Alliance for Aquatic Resource Monitoring

Study Design Manual

January 2010

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Background on ALLARM:

The Alliance for Aquatic Resource Monitoring (ALLARM) is a project of the Environmental Studies Department at Dickinson College. Since its founding in 1986, ALLARM has become a nationally recognized technical and programmatic support center for community organizations interested in watershed assessment, protection, and restoration. ALLARM program goals are to:

1) Enhance local action for the protection and restoration of Pennsylvania watersheds by empowering communities with scientific knowledge and tools to implement watershed assessments;
2) Provide Dickinson College students with opportunities to participate in community-based participatory research thereby enhancing the quality of undergraduate science education; and
3) Be the leader in volunteer monitoring in Pennsylvania and a national model for college-community partnerships.

Through the work of student and professional staff, ALLARM offers comprehensive services to enable groups to use critical scientific tools to enhance environmental quality and fully participate in community decision-making. The program staff includes a Director, an Assistant Director, a faculty Science Director, and 12-14 undergraduate student staff.

For more information on please visit: www.dickinson.edu/allarm or email: allarm@dickinson.edu

Background on Study Design Manual:

One of the most challenging aspects of a monitoring program is deciding what to focus on. In any given watershed the possible scientific questions to explore will exceed one program's feasibility. Therefore you and/or your organization will need to make decisions that reflect your resources and what you want to know. What are your primary watershed concerns? What parameters and/or methods are appropriate to answer your monitoring question? Where to monitor?

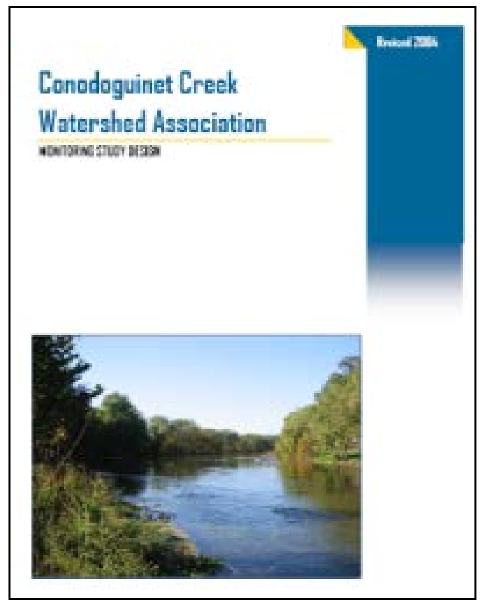
The process of making choices and decisions about your monitoring program is referred to as a "study design." This Study Design Manual has been developed to guide you through the steps required to develop an effective monitoring program.

In 2001, River Network along with the Pennsylvania Department of Environmental Protection's Citizen Volunteer Monitoring Program developed "*A Technical Handbook for Community-Based Monitoring In Pennsylvania.*" This handbook is a comprehensive tool for developing monitoring study designs. The Alliance for Aquatic Resource Monitoring (ALLARM) has used this handbook as the basis of its work with community-based watershed organizations in developing 34 monitoring study designs. The purpose of this Study Design Manual is to provide insight to ALLARM's approach to the process. This manual will guide you through the study design by focusing on the key choices you need to make and tools to help you think through your choices.

Project funding provided by the Foundation for Pennsylvania Watersheds.

Foundation for Pennsylvania Watersheds

Why Develop a Study Design?



Prior to developing a monitoring program it is essential to think through the scientific process and the steps necessary to create a program where the data collected match the monitoring objectives. The study design process facilitates the essential decisions that need to be made. Once your choices have been determined they should be documented. Your study design serves several purposes:

- It helps you focus on what you are trying to achieve with your monitoring program;
- It prevents waste of time and money on equipment/procedures that are inappropriate for your group or goals;
- It helps you match your monitoring program to your watershed goals;
- It clearly documents your sampling and analysis methods;
- It clearly outlines your quality assurance procedures; and
- It minimizes the impact of changing personnel on the continuity of your monitoring activities.

Once you begin monitoring, you should revisit your study design annually to determine if the data you are collecting are answering the questions that prompted you to monitor and to determine if your methods are appropriate.

Study Design Steps:

Once your organization has determined to conduct stream monitoring, you should develop a sub-committee to go through the study design process. The individuals on the sub-committee will not be responsible for the entire program, but will be responsible for the direction monitoring will take. It is recommended that 4-6 individuals make up the sub-committee. Suggested sub-committee guidelines:

- At least one board member or member of the organizational leadership
- Members concerned with water quality
- Historian or members that are familiar with the watershed
- Technical advisor – monitoring service provider (like ALLARM), watershed specialist

How to Use the Worksheets:

The worksheets are organized by the study design steps. For each step, there are questions and/or tables that prompt you to fill out the appropriate information. If the questions or tables are not appropriate for your monitoring program, leave them blank. The following sections take you through the worksheets, with explanations of the questions and tables.

Step 1: What are your organization's major objectives?

Prior to commencing a monitoring program it is important that there is organizational buy-in and the organization has determined that monitoring is a necessary program to advance the group's mission. As with any new organizational endeavor, the group should discuss how the monitoring program plays a role in and reports to the group as a whole.

1a: Define your group's mission

What is the organizational mission and goals – does monitoring advance the mission?

1B: List your organization's major programs

What existing programs does your organization have? Can the organization support another program? Are there financial and people resources available to implement this program?

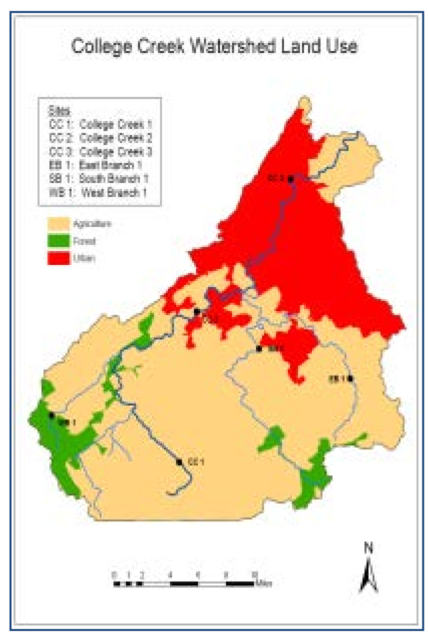
Step 2: Why are you monitoring?

It is important to note that this step is the most crucial in the process; all other steps build off of step 2. Equally important to note is this step is the most time consuming of all steps. It is helpful if prior to tackling this step you assign homework tasks to gather all of the necessary background information.

2a: Generate background information on your watershed including history, land use, size of community, and special features.

Prior to developing a monitoring plan it is important that the group understands key watershed features and background information – what is the story of your watershed? Why is it the way it is today? There are a lot of resources groups can use to develop this background information.

- History – historical societies, oral histories, county or quadrangle maps from over the years.
- Land use – talk to county and municipal planning. See if Geographic Information Systems (GIS) maps can be developed for your group with land use, permitted dischargers, geologic features.
- Water quality – see if the County Conservation District, PA Department of Environmental Protection, PA Fish and Boat Commission, and/or local universities has conducted studies in the watershed.
- Community size –use census data or ask watershed municipalities.
- Special features – consult your state's water quality standards. In Pennsylvania you will use the Pennsylvania Code – chapter 93 to determine what the designated uses are of your watershed.
- Watershed size – use county maps to delineate your watershed to outline the watershed boundaries



2b: Identify issues, concerns, and threats to your watershed.

As your study design sub-committee discusses the background information designate a member to record an on-going list of potential watershed problems as they come up in conversation. In addition, each member should express their top 3-5 watershed concerns. As the master list is developed see if some issues automatically rise to the top, i.e. a threat that is brought up by multiple members.

The group will then want to prioritize the issues that will focus your monitoring agenda. If the top 2-3 issues do not manifest through the listing process, give everyone three votes to choose their priority issues. Hopefully priority concerns will materialize.

2c: Identify what information you need to address these concerns.

What information needs to be gathered? What do you need to address your concerns? At this point, you will determine if stream monitoring is an appropriate tool in addressing your concerns. If monitoring does not seem like a logical solution or step to resolve priority issues then the sub-committee can bring those conclusions to the whole group and a different program area can be developed.

If monitoring seems like an appropriate tool, then move forward with the study design steps.

2d: Determine the questions that monitoring will help answer.

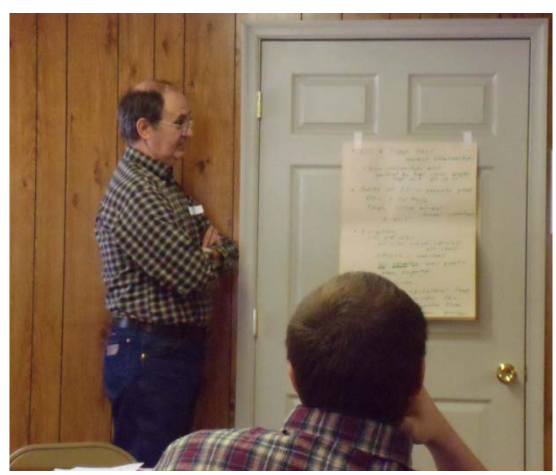
This is the step in the scientific process where you identify your research question. It could be exploratory, such as "what is the health of the watershed?" or it can be specific and targeted, such as "what effect are the CAFOs having on the health of the tributary?"

2e: Determine your overall watershed monitoring goals. How do your goals fit into your group's mission?

Your monitoring goals will align with your monitoring question they can be broad and/or specific but make sure that they are measurable. For example, a goal can be: understanding the health of the watershed or understanding the relationship between land use and water quality.

Step 3: How will you use the data you collect?

Now that you have determined your research questions you need to look ahead and think about how you are going to use your data. This question will be vital in determining what type of equipment, protocols, and quality assurance measures you will need to use. It is also important to keep in mind what your resources are.



Determine what action you expect to take with your data and who will use the data. Remember to align your data use objectives with your monitoring objectives.

Common data audiences:

- The group collecting the data
- The community
- The local government
- The State/Federal Government

Envision data outputs. For example perhaps your primary concern is the impact from zoning changing from agricultural to residential and your group has decided to collect baseline water quality. A potential data use goal is to develop data reports for your municipality to inform environmentally-friendly ordinances for residential development.

It is a common default for groups to identify the State/Federal Government as the audience for the data. Often people will determine that the group will collect data and then assumes the state will use it. Unless a relationship is established with a state entity upfront that they will use the data or be an audience for the data, ALLARM recommends that the group think more tangibly. How can the group analyze the data and use the data to communicate to others.

Step 4: What will you monitor?

Now you are getting to the nuts and bolts of your monitoring program. At this point, it is helpful to talk to a service provider like ALLARM to confirm that chosen monitoring parameters are the best parameters for your monitoring questions.

There are three basic stream evaluation measures: biological, chemical, and visual. ALLARM more often than not, recommends that organizations take a holistic approach to monitoring that involves all three evaluation measures. Each measure tells a different type of water quality story.

- *Biological*: Organisms live in water bodies 24/7, therefore you can use identification protocols to determine what percentage of organisms are sensitive, somewhat sensitive, or tolerant to pollution. An indicator often used by volunteer monitoring organizations is macroinvertebrates.   Often groups think about fish first but fish monitoring is resource intensive.
- *Chemical*: If you know that the stream is polluted, you can examine specific chemicals or indicators that will help you determine what is affecting the stream. Chemical monitoring is a snapshot view in time of the stream since water chemistry is constantly changing.
- *Visual*: It is important to take a step back and look at the stream as a whole. Visual monitoring evaluates physical characteristics that contributing to or degrading stream health.

List the water quality indicators and parameters you will examine:

Example from the Antietam Watershed Association:

Survey Type	Specific Indicators/Parameters
Physical	• Streamwalk, stream reach survey, discharge • Conductivity, temperature, turbidity
Chemical	• pH, alkalinity, nitrates, orthophosphates, dissolved oxygen • aluminum (to be tested by professional lab)
Biological	• macroinvertebrates • bacteria (professional lab) • fish species (work with Fish & Boat commission)

As mentioned earlier, it is helpful to consult with a service provider or someone in the water quality field that can make suggestions on parameters. It is a careful balance between choosing the correct parameters that help answer your questions and choosing too many parameters. You do not want to overburden your volunteers with too many tests. Think about whether one parameter can answer your question or if you need reinforcement from other parameters.

Below is a table to assist in making choices about what parameters are appropriate for common water quality concerns.

Table 1:

Stream Indicator	Monitoring Technique	Importance	Pollution Indicator					Difficulty
			PS	SW	AG	AR	AMD	
Biological	Macroinvertebrates	Indicates the overall health of a stream based on the types of aquatic organisms present	X	X	X	X	X	5
Visual	Adapted USDA Protocol	Measures the physical characteristics of a stream, which influence water chemistry as well as habitat quality for aquatic organisms	X	X	X			4
Chemical	Temperature	Temperature affects the variety and abundance of aquatic organisms. Some organisms prefer colder water, while others can tolerate warmer water. Temperature also influences the amount of dissolved oxygen in the water	X	X	X			1
	pH	A measure of the acidity of the water. Most aquatic organisms survive in a pH range of 6.5 to 8.5	X	X		X	X	1
	Alkalinity	A measure of the ability of the water to neutralize acid inputs and prevent a dramatic decrease in pH	X	X		X	X	2
	Turbidity	Turbidity measures the cloudiness, or amount of suspended matter, in the water. High turbidity can raise water temperatures, decrease light penetration, and smother organisms	X	X	X			1
	Dissolved Oxygen (DO)	Aquatic organisms require certain levels of dissolved oxygen in order to survive. Organisms will begin to suffer at levels below 5 mg/L	X	X	X			3
	Nitrate	Nitrates are a natural compound and necessary for vegetative growth. However high nitrate levels can lead to excess vegetative growth and be detrimental to aquatic systems	X	X	X			4
	Phosphate	Phosphates are also a natural compound and necessary for vegetative growth. As with nitrates however, high levels can be detrimental to aquatic systems	X	X	X			4
	Total Dissolved Solids	TDS is a measurement of the amount of dissolved solids in the water, specifically it is a measurement of the ions in the water (both positive and negative charges).	X	X			X	4

Table 1. Chart outlining the three stream monitoring techniques. **Key:** PS = point source, SW = stormwater, AG = agricultural runoff, AR = acid rain, and AMD = acid mine drainage**). Note:** "Difficulty" is rated from 1 (easy) to 5 (difficult).

This table is representative of common volunteer monitoring indicators and is far from inclusive.

Step 5: How will you monitor?

Okay, you have chosen your monitoring parameters. Now you have to determine the methods you will use to monitor. Are you going to use a monitoring kit, meter, and/or an outside lab?

When determining monitoring techniques it is important to reference the decisions that you made in Step 3: How will you use the data you collect. It should be noted that not all kits and meters are created equal.

Example 1: Let's say that your group is interested in evaluating agricultural runoff with middle school students. Since you are working with students and the data you are collecting is for educational purposes you might choose the Lamotte 3110 nitrate kit because it is easy to use, results in representative data, but most importantly does not contain hazardous chemicals.

Example 2: Let's say your group is interested in evaluating agricultural runoff for a "state of a watershed" report. You will want to use the Hach NI-14 kit. Even though it is more difficult to use and contains hazardous materials, the chemistry is the most similar to what a professional lab would use with a spectrophotometer.

Another key lesson with equipment choices: **<u>just because a meter provides a digital reading, does not mean that it collects the best data</u>**. ALLARM has spent years researching equipment and determining what kits provide the best data for their price. Certain pH strips are better than most of the cost effective meters out there. Additionally, ALLARM has found that the Hach NI-14 nitrate-nitrogen kit produces more persistent and accurate data than hand-held DR 800 series colorimeters.

Example from the Antietam Watershed Association:

Parameter	Equipment	Holding Container	Storage	Maximum Holding Time	Method
Temperature	Lamotte Hg-Free Thermometer	Measured at stream	N/A	Immediate	Field Thermometer
Total Dissolved Solids	Oakton Probe	Measured at stream	N/A	Immediate	Field meter
pH	Strips by EM Science	500 ml Nalgene Bottle	Refrigerate	2 hours	pH strips
Alkalinity	ALLARM Kit	500 ml Nalgene Bottle	Refrigerate	24 hours	Sulfuric acid titration with bromcresol green as an indicator
Dissolved Oxygen	Lamotte Kit #5860	60 ml glass container	N/A	Fixed at streamside, titrate within 8 hours	Winkler Titration
Turbidity	Lamotte Kit #7519	500 ml Nalgene Bottle	Store in cool, dark place	24 hours	Visual
Ortho-Phosphates	Hach Kit #PO-19	500 ml Nalgene	Refrigerate	Within 48 hours	Ascorbic Acid

		Bottle			
Nitrate- Nitrogen	Hach Kit #NI-14	500 ml Nalgene Bottle	Refrigerate	Within 48 hours	Cadmium Reduction
Benthic Macro-invertebrates	Kick net with 500-micron mesh (?)	Identify at stream side; OR Preserve in wide mouth 1 liter plastic screw cap container	Preserved in at least 70% ethanol	Indefinite	Adaptation of VA Save Our Streams Multi Metric Protocol
Bacteria	Professional Lab	500 ml Whirl-Pak Bag		24 hours	Standard Methods
Aluminum	Professional Lab	250 ml bottle	2% nitric acid	6 months	Standard Methods
Streamwalk	Field data sheet, camera	N/A	N/A	N/A	Adaptation of Tier I of USDA Visual Assessment Protocol
Stream Reach Survey	Field data sheet, camera	N/A	N/A	N/A	Adaptation of EPA Volunteer Stream Monitoring Protocol

Step 6: Where will you monitor?

In this step you will determine the monitoring site locations. Site locations can be a balancing act and ALLARM has seen a number of approaches to determining site locations. The first approach you want to take involves letting your monitoring question dictate the locations.

Example 1: Let's say that you are concerned with a point source discharger. Ideally you will have a site upstream, at the discharger, and downstream.

Example 2: Let's say that your group is interested in understanding the health of the watershed. That is a broad concept; depending on the size of your watershed you could have hundreds of monitoring sites (to help capture data from tributaries, the main branch, different land uses). Unless you have infinite amount of financial and people resources, you are going to need to prioritize locations.

Site location considerations:

- *Accessibility*: Are there public parks you can use? Bridges? Friendly neighbors? If you need to access the stream from someone's property, you will need to get the landowner's permission.
- *Number of sites*: Starting out, ALLARM recommends one site per monitoring team. Once feel people comfortable with the testing procedures and the amount of time it takes, ask your volunteers if they feel comfortable tackling a second site (remember that glassware will need to be washed between sites or duplicate supplies will need to be purchased).
- *Resources*: If you only have money to buy 1-3 kits, you will need to develop a timetable for volunteers to bring

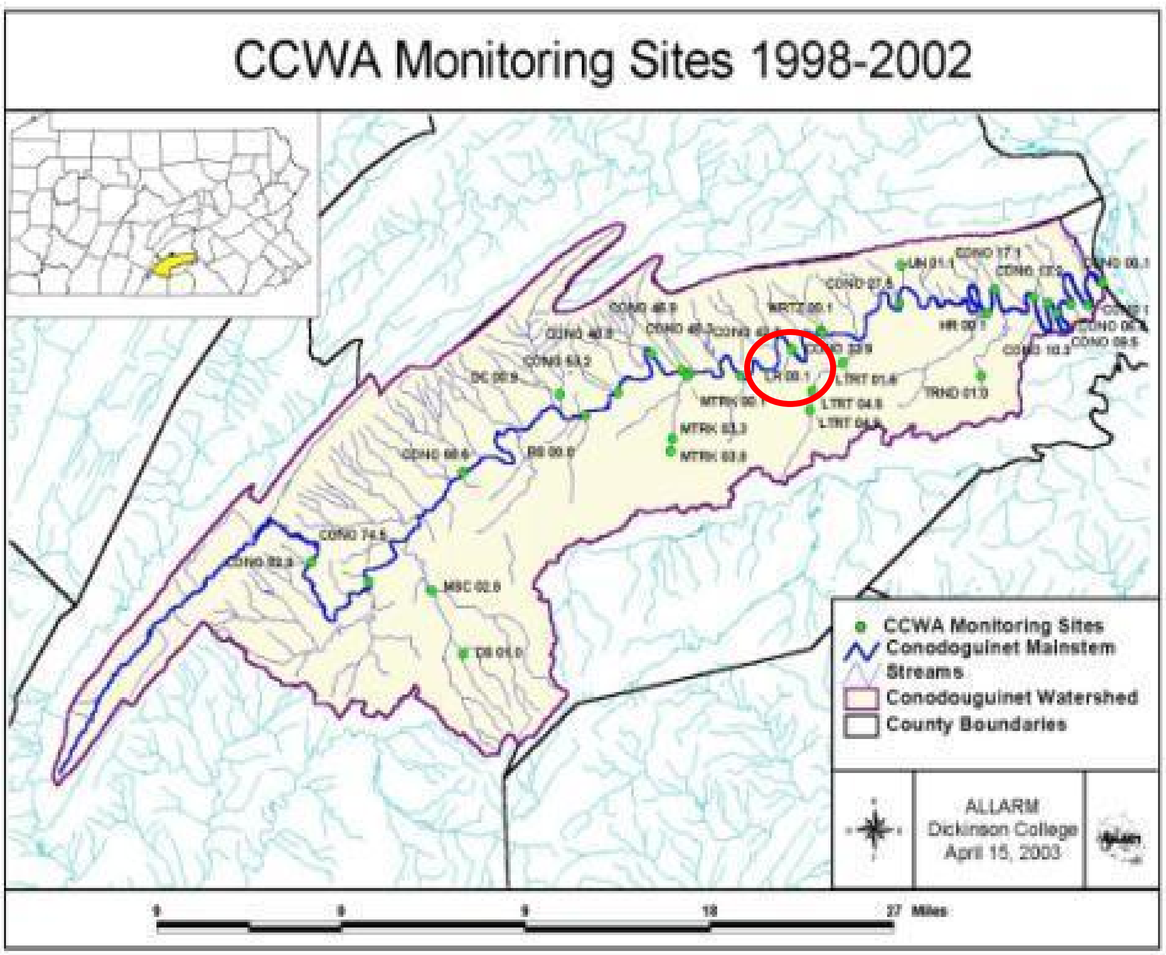
water samples to a central location to use the equipment for analysis. ALLARM generally recommends having a set of equipment per site. In cases of limited resources, ALLARM recommends no more than 2-3 sites per set of equipment.

- *Safety*: Can you wade in your streams? In order to collect representative water samples, ALLARM recommends that samples be taken from the center of the stream and ideally from the entire water column. If you cannot safely wade in your streams, you will want to consider bridges as sampling locations. Or you will need to explore purchasing or building a sampling pole or ask kayaker to assist.

Once you have determined your sites, you will want to document the exact location and give it a site number. You can use Global Positional Units (GPS) to obtain longitude and latitude coordinates that can be entered into Geographic Information Systems (GIS) for mapping purposes. If GPS is not available, at the minimum use a state atlas or county stream maps to mark locations.

Once site locations are determined, ALLARM recommends giving the site a name with the initials of the waterway and the stream mileage (stream miles from the site to the mouth of the waterway, if a tributary it is the mileage from the site to the confluence). For example:

Name of stream: LeTort Spring Run
Mileage from site to confluence with Conodoguinet Creek: 0.1 miles
Site name: LR 0.1



Step 7: When will you monitor?

You need to determine a clear monitoring schedule up front so that monitors are consistent and understand the time commitment and expectations from the beginning.

When you monitor depends on your monitoring question. Basic considerations include:

- *Time of year*: Human use and aquatic ecosystems change with the seasons. Seasonal cycles have an impact on common parameters such as stream flow, temperature, chemistry, food sources, and biological activity. Ideally you will sample throughout the all seasons to determine how your ecosystem varies.
- *Frequency*: How often should you monitor? The three different monitoring types (biological, chemical, and visual) have different monitoring frequencies. For baseline monitoring, ALLARM recommends the following:
    - Biological monitoring: 1-2 times a year
    - Chemical monitoring: once a month
    - Visual monitoring: 1-2 times a year
- *Time of day*: Indicators such as dissolved oxygen and pH vary according to the time of day; try to be consistent in your sampling.
- *Special weather conditions*: If your group is interested in monitoring the effects of a rain event, you will need a very specific sampling plan to collect data at different points during the weather event.
    - Before the event to establish baseline conditions.
    - As water levels rise and as water levels fall.
    - When the water levels return to pre-storm conditions.

If your group chooses to monitor on a monthly basis – choose a common timeframe each month for people to go out: for example the third Wednesday of the month or the first weekend. If your group conducts monthly analysis, it is important that monitors carry out sampling every month. For quality data analysis you need data a minimum of 10 out of the 12 months.

Step 8: What are your quality assurance/quality control measures?

Quality assurance refers to the measures you take to ensure that your data meet the standards of quality that you define (the plan), quality control refers to the actions you implement to achieve your quality assurance objectives (the steps). Essentially in this step you are determining the actions you will take to assure that your data meet your data quality objectives.

Items to consider include:

- *Training requirements*: Who is going to teach your monitors the techniques? What is their certification? When are monitors required to receive training? Are monitors required to go to refresher trainings?
- *Care and calibration of equipment*: Each piece of equipment you use will need to be maintained in a specific way, considerations:

  - Field kits: How do they need to be washed and stored between use? Many kits require a phosphate-free soap wash followed by a dilute hydrochloric acid and distilled water wash.
  - Meters: Will you calibrate the meters every use? How do meter membranes need to be stored or cared for in between uses?

- *Internal and external QA/QC measures for samples collected*:
  - Internal procedures refer to the measure monitors take to ensure quality data.
    - Replicates for chemical tests – establish a range of acceptable differences, if your replicates do not fall within the range, a third replicate will need to be completed.
    - Blanks: If you need to dilute a sample with distilled water, test your distilled water on the parameter and subtract that result from your final result. This is especially important for nutrient testing.

  - External QA/QC refers to measures taken by people and/or labs outside of your program.
    - Blind sample analysis – a standard of unknown value is provided to the monitor who analyzes it and sends it back to the lab where the results are compared to the true value.
    - Split sample analysis – monitors will collect an extra set of water samples and send the water samples and their data to an external lab where the water is tested using the monitors' equipment and more sophisticated equipment (provided by ALLARM).
    - Side-by-side analysis – the external lab conducts monitoring with the monitor and compares results.

- *Documentation of procedures*: It is essential that your methods are clearly documented. ALLARM provides manuals for monitoring groups as a way of teaching technique and recording the methods used.

Step 9: How will you manage and present the data?

In this step you will determine how you will record, store, and present the data. You will want to think about how data is submitted to the data manager, will you have data sheets – hard copy or electronic? Will you have a database? What software will be used? Who will enter the data?

ALLARM has sample data sheets, excel databases, and data interpretation instructions as a part of the "data interpretation" section in the online toolkit.

Step 10: What are the tasks and who will do them?

There are many responsibilities and roles that come with maintaining a successful volunteer monitoring program. It is important that responsibilities are shared so that volunteers are not overburdened.

Think through your first year and develop a timeline with the different tasks that need to be accomplished to achieve your goals. Look at the list of tasks and see if any can be grouped together. Afterwards develop titles for different roles and job descriptions.

Possible monitoring positions:

- *Program Coordinator*: Checks in with monitors, keeps track of training schedule, maintains QA/QC results and needs, and reminds volunteers of monitoring dates.
- *Volunteer Trainer*: Someone who understands the monitoring methodology and procedures, has accreditation, or has gone through a train-the-trainer program.
- *Data Management Coordinator*: Collects data sheets, enters data into database, and conducts data analysis.
- *Data Entry Volunteer*: A volunteer that double checks that the data have been entered into the database correctly.
- *Equipment Manager*: Keeps a schedule with reagent expiration dates, is responsible for ordering and distributing supplies.
- *Volunteer Monitors*: Carries out monitoring.

References:

River Network and PA DEP Citizen Volunteer Monitoring Program. 2001 *Designing Your Monitoring Program: A Technical Handbook for Community-Based Monitoring In Pennsylvania*.