

# Performance Based Criteria

## *A Panel Discussion*

**O**n July 9, 1991, five panel members representing several sectors of the environmental analysis industry convened in Washington, D.C., at the invitation of The University of Findlay, Wheaton Scientific, I-Chem Research and VWR Scientific. The objectives of the discussion were: 1) to increase awareness of sampling variability in environmental measurements, and 2) to suggest approaches to deal with sampling variability.

The panel was chaired by Michael T. Homsher of the Hazardous Material Management Program at The University of Findlay, Findlay, Ohio. Panel members in alphabetical order included: Dr. Fred Haeberer of the Quality Assurance Management Staff at the U.S. Environmental Protection Agency (EPA), Washington, D.C.; Dr. Paul J. Marsden, senior scientist at Scientific Applications Inc., San Diego, Calif.; Dr. Ronald K. Mitchum, president of Research Triangle Laboratories in Columbus, Ohio; Dr. Dean Neptune, Quality Assurance Management Staff at the U.S. EPA in Washington, D.C.; and Dr. John Warren, Office of Policy Planning for the U.S. EPA in Washington, D.C.

### WHAT ARE PERFORMANCE BASED CRITERIA?

Performance based criteria are quantitative estimates, developed from actual experience in applying experienced sampling and analysis plans, and determined to be appropriate for the intended purpose by the data user and review sources. Frequently, performance based criteria represent initial data quality objectives, qualitative and quantitative statements of data quality needs.

The ability to differentiate and resolve the components of variability in environmental measurement is an important issue. The source of this importance is the regulatory and risk assessment strategies that are increasingly being applied to environmental data for decisionmaking purposes.

Within the past four years, recognition of the components of variability in the environmental measurement process has been discussed at national level quality assurance conferences. It has been estimated that up to 90 percent of all environmental measurement variability can be attributed to the sampling process. Estimates of sampling variability have been determined in the acid rain studies, the Department of Energy Environmental Survey, and Superfund by using sample audit materials and on-site sampling audits. Extensive descriptions of processes to control sampling variability in the environmental measurement process have been prepared by the American Society of Testing and Materials and others. A recent recommendation by the American Chemical Society (ACS) to report data when requested at the Reliable Detection Limit, (the concentration at which a detection decision is extremely likely to be correct), makes discussion of this topic very relevant to any individual making decisions based on sampling and analysis. Figure 1 represents sources of errors in environmental measurements.

Consideration of these components of error in the initial planning for sampling and generation of environmental data is a critical step. The challenge is to ensure that decisionmakers are aware of the components of error and to effectively control these error sources in the form of performance based criteria for sampling. This may be the single most important step in providing data of known and documented quality for environmental decisions.

### THE PANEL'S VIEW

*Homsher:* A quotation that reflects the sampling variability issue is, "It is important to realize that if the error associated with the sample collection or preparation phase is large, then the best

**Analytical experts gather to raise awareness of sampling variability and to suggest approaches to deal with this problem.**

laboratory quality assurance program is inadequate." How would you describe our current approach to detection of sampling variability?

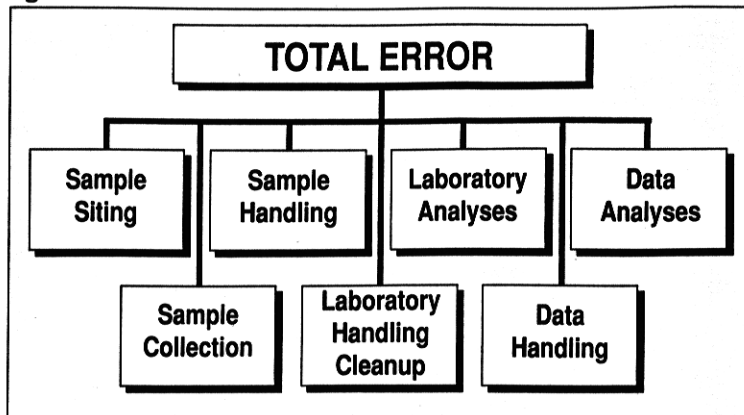
*Marsden:* Field duplicates would probably be our best effort. It would be my choice for at least assessing where we are on sampling variability. Yet, frequently it is said that we cannot afford to take field duplicates and pay for these additional analyses. It is an after-burner approach to data quality. We currently use post analytical techniques when we should emphasize cost-effective and timely planning, especially experimental design.

*Warren:* The way to determine sampling variability, from a statistical point of view,

is to take more samples in the field. Recognizing that you have a limited budget, simply taking more field samples is not in itself sufficient. I think you have to look very carefully at the statistical de-

trade-offs. From a statistical point of view, the components of variability that go into the total error can then be properly identified and some idea as to the magnitude of those can be assessed.

**Figure 1**



"Harmonization of Federal Agencies' QA Requirements for Environmental Data Operations—An Update," moderator G.L. Johnson, Stanley M. Blacker, Fourth Annual Interagency Meeting on Quality Assurance in Environmental Measurements, Jackson Hole, Wyo., Sept. 24-26, 1990, p. 115.

sign of an experiment in order to maximize the amount of information you get from sampling. Research and investigations must be done in making appropriate

*Homsher:* Do you think Figure 1 describing total error accurately illustrates sampling variability?

*Haerberer:* I think you have pretty well identified all the categories as far as total error. With environmental methods frequently we see analytical variability of approximately 10 percent. Yet when we take field duplicates from uniform waste streams, the differences we see in the analyses of these duplicates is technically 30 percent. So we should not be put out when we come up with figures of 30 percent differences from the field

with analyses. I think we need to come up with criteria for standard sampling designs so that the sample variability can be discerned from looking at the analytical data, given the inputs of the method variability and operator error.

*Mitchum:* Yes, it makes sense in terms of the total error being comprised of all errors. Typically in laboratory errors it might range 10 to 15 percent on methods that are measuring very low levels of some analytes. One of the problems I have found in sampling is that in many cases information we have from the field doesn't get relayed back to the people that are using the data. If you think you have deviations due to sampling error, what do you do? What you will usually find is that individuals will spend money to go back and run duplicates of the samples in the laboratory. However, the individuals will not go back to the field and collect more samples. The laboratory does not contribute, except for small percentages, to the error you will find in the data.

*Homsher:* Who is collecting information on sampling variability?

*Mitchum:* I am not certain that anyone is collecting information on sampling variability. The data may be out there in some of the EPA databases that we have, but I am not certain there are catalogs that you could readily access. That question is one which deals with sampling design that usually does not, in many cases, test sampling variability.

*Homsher:* Would you say this would be a useful piece of information?

*Mitchum:* If I designed the study, sampling variability would certainly have to be an integral part of the study. Ideally, what you want is for there to be no variability in sampling.

*Neptune:* I agree that not very much information is available on sampling variability. [The EPA's] Quality Assurance Management Staff (QAMS) has had the opportunity to facilitate the ap-

plication of the data quality objective process, an up-front planning tool, with several of the regions in Superfund.

We have actually gone to some Superfund sites and have helped them establish their data performance constraints for planning their survey design, and done some actual field pilots where we have tried to determine what by natural variability of the population, varies between 70 to 90 percent. Therefore, the contribution of the variability from the other sources in the figure—from sample collection, sample handling, laboratory handling and cleanup, laboratory analyses, data handling, data reporting, and data interpretation—makes up that other 30 to 10 percent. So when you think about where you might get the best advantage by spending another dollar, in the lab versus spending that same increment of money to get a better handle on that natural population variability, it is obvious that you get a much bigger bang for your buck by determining natural population variability. That is where the real bulk of the error is typically found.

I am not saying that it is always found in the natural population variability and that these other sources are not an important aspect of error. QAMS has been trying to help people understand through a diagram like Figure 1, what the typical major contributors of error are, to get some real world information from actual sites and share that information with people so that they can decide: do I wish to collect this array of quality assessment samples vs. just doing what other people have done in the past?

*Homsher:* What I hear you saying is that QAMS is working together with individuals to help clarify or draw out the information that will focus on variability. But when this was done in six pilots that you mentioned, you identified the sample population as being the major contributor. Did you use quality assessment samples and processes to make this determination?

*Neptune:* Absolutely. One of the key issues we try to get decisionmakers to face, who are responsible for survey designs, is to focus on knowing their sampling error vs. measurement error. They should be interested in knowing error levels so that when they complete their sample collection, sample analyses and data interpretation, they can compare their data performance results with their data quality objectives.

The reason to bring it down to that ultimate point in the hierarchy of error (simply telling them whether they were successful or failed) is because it does not require a lot of quality assessment samples. This allows them to quickly come to a conclusion that the data is good enough for the intended purpose and therefore, we have been successful. The bad part is that if you tell them no, they have not been successful, one of the knee-jerk reactions of most decisionmakers is to turn around and say "why?" If you have not conducted quality assessment to delineate the various sources of error, be it in the laboratory or in data handling or in the actual sample collection process, you can't determine where the failure is involved. So we have been trying to help decisionmakers trade off between wanting to know exactly what the diagnostic of

*Homsher:* We really don't have, as far as I can identify, much information being collected on sampling variability. That leads us into the question: is there a national mechanism for sharing information about sampling variability between agencies? I think it would be particularly important in both the short term and long term as we look at the Department of Defense and Department of Energy future involvement in very large multibillion-dollar environmental projects. Identification of those sources of sampling variability will be important.

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**"An important point that disturbs statisticians is, what is the base of representation?"**

**—Warren**

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*Mitchum:* First there are scant mechanisms for any type of information to be shared between government agencies, much less information as detailed as sampling variability. We have a very difficult time sharing information on analytical chemistry and site characterization. I think right now we don't have a very good definition about what might be shared. This topic might be well worth bringing up at a QA caucus that is held between the different agencies.

*Homsher:* Would this type of national pooling of information be related to the harmonization issue?

*Haeberer:* Exactly. Ken Brown from Environmental Monitoring System

Laboratory, Las Vegas (EMSL-LV) held a three-day workshop last February to address how to sample a site where you have everything from railroad cars to homogeneous materials. The proceedings of that workshop are currently being prepared. In terms of quality assurance meetings, there have been several. These grew out of meetings between EPA's Superfund and DOE's staff. The extent to which these agencies get into the statistical design of sampling an environmental site still has to be seen. Currently they have been dealing more on operational levels as opposed to addressing it from the standpoint of meeting data users' needs for acceptable total error levels. So the tie-in hasn't yet been made but there is the recognition that this needs to happen.

*Neptune:* This panel might be part of this information sharing, or an initial attempt. QAMS and the Office of Information Resource Management (OIRM) have begun a collaborative effort to deal with the important point Ron Mitchum made when he said, "What information is really important to collect in order to identify the quality of your data?" What we have begun to do in collaboration with OIRM is to outline an agency approach for database quality identifiers that should be collected and incorporated into that database. We are trying to take a logical approach to identify important data quality identifier information so that in the future, the agency databases can capture that vital information for interpreting data quality from a future user's point of view.

*Homsher:* So this effort is still in the informative stages.

*Mitchum:* I think that in many cases we confuse sampling error with what I call design error and if the end result is not what you wanted or expected, then you blame the samplers or the sample design. We have the same problem in terms of how to design the sampling of the site and the mechanics of taking a sample; how deep you take a sample, what kind of tool you should use, how you should wash it. So, if we scraped the first six inches off of an acre, piled it all up and mixed it really well and took

three, four or five sample measurements, we would probably have a pretty good composite of what is there. If we took only one sample we probably would not. We need to have generic guidance to describe how you sample various matrices. I think we need to define what we really need and what we are trying to measure in terms of sampling and sampling variability.

*Warren:* From a statistical point of view the concept of composite sampling is a very important one because it relates to the data quality objectives that Dean Neptune is talking about regarding why are you collecting and what is the decision you are going to make. I am going to go back to your original example of the railroad cars. Are you really going to composite a railroad car? The final decision is to determine whether composite sampling is appropriate or not. A more important point that disturbs statisticians and is always glossed over is, what is the base of representation?

For example, if we are talking about a hazardous waste site of two acres and we elect to take a single core sample, what area within that site does that core represent? It is of great importance if that single core represents two square meters. However, that is very different than a sample core which represents just that core itself. This must be factored into the actual sample design right from the very beginning. What is the area of support for the sample that is going to be drawn? If the sample must be representative of a certain larger area, then what sampling plan will be used in a composite sense to obtain a sample representative of that area and how does that affect the natural variability, which is what we wish to measure. Evan Englund of EMSL-LV has done some work on this but it still is very much an open question.

*Marsden:* That is certainly true. One thing that has bothered me about environmental sampling and analysis is the amount of disconnects between statistical design, field activities, chemistry and the decision process. Everybody seems to have their own turf. I recently did trawling in the ocean and looked at fish and various other organisms. If you observe the way biologists sample, there is no conceivable way to imagine that one would hire a sampling contractor to go out and run a trawl, bring the net back and then identify aquatic organisms. Yet, that is the way we do our chemistry measurements. We have a generic map and generate a sampling plan to go out and sample certain spots...give the map to some group whose specialty is ordering bottles and going out and filling them up. Those bottles are sent to a laboratory which analyzes what is inside of the bottle and they fill out forms and send that information to 15 people who look at those numbers to evaluate and interpret the data.

## **DRAWING CONCLUSIONS**

Careful planning, including sampling designs that address the statistical issue of errors in sampling variability in the field, are vital to the overall success of environmental data generation on which decisions will be based. □

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*Part 2 of this article, in the December/January issue of ENVIRONMENTAL LAB, will further explore the complexities of sampling variability and discuss the panel's recommendations.*

# Performance Based Criteria

## *A Panel Discussion: Part II*

**Analytical experts gather to raise awareness of sampling variability and to suggest approaches to deal with this problem.**

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### SUMMING UP PART I

From Part I of this article (October/November 1991, ENVIRONMENTAL LAB): "Within the past four years, recognition of the components of variability in the environmental measurement process have been discussed at national-level quality assurance conferences. It has been estimated that up to 90

percent of all environmental measurement variability can be attributed to the sampling process."

In Part II, which follows, our panel members continue their discussion of this topic.

*Homsher:* We are discussing communication issues in terms of disconnects and suggesting an integrated type of approach with oversight, which probably would be QAMS (Quality Assurance Management Staff). Do we have any generic approaches?

*Warren:* This is a new area, this interaction between engineers taking the samples, the chemists who analyze the samples and the statistician who is doing the planning; we know it as chemometrics or as chemostatistics. I am pleased to say that the American Statistician Association has formed a subset on chemometrics within one of our sections. In addition, there is a new organization within EPA, and also the Center for Vital Statistics. The initial planning attempt is to integrate some of the work being done by DOE and DOD with EPA.

*Homsher:* It sounds as though an effort is being made to identify important characteristics and prepare a generic plan. A publication from EMSL-Las Vegas entitled "A Rationale for Assessment of Errors in Sampling Soil" discusses important sampling and analysis characteristics. Statistical equations are presented that point out the sources of variability seen in the total error diagram. How is sampling variability, once detected and documented, reduced and actually corrected?

*Warren:* We are sponsoring research (Office of Policy Training/Evaluation) by Penn State University. We have some of the best sampling statisticians available working on this problem.

How do you use composite sampling when you can only afford a certain number of samples from a site or given matrix? Work is being done on reduc-

tion of sampling variability. But don't forget, it has to be in the context of the basic quality objective. It comes back to what do you want. It is not a matter of taking the sample first and then deciding what does the sample tell us; it must be the other way around.

*Marsden:* When you talk about variability in sampling, we occasionally lose sight of the goal. The goal is to assess the site and clean it up. The

mathematical model works when everything is a flat plane or homogenous cube, but there are many complications such as soil horizons, clay lenses, etc. It has been my experience that you never see consideration for these factors in the planning or sampling.

*Warren:* In the planning stages of the sampling expedition, the statistician should be told that there are different soil types. This enables the statistician

to recommend that you stratify the site you are sampling and make it into contiguous units. The precision will be greatly enhanced by the use of this prior information.

*Mitchum:* I agree. One of the problems is defining what we want to get out of the data when we talk to someone designing the experiment. For example, if gold was being mined and you sampled the first six inches of soil in Nevada, Nevada would be seen as one of the poorest gold producing states in the country. It is known to miners that gold in a particle form lies on the bedrock, not on the strata above it. So you have to dig down to the bedrock to find the gold because that is where it will be.

*Neptune:* This discussion is music to my ears because we have been trying to foster up-front planning. The tool that the EPA uses to facilitate up-front planning is the data quality objective (DQO) process. Too often, people have a historical recipe they use for collecting field data, bring it in and say, "What does this tell me, or what decisions can I make about this?" Instead, decision-makers should involve all participants *before* collection.

*Mitchum:* Let me give an example of just that sort of thing. I did a study for dioxins in fish. After I had collected a lot of fish and found very low levels of dioxins, I decided to examine fish-eating snakes. I thought I knew that snakes eat fish. I called my local wildlife biologist and asked him to collect 25-30 water moccasins. I chopped, sliced, diced and analyzed the snakes and they had no detectable dioxin in them. In fact, water moccasins don't collect dioxin. My theory was wrong. I needed snakes that bioaccumulate dioxin. I spoke with a herpetologist (an expert on reptiles and amphibians) and learned that water moccasins eat rats, not fish. He recommended a particular species of snake which was then collected and they were very good. They had a bioaccumulation factor for dioxin of about 200.

*Haebeler:* If I may build upon your anecdote and our discussion, the herpetologist should have been involved at

the planning stage during your DQO process. That is the same thing that Dean and I have been finding. Unless you have the right people involved initially, you have a long up-hill climb. This involvement cuts down repeated sampling, sampling the wrong type of matrix and so on.

*Warren:* What Ron's example illustrates is called stratification on the wrong variable. He was absolutely correct in saying that snakes accumulate dioxin, so what he did was essentially stratified, but he stratified on the wrong snake. In statistics we are very sensitive to this. If you have a list of cases and someone just takes one off the shelf and says this is what I want to do, then you run the risk that Ron identified in his example. In fact, it was a right idea, wrong snake.

*Mitchum:* If you had taken enough data you could throw things out that didn't make sense.

*Warren:* Absolutely. As Fred said, there should have been a herpetologist in the initial planning stage. Stratification is a very powerful tool. I think the concept of stratification of samples should be made up front.

*Mitchum:* Give us a definition of performance based criteria and what you really mean by that in this context.

*Homsher:* Performance based criteria for sampling are quantitative estimates that have been developed by experience in applying sampling and analysis and they are determined to be appropriate for the intended purpose by the data-user and the review sources.

I first became involved with performance based criteria when Fred (Haeberer), Dean (Neptune), myself and others were involved with the Superfund analytical methods for the Contract Laboratory Program. Performance based criteria were one of the things people requested. Now I think we see other areas for variability in the total environmental measurement process. If we look within the sampling area, is it possible that one can find and establish performance based criteria for sampling?

*Warren:* I would like to throw the question back to the decisionmaker. If you come to a statistician and say; "I want to know how many samples, I want to know the sampling plan, I want to know the following characteristics," the statistician, given enough information, can work out a plan to do that. The biggest problem for a statistician is to understand the decision you want to make. The decisionmaker should also be able to say what the consequence is of mak-

ing the wrong decision. That is where there is the big disconnect in the agency process. If it is a health risk, what is the consequence of not collecting enough samples to make this decision? What is the consequence if I reached a wrong decision? I think this leads back to data quality objectives. Dean, don't you agree?

*Neptune:* Absolutely! I recognize that managers would like to view data col-



lection and data analysis as simply a technical problem, something that the scientists and engineers should take care of. The communication that I have heard here today needs to be conducted during the initial planning, to determine what is important.

The consequences of incorrect decisions can be many: economic, human health, environmental and social. The decisionmaker has to communicate, during the planning process, what consequences are of great import to him so that they can be accommodated in the development of the data quality objectives. The scientists, engineers and managers need to be specific about their data performance requirements and then involve a statistician to develop a statistically based survey design. Frequently, the statistically based design is not only practical, but also more cost effective than the hodgepodge approach to reducing sampling variability that we have done in the past.

*Warren:* Unfortunately, there is frequently a failure of decisionmakers to consider what the consequences are in making wrong decisions. If they don't want to make a decision, they don't want to ask questions because they are potentially frightened by the answer. The decisionmaker ducks the issue by throwing it back to the statistician and saying; "You tell me how many." The decisionmaker should make a decision, not merely endorse what somebody else has done.

*Neptune:* We have struggled with this in the Quality Assurance Management Staff for years and it centers on one important issue; responsibility and accountability of managers. What we need is a cultural change and I believe the emphasis in society on quality is helping to bring that cultural change.

*Homsher:* Accountability, responsibility and willingness to face the issues and identification of consequences involved has to come from the decisionmaker.

*Neptune:* QAMS is a facilitator to the regional Remedial Project Manager and other decisionmakers. Two prime examples are EPA Regions IV and VII

where they have successfully gone through the data quality objective process, involved all the parties, and management has lived up to their responsibilities to be accountable. It has taken courage on the part of many of those managers. When we were studying a dioxin site in Region VII, management had to defend it at both the state and headquarter levels. Managers in Regions IV and VII were able to take responsibility for what they were doing, explain it in an understandable way and demonstrate to their colleagues and se-

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**—Warren**

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nior managers within the agency that this was worthwhile. This approach helped them make more defensible decisions; get to the root of the problem and remedy it quicker in a cost effective, practical manner. This is particularly important in Superfund. The Community Right To Know Program provides funds for communities to hire experts to look over regulators' shoulders. This provides oversight for the agency and contractors. You are going to be held accountable by the citizens who live in that particular area.

*Marsden:* Is it possible to have performance based criteria? I think this is a tough question. Just as we have method performance differences matrix to matrix, we are going to have significant sampling differences matrix to matrix. This is a critical item in terms of RCRA permitting; is your waste hazardous or not?

*Homsher:* Would you say that there is enough benefit to look into it?

*Marsden:* I would certainly say so.

*Haeberer:* You started out with the statement that about 90 percent error is associated with sampling vs. analytical error. That clearly indicates that effort needs to go into further developing sampling approaches, sampling schemes, sampling design, whether it is statistical, whether it is stratified, whether it is selective. That is where we are finding our error levels. We need to focus a lot more on sampling than the analytical laboratory.

*Neptune:* The first thing we do when we are investigating the Superfund sites is examine the historical data to determine if the data will give us a sense of the variability associated with that population. Frequently, we find that the historical data is lacking and we run a pilot study to determine the variability for the population of interest. This allows us to design a survey that is more efficient than if we just tried to take a guess.

*Marsden:* In terms of doing research to assess sampling variability, this has to be an integrated approach. You need to integrate input from the people who physically go out and take the samples, the statistical design people, the analyst and the engineer. The research should focus on how sampling variability affects our ability to make a decision.

*Homsher:* Documents on data validation are almost exclusively analytical. Considerations of the sampling variability are minimal. The topic should be approached in a focused attempt that involves the data quality objective approach.

*Mitchum:* The primary objective is to get the data users involved, to define the

error level they can live with in making decisions and applying this data. With this involvement, sampling can be designed to meet acceptable error levels.

*Homsher:* Can we go around the table and summarize where we think we are with our discussion?

*Neptune:* First we must engage management in a proactive way to specify what is important to them in their decisionmaking process. One of the issues that is very important for managers to resolve is to determine what is on the critical path for decisions. By giving that focus up-front, the efficiencies in our overall environmental data collection activities can be tremendous. The ability to speak with greater confidence and specificity about a given question and the data that we are now collecting to support answering that question, gives us the chance to engage our statistical colleagues up-front in the planning. Now we can give the specificity to the statisticians to allow them to help us develop a probability-based survey design.

*Mitchum:* I think where we are headed is, yes, we can put a number on the variability in the laboratory. Now, can we put a similar error bar on something that happened in the field?

I think the most important thing is representativeness and what was the sample just taken and what did it really represent. There are a lot of errors in sampling design, where we take the samples and representativeness. A sampler can make very few errors in the field if you tell him how to sample, you watch him, and you have a procedure. When he gets back to the laboratory, we start getting into representativeness of the sampling in terms of the composite the laboratory is going to take and the distribution of these analytes in the site you are looking at.

We need to define what will minimize sampling error, but I think the rest of it simply is how to design the study so that we get the answer and the kind of quality we desire. Unfortunately, I think what is happening is that people don't like the numbers. The conclusion is there must have been sampling error since that is an item we don't know much about.

*Neptune:* We are interested in the probability of making an incorrect decision, not just in the performance and error bars around a given number one might generate. Just generating information on how good a measurement is falls short of where we really need to be. We need to understand what the impact of that error in the decision is, not the error in the measurement, not the error in the population being sampled; those are all components of that error in the decision.

*Mitchum:* Exactly right. At the limit you are trying to regulate, or at a risk

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level, the probability for making a mistake is very high. That is the problem in making the measurements and the criteria we use in the laboratory. These are the best criteria we have, but especially near the detection limit, we neglect what sort of errors are associated with those measurements. In some cases measurements may have error as high as 30 to 40 percent, not even counting sampling error, but we are making decisions.

*Haebeler:* Let me try to give a little more of a philosophical view. We in QAMS have been busy for the past few years attempting to institutionalize the

DQO process. What is really needed is the education of the data user. Hopefully we can come to a point where we can design a sampling and analysis operation to adequately and consistently meet the needs of the data user.

*Warren:* I am going to address the question of the importance of sampling variability in environmental measurements. First, the fact that the decisionmaker and the error rates must be specified and discussed at the early planning stage. Second, determination of the area of support; what does this sample really tell me about where it came from? Third, the importance of stratification of the areas of interest so that the planner can get the biggest bang for the buck. And lastly, the importance of including a statistician in the planning stages so that there can be some form of integration across the entire process.

*Marsden:* I believe we should develop some systematic information about how much variability we really are talking about. If the numbers are bad, we can't make a decision. I think that the multidisciplinary approach to planning would result in an initial buy-in from everyone involved. I think we need to break down communication barriers between planners, samplers, analysts, validators and decisionmakers.

#### IN CONCLUSION...

Efforts should continue and increase to define the criteria needed for accurate decisionmaking to occur for all environmental sampling projects. This can best be achieved through the cooperative efforts of decisionmakers, planners, statisticians, chemists and engineers from the initial stages and throughout all phases of environmental projects. □

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*CLARIFICATION:* A portion of one panel member's comments was inadvertently omitted from Part I of this article (ENVIRONMENTAL LAB, October/November, page 14). It should have read:

**Neptune:** So we have been trying to help decisionmakers trade off between wanting to know exactly what the diagnostic causes of failure might be versus just knowing whether the data collected is adequate or not. It is a balancing act and it is not an easy job.