is collected for analysis. For intermittent streams, a flow-proportional composite sample is collected during each of 20 runoff events each year. Land use/land treatment tracking is performed 2x/yr in both watersheds for both options via windshield survey and collection of data from cooperators (e.g., USDA, Soil and Water Conservation District).

6I. Intermittent Stream Option: Twenty runoff events sampled per year at each site.

Equipment and sampling assumptions for this scenario are:

- Equipment: sample bottles and cooler, 2 sample sheds, 2 tipping bucket rain gages and data logger, 2 staff gages, 2 refrigerated automatic samplers (with bubble flow module, battery backup, 2-bottle kit), data transfer device and software, 2 surge protectors, pygmy-type current meter and data logger
- Sampling: TP, continuous flow, precipitation

6P. Perennial Stream Option: Weekly flow-proportional composite samples at each site.

Equipment and sampling assumptions for this scenario are:

- Equipment: sample bottles and cooler, 2 sample sheds, 2 tipping bucket rain gages and data logger, 2 staff gages, 2 refrigerated automatic samplers (with bubble flow module, battery backup, 2-bottle kit), data transfer device and software, 2 surge protectors, pygmy-type current meter and data logger
- Sampling: TP, continuous flow, precipitation

Scenario 7: Soil Testing

This scenario involves random selection of 20 agricultural fields for annual soil sampling. Ten fields are beginning to adopt nutrient management, and the other ten are conventionally managed. Local precipitation records are used in lieu of on-site collection of precipitation data. Annual data on nutrient application and crop yields are provided by a cooperator (e.g., the landowner, USDA).

Equipment and sampling assumptions for this scenario are:

- Equipment: 2 soil probes, 2 buckets, and a supply of bags and ties for soil samples
- Sampling: soil P, textural class (covariate), and organic matter (covariate)

Appendix 9-4. Cost Estimates for Five-Year Trend and Above/Below Monitoring

As described in Appendix 9-1, a large number of assumptions must be made to estimate costs for various monitoring scenarios. Thus, while these cost estimates are intended to be informative, they are more or less relevant to any particular monitoring effort based on how well the assumptions match the realities of that specific situation. Cost estimates given here are more likely to be high than low because it is always assumed that contractors perform the monitoring (i.e., no use of in-house labor that was hired to do monitoring) and all monitoring equipment must either be leased or purchased.

The basic scenarios (n=160) assumed for this analysis are summarized in Table 9A4-1. The trend design assumes one monitoring site and the above/below design assumes two monitoring sites. All monitoring is assumed to continue for five years. Tracking of land use and land treatment is assumed to occur twice per year, with costs identical for all scenarios. The five-year costs for this tracking range from about $100 to $16,500 for all scenarios. Costs vary considerably based on the size of and distance to the watershed.

Table 9A4-1. Factors used in creating cost estimation scenarios

Scenario	Monitoring Variables Set (and source)	Sampling Frequency (times/year)	Monitoring Designs	Watershed Sizes (ha)	Distances to Watershed[1] (km)
Biological	BioK (Table 9A1-4)	2	Trend and Above/Below	202	0
Nutrient and Sediment Concentration	NSC (Table 9A1-2)	26		2,023	40
Nutrient and Sediment Load	NSL (Table 9A1-3)			10,117	80
Sondes for Nutrients and Turbidity	SNT (Table 9A1-5)			20,234	121
					161

[1]Distance sampling team must travel to reach the watershed or nearest watershed being monitored.

Labor costs for these estimates use the same rates shown in Table 9A2-1. All scenarios include a mix of fixed labor assumptions (e.g., QAPP development cost is $1,400 for all[4] scenarios) and variable labor assumptions that are based on the monitoring design and watershed size. For example, watershed characterization costs vary depending on design and watershed size as illustrated in Table 9A4-2. A simple algorithm in the simplified spreadsheet estimates travel distances and drive times based on watershed size, affecting both labor and vehicle costs for watershed characterization.

[4] "All" scenarios refers to the base scenarios for which pay rates are those found in Table 9A2-1.

Table 9A4-2. Watershed characterization costs as function of design and watershed size

Design	Watershed Size (ha)			
	202	2,023	10,177	20,234
Trend	$1,516	$1,780	$2,952	$4,790
Above/Below	$1,888	$2,152	$3,324	$5,162

Distance to watershed is assumed = 80km.

Labor and vehicle requirements for sampling vary depending upon design, watershed size, and monitoring variables set. The variability of labor costs for data analysis and report development is illustrated in Table 9A4-3. These costs reflect the assumption that biological data require more time for analysis (at species level) than chemical/physical data collected using the other variable sets. Estimation and analysis of pollutant loads, likewise, is assumed to be more time-consuming than for either sonde or concentration data. Spreadsheet users, of course, can change these assumptions.

Table 9A4-3. Variability of costs for data analysis and reporting

Design	Variable Set	Samples/Year	5-Year Labor Cost for Data Analysis and Reporting
Trend	BioK	2	$15,889
	NSC	26	$10,051
	NSL	26	$16,271
	SNT	26	$11,899
Above/Below	BioK	2	$27,068
	NSC	26	$16,177
	NSL	26	$27,047
	SNT	26	$19,873

Assumes 2,023-ha watershed and 50 mile distance.

QA/QC is addressed in a number of ways. For sample analysis, sample size is increased by 10% to account for replicates. In addition, a QA/QC officer is assumed to join the sampling team once per year, and stage-discharge relationships are checked 8 times per year.

The results of running 160 scenarios for these above/below and trend monitoring designs are discussed in section 9.3.3 and summarized in Figure 9-4. Paired designs would have costs similar to those for the above/below design.

Additional cost estimates were run using a salary adjustment factor to see how this would affect total costs. Salaries were adjusted across the board by reducing them to 70%, 50%, and 0% of those in Table 9A2-1. Similarly, a rough assessment of the effects of equipment costs on total costs was performed by estimating costs where all or no equipment was purchased. These two equipment scenarios were also combined with the four salary options (0%, 50%, 70%, and 100% of the rates in Table 9A2-1) to explore the impacts of both adjustments on total costs. The results of these analyses are presented in section 9.3.3 and summarized in Table 9A3-3.