UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF
PREVENTION, PESTICIDES AND
TOXIC SUBSTANCES

MEMORANDUM

DATE: August 11, 2009

SUBJECT: Transmittal of the Meeting Minutes of the FIFRA SAP Meeting Held May 12-14, 2009 on the Scientific Issues Associated with "The Ecological Significance of Atrazine Effects on Primary Producers in Surface Water Streams in the Corn and Sorghum Growing Region of the United States (Part II)"

TO: Debbie Edwards, Ph.D.
Director
Office of Pesticide Program

FROM: Sharlene Matten, Ph.D.
Designated Federal Official
FIFRA SAP Staff
Office of Science Coordination and Policy

8/11/09.

THRU: Laura Bailey
Executive Secretary, FIFRA SAP
Office of Science Coordination and Policy

Laura Bailey

Frank Sanders
Director
Office of Science Coordination and Policy

Please find attached to this memorandum the meeting minutes of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) Scientific Advisory Panel (SAP) open meeting held in Arlington, Virginia on May 12-14, 2009. This report addresses a set of scientific issues associated with "The Ecological Significance of Atrazine Effects on Primary Producers in Surface Water Streams in the Corn and Sorghum Growing Region of the United States (Part II)."

Attachment

cc:
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FIFRA SAP Members

Kirby C. Donnelly, Ph.D
Steven G. Heeringa, Ph.D. (FIFRA SAP Chair)
Kenneth M. Portier, Ph.D.
Daniel Schlenk, Ph.D. (FIFRA SAP Session Chair)

FQPA Science Review Board Members

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James Randolph, Ph.D.
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SAP Minutes No. 2009-06

A Set of Scientific Issues Being Considered by the Environmental Protection Agency Regarding:

The Ecological Significance of Atrazine Effects on Primary Producers in Surface Water Streams in the Corn and Sorghum Growing Region of the United States (Part II)

May 12-14, 2009
FIFRA Scientific Advisory Panel Meeting
held at
Potomac Yard I
Arlington, Virginia

NOTICE

These meeting minutes have been written as part of the activities of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), Scientific Advisory Panel (SAP). The meeting minutes represent the views and recommendations of the FIFRA SAP, not the United States Environmental Protection Agency (Agency). The content of the meeting minutes does not represent information approved or disseminated by the Agency. The meeting minutes have not been reviewed for approval by the Agency and, hence, the contents of these meeting minutes do not necessarily represent the views and policies of the Agency, nor of other agencies in the Executive Branch of the Federal government, nor does mention of trade names or commercial products constitute a recommendation for use.

The FIFRA SAP is a Federal advisory committee operating in accordance with the Federal Advisory Committee Act and established under the provisions of FIFRA as amended by the Food Quality Protection Act (FQPA) of 1996. The FIFRA SAP provides advice, information, and recommendations to the Agency Administrator on pesticides and pesticide-related issues regarding the impact of regulatory actions on health and the environment. The Panel serves as the primary scientific peer review mechanism of the Environmental Protection Agency, Office of Pesticide Programs (OPP), and is structured to provide balanced expert assessment of pesticide and pesticide-related matters facing the Agency. FQPA Science Review Board members serve the FIFRA SAP on an ad hoc basis to assist in reviews conducted by the FIFRA SAP. Further information about FIFRA SAP reports and activities can be obtained from its website at http://www.epa.gov/scipoly/sap/ or the OPP Docket at (703) 305-5805. Interested persons are invited to contact Sharlene R. Matten, Ph.D., SAP Designated Federal Official, via e-mail at matten.sharlene@epa.gov.

In preparing these meeting minutes, the Panel carefully considered all information provided and presented by EPA, as well as information presented in public comment. This document addresses the information provided and presented by EPA within the structure of the charge.

TABLE OF CONTENTS

SAP Minutes No. 2009-06

A Set of Scientific Issues Being Considered by the Environmental Protection Agency Regarding:

The Ecological Significance of Atrazine Effects on Primary Producers in Surface Water Streams in the Corn and Sorghum Growing Region of the United States (Part II)

May 12-14, 2009
FIFRA Scientific Advisory Panel Meeting
held at the
Potomac Yard I
Arlington, Virginia

8/10/09.

Daniel Schlenk, Ph.D.
FIFRA SAP Session Chair
FIFRA Scientific Advisory Panel

Date: August 8, 2009

Sharlene R. Matten, Ph.D.
Designated Federal Official
FIFRA Scientific Advisory
Panel Staff
Date: August 10, 2009

Federal Insecticide, Fungicide, and Rodenticide Act
Scientific Advisory Panel Meeting
May 12-14, 2009

The Ecological Significance of Atrazine Effects on Primary Producers in Surface Water Streams in the Corn and Sorghum Growing Region of the United States (Part II)

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TRIBUTE TO DR. KIRBY C. DONNELLY, MEMBER OF THE FIFRA SCIENTIFIC ADVISORY PANEL

Dr. Kirby (K.C.) Donnelly died from cancer July 1, 2009 prior to the completion of this report. The Environmental Protection Agency's Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) Scientific Advisory Panel (SAP) dedicates this report in his memory. In July 2008, Dr. Donnelly joined the FIFRA SAP and brought his valuable insight and perspective to the SAP. In that short time, he was able to demonstrate his vast collective professional experience, his sincere commitment as a public servant to the goals and objectives of the Panel, his dedication to protecting the environment, and his genuinely pleasant personality. He will be missed by all of us who worked with him.

INTRODUCTION

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) Scientific Advisory Panel (SAP) has completed its review of the Agency's analysis of **The Ecological Significance of Atrazine Effects on Primary Producers in Surface Water Streams in the Corn and Sorghum Growing Region of the United States (Part II).** Advance notice of the SAP meeting was published in the *Federal Register* on **February 20, 2009**. The review was conducted in an open Panel meeting May 12-14, 2009 held at Potomac Yard I, Arlington, Virginia. Dr. Daniel Schlenk chaired the meeting. Dr. Sharlene Matten served as the Designated Federal Official. Dr. Steven Bradbury, Deputy Director, Office of Pesticide Programs (OPP) and Dr. Donald Brady, Director, Environmental Fate and Effects Division (EFED), OPP, provided opening remarks at the meeting. Presentations of technical background materials were provided by Mr. Mark Corbin and Mr. Nelson Thurman, EFED, OPP; Dr. Russell Erickson, Mid-Continent Ecology Division, Office of Research and Development; and Mr. Charles Delos, Health and Ecological Criteria Division (HECD), Office of Science and Technology (OST), Office of Water (OW).

The Agency issued the Interim Risk Assessment Eligibility Document (IRED) for atrazine in 2003. The Agency determined in its ecological risk assessment that atrazine posed potential risks to sensitive aquatic plant species and that effects might occur at the populations and community levels of biological organization. As a condition of reregistration, the atrazine registrants were required to develop a monitoring program to determine the extent to which atrazine concentrations and exposure durations associated with corn and sorghum production may be exceeding levels that could cause effects on aquatic plants. Forty watersheds were selected for monitoring of atrazine exposure profiles from a total set of 1172 watersheds that exhibited high atrazine use and were estimated to be most vulnerable to atrazine runoff on the basis of the USGS Watershed Regression for Pesticides (WARP) model. Sampling within these watersheds began in 2004 and is ongoing in selected watersheds. The Agency intends to evaluate the results of the atrazine monitoring study in order to identify the characteristics of those watersheds that resulted in atrazine exposures that exceeded the Agency's Level of Concern (LOC) and to extrapolate those results to other non-monitored locations to determine where and when other exceedences of the LOC may occur.

In December, 2007, the Agency presented the Comprehensive Aquatic Systems Model (CASM) to the FIFRA SAP. CASM serves as a tool to determine a level of concern (LOC) that compares atrazine concentrations and exposure durations from monitoring data to effects measured in a series of microcosm and mesocosm studies which were used in the original atrazine (IRED) assessment. In addition, the Agency presented an approach for use in identifying other potential sites outside of the 40 original monitoring sites based on similar atrazine use-patterns, watershed vulnerability and other factors. The SAP recommended that the CASM Atrazine model should be revised with respect to parameterization, process formulation, and functionality to more accurately model 2nd and 3rd order Midwest stream characteristics and that a more comprehensive sensitivity analysis should be conducted (see FIFRA SAP 2008).

During the May 12-14, 2009 FIFRA SAP, the Agency presented new evaluations of the applicability of the revised CASM Atrazine model to freshwater atrazine risk assessments and provided reasons in support of its decision not to proceed with further development and application of this model. A simpler alternative to the CASM-based approach, Plant Assemblage Toxicity Index (PATI), was presented for relating atrazine surface water exposures to the microcosm and mesocosm effects data. Other issues presented included a revised assessment of the microcosm and mesocosm exposure profiles, a review of the literature and subsequent analysis of single-species toxicity tests to develop statistical estimates of Effects Concentrations (ECs) and Specific Growth Rate (SGR) parameters for major taxonomic groups, an update on the monitoring program results, interpretation of the surface water monitoring results with both the revised CASM and the alternative PATI model, identification of the primary watershed characteristics driving atrazine exposure, and extrapolation of those results to the entire atrazine use area to identify other areas where atrazine exposures may exceed the LOC. Finally, the Office of Water provided an example of statistical alternatives for expressing the model results to develop numeric aquatic life criterion for atrazine that integrate both concentrations and exposure durations of atrazine.

PUBLIC COMMENTERS

Oral statements were presented by:

1) **On behalf of Syngenta Crop Protection, Inc.**
   - a) Keith Solomon, Ph.D., University of Guelph, Canada
   - b) David Vost, Paul Henley, Ron Williams, Syngenta Crop Protection, Inc.
   - c) Steve Bartell, E2 Consulting Engineering, Inc.
   - d) Chris Harbourt, Waterborne Environmental Inc.
   - e) Richard Fawcett, Ph.D., Fawcett Consulting

2) **On behalf of The Triazine Network**
   - a) Jere White, Chairman, Triazine Network, Garnett, KS
   - b) Ken McCauley, Corn Farmer, Past President, National Corn Growers Association, White Cloud, KS
   - c) Gary Marshall, CEO, Missouri Corn Growers Association, Jefferson City, MO
   - d) Todd Barlow, Executive Director, Kentucky Corn Growers Association, Louisville, KY
   - e) Tim Lust, CEO, National Sorghum Producers, Lubbock, TX
   - f) Toby Bostwick, Grain Sorghum Farmer, President, National Sorghum Producers, Melrose, NM
   - g) Greg Shelor, Grain Sorghum and Corn Farmer, President, Kansas Grain Sorghum Producers Association, Minneola, KS

3) Mark White, Executive Director, Environmental Resources Coalition

4) Scott Slaughter, The Center for Regulatory Effectiveness

5) Dee Ann Staats, Ph.D., Crop Life America

6) Rick Robinson, Environmental Policy Advisor, Iowa Farm Bureau Federation

7) Scott Merritt, Executive Director, Nebraska Corn Growers Association

8) Rod Snyder, Public Policy Director, National Corn Growers Association

9) Tyler Wegmeyer, Director of Congressional Relations, American Farm Bureau Federation

10) Stephanie Whalen, Executive Director, Hawaii Agricultural Research Center

11) Jennifer Sass, Ph.D., Natural Resources Defense Council

Written statements were provided by:

1) Syngenta Crop Protection, Inc.

2) Jennifer Sass, Ph.D., Natural Resources Defense Council

SUMMARY OF PANEL DISCUSSION AND RECOMMENDATIONS

1. Topic A: Model Effects Index (MEI) (Questions 1-3)

Question 1: The effects models considered in this document require effects concentrations (ECs) from single-species plant toxicity tests with atrazine that are consistent with respect to the nature and magnitude of the toxic effects. Reports on and reviews of such tests provide ECs that vary widely in meaning, so a new review was conducted and test results were used to develop a compilation of plant specific growth rate vs. concentration relationships (Section IV.B). Please comment on the strengths and limitations of this review and synthesis of plant toxicity tests for providing toxicity sensitivity distributions for use in the atrazine assessment methodology.

The Panel agreed that the plant species sensitivity distribution (of EC_{50}'s) derived by EPA from the single species assays provides a reasonable approach to synthesize these toxicity tests in plants and minimizes bias across datasets. The Panel, however, noted that this method is not without some weaknesses. Use of the plant species sensitivity distribution is an improvement over previous single-species datasets used in past atrazine risk assessments and moves assessment of atrazine risks toward a common endpoint and statistical methodology. As such, the Panel agreed that the data presented can be used to estimate concentrations of atrazine that protect plant populations or the community from adverse effects. In addition, these data can be used to parameterize models such as Comprehensive Aquatic Systems Model (CASM) or Plant Assemblage Toxicity Index (PATI) for developing a model effects index (MEI) for atrazine.

The Panel went on to discuss the use of Brock Scores to discriminate among the severity of atrazine effects observed in the mesocosm ("cosm") studies. The Panel concluded that some of the studies summarized in the Brock Scores were not adequately scrutinized for actual effects and quality of the data. There were limitations in the discriminatory power of Brock Scores (i.e., 1 and 2 versus 3, 4, and 5) used to evaluate the severity of atrazine effects in the cosm studies and link them to the effects predicted by $CASM_{ATZ2}$. One panel member provided an analysis of several cosm studies used by the Agency to illustrate some of the quality issues. The Panel recommended other approaches be used to separate the severity of atrazine effects in the cosm studies. The Panel elaborated on many of these points in its response to Charge Question 3.

Question 2: One source considered for the desired MEI is the Comprehensive Aquatic Systems Model (CASM), a community simulation model. In response to a previous SAP review, this model was modified to give a more realistic, dynamic simulation of a Midwestern stream ($CASM_{ATZ2}$). Sensitivity analyses for this revised model were conducted, including some additional analyses suggested in the previous SAP review. These analyses indicated considerable sensitivity of risk determinations to the selection of species toxicity parameters and to various physicochemical variables (Section IV.C). This indicates that $CASM_{ATZ2}$ is more suitable for a site-specific, data-intensive assessment than the generic application that is desired for these atrazine assessments. Please comment on the advisability and value of using $CASM_{ATZ2}$ for generic

assessments given these findings and on the nature and feasibility of additional development efforts that would be needed to implement this model.

The Panel agreed that most of the SAP recommendations given in 2007 were implemented and that the refined $\text{CASM}_{\text{ATZ2}}$ model provides more realistic simulations in Midwestern streams, although the proposed sensitivity analysis suggested by the previous SAP to account for correlations among factors was not fully completed. Despite the model's improvements, EPA concluded that the $\text{CASM}_{\text{ATZ2}}$ model is more suitable for site-specific, data intensive assessments than for a generic application for atrazine assessments and proposed the PATI model as a substitute (see response to Charge Question 3). Many on the Panel agreed that the $\text{CASM}_{\text{ATZ2}}$ model (and the probabilistic $\text{CASM}_{\text{ATZ2}}$ model) appeared to be well-suited for atrazine assessments because the model can incorporate site-specific variables into the results. The Panel, however, did not have any opportunity to review the probabilistic $\text{CASM}_{\text{ATZ2}}$ model in any detail. The Panel agreed with the Agency that the in-depth functionality in $\text{CASM}_{\text{ATZ2}}$ may be too complex to serve as the generic, broader scale tool it was expected to be. The Panel noted that several simplifying assumptions with respect to parameterization and functionality would likely be needed for the $\text{CASM}_{\text{ATZ2}}$ model to be used as a generic assessment tool.

Question 3: An alternative source considered for the desired MEI was an index of the severity of toxic impact on a plant assemblage (Plant Assemblage Toxicity Index, PATI) based directly on single-species plant toxicity relationships (Section IV.D). Please comment on the merits and limitations of this source for the MEI. Based on the coherence of risk evaluations between the PATI-based and the CASM-based methodologies, EPA has concluded that the additional processes included in CASM are not needed for the assessment methodology and that the PATI-based methodology should be adopted. Please comment on the merits of this conclusion.

The Panel concluded that both CASM- and PATI-based approaches have their own merit in estimating MEIs. The PATI-based approach is favored by EPA, while the CASM-based approach is favored by Syngenta. Most of the Panel recommended that the Agency continue developing and evaluating both modeling options, with PATI perhaps serving as a first-tier classification and CASM for use in systems where uncertainty is greater. Once atrazine vulnerable watersheds are identified and Level of Concern (LOC) exceedances discerned, then some panel members stated that CASM modeling could be used to develop possible mitigation strategies to reduce exposure to atrazine.

The Panel also stressed the importance of distinguishing between uncertainties in model output which arises because of uncertainties in toxicity data and imprecision in modeling complex systems; and variability, that arises because of natural variation in species composition and physico-chemical factors. Reducing uncertainty will simplify decision-making, while variability is inherent to natural systems and cannot be reduced. The PATI approach cannot deal with the latter, while CASM can.

The Panel stated that the Agency should not rely solely on one model and they recommended that multiple approaches be used and compared. There was agreement amongst many on the

Panel that the optimal approach for determining a MEI was to continue using the CASM-based modeling approach ($\text{CASM}_{\text{ATZ2}}$) for atrazine risk assessment; however, the Panel suggested that the Agency should consider other approaches including PATI, additional focused microcosm/mesocosm studies, and probabilistic risk assessment approaches that overlay plant sensitivity distributions with exposure profiles such as that illustrated by Solomon et al. (1996). For example, several panel members strongly recommended the use of a simple and transparent time and concentration-based LOC for the first level of a tiered risk assessment. The Panel thought that it was likely that ultimately all approaches will reach concordance setting a time and concentration-based LOC. The Panel strongly recommended that alternatives to the Brock scoring metric be used. The Brock Scores, originally proposed by Brock et al. (2000), were categorical assignments that were made on a subjective basis. Therefore, the Panel recommends that the Agency should re-evaluate all cosm studies in regards to study quality and for concentration-specific effects data. In addition, the Panel highly recommended that the Agency use all of the available cosm data in addition to single species data evaluated as continuous data distributions (as opposed to categorical responses or Brock Scores) and use a probabilistic approach to determine an acceptable LOC. An alternative to working with Brock scores is an approach based on probability threshold levels (**See Appendix 1)** used to develop the Sediment Quality Guidelines (SQGs) (Long et al. 1995; MacDonald et al. 1993; 1994).

2. Topic B: Agency's Watershed Analysis (Questions 4-5)

Question 4: Based on an analysis of watershed characteristics of the 40 monitoring sites, the US EPA concluded that the presence of soils that either have a high runoff potential or are in hydrologic soil group C or D, and have a shallow layer with a moderately low saturated hydraulic conductivity best distinguish sites that exceed the LOC in multiple years from those that do not exceed the LOC. Please comment on the merits of the watershed criteria the Agency used to identify watersheds that might exceed the atrazine LOC.

In 2007, the SAP encouraged EPA to take advantage of improved national databases such as the United States Department of Agriculture-National Resources Conservation Service (USDA-NRCS) Soil Survey Geographic Database (SSURGO) and the United States Geological Survey (USGS) National Hydrology Dataset Plus (NHDPlus) to help identify vulnerable watersheds. The current Panel commended EPA and Syngenta for the massive efforts and progress they have made in identifying vulnerable watersheds, illustrating the importance of depth to impervious layer and slope to atrazine runoff. The Panel recommended these efforts continue with the sharing of database and software tools between EPA and Syngenta as well as the development of a Cornbelt "Watershed Regression for Pesticide (WARP) Model" that utilizes data from all 40 Atrazine Ecological Exposure Monitoring Program (AEEMP) sites in combination with a raw MEI score or a concentration metric. With respect to explanatory variables, the challenge of identifying appropriate categorical thresholds was noted, and the Panel recommended avoiding such classifications where possible. Additional data that may be useful for this regression analysis include planting date estimates, timing of atrazine application and rainfall intensity and duration, minor soil groups, riparian buffers/setback areas, management factors (tillage, conservation practices, Roundup Ready® corn, etc.), runoff propensity index/surface area to flow volume ratios, composite curve numbers, and geometry of conveyance systems (i.e., field and/or watershed physical characteristics).

The Panel expressed concerns regarding the compatibility of scale between explanatory variables and watershed concentration metrics, as well as identifying a minimum scale of concern for aquatic community integrity, and co-occurrence of vulnerable sub-watersheds and implications for larger drainage areas. The Panel was very pleased with, and encouraged EPA to continue, the spatial analysis with respect to comparable (i.e., with respect to drainage area and the 2004-2008 time period) atrazine water quality data collected from the USGS National Water Quality Assessment Program (NAWQA) and state government agency monitoring stations. Finally, the Panel expressed concerns regarding the EPA effort to identify Corn Belt watersheds with significant atrazine exposure risks to aquatic communities by identifying NHDPlus watersheds within a focused 10 state area that have similar characteristics with respect to the identified factors as the AEEMP sites which exceeded the LOC in multiple years. For instance, the relatively short AEEMP monitoring period does not adequately capture climate fluctuations and there may be other factors that influence atrazine runoff potential which were not captured in the AEEMP study design (e.g., see Frey et al. (2009) discussion regarding preferential flows and tile-drainage). A means of assessing the accuracy of this vulnerability assessment is needed, such as comparing measured and calculated (on the basis of flow contributions from vulnerable watershed areas) atrazine loads in major drainage basins (Illinois, Ohio, Mississippi).

Question 5: Neither atrazine use intensity or rainfall data (annual or monthly) correlate positively with watersheds that exceed the LOC. The Agency noted that the monitoring site selection already focused on areas with sufficient atrazine use to potentially result in high atrazine exposures in streams. Please comment on the Agency's proposed approach to establish a minimum criteria for atrazine use intensity (> 0.1 lb ai/A) and rainfall (>23 inches annually).

The Panel indicated that the Agency should pay careful attention to temporal scale when identifying correlations that can be used to identify watersheds likely to be vulnerable to have high atrazine exposures. The two minimum criteria suggested by the Agency, atrazine use intensity (> 0.10 lb ai/A) and rainfall (> 23 inches annually), are annual measures. Rainfall timing and intensity related to atrazine application are important factors that greatly influence atrazine runoff potential; however, additional factors such as land use, land cover, soil conditions, crop management practices and other variables should also be evaluated. These runoff events generally occur during three months each year. The Panel, therefore, suggested that the Agency use a shorter, more appropriate time interval, such as days, weeks or months (Pappas et al. 2008). The Panel expressed doubt that these criteria, even at a shorter time scale, would be able to adequately identify vulnerable watersheds. The Panel recommended that a multiple regression approach be used instead of the proposed indicators of rainfall and atrazine use intensity. The Panel also considered a logistic regression approach as another alternative. Each of these regression approaches was discussed including an example of how to use a multiple regression approach.

DETAILED RESPONSES TO CHARGE QUESTIONS

1. Topic A: Model Effects Index (MEI) (Questions 1-3)

The foundation of the US EPA methodology for specifying levels of concern (LOCs) for atrazine exposures in natural freshwater systems is the relationship of atrazine exposure to effects on aquatic plant community structure and function in microcosm and mesocosm (cosm) studies. Comparing effects among the different atrazine exposure time-series in the cosm studies and extrapolating effects to other exposure time-series in natural systems requires an effects model that can be applied to any exposure time-series to provide a consistent, quantitative index for toxic effects on the plant community (Model Effects Index, MEI). MEI values for cosm exposures are used to develop an LOC for the MEI (LOC_{MEI}) that best discriminates between cosm exposures with and without significant effects. MEI values for exposures in natural systems can then be evaluated relative to this LOC_{MEI}.

Question 1: The effects models considered in this document require effects concentrations (ECs) from single-species plant toxicity tests with atrazine that are consistent with respect to the nature and magnitude of the toxic effects. Reports on and reviews of such tests provide ECs that vary widely in meaning, so a new review was conducted and test results were used to develop a compilation of plant specific growth rate vs. concentration relationships (Section IV.B). **Please comment on the strengths and limitations of this review and synthesis of plant toxicity tests for providing toxicity sensitivity distributions for use in the atrazine assessment methodology.**

Panel Response

A. General Response

The Panel agreed that the plant species sensitivity distribution (of EC_{50}'s) derived by EPA from the single species assays provides a reasonable approach to synthesize these toxicity tests in plants and minimizes bias across datasets. The Panel, however, noted that this method is not without some weaknesses. Use of the plant species sensitivity distribution is an improvement over previous single-species datasets used in past atrazine risk assessments and moves assessment of atrazine risks toward a common endpoint and statistical methodology. As such, the Panel agreed that the data presented can be used to estimate concentrations of atrazine that protect plant populations or the community from adverse effects. In addition, these data can be used to parameterize models such as Comprehensive Aquatic Systems Model (CASM) or Plant Assemblage Toxicity Index (PATI) for developing a model effects index (MEI) for atrazine.

The Panel went on to discuss the use of Brock Scores to discriminate among the severity of atrazine effects observed in the mesocosm ("cosm") studies. The Panel concluded that some of the studies summarized in the Brock Scores were not adequately scrutinized for actual effects and quality of the data.. There were limitations in the discriminatory power of Brock

Scores (i.e., 1 and 2 versus 3, 4, and 5) used to evaluate the severity of atrazine effects in the cosm studies and link them to the effects predicted by $CASM_{ATZ2}$. One panel member provided an analysis of several cosm studies using the ranking system described in the Agency's issue paper and author to illustrate some of the quality issues. The Panel recommended other approaches be used to separate the severity of atrazine effects in the cosm studies. The Panel elaborated on many of these points in its response to Charge Question 3.

B. Specific Response

As described in the Agency's issue paper, atrazine is one of the most widely studied pesticides in existence. Hundreds of toxicity tests have been published regarding the effects of atrazine on aquatic plants. However, these tests vary widely in terms of study conditions, experimental design, concentrations, test duration, and test endpoints. Previous risk assessments of atrazine have evaluated the effects of atrazine on aquatic plants using a wide-variety of measurement endpoints ranging from short-term cellular responses to changes in plant community biomass (Solomon et al. 1996); therefore, there is a need to evaluate plant toxicity data with a more standardized endpoint and statistical approach in order to develop a "common currency" for comparison. The data presented by the Agency represents a summary of independent, single species plant bioassays that approximate a wide range of aquatic plant types including green algae, cryptomonads, blue-green algae, diatoms and macrophytes. The Panel agreed that the Effective Concentrations (ECs) derived by EPA from these assays provide a reasonable approach to evaluatethe results of the toxicity tests in plants. However, there are several concerns with respect to assessing the ecological impact of atrazine exposures on aquatic communities using EC_{50} values for individual plant species, since the latter do not reflect plant community population dynamics with respect to trophic levels, functional redundancy, life-cycle demographics, nutrient cycling, mass and energy capture and transfers, etc. A more complete description of concerns with respect to using such data to assess community effects has been outlined by Forbes and Calow (2002a and 2002b) and Forbes et al., (2008). These authors identify the following characteristics that need to be considered in the assessment: initial condition demographics (e.g., the distribution of life-cycle stages of plant species at the start of the experiment), density dependent effects such as nutrient limitations or excess, and especially, disparity between the target generic community and the species for which toxicity data are available. This disparity can introduce considerable bias in risk assessment. Thetoxicity distributions should be derived from random samples, with respect to ecosystem function, biomass, or some other specified criteria, of the generic aquatic community of interest.

While there are numerous complexities and shortcomings associated with single species toxicity testing in terms of test endpoints, the variety of species and test end points measured provide a collection of data that may be used to extrapolate individual species response to estimate a community level response. Each of these different plant bioassays may have differences in design and measures of plant effects. The shortcomings of each plant growth bioassay are emblematic of the ecological complexity in assessing plant community responses to atrazine exposure. Forbes et al. (2008) noted the following:

> "Most standard laboratory tests focus on effects at what are considered to be the most sensitive stages of the life cycle in a limited number of species. Effects on the most sensitive life stages, however, do not necessarily drive population-level effects, and indeed, effects on less sensitive life-history traits may actually drive the impacts at the population level."

This makes it extremely difficult to integrate all of the complexity and test differences in sensitivity/bias into a simple framework for estimating atrazine's ecological impact on aquatic communities. Yet, in association with the cosm data, that is essentially the challenge the Agency faces in developing both the PATI and CASM methods. These methodologies exploit this "common currency" database of measured individual and plant community responses to atrazine to develop appropriate risk assessments amid large amounts of ecological complexity, variability and uncertainty.

To alleviate these concerns, the Agency presented the Panel with a species sensitivity distribution using a smaller set of single species data based on a single endpoint; the EC_{50} estimate derived from the re-calculated specific growth rate (SGR) based on the original datasets (i.e., the SGR EC_{50}). The SGR EC_{50} can be used to compare responses of a variety of species, including those that feed on the primary producers. The Panel suggested that some of the variance expressed in the use of SGR EC_{50} metric might be reduced if comparisons were made among similar-sized species. That is to say, comparisons among macrophytes, green algae and diatoms (phytoplankton and periphyton) may be enhanced by limiting the comparisons to those of similar growth parameters. For instance, the response time for single-celled algae is shorter in terms of toxic response and recovery than that for rooted macrophytes. The report correctly notes that macrophyte tests are less subject to the effects of nutrient limitation or self-shading due to inherent factors in study design. In addition, macrophyte data is often presented as changes in dry weight biomass over time which makes interpretation easier.

The strength of this approach is that the Agency has re-evaluated the original plant datasets using a consistent set of methodologies to calculate the endpoint. The report provides excellent discussion of the various factors that have led to apparent variation in reports of the sensitivity of aquatic plants to atrazine. Algal data are particularly problematic due to study-specific conditions and methods which may alter apparent plant sensitivity to atrazine. Algal population growth usually occurs in a sigmoidal fashion with a maximum growth rate occurring under conditions limited only by the toxicant such as atrazine. To maximize comparison across species and datasets it is optimum to calculate the SGR EC_{50} during the period of exponential growth. This limits study-specific bias in which nutrient limitation and algal self-shading may alter plant productivity in addition to the primary effects of atrazine.

The Panel identified several vulnerabilities in the Agency's interpretation of the cosm data collection as mentioned in the Agency's issue paper. One of the primary weaknesses is the lack of clarity in how cosm studies were screened and selected for the analysis (i.e., clearly identify the search and inclusion criteria). Some datasets were used in spite of stated concerns over methods and interpretation (e.g., Larsen et al. 1986), C^{14} uptake as endpoint (e.g., Versteeg 1990) and lack of chemical exposure verification (e.g., Van der Heever and

Grobbelaar 1996). This is evident in the *Selenastrum* data presented in Appendix IV-1 of the Agency's issue paper. Granted, the appendix did illustrate how the data were transformed to allow its inclusion in the overall database. Use of these various endpoints may be why the results for individual genera still vary widely in spite of the re-analysis of the data. Based on these concerns, a stronger case could have been made to only use data based on direct measurements such as dry weight (when appropriate) because this has the least bias and greatest potential for use in a bioenergetics model. However, this may have greatly limited the data available for evaluation.

The Panel also noted the lack of clarity as to how the sensitivity curves handled variability among studies. The Panel recommended that the Agency consider weighting the analysis of each species sensitivity distribution inversely to the variability within each study or among studies (if using a mean or median from multiple studies). The Panel suggested that careful consideration should be given to how to combine information from multiple studies, each with different variance estimates for each species in the species sensitivity distributions. Further, the Panel recommends that a 95% confidence interval be constructed for the species sensitivity curve, which would be less arbitrary than the currently used plus or minus a factor of 2 (see p. 46 of the Agency's issue paper for an explanation of the derivation of the application factor of 2), an approach analogous to the "Application Factor" method of risk assessment.

The Panel would have liked for the Agency to determine how well the results of the Agency's new analysis of the SGR EC_{50} compared with the original EC_{50}'s reported in the literature. Without this analysis, the Panel compared the macrophyte data from the publication of Fairchild et al. (1998) and the Agency's SGR EC_{50} values and found that they are very close to the originally published estimates of the 14-d EC_{50}'s. The duckweed data in the Agency's analysis was approximately 50% less sensitive than the data in Fairchild et al. (1998); however, this may be due to re-calculated growth rate of the duckweed test which is a population-level endpoint possibly subject to time lags, nutrient limitation, or other factors.

In addition, the Panel would have preferred to have seen the species sensitivity distributions plotted separately for algae/duckweed and macrophytes to evaluate the differences between these plant groups that vary greatly in terms of phylogeny as well as levels of biological organization (e.g., population-level effects for algae/duckweed and individual effects for macrophytes). Although the Agency calculated geometric means for each major plant group to determine relative sensitivity, the data as presented cannot be used to accurately interpolate an actual cumulative species distribution across major taxa. Regression analysis of the data related to atrazine concentration would allow a comparison of plant sensitivity distributions to previously published data that has proposed levels (concentrations) of concern for atrazine ranging from 20 to 50 µg/L (e.g., Solomon et al. 1996).

The question posed by the Panel is whether the single species sensitivity distribution is accurate in interpolating a Hazard Concentration (i.e., HC_5) that is protective of 95% of the community. The Panel determined that the Agency is seeking a MEI that accounts for both species sensitivity in addition to exposure dynamics. The Panel stated that the Agency should not ignore data from previously published peer review articles; rather, they recommended that the Agency estimate atrazine LOCs using multiple lines of evidence such as cumulative species sensitivity distributions; cosm data; and MEIs including $CASM_{ATZ}$, and PATI. The relevant question is, "Are the results of these different approaches consistent in identifying a general estimate of the LOC?" (Note: The various approaches may be "consistent" with the understanding that the more simple approaches are typically more conservative, Forbes et al. 2008.) If general consistency in LOC estimates can be shown, then the actual approach to calculate an atrazine level or exposure of concern is not that critical. Regardless, the main objective, as stated by the Panel, should be to employ a method that utilizes the best scientific data available for atrazine risk assessment.

The Panel also noted that results in the literature (provided in EPA's issue paper) suggested that the SGR EC_{50} is a rather conservative effects value for any given aquatic plant species compared to concentrations resulting in actual reductions in final plant biomass. For example, Hughes et al. (1988) provided detailed discussion of the differences in interpretation of plant toxicity data compared to invertebrate and fish data. Aquatic plant toxicity data (e.g. algae and duckweed) is usually expressed as an EC_{50} or a Relative Growth Rate (RGR) EC_{50} leading to a suppression of overall population growth compared to controls; this is in contrast to invertebrate and fish toxicity data which is expressed as the *lethal concentration* (LC_x value) leading to actual mortality of a group of individual organisms. Hughes et al. (1988) calculated the EC_{50}'s for four aquatic plant species (*Anabaena flos-aquae*, *Navicu pellicosa*, *Dunaliella tertioecta*, and *Lemna gibba*) exposed to atrazine for 5 days and found that the average EC_{50} of 115 µg/L atrazine was an order of magnitude less that the average algistatic (2,462 µg/L) and algicidal (>3,200 µg/L) concentrations of atrazine. In addition, Hughes et al. (1988) conducted a 9-day recovery phase experiment and found that all four species were able to recover from the 5-day exposure to atrazine at the highest concentration of atrazine studied (3,200 µg/L). Therefore, the Panel concluded that the EC_{50} for aquatic plants, as commonly applied in a risk assessment framework, is a short-term, non-lethal estimate of toxicity that will not likely produce long-term effects on aquatic plants once exposure decreases, due to the ability of aquatic plants to rapidly recover from atrazine impacts.

The Panel indicated that the risk estimates, based on aquatic plant EC_{50} values for individual plant species, may overestimate the hazard because they do not reflect functional redundancy. Although studies have shown that some species appear to be very sensitive under laboratory conditions, adverse effects are not always seen at the community level in natural aquatic systems when effects are based on plant biomass or net primary production. For example, Fairchild et al. (1998) examined the effects of atrazine (i.e., 96-h EC_{50}, or concentration reducing plant biomass by 50%) on six species of algae, one species of duckweed, and four species of aquatic macrophytes. Macrophytes in general were more sensitive than algae, with the most sensitive genera of macrophytes being *Elodea sp.* ($EC_{50} = 21$ µg/L), *Ceratophyllum sp.* ($EC_{50} = 22$ µg/L), and *Najas sp.* ($EC_{50} = 24$ µg/L). These three species are at the higher end of plant sensitivity to atrazine and are included in the Agency's submission to the Panel. Fairchild et al. (1994) evaluated the ecological effects of 50 µg/L atrazine in lentic mesocosms and found that *Najas sp.* were gradually replaced by the more resistant *Chara sp.* There were, however, no effects on total macrophyte biomass, system metabolism, or fish growth. Single species data alone would have predicted severe effects at the 50 µg/L level, but this did not occur due to species replacement which maintained functional redundancy of the aquatic plant community and sustained fish production. Similar observations of functional redundancy in mesocosms were observed in a series of studies in lentic mesocosms exposed to atrazine for 136 days at three concentrations (1 μg/L, 20 μg/L, and 50 μg/L) at Kansas University (DeNoyelles et al. 1989). Although laboratory effects were demonstrated in short-term algal assays at test concentrations as low as 1 μg/L atrazine, overall measures of phytoplankton biomass were not observed even at the 20 μg/L level due to replacement of sensitive species by more resistant species. In fact, algal biomass in the 20 μg/L treatment was significantly higher at the end of the 136-d study. The 50 μg/L concentration significantly reduced algal biomass and altered algal succession dynamics which were both statistically and ecologically significant. However, this concentration, as the authors indicated, is not environmentally relevant in aquatic systems and only occurs under edge-of-field conditions (DeNoyelles et al. 1989). Therefore, functional redundancy must be considered as a mitigating factor when extrapolating single species aquatic plant data to predict effects on plant communities in higher order systems such as aquatic mesocosms.

The foregoing analysis raises the larger question posed by the Panel as to what risk assessment endpoint should be employed. Should this be biomass, biodiversity, net primary production, ecosystem function, and/or resilience? The Panel thought that the Agency might only be concerned with biomass as the ecological endpoint.

Lastly, the Panel found that the macrophyte data in Table IV-1 of the Agency's issue paper cites the wrong publication. Although Fairchild et al. (1998) published EC_{50} data for macrophytes it did not contain the raw data used to calculate the SGR EC_{50}. The raw data used by the Agency in the recalculation the EC_{50RGR} was derived from a report by Fairchild et al. (1994b) provided to the Agency. This new citation should be Fairchild et al. (1994b), cited as follows:

Fairchild, J.F., D.S. Ruessler, M.K. Nelson, and P.Haverland. 1994b. Bioavailability and toxicity of agricultural chemicals in runoff from MSEA sites: Potential impacts on non-target aquatic organisms. An Aquatic Hazard Assessment of four herbicides using six species of algae and five species of aquatic macrophytes. Final Report to the USEPA under IAG DW14935600-01-2. 123 p.

In summary, the Agency has developed a new species sensitivity distribution based on discrete criteria to minimize bias across datasets. This data set is not without some weaknesses, but is an improvement over previous single-species datasets used in atrazine risk assessments and moves toward use of a common endpoint and statistical methodology. As such, the data presented can be used to estimate concentrations of atrazine that are protective of a plant population or community as well as to parameterize models, such as developing a MEI for atrazine. However, as stated above, these estimates are generally conservative compared to community-level effects in the mesocosms and likely field conditions (e.g., see Van den Brink et al. 2006).

C. Brock Scores

The use of Brock Scores and rationale were previously presented to the 2007 Panel by the Agency along with the basic intent of its use. New information was provided to the 2009 Panel, e.g. Giddings et al. 2005; Volz et al. 2007, that caused the 2009 Panel to reflect more carefully about the utility of Brock scores. Many members of the Panel indicated that the Brock scores, originally proposed by Brock et al. (2000), were categorical assignments that were made on a subjective basis. Furthermore, the scores by Brock et al. (2000) were not intended as the primary basis of conducting a risk assessment for atrazine. Rather, it was one option that could be used. Brock et al. (2006) recently discussed the Brock scoring procedure in the larger concept of the overall risk assessment process. The Panel recommended that this process should consider multiple lines of evidence appropriate for the problem formulation step in the risk assessment process. In addition, some of the panelists pointed out societal values for environmental protection will influence whether low level plant effects are more or less of a concern compared to effects on higher level consumers such as fish or humans. One panel member was concerned that Brock et al. (2006) was not cited or considered as it is one of the most highly cited recent articles regarding ecological risk assessment for aquatic systems.

The Panel spent a considerable time discussing the quality of cosm studies used in the Brock Scoring analysis. Most of the concerns expressed were in regard to the quality of some of the data that resulted in high Brock Scores in spite of low reported atrazine exposure concentrations. The Panel also discussed the limitations in the discriminatory power of Brock Scores (i.e., 1 and 2 vs. 3, 4, and 5) used to link atrazine effects in the cosm studies in the mesocosm studies with effects predicted by $\mathrm{CASM}_{\mathrm{ATZ2}}$. In effect, there was little distinction between Brock Scores. However, part of the reason for lack of discrimination among studies is the fact that some of the studies summarized in the Brock Scores were not adequately scrutinized for actual effects and quality of the data.

One panel member provided the following analysis of several cosm studies cited by number (i.e., the ranking number used in the Agency's issue paper) and author to illustrate some of the quality issues:

1) Cosm study # 2, DeNoyelles et al (1989), Dewey (1986), and Kettle et al. (1987). Multiple studies were cited in regards to the effects of 20 µg/L atrazine and were all given a Brock Score of 5. This panel member stated that these studies should be closely evaluated for several reasons. These studies were conducted in the same pond over multiple years. Each study must be evaluated on its own merits to determine if it belongs in the EPA dataset. The studies authored by Dewey (1986) and Kettle et al. (1987) report effects on insect emergence and bluegill reproduction. The data is not presented with credible measures of critical plant variables such as algal and plant biomass. In addition, it appears that these two studies were conducted in ponds that contained grass carp that were stocked at approximately 30 fish per hectare. This is an extremely high biomass and likely led to severe fish grazing impacts on aquatic plants, which will lead to indirect impacts on insect emergence and predation on young bluegills by adult bluegills and young channel catfish; these effects are the result of

grass carp in the 20 µg/L ponds and not by atrazine as documented in the review publication of DeNoyelles et al. (1989). The studies reported by DeNoyelles et al. (1989) were conducted at atrazine concentrations of 100 µg/L (cosm study #41) and 200 µg/L (cosm study #42) and given a Brock Score of 3. This paper is a synthesis of a series of studies conducted from 1978 to 1982. Embedded within these studies were some assessments based on 1-h and 4-h uptake of C^{14} and not actual assessments of changes in overall algal and macrophyte biomass. These short-term bioassays must be interpreted in relation to observations made in the mesocosm in respect to overall phytoplankton biomass.

2) Cosm study # 6, Fairchild et al. (1994). This study was given a Brock score of 5 even though there was no effect on total macrophyte biomass, community metabolism, or fish production. There were only two macrophyte species present, which seems to create bias in the PATI model using the Steinhaus Similarity Index (SSI) option and would have no effects giving the PATI option of Total Biomass Production (TPB). This study could have easily been scored as a 1 or 2 based on the TPB option depending on a more explicit Problem Formulation Statement for this exercise.

3) Cosm study #16, Berard et al. (1999). This study evaluated an exposure of 10 µg/L atrazine and was scored by the Agency as a Brock Score of 4. Given the comments, this panelist had considerable concern over this study, e.g., no chemical confirmation, and does not believe the paper actually used biomass as an endpoint. The paper indicated that biomass was measured, but only biovolumes were reported and the methodology used to calculate algal biovolumes are poorly explained. Furthermore, the study appears at odds with a subsequent study (Sequin et al. 2001) which showed little to no effects on phytoplankton biomass at 10 and 20 µg/L atrazine, but cites and apparently used data from Berard et al. (1999). These discrepancies need to be clarified due to the Brock score of 4 at a very low level of atrazine.

4) Cosm study #28, Kosinski (1984). This study evaluated a concentration of 10 µg/L atrazine and was given a Brock score of 4. Notes regarding the study indicate that there was a 40% decrease in "apparent productivity but only a slight decrease in algal biovolume. In addition, the notes indicate that atrazine had a half-life of 3.2 days in the streams. This study should be re-evaluated because the algal sensitivity and atrazine half-life simply do not fit with the tremendous amount of information in the literature regarding both single species and cosm studies.

5) Cosm study # 31, Krieger et al. (1988). This study received a Brock Score of 4 even though there were no effects at 10 degrees C in the 24 µg/L atrazine concentration. There were effects observed at 25 degrees C at both the 24 and 100 ug/L atrazine levels, but the magnitide of effects at these two concentrations was similar which is surprising given the steep slope of the atrazine dose-response curve. Furthermore, the paper states that after exposure to atrazine, there was complete recovery which is at odds with the cosm table. This study should be re-evaluated.

6) Cosm study #58, Lampert et al. (1989). This study evaluated the effects of atrazine in pelagic limno corals and proposes effects at a concentration of 1 µg/L and received a

> Brock score of 4; thus, indicating a severe effect. The data showed that there were opposite trends in chlorophyll a and particulate organic carbon. This implies a shift in the atrazine treatment from an algal-dominated community to a bacteria-dominated community. Giddings et al. (2005) indicated that both Brock et al. (2000) and the original study by Fleckner (1988) indicated that ethanol was added to the atrazine bags but not the controls. This is consistent with the apparent shift from an autotrophic community to a heterotrophic community with ethanol as the primary factor. This study should be re-evaluated with respect to the original data and methods and should probably be dropped.

This panel member summarized his analysis as follows. The collective assessment of the set of cosm studies and Brock Scores as presented by the Agency contain high scores of several studies ranging from 1-20 μg/L; these levels of effect depart from the vast majority of 30 years of literature on atrazine and may be due to artifacts of the study or data quality and interpretation. These studies particularly should be re-evaluated for credibility. This analysis is critical because high Brock Scores at such low levels of atrazine may result in setting an LOC that over estimates the risk of atrazine. If the studies conducted at lower concentrations of atrazine are discredited, then the Agency will have a tremendous gap in cosm studies conducted at environmentally relevant concentrations of atrazine. This would lead to two options which are not mutually exclusive: 1) The Agency may want to shift to primary use of laboratory plant toxicity data; single species data can be used effectively in many ways, such as parameterization of a model effects index such as $\mathrm{CASM}_{\mathrm{ATZ2}}$ or PATI, in addition to other risk assessment approaches such as a species exposure effects probability distribution; 2) The Agency may want to consider conducting additional cosm studies that might lead to higher quality mesocosm data at levels of atrazine that are environmentally relevant. This would add greatly to the quality and confidence in the overall atrazine risk assessment.

The Panel discussed alternative approaches to the Brock score metric following its response to Charge Question 3.

Question 2: One source considered for the desired MEI is the Comprehensive Aquatic Systems Model (CASM), a community simulation model. In response to a previous SAP review, this model was modified to give a more realistic, dynamic simulation of a Midwestern stream ($\mathrm{CASM}_{\mathrm{ATZ2}}$). Sensitivity analyses for this revised model were conducted, including some additional analyses suggested in the previous SAP review. These analyses indicated considerable sensitivity of risk determinations to the selection of species toxicity parameters and to various physicochemical variables (Section IV.C). This indicates that $\mathrm{CASM}_{\mathrm{ATZ2}}$ is more suitable for a site-specific, data-intensive assessment than the generic application that is desired for these atrazine assessments. **Please comment on the advisability and value of using $\mathrm{CASM}_{\mathrm{ATZ2}}$ for generic assessments given these findings and on the nature and feasibility of additional development efforts that would be needed to implement this model.**

Panel Response

A. General Response

The Panel agreed that most of the SAP recommendations given in 2007 were implemented and that the refined CASM$_{ATZ2}$ model provides more realistic simulations in Midwestern streams, although the proposed sensitivity analysis suggested by the previous SAP to account for correlations among factors was not fully completed. Despite the model's improvements, EPA concluded that the CASM$_{ATZ2}$ model is more suitable for site-specific, data intensive assessments than for a generic application for atrazine assessments and proposed the PATI model as a substitute (see response to Charge Question 3). Many on the Panel agreed that the CASM$_{ATZ2}$ model (and the probabilistic CASM$_{ATZ2}$ model) appeared to be well-suited for atrazine assessments because the model can incorporate site-specific variables into the results. The Panel, however, did not have any opportunity to review the probabilistic CASM$_{ATZ2}$ model in any detail. The Panel agreed with the Agency that the in-depth functionality in CASM$_{ATZ2}$ may be too complex to serve as the generic, broader scale tool it was expected to be. The Panel noted that several simplifying assumptions with respect to parameterization and functionality would likely be needed for the CASM$_{ATZ2}$ model to be used as a generic assessment tool. The Panel wondered why the Agency was not considering using the CASM$_{ATZ2}$ model given that it has the analytical capabilities to handle data-intensive computations. With continued development of model parameters, testing explicit and implicit assumptions, and with model validation, the new version of CASM allows for impact assessment at the community level, and lends itself well for a probabilistic approach to determine effects for different types of aquatic communities. There was a consensus among the Panel that CASM $_{ATZ2}$ appears to work very well in this instance because atrazine has such a vast data record with which to run the model. This being the case, the Panel thought the model presented an opportunity to assess community level responses to scientifically support a potential regulatory action level set by the Agency. If other compounds do not have the luxury of having such large data sets available then more conservative methods may be needed.

B. Specific Response

1) The Panel's understanding of CASM

CASM attempts to predict and model atrazine toxic effects on aquatic communities using a bioenergetics-based community model. This bioenergetics approach explicitly models key ecological processes that govern community structure and population dynamics and thus provides an estimate of the community level impact of individual species response to atrazine exposure. The phytoplankton compartments of CASM are based primarily on photosynthesis and respiration functions. Because not all plant toxicity test endpoints directly measure these bioenergetic aspects, incorporation of single species toxicity test results in CASM is nontrivial. To address this limitation, CASM uses measured relationships for toxic effects versus atrazine concentration to estimate Toxic Effects Factors which are incorporated into the model via a General Stress Syndrome or a Photosynthetic Stress Syndrome. MEIs are then calculated based on predictions of Total Plant Biomass, or by comparing model estimates of plant community responses with and without atrazine exposure to produce SSIs.

2) Modifications of CASM$_{ATZ}$ following the 2007 SAP meeting: CASM$_{ATZ2}$

In 2007, the SAP reviewed the CASM$_{ATZ}$ model and concluded it was suitable for use in atrazine risk assessment (see FIFRA SAP 2008). The 2007 Panel recommended that the Agency perform additional model validation and expand the sensitivity analysis of several variables, including possible interactions (see FIFRA SAP 2008). The original CASM$_{ATZ}$ was then modified to 1) allow physicochemical factors to be specified as inputs as well as state variables (the former may be more consistent with stream hydrology), 2) more accurately reflect community structures for 2nd and 3rd order streams, 3) represent stream velocity variations (flowing water systems), 4) accommodate arbitrary time steps in simulation, 5) represent more realistically (via bioenergetics equations) the processes governing energy and mass transfers between the environment and the biological community and allow increased flexibility in modeling the same, and 6) employ parameters that are consistent with the relevant literature for similar aquatic environments.

3) CASM applications: the Agency and Syngenta

Both Syngenta and EPA evaluated CASM$_{ATZ}$ as a tool for ecological effect assessment for atrazine in Midwestern streams. Both evaluations used the Photosynthetic Stress Syndrome to calculate CASM-based estimates of aquatic community response to atrazine. Another similarity between the two approaches was the use of an internal nutrient cycling option. The Panel recommended that EPA evaluate the model with respect to headwater watershed nutrient fluxes to determine if nutrients should be fixed or allowed to internally cycle.

4) Concerns expressed by the Panel with CASM $_{ATZ2}$

The Panel noted some concerns with CASM $_{ATZ2}$. If not explicitly stated, these concerns are related to both approaches presented, i.e. the Agency's approach and Syngenta's approach.

1) The Panel recommended the Agency evaluate the model with respect to headwater watershed nutrient fluxes to determine if nutrients should be fixed or allowed to internally cycle. A simple mass balance approach which estimates nutrient loads over a 30-, 60-, 90-day period, for example, into the "prototype" stream segment versus the nutrient uptake into biomass during the same corresponding period would allow determination of which approach is appropriate. If the nutrient uptake mass is a relatively small fraction of the nutrient load (e.g., less than 10%) then it seems more appropriate to use the fixed nutrient input option for small headwater watersheds.

The number of parameters and the mathematical construct in the CASM $_{ATZ2}$ model make it extremely robust for extrapolating from individual species responses to community level effects, data exploration, sensitivity analysis, and forecasting a range of possible outcomes. Some panelists, however, commented that this type of robust analysis may not be what the Agency is looking for when it is looking for a specific level of concern for atrazine, a "bright line." In the 2007 SAP meeting (see FIFRA SAP 2008), Syngenta and the Agency proposed that the assessment endpoint was to use CASM_{ATZ} to establish a Hazardous Concentration (HC_5 or HC_{10}) LOC based on the SSI. This endpoint, according to the 2003 IRED document (USEPA 2003), ranged from 10-20 µg/L. Some panel members felt that $\text{CASM}_{\text{ATZ2}}$ may be too complex for use in a preliminary assessment of risk and may be more useful in a higher order risk assessment.

2) The presented applications of $\text{CASM}_{\text{ATZ2}}$ did not address how chronic low level atrazine exposure may predispose aquatic ecosystems to greater sensitivity to subsequent atrazine exposure. One panel member provided two examples of this circumstance. Pennington (2002) used a pulsed exposure of atrazine (261 ug/L) to dose a salt marsh mesocosm system that had not been previously exposed or had previously been chronically exposed to atrazine (5-6 ug/L) to simulate low levels of atrazine measured along the South Texas Coast. Microalgae and the bacterial portion of the microbial loop community in the chronic dosed atrazine system were adversely affected by the pulsed acute atrazine dose, while those systems without the previous chronic atrazine exposure were not affected. Similarly, Lawton et al. (2006) reported effects in clam bioassays well below the acute and chronic toxicity endpoints of 62.5 and 70.7 µg/L, respectively.

3) Another criticism of the manner in which the model was used is the somewhat arbitrary choice of the number of samples randomly drawn from the parameter joint probability distributions (i.e., 50 iterations). The Panel suggested that a formal convergence criterion be developed. The number of iterations is a technical/mathematical issue and is not related to the uncertainty vs. variability issues. In addition, one panel member stated that the comparison of two sample outputs generated through iterative modeling via traditional statistical testing, as done in the Syngenta approach, is not recommended. As with virtually all formal tests, the cited Wilcoxon rank-sum test depends on the number of iterations chosen which makes ecological risk a function of this number of iterations. Additionally, the Wilcoxon rank-sum test only tells if the locations of two distributions are different. It does not inform us about differences in the amount of scatter between both distributions. This panel member suggested a better approach would be to calculate the quotient of both distributions so that a probability of that effect, given a particular exposure, can be derived.

4) The Panel expressed concerns about CASM's (note: that the following comments are relevant with respect to PATI also) use of experimental ecosystems (mesocosm) data for: (a) CASM validation and (b) LOC determinations using mesocosm data from pond experiments and comparing this to the revised CASM that represents a river stretch. The combination of pond-cosms with the revised stream-CASM seems inconsistent with the motivation to transform the pond-CASM to a stream-CASM, and its ecological relevance. The pond-cosm data may still be useful in developing an LOC as they add information regarding interactions between atrazine exposure and community dynamics (and are thus considerably more relevant than laboratory bioassays), but the lotic systems should receive considerably higher weight.

Additionally, the use of the Brocks Scores is a limitation in the way the mesocosm studies were used. The discriminatory power of Brock 1 and 2 versus 3, 4 and 5 appears to be limited is discussed in greater detail in the Panel's response to Charge Question 3).

Question 3: An alternative source considered for the desired MEI was an index of the severity of toxic impact on a plant assemblage (Plant Assemblage Toxicity Index, PATI) based directly on single-species plant toxicity relationships (Section IV.D). Please comment on the merits and limitations of this source for the MEI. Based on the coherence of risk evaluations between the PATI-based and the CASM-based methodologies, EPA has concluded that the additional processes included in CASM are not needed for the assessment methodology and that the PATI-based methodology should be adopted. **Please comment on the merits of this conclusion.**

Panel Response

A. Panel Conclusions and Recommendations Regarding CASM and PATI

The Panel concluded that both CASM- and PATI-based approaches have their own merit in estimating MEIs. The PATI-based approach is favored by EPA, while the CASM-based approach is favored by Syngenta. Most of the Panel recommended that the Agency continue developing and evaluating both modeling options, with PATI perhaps serving as a first-tier classification and CASM for use in systems where uncertainty is greater. Some panel members believed that once atrazine vulnerable watersheds are identified and the LOC exceedances discerned then CASM modeling could be used to develop possible mitigation strategies to reduce exposure to atrazine.

The Panel also stressed the importance of distinguishing between uncertainties in model output and imprecision in modeling complex systems and variability that arises because of natural variation in species composition and physico-chemical factors. The PATI approach cannot deal with inherent variability while CASM can.

The Panel stated that the Agency should not rely solely on one model; rather, they recommended that multiple approaches be used and compared. There was agreement amongst many on the Panel that the optimal approach for determining a MEI was to continue using the CASM-based modeling approach ($\text{CASM}_{\text{ATZ2}}$ for atrazine risk assessment); however, the Panel suggested that the Agency should consider other approaches including PATI, additional focused microcosm/mesocosm studies, and probabilistic risk assessment approaches that overlay plant sensitivity distributions with exposure profiles such as that illustrated by Solomon et al. (1996). For example, several panel members strongly recommended the use of a simple, transparent time and concentration-based LOC for the first level of a tiered risk assessment. The Panel thought it likely that ultimately all approaches will reach concordance setting a time and concentration-based LOC.

One panel member noted that there was not much difference in the number of AEEMP sites identified by the Agency at the 50% confidence level that exceeded the LOC using either

$\text{CASM}_{\text{ATZ2}}$ or PATI. This panelist expressed concern that such slight differences obfuscates the purpose of modeling, i.e., to identify vulnerable sites that are likely to have high enough atrazine runoff to impact stream communities. In contrast, Syngenta found that PATI would have slightly more exceedences than probabilistic $\text{CASM}_{\text{ATZ26}}$. The use of probabilistic models coupled with the probabilistic nature of heavy rains occurring after application will cause runoff to be variable in different years, even at the same site. Thus, the purposes of all the models is to demonstrate which watersheds are vulnerable to high levels of atrazine that will exceed the LOC, and with probabilistic models, the output is likely to have small changes. Given the alternative of monitoring all watersheds, the use of models to identify the sites most likely to have problems is reasonable. Farm industry representatives (during the public comment period) expressed concern that more cases would be flagged as exceeding the LOC with PATI, and they were opposed to PATI development. This panelist went on to discuss the use of a cumulative risk reduction strategy (Scott et al. 1999) to address the complex issues of atrazine risk reduction and management at sites that may exceed the LOC using either CASM- or PATI–based approaches.

B. Potential of PATI

Some panel members were encouraged by several factors regarding the use of PATI, which include the following:

1) There was a clear similarity in PATI and CASM MEIs for both the cosm calibration and example chemographs.

2) The PATI model is conceptually much simpler to understand and use.

3) The model uses an ensemble of individual plant sensitivity bioassays that greatly reduces ambiguity in classifying a chemograph with the respect to the LOC. Note: The extent to which either CASM or PATI produces useful or accurate results have yet to be fully assessed.

4) The model might be simpler to implement should the model outputs be comparable.

C. Concerns Expressed by the Panel Regarding PATI

The PATI-based methodology is a modified form of the Species Sensitivity Distribution (SSD) approach for assessing ecological risk associated with atrazine exposure. It relies on a summary of independent, single species plant bioassay results that approximate a wide range of aquatic plant types including: green algae, cryptomonads, blue-green algae, diatoms and macrophytes. There is a well respected body of literature that highlights the advantages and disadvantages associated with such an approach (e.g., Forbes and Callow 2002b and Forbes et al. 2008).

The 2007 SAP stressed the importance of model evaluation with respect to CASM (e.g., how realistic is CASM_{ATZ} for modeling a stream, can it extrapolate from a static system to a variable flow system with varying environmental factors, etc.) (see the 2007 SAP Report, FIFRA SAP 2008). The Panel concluded that this was even more of an issue with respect to PATI. Some on the Panel commented that PATI lacked objectivity because model outcomes/predictions are difficult to validate although PATI does provide an MEI which can be used as a relative measure of ecological impact and could thus serve as a basis for evaluating model performance.

The Panel stated that the PATI-based approach allows integration of individual species testing with the mesocosm based community response data to calibrate PATI-based predictions for individual plant species accurately predict plant community responses (e.g., multiple plant species interactions) to atrazine exposure. The individual species tested for PATI have no direct measure of plant community response *per se* other than their summed response; whereas, the calibration to the mesocosm data incorporates multiple plant species responses if observed.

Panel members had the following concerns regarding the PATI approach as listed below.

1) The model is not objective, in the sense that model outputs cannot be measured; thus, there is no way to evaluate how well the model performs in assessing the ecological impacts of atrazine exposures.

2) As noted above, the fact that the model is not sensitive to environmental factors was viewed as a positive aspect. However, given that the ecological risk associated with atrazine exposures does depend on environmental factors, then it is perceived as a weakness that PATI cannot account for these variations. This inability to adequately reflect the risks associated with uncertainty is also evident in Tables V-1 and V-2 of Section C in the Agency's issue paper (p. 57-59). Also, the extrapolation from cosm calibration to real-world chemographs with variable flow and greatly varying Total Suspended Solids (TSS), Dissolved Inorganic Nitrogen (DIN), Dissolved Inorganic Phosphorus (DIP), light, etc., entails a greater risk of radical error using PATI rather than CASM, since the former is an empirical, non-mechanistic model.

3) The model as currently employed does not reflect the aquatic community composition in 2nd and 3rd order streams in the Midwest. The composite PATI MEI is obtained by integrating over the entire ensemble of EC_{50} and slope distributions, and thus reflects the species composition employed in deriving toxicity lab data, not that encountered in the headwater streams in the Corn Belt (see discussion of bias in Forbes and Callow 2002b and Forbes et al. 2008). Furthermore, each species employed to derive the EC_{50} distributions is weighted equally in the PATI model, regardless of whether such species are expected to represent key ecosystem functions, relative biomass, etc.

4) The selection of the PATI MEI is unclear. The Panel recommended the Agency follow the CASM approach and use a maximum observed 30-day running average MEI as computed over the entire exposure duration. Also, the current formulation provides an equal weighting of daily Specific Growth Rate (SGR) reductions, regardless of the magnitude of the reduction. If the attempt is to develop an MEI that reflects changes in biomass due to atrazine exposure, then the Panel stated that simply

averaging SGR reductions would be inappropriate. The Agency recognized this issue and performed a preliminary evaluation, but the Panel did not see any scientific basis for assigning weights to relative SGR reductions. The Panel thought that the only recourse for identifying appropriate weights would be to use a mechanistic model such as CASM that estimates corresponding biomass changes.

5) PATI seems to be a step back with respect to the Ecological Risk Assessment (ERA) paradigm, using SSDs which rely on extrapolating individual species bioassays to estimate community level effects (e.g., no demographic dependencies nor interactions between species nor assessments of ecosystem functioning), rather than using a community population/energy budget model (e.g., CASM) to connect individual species response to community dynamics.

6) In addition to ignoring the impact of demographics and aquatic community composition, PATI also does not account for the influence of physico-chemical factors on the impact of atrazine exposures. For example, it is well established that physico-chemical factors impact SGR (e.g., light, temperature, nutrients). It seems quite plausible, and the CASM model simulations support this, that the relative impacts of atrazine exposures are a function of these environmental variables. The fact that the model ignores this input uncertainty is evident in Table V-2, Section C of the Agency's issue paper. There is almost no difference between the 50th and 90th percentiles for the estimated risk factors for the 40 AEEMP sites.

7) The Panel commented that it would be extremely difficult to integrate all of this complexity and the differences in sensitivity/bias into a simple equation; yet, that is essentially what PATI attempts to do. However, the PATI approach is more advanced than the traditional SSD approaches in that the LOC is developed on the basis of the cosm data and the model accounts for variable chemograph exposures. However, care needs to be taken to establish a scientific basis for assigning weights to each species in the SSDs to avoid the occurrence of both false positives and false negatives (see Forbes et al. 2008) and to more accurately reflect watershed species composition and/or species biomass and ecological function. If the approach can be modified to provide a consistent, accurate, and conservative estimate of atrazine ecological impact amid the large amounts of ecological complexity, variability and uncertainty, then it would be a great 1st tier tool for risk assessment.

D. Comparison of CASM versus PATI

In their issue paper (Figure IV-12), the Agency illustrated the similarities between risk factors predicted by their application of $\mathrm{CASM}_{\mathrm{ATZ2}}$ and PATI derived risk factors. These similarities support the idea that the ecological interactions included in CASM are less important than the toxicity forces in determining ecological risk of atrazine in surface waters.

Another $\mathrm{CASM}_{\mathrm{ATZ2}}$ application, conducted independently from the Agency's application, was presented by Syngenta (see Panel's response to Charge Question 2). Their probabilistic $\mathrm{CASM}_{\mathrm{ATZ2}}$ was shown to provide more accurate, precise, and fine tuned atrazine risk assessments than do PATI-based approaches. Therefore, the Panel thought that the CASM-approach appears to be well suited to site-specific risk assessment and development of risk mitigation approaches in vulnerable watershed. CASM is responsive enough to evaluate multiple factors that co-determine ecological effects of atrazine and may thus be useful in developing and evaluating risk mitigation measures.

Whether by use of CASM or PATI, the Panel agreed that there was enough information from these models for atrazine to be able to use a solid probabilistic approach to estimate a given effect level with a given probability of exposure. There was agreement amongst many on the Panel that the optimal approach for determining a MEI was to continue using the CASM-based modeling approach ($\text{CASM}_{\text{ATZ2}}$) for atrazine risk assessment first illustrated by Solomon et al. (1996). The key to $\text{CASM}_{\text{ATZ2}}$, as stated by the Panel, is its ability to include time-varying exposures to time-varying baseline growth and species-specific susceptibility to atrazine exposure. In addition, there is also the possibility of including secondary effects on primary consumers in the system. The increased sensitivity of the revised $\text{CASM}_{\text{ATZ2}}$ model to changes in input parameters relative to the previous CASM_{ATZ} model should not be regarded as an argument against its use for risk assessment purposes. Rather, the sensitivity of the $\text{CASM}_{\text{ATZ2}}$ model output to changes in its input parameters indicates its ability to quantify the influence of variable ecology on the risk atrazine may pose to aquatic ecosystems. The Panel thought that this information will likely help the Agency.

The Agency discussed the relationship between CASM and PATI, and suggested that, given that both approaches (using median parameter values for CASM) indicate similar MEI responses to a wide variety of chemograph exposure profiles, the dominant factor in the ecological risk assessment (ERA) appears to be atrazine exposure impact on SGR. The Panel recommended further effort in identifying differences and similarities between the models, such as for what situations the MEIs differ, and why, and also in determining when the simpler approach may fail, etc. Following the Agency's suggestion, some Panel members commented that it might be useful for the Agency to consider PATI as a special case of CASM. That is, the PATI-based estimations can be viewed as a subcomponent of the CASM-based indices (i.e., Total Plant Biomass and SSI). Application of PATI and CASM-based methods to the 16 example chemographs resulted in similar predictions of MEIs using both methods. Comparison of PATI-based and CASM-based MEIs for these data indicated they never differed by more than a factor of 1.4. This suggested that the two methods yielded comparable MEI predictions. In addition, evaluation of both models demonstrated that the PATI-based MEIs for atrazine resulted in risk factors that are insensitive to uncertainties to both variations in environmental factors as well as uncertainties in parameterization. This contrasts the CASM-based approach, whose output reflects both uncertainty in parameterization and environmental variability. This sensitivity was reflected in the number of AEEMP sites that exceeded the LOC and greatly increased the confidence level for the CASM model from 50 to 90%. There was only one additional site added with the corresponding PATI estimates.

The Panel thought it would be instructive to explore the relationship between PATI and CASM, especially if the aquatic community in the latter is representative of 2nd and 3rd order stream structures while the former reflects the arbitrary species composition resulting from laboratory assays. This exploration could be done, for example, by using CASM to calculate a surrogate PATI MEI[1]. Evaluating the correlation between this surrogate PATI and the SSI% MEI used by CASM under different chemographs and environmental scenarios may help identify when the simple approach is justified and when it is not. If the dominant impact of atrazine can be modeled using a single species toxicity index, then the Panel thought that PATI approach might be a wonderful tool.

Application of both approaches to AEEMP field data collected by Syngenta indicated that the PATI based approach was more sensitive in predicting the total number of LOC exceedances than CASM based approaches (18/98 = 19% for PATI vs. 8/108 =7%). Additionally, the PATI method predicted a higher number of sites with LOC exceedances (e.g., 9 LOC exceedances with PATI versus only 4 for CASM) as well as a lower percentage of sites below the LOC than the CASM method. This suggests that the PATI-based approach may overestimate atrazine sensitivity compared to CASM, but the Panel thought that this was a conservative bias.

The Panel spent considerable time comparing the CASM-based approach to the PATI-based approach as part of this Charge Questions. These discussions are summarized below.

Following the Panel's formal response to the five charge questions, the Panel further discussed both the CASM $_{ATZ2}$ and PATI modeling frameworks for deriving a Model Effects Index Level of Concern (LOC$_{MEI}$) from the cosm studies. Several factors, listed below, may have contributed to the Panel's difficulties in evaluating both the CASM $_{ATZ2}$ and PATI modeling frameworks for deriving a LOC$_{MEI}$ from the cosm studies.

1) The fact that there was relatively little discussion and/or presentation by the Agency regarding the scientific foundation for the PATI model, despite the apparent preference of the Agency to use this simpler approach.

2) There was a seemingly "last-minute" analysis and corresponding presentation by Syngenta of a "probabilistic" CASM$_{ATZ2}$ analysis which suggested that the model, after appropriately accounting for toxicity data uncertainty and physico-chemical variability, could be used to identify real-world chemographs that exceed a cosm-calibrated LOC.

3) There were two "last-minute" additions (May 14th) to the docket by both Syngenta and the Agency regarding CASM $_{ATZ2}$.

The Panel compared both CASM- and PATI-based approaches to formulate MEIs. The PATI-based approach is favored by EPA, while the CASM-based approach is favored by Syngenta. While in most cases, PATI and CASM (using median parameter values) provided

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[1] For instance, by setting interaction terms between species to zero, modifying CASM such that each species is in an optimal environment with respect to all physico-chemical factors (e.g., using the fixed nutrient option with nutrient, light, and temperature levels set to optimal for each species), calculating SGRs for each species as a function of exposure profiles, compute a daily average value of the SGRs over all species, and then sum this daily average value over the assessment period.

similar predictions, the Panel pointed out that there were fundamental differences in the underlying assumptions implicit in these approaches.

The Agency found that the CASM model estimated a higher number of sites exceeding the LOC than did PATI (Section C, Tables V-1 and V-2 of the Agency's issue paper). At 7 of the 40 AEEMP sites, the median CASM $_{LOC}$ was exceeded in multiple years (in contrast to 3 of the 40 sites for the corresponding PATI $_{LOC}$), and at 10 of the 40 sites the median CASM$_{LOC}$ was exceeded in at least one year (8 of 40 sites for the corresponding PATI $_{LOC}$). This was to be expected as median predictions by PATI and CASM are similar, yet, not identical (see Figure IV-12 of the Agency's issue paper).

Another application of the CASM (i.e., probabilistic CASM$_{ATZ2}$) was performed by Syngenta and presented during the SAP meeting (see Charge Question2). The probabilistic CASM$_{ATZ2}$ consistently predicted lower numbers of sites that exceeded the LOC than the PATI model. At a 90 % confidence level, the probabilistic CASM $_{LOC}$ was exceeded at only 4 of the 40 sites in contrast to 9 of 40 sites for the 90% PATI $_{LOC}$. Thus, from these presentations, the Panel stated that it was clear that the way in which the CASM model is applied influences the number of sites classified as "exceeding the LOC," that makes it nontrivial to state which model (CASM or PATI) labels most sites as exceeding the LOC. The Panel noted that the probabilistic CASM$_{ATZ2}$ was not reviewed in detail as it was only presented during the meeting.

In general, the model to be relied on most would depend on whether the additional variance brought in by CASM represents uncertainty or variability. In the former case, one might find PATI preferable; in the latter case, one might find CASM preferable. For instance, PATI follows the SSD paradigm, and implicitly makes several assumptions; some of these are summarized below Forbes and Callow (2002b; from p. 477 and p. 480).

1) The distributions of EC$_{50}$s and slopes derived by the Agency represent the aquatic community structure of generic 2nd and 3rd order Midwest streams. (The word "represent" implies a random sample with respect to a specific feature such as the number of species, ecological function, biomass, etc.).

2) The conversion of observed endpoints in these bioassays to SGR estimates is appropriate (e.g., factors such as density dependent growth, initial demographics, do not unduly influence estimates) and the individual-level responses correlate accurately with community level dynamics (i.e., interaction among species and between trophic levels is not significant). The validity of this assumption, however, is species dependent and varies considerably.

3) The LOC and associated confidence limits are chosen on the basis of sound scientific justification. These decisions are very important as they have considerable impact on how they will be interpreted.

4) An adequate number of relevant species have been bioassayed and values have been weighted appropriately to accurately characterize the specific shape of the SSD. This

is especially important since the tails of these distributions is the primary measure that corresponds with the chosen protection level and SSDs are typically skewed distributions, making tail extrapolation a challenge.

CASM, an energy budget model, results in quite different assumptions to develop community-based risk assessments. While the bioenergetic equations employed in the model to account for photosynthesis, respiration, mortality, competition, population dynamics, nutrient cycling, for example, are well grounded in ecological theory, there are several challenges with respect to achieving the desired end point. Two of these are highlighted.

1) One challenge is with respect to model evaluation. There are numerous parameters in the model and considerable ambiguity in identifying (and verifying) appropriate values for generic 2nd and 3rd order Midwest streams. This increases uncertainty in model output.

2) A related issue involves model complexity. As the ability to model more complex interactions increases, so does the challenge with respect to parameter uniqueness and model output objectivity.

Syngenta provided evidence of how CASM-based approaches may provide more accurate, precise, and more fine-tuned atrazine risk assessments than do PATI-based approaches. This is done by factoring in multiple water quality parameters and other environmental variables. However, many on the Panel expressed concern about the uncertainty of assumptions made in simulations using CASM-based approaches. For the most part, the Panel agreed that CASM-based approach appears to be well-suited to site-specific assessments and can be used to investigate the influence of water quality parameters and other environmental variables. Some on the Panel thought that CASM may be very useful to scientifically support possible mitigation approaches in vulnerable watersheds. If PATI can be formulated to be consistently more conservative than CASM, many on the Panel suggested that a useful approach might be to use PATI-based modeling of the larger watershed scale to predict atrazine risk.

Some panelists stated that the CASM model is the best approach to create a model effects index. It captures the natural variability, context dependencies, and indirect effects that are known to exist in the real world. Many of these context dependencies and indirect effects can increase the LOC for chemicals, while at other times, they might decrease it. The considerable sensitivity to parameter estimates is expected; therefore, it explains why the Agency's application of the CASM model classified a much higher percentage of sites exceeding the LOC than did the PATI model. Many on the Panel stated that the PATI model does not reflect nature (i.e., context dependencies, indirect effects and the derived SSDs do not correspond to those in 2nd and 3rd order Midwest streams). What is left is the illusion that the PATI model is insensitive to parameters because it simply has no free parameters. The Panel indicated that the weaknesses of the PATI model must be made clear. If the PATI model, however, consistently identifies the same watersheds as being vulnerable, with perhaps the addition of a few more watersheds, then the Panel views the simplicity of the model as a strong argument for its use when the purpose is to identify watersheds vulnerable to high levels of atrazine.

The Panel discussed the strengths and weaknesses of both PATI-based and CASM-based approaches. As noted above, Forbes and Calow (2002b) detailed the strengths and weaknesses of the SSD approach to risk assessment. The Agency stated that the PATI- and median parameter value CASM-based results were in agreement and that the incorporation of ecological interactions (i.e., use of CASM provided little added value to the risk assessment outcome).[2] However, some of the Panel indicated that the higher degree of variability for CASM should be regarded as an added value of using this model, because it is capable of translating biological variability to risk outcomes. The PATI method does not account for ecological interactions between populations which appear to magnify the scatter associated with single-species toxicity data, as shown by the sensitivity analyses in the review document. The validity of the PATI method relies on the accuracy of key assumptions regarding certain environmental and ecological factors. Examples of such assumptions are: 1) interactions between species are nonexistent, 2) variations in environmental factors such as nutrients, temperature, and flow rate do not influence the relative impact of atrazine exposures on periphyton and other species growth rates, and 3) individual level responses are representative of community level outcomes. In general, the choice for a simpler model often has such implications; yet, these are often not explicitly stated or listed. EPA and Syngenta presenters stated that simulations at lower/higher temperatures would require data on the effect of temperature on bioenergetics of the involved populations and that such data are not available. However, CASM contains a module for temperature-dependence of bioenergetics that is built on such data.

E. Concerns Associated with Both Approaches

The Panel recommended that the Agency provide a justification for the use of the SSI used by PATI and CASM, rather than the well-known community index such as the Bray Curtis Index of Similarity. The Panel surmised that the SSI was being used because of the focus on capturing biomass changes rather than per capita changes *per se*. Forbes and Calow (2002b, 2008) reviewed the use of SSDs and concluded that if a sensitivity distribution would produce an estimate that accurately reflects the target aquatic community (e.g., with respect to distribution shape, ecological function, number of organisms, biomass, or resilience, etc.) then this approach is an improvement over the older generation of risk assessment which relied on an arbitrary multiplicative factor to account for risk uncertainty (i.e., the Application Factor (AF) approach). Although this approach uses the entire toxicity database, only a small portion of the data actually contribute to determining the apparent effects threshold (e.g., this is especially true for SSDs which rely on small numbers of species, say 20 to 50, from which, if an Effects Threshold (EF) of 5% is used then results in a level set by the 1 to 3 most sensitive species). Despite these limitations, apparent effects thresholds such as described in the

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[2] If, as suggested here, the ecological impact of atrazine exposures is not a function of species interactions, then that is a remarkable outcome. One member of the panel believed that more verification of this precept than the preliminary comparison between PATI and CASM was warranted. The validity of this assumption would be context dependent. For example, in nutrient limiting environments with high competition among species of varying sensitivity, population dynamics would likely change considerably with atrazine exposures.

Sediment Quality Guidelines (Long et al., 1995; MacDonald et al. 1993; 1994) have been successfully used in conducting field- and laboratory-based risk assessment for sediment contaminants. These guidelines have been routinely applied to evaluating sediment contaminant levels in national and regional monitoring programs and in developing national report cards of environmental quality (e.g., National Coastal Condition Report). The Panel also stated that the SSI index is predominately a biomass weighted indicator. Consider this extreme example, if one species accounts for >90% of the community biomass, and this species is relatively insensitive to atrazine exposures, then if all other species immediately die off and do not recover following atrazine exposure then the 30-day rolling average 5% SSI will not be triggered [i.e., SSI % > (1-180/200)*100]. Is this biomass weighting the appropriate MEI? This approach does not take into account ecosystem functioning and diversity (resilience, etc.) other than how the latter indirectly impacts biomass formation. Concerns were also expressed regarding the PATI MEI (i.e., the composite fractional reduction at a given exposure concentration as the sum of the "ensemble" SGR fractional reductions averaged over a somewhat arbitrary assessment period). An alternative to the PATI MEI would be to assign a weight to each species that corresponded to either the relative biomass or a metric related to ecosystem functioning.

Some concerns were expressed by the Panel about the way in which simulation results, whether produced by PATI or CASM, were used to derive a LOC. EPA evaluated alternative MEI options and decided on a 30-day running average SSI deviation. EPA also evaluated the relatively large impact of toxicity data uncertainty on estimating an LOC_{MEI} and concluded that the large sensitivity encountered confounds the ability to identify an appropriate risk threshold. In contrast, Syngenta presented a probabilistic approach that attempts to estimate an appropriate risk threshold. In this approach, the same parameter distribution is used to compute paired MEIs for cosm and real world chemographs, although this is not entirely justified because it can be readily argued that the underlying distributions would be different in these two cases. In Syngenta's Monte Carlo analysis, 200 stratified random "realizations" were drawn from joint probability density functions of the toxicity and physicochemical factors. The joint probability density function reflects not only the means and variances of the factors, but also the correlation among them[3]. For each set of parameters, an LOC was identified from the cosm data, providing a specific LOC for each parameter set. To determine if a specified "real-world" chemograph exceeded the LOC, the model was run with each of these 200 parameter sets to provide 200 MEI values. The statistics between the 200 LOC_{MEI} values and the 200 MEI values computed for the real-world chemograph were compared and conclusions were drawn regarding the significance of differences between the two distributions. The Panel raised two concerns with this approach.

The first caveat to the approach pursued by Syngenta is that the cosm data typically represent systems in which the physicochemical variables are known (e.g., optimal growing conditions

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[3] Correlations between flow velocity, atrazine concentration, TSS, etc., are likely event and watershed specific. Positive correlations between these several variables may result in a relative reduction (or increase) in atrazine impact on aquatic communities as a result of the environmental stresses created by velocity, TSS, and other relevant factors. The Agency needs to identify if such correlations are present in actual measured hydrological data for 2nd and 3rd order Midwest streams, and if so, then a further evaluation is required to assess what the relative impact of such correlations are upon the generic risk assessment. The latter question can conceivably be addressed within the CASM framework.

in terms of nutrients, light, Total Suspended Solids (TSS)). In contrast, the conditions of the real-world chemograph are typically unknown. Therefore, uncertainty in physicochemical factors should not apply in developing the 200 LOC MEI values. This uncertainty, however, would apply in developing the real-world MEIs (this would presumably entail a nested Monte Carlo analysis to account for the impact of physicochemical model uncertainty). The physicochemical joint probability functions developed by Syngenta could be used for the 6-year record of observations at Upper Honey Creek, Ohio; AEEMP sites, and NAWQA sites to ensure that these joint probability density functions are consistent with similar watersheds in the Corn Belt.

Second, the approach used to compare the 200 $\mathrm{LOC_{MEI}}$ values and the 200 MEI values computed from the real-world chemograph does not have an adequate statistical foundation. This is also explained in the answers to Charge Question 2. One issue is that the Wilcoxon rank-sum test is used to compare the medians of two distributions, but the test of interest here is a comparison of the two distributions. The Kolmogorov-Smirnoff test, or some other test designed to compare two population distributions, would be more appropriate here. Another issue is that, by generating 200 MEIs for each of the two populations (LOC and real-world chemographs) and then conducting the test, a sample of size 200 is generated for each population. The power of the test increases with sample size. Because it is highly improbable that the two distributions are exactly equal, one must simply generate a large enough sample to reject the hypothesis that the two are equal, and this is true regardless of the test used. That is, this approach will almost surely reject the hypothesis that the two distributions are equal if enough simulations are done for each population. A possible approach would be to use a Monte Carlo test to assess whether the distribution functions are equal. This would involve generating a number of distribution functions for the comparison.

The Panel questioned how individual chemographs were generated for each cosm study. One panel member stated that most cosm studies did not monitor atrazine concentrations long enough for these studies to reflect realistic field concentrations. In most studies, only initial concentrations are reported, while in a handful of studies, both initial and final concentrations are recorded. Other questions raised included the following: What was the atrazine half-life used? Was this half-life assumed to be constant throughout the study? How sensitive were the analyses to these individual cosm chemographs?

Most of the Panel suggested that a useful approach would be to use PATI based approaches across the larger watershed scale as a Tier I screen for atrazine risk. CASM could be used as a site-specific Tier II probabilistic method. The issue here is less with the $\mathrm{CASM_{ATZ2}}$ model than with the summarization index used to convert the multi-dimensional outputs from the model to a one-dimensional metric on which an LOC is based. The Panel recommended that EPA put additional effort into creative thinking about new metrics (not Brock scores) that are not so affected by any one dimension.

F. Alternatives to the Brock Scores

The Panel was concerned by the use of Brock scores to relate PATI and CASM output to cosm data. They made it clear that the Brock score approach is not recommended because it

1) is highly dependent on the sample size used in the study, 2) turns a continuous variable into a discrete variable, thus resulting in a considerable loss in data, 3) requires unnecessarily made judgment calls on which studies are appropriate in specific arbitrary categories, and 4) seems to preclude a probabilistic-based risk assessment. Studies with small effects and large samples sizes will likely detect significant effects of atrazine; whereas, studies with enormous effects and small sizes will not. These issues were discussed earlier in the Panel's response to Charge Question 1. They stated that ideally there should be a sample size independent measure of effect; i.e., one which standardizes or normalizes effects. The Panel discussed alternative approaches to the Brock score metric.

Effect size estimators are used in many meta-analytical approaches (e.g., Metawin as described in Rosenberg et al. 1997). One panel member outlined several benefits of a meta-analysis approach:

1) It will allow you to test for effects of concentration, exposure duration, study latitude, flowing versus stagnant water effects, etc. using the actual data from the studies.
2) It uses a regression-based approach which provides parameter estimates for each effect (and standard errors) andfacilitates prediction of effects.
3) It provides a probability and variation estimate associated with each tested effect so that there is defensible justification for including or excluding factors.
4) It is much more transparent and familiar to scientists and the general public than the more convoluted $\mathrm{LOC_{MEI}}$ approach. The complexities of the risk factor calculations are not easily understood by the public or even by traditional toxicologists familiar with the use of advanced statistics.
5) It also provides the probability or likelihood of an effect given a particular concentration, duration, ecosystem, location (e.g. latitude/longitude) as well as other variables.

This panelist believed that this was especially important given the desire to conduct probabilistic ecological risk assessments. The Panel recommended that the Agency move away from setting an LOC and move toward a probability density function. The cosm-based LOC would be replaced with an acceptable cosm-based probability of an effect.

An alternative to working with effect sizes is an approach based on apparent effects thresholds used to develop Sediment Quality Guidelines (SQGs) (**See Appendix 1**). The paper by Long and Morgan (1990) set in motion attempts to develop SQGs by summarizing bioeffects data based upon sediment toxicity and biomonitoring studies for a wide variety of persistent chemicals, e.g., **Table 1 below and Appendix 1**. Long et al. (1995) published SQGs for trace metals, pesticides, PAHs and PCBs using all published QA/QC data from estuarine, marine and freshwater. The diversity and complexity of this data set used to define SQGs mirrors the diversity and complexity of the cosm data set EPA used to derive bioeffects and LOCs for atrazine. Only significant effects data (the equivalent of cosm data with Brock scores of 3, 4 and 5) were included in computing SQGs and "no effects" or "no significant effects" data were excluded. In this approach, a cumulative frequency distribution curve was developed for each compound, ranking data from the lowest to highest concentration causing effects. Two terms are derived from this distribution of studies with adverse effects: 1) *Effects Range Low* (ERLs = 10% of the cumulative frequency distribution of published data) and 2) *Effects Range Median* (ERMs = 50% of the cumulative frequency distribution of published data) (see Figure 1 in Long et al. 1995).

MacDonald et al. (1993; 1994) developed a similar approach to the assessment of sediment quality in Florida coastal waters using a more limited data set for the southeastern U.S. Data were divided into "No Effects" and "Effects" data sets that were ranked from low to highest concentration for each data set to define a cumulative frequency distribution. MacDonald et al. (1993) then calculated two terms: 1) *Threshold Effects Levels* (TELs) = the geometric mean of the 50th percentile of the "No Effects Data" and the 15% percentile of the "Effects Data" distributions; and 2) *Probable Effects Levels* (PELs) = the geometric mean of the 85th percentile of the "No Effects" Data and the 50th percentileof the "Effects Data" distributions.

These two slightly different approaches generally result in very similar estimates of SQGs for different chemical contaminants as seen in **Table 1**. While there can be departures between the approaches, generally they derive similar levels of bioeffects for both threshold effects (ERLs/TELs) and for highly probable levels of effects (ERMs/PELs).

Comparisons of bioeffects from laboratory- and field-derived sediment effects have also been generated by Long et al. (1985) and Hyland et al. (1999). These comparisons have generally indicated that field-derived effects occur at lower levels than predicted from laboratory-based estimations. This may result in part from the fact that laboratory assays use mortality as an end point versus sublethal endpoints in the field (e.g., changes in benthic diversity). This point may have great relevancy to the approach used in applying cosm studies, most of which are based on sublethal endpoints for plant bioeffects (growth, photosynthesis, biomass) following exposure to atrazine.

The general point of this discussion is that a probabilistic approach should be used to derive apparent effects thresholds for the cosm studies in determining atrazine action levels for discerning field bioeffects. Note that there would have to be some modification of the SQG approach to account for atrazine concentration-duration exposures and how these influence "significant effects." For example, it is conceivable that a low concentration-long duration exposure may result in a similar effects threshold as a high concentration-short duration exposure. A dosage metric would be appropriate in this regard, which may be non-linear with respect to concentration-duration relationships and effects thresholds.[4] The SQG approach has been used by EPA and National Oceanographic and Atmospheric Administration (NOAA) in assessing the health of sediments throughout the U.S. in the National Coastal Condition Report. This means there is precedent for using this approach. In addition, this approach allows determinations of the percent healthy, percent marginally affected and

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[4] Consider for example the Acute Exposure Guideline Levels (AEGLs) employed in air monitoring. For GB/Sarin nerve agent airborne exposures of equivalent dosage (area under the concentration versus time curve) a high concentration-short duration exposure has a much greater impact than a low concentration-long duration. In contrast, the risk associated with equivalent AEGL-1 or AEGL-2 HD/Mustard gas exposures is only a function of the dosage and does not depend on the concentration-duration combination. It may be possible to modify the SQG approach to atrazine exposures if a similar classification of dosage relationships can be identified.

percent degraded habitat estimations to be made. These characteristics can be color-coded on a map to alleviate some of the difficulty in explaining the complexity of this approach to the public. The Panel indicated that a model MEI will still be required to extend probabilistic SQG classifications to the real world given the highly variable exposure concentration time-series observed in the AEEMP study, and the fact that it is not feasible to perform empirical cosm studies to capture the range in atrazine exposure chemographs that may occur in the Corn Belt.

Table 1. Comparison of ERLs/ERMS and PELs/TELs used as SQGs for different classes of chemical contaminants.

Contaminant	**TEL (ppm)**	**ERL (ppm)**
	Trace Metals	
As	7.24	8.2
Cd	0.68	1.2
Cr	52.3	81.0
Cu	18.7	34
Pb	30.2	46.7
Hg	0.13	0.15
Ni	15.9	20.9
Ag	0.73	1.0
Zn	124	150
	Polycyclic Aromatic Hydrocarbons	
Acenapthene	6.71	16
Acenpathylene	5.87	44
Anthracene	46.9	85.3
Fluorene	21.2	19
Napthalene	34.6	160
2-methylnapthalene	20.2	70
Phenanthrene	86.7	240
Total Low MW PAHs	312	552
Benzo(a)anthracene	74.8	261
Benzo(a)pyrene	88.8	430
Chrysene	108	384
Diben(a,h)anthracene	6.22	63.4
Fluoranthene	113	600

Contaminant	TEL (ppm)	ERL (ppm)
Pyrene	153	665
Total High MW PAHs	655	1700
Total PAHs	1684	4022

In summary, the Panel strongly recommended that alternatives to the Brock scoring metric be used. The Brock Scores, originally proposed by Brock et al. (2000), were categorical assignments that were made on a subjective basis. Furthermore, the scores by Brock et al. (2000) were not intended as the primary basis of conducting a risk assessment for atrazine. Rather, it was one option that could be used.

One member of the Panel, and a Syngenta representative noted that many of the Brock scores were incorrect or were derived from studies that lacked sufficient quality assurance (see above). For example, the series of papers by Denoylles et al. (cosm study #2) did not find effects of atrazine at 20 µg/L as stated in the table (see Denoylles et al. 1989, figures 4 and 7); effects noted by Brock et al. (2000) and the Agency were actually due to grass carp and not atrazine. In addition, cosm study # 6 (Fairchild et al. 1994) was assigned a Brock score of 5 even though there was no effect on total macrophyte biomass, community metabolism, or fish production. Furthermore, in cosm study #58 (Lampert et al. 1988), the researchers applied atrazine using ethanol as a solvent; ethanol was not added to the control, which led to a shift in the atrazine treatment to a heterotrophic community that was incorrectly attributed to atrazine (Giddings et al. 2005).

In conclusion, the Panel recommended that the Agency should re-evaluate all cosm studies in regard to study quality and for concentration-specific effects data. In addition, the Panel highly recommended that the Agency use all of the available cosm data in addition to single species data evaluated as continuous data distributions (as opposed to categorical responses or Brock Scores) and use a probabilistic approach to determine an acceptable LOC. An alternative to working with Brock scores is an approach analogous to that discussed above, based on probability threshold levels (**See Appendix 1**) used to develop the SQGs (Long et al. 1995; MacDonald et al. 1993, 1994).

G. Possibilities for improvement of both models

To improve upon the cosm-derived LOCs, some panel members suggested additional cosm studies are needed that are more representative of real-world exposure profiles, while others thought that it was possible that several cosm studies were not included in the meta-analysis database (**Appendix 2**) and that inclusion criteria and justification for why studies were excluded needed to be made more transparent. After all, the results of both PATI and CASM are only as good as the cosm data that are used to calibrate both models. In addition, other panel members suggested exposure response monitoring involving estimates of aquatic community structures in headwater watersheds with and without atrazine exposure. The issue of confounding was brought up in this regard, with respect to other factors (e.g., TSS, flow velocity and historic atrazine use in the sub-watershed). Physico-chemical confounding has been overcome using trait-based, pesticide sensitivity indicators (Van den Brink 2008; Liess et al. 2008). However, historic use is of particular concern since there have been several decades of higher atrazine use in the Corn Belt than currently accepted practices, and thus aquatic community structures in vulnerable streams may reflect such long-term temporal stresses. The Panel thought that it may be possible to identify nearly adjacent headwater watersheds with and without historic atrazine use and compare aquatic community structures to evaluate such long-term stressors.

EPA presenters stated that the breakdown products of atrazine are much less toxic than the parent compound. One panel member asked the Agency about the toxicity of atrazine metabolites and how these metabolites were evaluated. In the environment, atrazine degradation is enhanced by light and by the presence of organic matter or minerals, in particular humic and fulvic acids. Several processes such as microbial decay, hydrolysis, and photolysis have the potential to impact atrazine degradation in aquatic ecosystems. Its accumulation and persistence in sediments contribute to the transport of atrazine and its metabolites to surface and subsurface waters. The atrazine degradation pathway proceeds through chemical transformations at low sediment pH to hydroxyatrazine. Additionally, microbial N-dealkylation of the ethyl and isopropyl side chains can produce deethylatrazine (DEA) and deisopropylatrazine (DIA) (Kaufman and Kearney 1970). The formation of hydroxyatrazine, a primary intermediate, occurs under acidic conditions in the presence of humic acids. Hydroxyatrazine is relatively polar and has the potential to bind tightly to soil organic carbon, becoming unavailable and nontoxic due to the loss of chlorine at the two-position (Houout et al. 1998). The dealkylation products deethylatrazine and deisopropylatrazine, on the other hand, retain the chlorine atom and are considered to be phytotoxic (Houout et al. 1998; DeLorenzo et al. 1999). Based on results from spiked sediments, sediments with less carbon and limited binding sites showed increased formation and persistence of DEA (Smalling and Aelion 2006). A non-polar secondary metabolite, methylated atrazine (M-ATR) not previously documented to be derived from atrazine, was found to be chemically produced, and concentrations were an order of magnitude higher than DEA. M-ATR may have potential to be persistent in the aquatic environment due to the inability of microorganisms to remove the isopropyl groups on the triazine backbone (Smalling and Aelion 2006).

EPA responded to the Panel's question regarding evaluation of atrazine metabolites. The Agency provided information to the Panel on this topic (see Appendix A, Atrazine IRED, EPA 2003). Review of these data by the Panel found that the EPA Tier II analysis of atrazine degradates indicated that deethylatrazine is more toxic than the other four degradates, and the most sensitive algae of the five species is generally the blue-green alga *Anabaena inaequalis* with EC_{50} values ranging from 100 to > 100,000 ppb. The parent atrazine, however, is more toxic to these algal species than any degradates and the order of descending toxicity for these algal species are atrazine > deethylatrazine > deisopropylatrazine > diamino-atrazine > hydroxy-atrazine. Two studies clearly indicated that deethylatrazine, atrazine's primary degradation product, is almost as toxic to microalgae as atrazine (DeLorenzo et al. 1999; Winkelmann and Klaine 1991). Kotrikla et al. (1997) have also examined toxicity of several atrazine metabolites on microalgal growth rate. They showed that the removal of the propyl group from atrazine results in a 3.5 times less toxic derivative than the removal of the ethyl group (Kotrikla et al. 1997). In the information provided to the Panel, EPA stated that "in an anaerobic aquatic study, atrazine overall (total system), in water, and in sediment half-lives were given as 608, 578, and 330 days, respectively." With half-lives this long, i.e., that exceed a year in duration, the Panel indicated that there will be cumulative effects of atrazine from repeated annual use of atrazine in continuous annual agricultural production cycles in anaerobic environments. This suggests that both metabolites and the parent compound will be a major part of the total atrazine exposure. If metabolites are toxic and only parent atrazine levels are being reported then there would be an underestimation of true atrazine risks within the monitored watersheds. The Panel concluded that the use of only parent atrazine levels in risk assessment may underestimate the risks of atrazine at field locations and they recommended that the models should be run with and without metabolite measurements to discern the impact on risk estimations from each model used. The Panel recommended that the EPA should provide considerable empirical justification for not including metabolite levels in estimations of risk and should also carefully consider studies that do not find considerable differences in toxicity among breakdown products. Combining the breakdown products and the parent compound may have resulted in more chemographs and sites above the LOC which would suggest that effects of atrazine are currently being underestimated.

The LOC MEIs are calculated for both PATI and CASM and false negatives or false positives balanced in a somewhat arbitrary fashion. In the plots that displayed this, the vertical axis is commonly shown as a mean concentration even though the atrazine concentration, when measured, often decreased significantly during the study periods. One panel member was not convinced that mean concentrations for the cosm studies are the appropriate metric for these figures. This panelist suggested that EPA look at other metrics, such as dosage, i.e., the area under the C(t) vs. time curve which is similar to the AEGLs employed in air monitoring) the median (a more robust measure of central tendency for skewed data), or the peak concentration. The AEGL framework has been very useful at categorizing the human risks associated with variable chemical concentration-exposure time-series for air-borne hazards. The goal is to identify an exposure metric that better coincides with the observed effect levels.

The Panel commented on the use of the terms "false negative" and false positive" used in the Agencies analysis of Brock scores. In actuality, these apparent departures from expected results were largely due to misinterpretation of the original cosm datasets as classified by Brock et al. (2000). Many examples were provided to support this conclusion as indicated in the Panel response to Charge Question 1 above as well as illustrated in Giddings et al. (2005) and Volz (2007). The Panel suggested that the Agency thoroughly re-evaluatethe cosm studies cited as "false positives" or "false negatives" and move away from these distinctions. The Panel thought that the Brock scores from these studies would be reclassified based on this new analysis and, as a consequence, the confidence in the overall distributions of cosm studies in relation to the proposed LOC would be increased.

Several panel members recommended that atrazine effects on edge-of-field standing water ecosystems (e.g., ephemeral wetlands, retention ponds, and small farm ponds) be more thoroughly evaluated. Maximum reported concentrations in these systems are often 2.5 to 10 times higher (1000-3130 μg/L) than the maximum concentrations observed in 2nd and 3rd order perennial streams (Baker and Laflen 1979; Edwards et al. 1997; Evans and Duseja

1973; Frank et al. 1990; Kadoum and Mock 1978; Kolpin et al. 1997). It is these systems that undoubtedly will regularly exceed LOC values based on any calculations. Although many of these systems are retention ponds intentionally designed to capture pollution, in many cases they are also managed for fish and wildlife habitat (Downing et al. 2006). In coastal regions Harmful Algal Blooms (HABs) are often observed in retention ponds that may contain atrazine and certain HAB species may be more tolerant to atrazine than non-HAB phytoplankton species (Dr. JoAnn Burkholder, NC State University, Raleigh, NC; personal communication to Dr. Geoffrey Scott, USGS-NOAA).

The Panel thought it was important to separate uncertainty from variability in all models under consideration. They agreed with the suggestion that EPA should conduct some exploratory and influential outlier analysis to determine if there are any extreme data points with undue influence on the analyses. The Panel reflected that EPA should not arbitrarily decide to remove these data points. A solid scientific justification should be given for the removal of any data point, and the effects should be compared with and without their removal from the data sets. Analyses should also be run giving each taxa or species equal weight at all times of the year to assess how these changes might affect the conclusions. The Panel stated that it would be difficult to justify weighting by biomass, individuals, or providing equal weight and thus recommended doing these analyses all possible ways to see how each one affects the output.

2. Topic B: Agency's Watershed Analysis (Questions 4-5)

The Agency identified three sites that exceeded the PATI LOC_{MEI} in multiple years and six sites that exceeded the LOC_{MEI} in one year (Section V of the Agency's Background Document). Based on the results of the Agency's watershed analysis in Section VI to identify additional sites that might exceed the atrazine LOC, US EPA proposed two questions for the SAP.

Question 4: Based on an analysis of watershed characteristics of the 40 monitoring sites, the US EPA concluded that the presence of soils that either have a high runoff potential or are in hydrologic soil group C or D, and have a shallow layer with a moderately low saturated hydraulic conductivity best distinguish sites that exceed the LOC in multiple years from those that do not exceed the LOC. **Please comment on the merits of the watershed criteria the Agency used to identify watersheds that might exceed the atrazine LOC.**

Panel Response

A. General Response

In 2007, the SAP encouraged EPA to take advantage of improved national databases such as the United States Department of Agriculture-National Resources Conservation Service (USDA-NRCS) Soil Survey Geographic Database (SSURGO) and the United States Geological Survey (USGS) National Hydrology Dataset Plus (NHDPlus) to help identify vulnerable watersheds. The Panel commended EPA and Syngenta for the massive efforts and progress they have made in identifying vulnerable watersheds, illustrating the importance of depth to impervious layer and slope to atrazine runoff. The Panel recommended these efforts continue with the sharing of database and software tools between EPA and Syngenta as well as the development of a Cornbelt "Watershed Regression for Pesticide (WARP) Model" that utilizes data from all 40 Atrazine Ecological Exposure Monitoring Program (AEEMP) sites in combination with a raw MEI score or a concentration metric. With respect to explanatory variables, the challenge of identifying appropriate categorical thresholds was noted, and the Panel recommended avoiding such classifications where possible. Additional data that may be useful for this regression analysis include planting date estimates, timing of atrazine application and rainfall intensity and duration, minor soil groups, riparian buffers/setback areas, management factors (tillage, conservation practices, Roundup Ready® corn, etc.), runoff propensity index/surface area to flow volume ratios, composite curve numbers, and geometry of conveyance systems (i.e., field and/or watershed physical characteristics).

The Panel expressed concerns regarding the compatibility of scale between explanatory variables and watershed concentration metrics, as well as identifying a minimum scale of concern for aquatic community integrity, and co-occurrence of vulnerable sub-watersheds and implications for larger drainage areas. The Panel was very pleased with, and encouraged EPA to continue, the spatial analysis with respect to comparable (i.e., with respect to drainage area and the 2004 to2008 time period) atrazine water quality data collected from the USGS National Water Quality Assessment Program (NAWQA) and state government agency monitoring stations. Finally, the Panel expressed concerns regarding the EPA's effort to identify Corn Belt watersheds with significant atrazine exposure risks to aquatic communities by identifying NHDPlus watersheds within a focused 10 state area that have similar characteristics with respect to the identified factors as in the AEEMP sites which exceeded the LOC in multiple years. For instance, the relatively short AEEMP monitoring period does not adequately capture climate fluctuations and there may be other factors that influence atrazine runoff potential which were not captured in the AEEMP study design (e.g., see Frey et al. 2009 discussion regarding preferential flows and tile-drainage). A means of assessing the accuracy of this vulnerability assessment is needed, such as comparing measured and calculated (on the basis of flow contributions from vulnerable watershed areas) atrazine loads in major drainage basins (Illinois, Ohio, Mississippi).

B. EPA and Syngenta Progress Review

In 2007, the SAP encouraged EPA to take advantage of recent advances in national databases such as SSURGO and NHDPlus to identify watersheds that exceeded the LOC. The Panel commended EPA and Syngenta for the massive efforts they have made in this regard. For instance, EPA aggregated the NHDPlus catchment polygons for each AEEMP monitoring site to accurately delineate each monitoring site watershed area. They then evaluated soil and watershed characteristics for each of three LOC categories (i.e., exceeded LOC in multiple years, exceeded in 1 year only, and never exceeded LOC during monitoring period).

The soil and watershed characteristics studied in this analysis were obtained from geospatial data that have a higher spatial resolution (i.e., large scale) and were more accurate than the smaller scale geospatial data used prior to the SAP meeting in 2007 and included the following:

1) Updated average atrazine use data for the 2004 to 2007 period were provided to the Agency from Syngenta. Syngenta estimated these data for each NHDPlus catchment by combining the Doanes multi-county crop reporting district (CRD) average application rate per corn/sorghum acre with an estimate of the number of corn/sorghum acres in each catchment. For the majority of the Corn Belt, the latter were derived from the 2007 USDA-National Agricultural Statistics Service (NASS) cropland data layer (56-m resolution) and from the 2002 Agricultural Census and the 2001 National Land Cover Dataset (NLCD) where the NASS database was not available. In addition, for each AEEMP catchment, Syngenta provided yearly estimates of atrazine use. EPA, however, chose not to use these data because of questionable accuracy of the data sources between different years.

2) EPA used the SSURGO database to identify claypan soil areas. EPA noted during the 2007 SAP that research suggested that prolonged periods of elevated atrazine exposures in streams indicate the existence of "claypan soils" in the affected watersheds, where claypan is a "flow restrictive subsurface layer" which is much less permeable than overlying soil. Following the 2007 SAP meeting, EPA focused on identifying the "claypan soil" feature from the SSURGO database. Because the restrictive soil layer classification is not included in all SSURGO survey areas, EPA derived various metrics from the available SSURGO database to identify such restrictive horizons, as well as other metrics that may influence watershed vulnerability. These metrics included:

    a. % watershed area (WA) within various depth dependent classes (25cm…) of K_{sat}
    b. % WA within various classes of surface horizon organic matter% (OM%)
    c. % WA within various classes and depth dependence of clay content
    d. % WA within high and very high runoff classification
    e. % WA within various hydrologic soil groups (i.e., C and D)
    f. % WA within average slope classes for polygon dominant soils
    g. % WA in various soil drainage classes
    h. % WA within various classes of available water storage capacity
    i. WA-weighted average soil erodibility factor

In addition, EPA evaluated weather (monthly and annual rainfall, and rainfall intensity) and hydrology parameters (Dunne's overland flow and Horton's overland flow) for each WA. Upon evaluating relationships between these factors and the three LOC categories, the Agency concluded that atrazine use, depth (i.e., 25-, 50-, 100-, 150-cm) to low Ksat, High/Very High runoff potential, and soil hyrodologic group C or D were the most promising explanatory variables.

EPA identified additional comparable (i.e., with respect to drainage area and the 2004 to 2008 time period) atrazine water quality data collected from NAWQA and state government agency monitoring stations. The Agency is in the process of determining how effectively the classification factors cited above identify vulnerable watersheds as these are indicated by the additional monitoring data. EPA has also identified NHDPlus watersheds within a focused 10 state area that have similar characteristics with respect to the identified factors as in the AEEMP sites which exceed the LOC in multiple years. They are currently in the process of further refining the relationship between explanatory factors and watershed LOC exceedance.

Similarly to what EPA had done following the 2007 SAP meeting, Syngenta developed a method to identify vulnerable watersheds using combined national databases. Rather than the approach pursued by EPA that explored a wide variety of causative factors, Syngenta focused on only several variables, which they concluded from the literature, were the most relevant as explanatory variables of pesticide runoff vulnerability. These factors were: depth to impervious/restrictive layer, landscape slope, and land use. Syngenta developed a suite of software tools specifically for extracting, compiling, and analyzing the SSURGO and NHDPlus data, which provides tremendous flexibility and can be readily used to develop a variety of descriptive variables. In particular, and in contrast to EPA, they employed the NHDPlus Digital Elevation Model (DEM) data to create a national 10-m raster data set that they then populated with relevant features from both databases, upon which they subsequently based their analyses. The "slope" factor in the Syngenta analysis was derived from the 30-m resolution NHDPlus DEM files. Syngenta employed two alternative slope classes (0-2%, 2-5%, and >5% slope and <1%, 1-3%, and >3% as estimated at each 10-m grid node). In contrast to EPA's analysis, Syngenta used the older 2001 NLCD database for estimating land use as this database has complete, albeit dated, national coverage.

Syngenta also noted that the restrictive layer/argillic/fragipan horizon attribute data are neither complete nor available within all of the relevant counties in the SSURGO database, so they derived a related metric for each SSURGO polygon using the vertical distribution of Ksat values for the corresponding dominant soil series. They defined the depth to restrictive layer as being the depth at which the Ksat was less than or equal to 1.25 μm/s, with classification of depths of 0-30 cm, 30-60 cm, >60 cm restrictive layers.

The combined metric developed by Syngenta for assessing watershed vulnerability to atrazine runoff was slightly different than that developed by EPA and includes depth to impervious layer, slope, and land use (i.e., cultivated crop or other land use). They qualitatively examined the relation between this combined metric and the AEEMP results, which indicated a greater percentage of shallow impervious layer soils and higher slopes in the Missouri and Nebraska sites. Finally, they computed the occurrence of similar characteristics within the Corn Belt at both the NHDPlus catchment and AEEMP watershed scales. An additional effort was made to estimate runoff potential at the NHDPlus catchment scale using the PRZM model. Syngenta indicated during the meeting that these results will be forthcoming. Finally, they proposed continued efforts to improve land use classification to identify those soils under corn cropping, irrigation, etc.

C. Review of Agency and Syngenta Progress in Predicting Vulnerability

The Panel noted that the Agency and Syngenta have spent considerable time and effort in conducting background work to explain why watersheds in the AEEMP study had atrazine detections that exceeded the LOC in one or more years. The Panel was introduced to facts by the Agency that 10 of the AEEMP watersheds were classified as vulnerable (atrazine detections > PATILOC) to off-site atrazine movement and that these watersheds occur in the mid-west region of the USA (i.e., Ohio, Indiana, Illinois, Missouri, Nebraska, and Kansas). Syngenta provided a detailed soil, atrazine, and weather-based explanation for high runoff in the two to three Missouri sites, and indicated that they are in the process of refining the assessment of atrazine runoff in Nebraska, particularly at the 'dry-down' sites.

1) Atrazine use intensity and the percent of corn and sorghum acres

The factors considered by both the Agency and Syngenta were atrazine use intensity and the percentage of corn and sorghum acreage in upstream catchment areas. The Panel observed that it was intuitive to expect that regions with high atrazine use intensity or with crops that typically use atrazine would eventually experience some off-site transport of atrazine into nearby surface waters. Based on the data available to the Panel, the two crop management categories did not correlate very well with differences in atrazine exposure among the population of AEEMP monitoring sites. This lack of relation may be due in part to the fact that all of the monitoring sites are located in relatively high atrazine use areas; thus, reducing variance in use conditions within the data set analyzed. The Panel also observed that corn/sorghum production acreage as a characteristic may be an outdated parameter because of the use of Round-up Ready® corn is possibly reducing use intensities on corn over time.

The Panel recommended that the Agency and Syngenta continue to use these two factors as "first tier" threshold criteria for identifying watersheds at risk despite the lack of a strong relationship between these two factors (i.e., atrazine use intensity and relative percent of corn/sorghum acreage), The Panel determined that these criteria could be further simplified to: 1) minimum use intensity and/or 2) a fraction of the watershed in corn and sorghum, and that only one of these two criteria would need to be met The Panel also recommended using land use criteria based on the fraction of the watershed in corn and sorghum; for example, a threshold of ~10% of the watershed drainage area, rather than atrazine use intensity data due to the difficulty in acquiring it.

2) Soil series and slope influence on off-site atrazine movement

Atrazine use intensity could also have been a poor predictor because the chance of off-site atrazine movement may be low due to the majority of field sites containing soil series with modest organic matter content as thisis known to increase atrazine retention (Novak et al. 1996; Novak 1999). Based on the site selections of the original study design, the limited number of watersheds with detections suggests that other factors or processes which were not included in the WARP model may be controlling atrazine surface runoff potential in these watersheds. The Panel recommended that the EPA evaluate additional land use and management information in all of the monitored watersheds. For example, soil conservation best management practices (riparian buffers, filter strips, grassed waterways, terraces, strip cropping, etc.) could be effectively reducing surface runoff and thereby decreasing atrazine transport and the resulting number of detections in this set of watersheds. Such factors impact the Critical Source Areas (CSA) and contribute to pesticide runoff to surface waters (e.g., see Frey et al. 2009). Also, producer agronomic management decisions (e.g., incorporation of atrazine following application), timing of application in relation to rainfall events that generate surface runoff, and other variables may potentially influence atrazine losses via surface runoff.

Because there was a poor-to modest correlation between atrazine use and crop coverage, both entities selected the next logical course of action and that was an attempt to identify relationships between vulnerable AEEMP sites, local hydrology, and soil physical/chemical properties. Using data available from the USDA and others, EPA determined that vulnerable watersheds shared the following soil and landscape properties: shallow impervious layers (claypan), slopes > 2%, and cultivated crops that used atrazine for weed control. Considering that the watersheds with high atrazine MEIs were in areas that contained sloping soils with a clayplan (e.g., MO-01 and MO-02), the Panel considered these two soil features as likely factors involved in off-site atrazine movement. Syngenta presented visual evidence that water seeps from such soils and exits the agricultural field into streams. At one location shown in their photograph, they noted that the topsoil was eroded in an agricultural field and the claypan was exposed at the surface, thereby facilitating seep formation.

As reported by Lerch et al. (2008), there are several soil series in the Missouri region such as the Mexico silt loam, Putnam silt loam, etc. that have a very high content of clay (35 to 60%) that limit the transmission of water through the profile. Additionally, the clay fraction in these soil series are predominantly 2:1 smectitic clay, when wet, will swell and retard water transport. Thus, a profile layer is created with low hydraulic conductivity. Lerch et al. (2008) indicated that these soil features can promote water ponding during high rainfall periods and, if on a 2% or greater slope, can accelerate runoff. Most of these soils in Lerch et al. (2008) were classified as hydrologic group C and D (USDA-NRCS 2005) and have profile characteristics, such as claypans, that impede drainage and facilitate runoff.

The Panel thought that EPA should have identified a strong relationship between the slope factor used in their analysis and surface runoff (as the latter is indicated from stream atrazine concentrations) because this relationship has been demonstrated by numerous field-based observations. The Panel suggested that the lack of correlation between slope and surface runoff could result from scale compatibility problems between the DEM-derived slope coverages and the SSURGO soils data or possibly was indicative of other environmental variables that influence the monitoring results. The Panel recommended that EPA explore something similar to what Syngenta employed (e.g., terrain analysis using digital elevation models) to help identify additional environmental variables related to landscape configuration and landform geometry using GIS analysis. Conversely, these environmental variables may be operating at a more local geographic scale which is not considered in the Geographic Information System (GIS) analysis.

The majority of the geospatial data used in both the Agency and Syngenta analyses are in the public domain and are available to all researchers; whereas, the atrazine use intensity dataset is proprietary data from the Doanes database supplied to EPA by Syngenta. As discussed above, the Panel recommended that EPA use public domain data whenever possible (e.g., land use or USDA NASS pesticide use survey data) so that the GIS analysis can be independently re-examined and verified by other competent scientists as a component of scientific peer review. When proprietary data are used, every effort should be made to reach agreement on releasing the data on an aggregated scale, such as by watershed.

3) LOC exceedances

The Panel also noted that sites exceeding the LOC in one year seemed to receive less attention by both the Agency and Syngenta. These sites could be an exception, but this conclusion remains an uncertainty, especially given the summary of 15 years of monitoring data in Missouri (see **Table 1**, data provided by Dr. Robert Lerch, USDA-Agricultural Research Service (ARS)). Based on these data, 6 out of 40 AEEMP watersheds exceeded the LOC criteria in one year. The Panel indicated that these sites warrant further study of site parameters that might have resulted in these exceedances.

For example, the Panel recommended that the Agency consider one of these sites, NE-2, which exceeded the LOC in only one year, yet had relatively high detections in multiple years. There was one sample collected in 2006 with a concentration of 82 ppb following a 1cm/day rainfall. The previous year, this site had two maximum peaks of atrazine around 20 ppb each in conjunction with a 5-6cm/day rainfall. Yet, this watershed was characterized as containing ~40% soils with a high runoff potential and did not meet the C and D soil class criterion or the impervious layer criterion. The Panel recommended that other features that may explain why this site results in such a high atrazine runoff potential should be analyzed using both available datasets and visual observations. A visual site description might note setback area characteristics such as widespread presence of gullies or channelized flow which might increase likelihood of higher concentrations reaching streams. Typically, headwater watersheds have only intermittent flows, but, when flow does occur, significant atrazine detections have been observed. The Panel thought it would be wise to monitor the AEEMP Nebraska sites further downstream where flow is not intermittent and examine the atrazine loads for such areas.

In summary, the Agency reported that 70 percent of the catchment areas upstream of the three Misssouri monitoring sites that exceeded the LOC in multiple years had soils with a high-clay subsurface horizon (with > 40% clay as described by Lerch et al. 2008) within 50 cm of the surface. Syngenta indicated that sites with the co-occurrence of vulnerable soil factors along with atrazine use will inevitably experience atrazine concentrations exceeding the LOC in some years. This was demonstrated in both the chemographs and the modeled data. The Panel concluded that this was an acceptable explanation for the high correlation of these soil properties in watersheds with stream samples that exceeded the LOC. Hence, the Panel agreed with the Agency's identification of these soil characteristics along with the co-occurrence of certain landscape features and atrazine use, as salient features that contribute to off-site atrazine movement.

D. Comments on the Agency's Follow-up on Recommendations from the December 2007 SAP Meeting

The current Panel determined that EPA has not adequately addressed several recommendations made by the 2007 SAP (see FIFRA SAP 2008) with respect to identifying watershed vulnerability. These issues are summarized here:

1) Scale Issues

a) The Panel stated that the Agency has not clearly identified the scale of concern with respect to impaired stream segments. The relationship between chemographs and watershed scale was discussed during the 2007 SAP meeting, e.g., the concept that atrazine peaks may be attenuated with increasing watershed scale while frequency and duration of detections may or may not increase. This implies that the likelihood of exceeding an LOC will be a function of watershed scale. In particular, for stream segments within headwater watersheds that are situated adjacent to corn fields on runoff vulnerable soils, an LOC may very well be exceeded while a downstream monitoring station (such as at the AEEMP monitoring scale of 9 – 40 sq mi) may not indicate any ecological concern. The Panel posed the following questions for EPA: 1) "What is the minimal scale of concern?" and 2) "What are the ecological implications of this?" The implication of these questions is that EPA can identify more vulnerable areas and focus in on smaller NHDPlus catchments. The Panel also asked, "How do "flow scales" impact this scale of concern (i.e., intermittent flows)?"

b) The Panel suggested, as it did in the previous SAP, that an effort should be made to identify confluence of vulnerable sub-watersheds for which the larger watershed may be at risk. For example, Schriever et al. (2007) developed a simple model for estimating pesticide runoff in which they demonstrate that up to 77% of the variability in pesticide concentrations in streams (~20 ha headwater watersheds) could be explained by land use, topography, and precipitation within a 100 m strip on each side of the stream, which highlights the importance of proximity to the stream. Taking this analysis further suggests the hypothesis that watershed shape will have an impact on vulnerability, e.g., all else equal, long narrow watersheds will be more vulnerable than round wide ones. A metric related to median distance of watershed area from the stream may thus be related to vulnerability. Similarly, evaluation of land use/topography/atrazine use within a specified distance of the stream edge (i.e., 200-, 300-m on each side) may be a useful explanatory factor in regression efforts that relate watershed characteristics with vulnerability.

2) WARP Style Regression Analysis

The 2007 SAP recommended that the Agency use improved databases to perform a higher resolution spatial regression analysis similar to the WARP prototype (see the 2007 SAP Report, FIFRA SAP 2008). The Panel observed that Syngenta and EPA have made great progress in developing appropriate metrics for this type of analysis and recommended that such an analysis be performed. The majority of the Panel suggested that the Agency conduct a multiple regression analysis using a continuous response variable, such as MEI, or a direct concentration metric, such as the maximum annual 30-day rolling average. This approach would be very similar to WARP, (e.g., "Corn Belt" WARP, CB-WARP) and consist of a set of multiple linear regression models for selected percentiles (e.g., 5th, 25th, 50th, and so on) using the entire AEEMP monitoring data set. In addition, CB-WARP could be correlated to running averages (e.g., 14-, 30-, 60-, and 90-day running average triggers) to take concentration and duration into account. Keeping the focus on atrazine concentrations for the watershed analysis has the advantage of keeping a clear and transparent linkage between watershed characteristics and the levels and timing of atrazine in streams. This approach would also serve to support most possible approaches to LOC analysis rather than being locked in on a single type of MEI. Most importantly, however, is to use a continuous variable analysis over all possible sites rather than a categorical analysis to focus on just the few sites out of a small number that have LOC exceedances. In this analysis, some of the other parameters in WARP may need to be kept as well, such as the rainfall factor, watershed area, and Dunne overland flow. Atrazine use intensity is the preferred source term for the regression, but the percentage of watershed land in corn/sorghum may work as a surrogate if use estimates are not available. One member of the Panel indicated that USGS could provide guidance to the Agency on the development of CB-WARP and its application to discerning vulnerable from non-vulnerable sites.

E. Suggestions for Further Development of Watershed Vulnerability Assessments

The Panel indicated that the Agency has made excellent progress in assessment of watershed vulnerability. For the 40 AEEMP sites, soil properties show much greater variation than land use or atrazine use intensity, but no single property sufficiently distinguishes among vulnerable sites, as shown in Agency's issue paper, Figures VI-1 to VI-3. The Panel recommended that the properties listed in Agency's issue paper, Table VI-1, should be explored in a more quantitative way. They thought it was unclear whether or not some of the specific criteria proposed in Table VI-1 are the most appropriate (e.g., watershed area with >40% clay as opposed to some other percentage); however, the soil characteristics represented in the table are the appropriate properties for assessing vulnerability. The Panel noted that the Agency might reconsider the use of K_{sat} <1 µm/s (see soil criteria in Table VI-1) because the SSURGO database contains a number of mapping units with K_{sat} values equal to or slightly greater than 1 µm/s. Two public commenters for Syngenta provided a rationale for using K_{sat} <1.25 µm/s. The Panel explained that this is just a practical issue to avoid exclusion of soils that have limited hydraulic conductivity. The Panel concurred with the Agency's focus on impermeable soils as this factor has been found to be highly correlated with non-point source pollution of fecal coliform bacteria, chemical contaminants, and nutrients.

The Panel offered the Agency the following recommendations to further assist them in developing the means to identify and classify watersheds that are vulnerable to atrazine exposures.

1) The Panel recommended that the Agency and Syngenta share common databases and software tools in this effort, such as the 10 m grid raster national database developed by Syngenta to estimate runoff potential. Syngenta created a 10 x 10 m nationwide master grid which has soil type and soil characteristics, and then employed the NHDPlus 30 m DEM to estimate the slope at each grid node, and employed these estimates to calculate a fractional percent of each headwater watershed within specific slope classes. In contrast, EPA uses the high to very high runoff potential for each dominant soil type/soil polygon in SSURGO (an estimate which is a function of average slope for the polygon and surface horizon K_{sat}).

2) The Panel agreed with EPA that hydrologic soil groups D and C, and shallow impervious layers can be indicators of high runoff potential that may affect atrazine fate and transport to adjacent streams/sites. They are, however, not the only factors that result in high atrazine exposure levels. In some cases there may be a relationship and, in other cases, the relationship might be very weak or these factors may have no relationship at all. The Panel recommended that the Agency consider other major factors, such as topography, buffer areas, and timing of rainfall (particularly with respect to planting date), in addition to atrazine use intensity and the present suite of explanatory factors in order to identify vulnerable watersheds Further, the Panel recommended that the Agency consider the distribution of composite curve numbers (CN) because CNs integrate both soil and land use information, and these variables have been shown to correlate well with TSS, chemical contaminants, nutrients and fecal coliform bacteria.

3) The Panel recommended that basin slope and channel slope can be better predictors that affect surface runoff and atrazine transport instead of using a point scale or dominant soil average slopes. These values would provide an assessment of the impact of geometry on the conveyance system which determines in part the runoff vulnerability potential.

4) The Panel recommended that the NHDPlus data set should be re-examined to study the potential effects of flow line elevation, flow volume and other elevation-derived data which influence surface runoff and soil hydrology. More detailed, larger scale elevation data may be needed for spatial analysis at the watershed or catchment scale. An index that has proven useful elsewhere is the relationship between the volume of the receiving stream and the surface area of watershed/agricultural land use area. This ratio has been shown to be a highly predictive indicator of stream vulnerability.

5) The Panel recommended other options to further improve the assessment of the interaction of topography, land use, soil characteristics, and regional precipitation patterns might include a Runoff Propensity Index, something recommended by the 2007 SAP (see FIFRA SAP 2008). This index can be created if historic flow data are

available and is given as the ratio of the 90th percentile Q/10th percentile Q >2, where Q is volumetric flow rate. When such information is not available, modifications of the Organization for Economic Cooperation and Development's (OECD) Simplified Formula for Indirect Loadings caused by Runoff (SFIL) may be a possible alternative. Two examples that illustrate such applications to derive a generic Stream Runoff Potential are Schriever et al. (2007) and Berenzen et al. (2005). Both of these approaches rely on regional or national databases. These approaches have predicted from about 45 to 77% of the variability in pesticide runoff in small streams (~20 ha drainage areas). The methods employed in these papers only consider land use and topography within 100 m of the stream edge, which highlights the importance of the stream buffer areas. During the 2009 SAP meeting, several panel members pointed out the importance of the setback area between the fields and streams. Presence of riparian buffers in these areas can drastically reduce atrazine concentrations in surface runoff. In contrast, bare soil, presence of gullies, and seeps in the setback areas would not diminish concentration and potentially could enhance movement of atrazine from the field to streams.

F. Stream Concentration Metric for Assessing Watershed Vulnerability

One panel member noted that several sites have fortuitously been identified, and thus, there is now an increased focus on identifying regions with shallow impervious layers in co-occurrence with sloping topography. The question is whether other watershed areas have physical and land use characteristics that also lead to elevated exposures. For example, the current AEEMP design ignores the presence of tile-drainage in each watershed, yet studies have shown that tile-drainage and similar preferential flow paths can result in elevated pesticide concentrations in surface waters (e.g., Frey et al. 2009). It is essential to consider that such factors may play a significant role in increasing watershed vulnerability to atrazine exposures yet the current Agency approach to assess vulnerability does not include consideration of such factors. The Panel stated that to answer the question of whether there are other factors that lead to elevated exposures which enhance the ability to identify vulnerable watersheds, it may be more useful to shift the analysis to a logistic or multiple regression method (such as WARP-CB) and supplement the analysis to include the existence of tile-drainage and critical source areas within the AEEMP sites. The logistic approach would provide an estimate of the probability that a given watershed will exceed the LOC; whereas, the multiple regression method could be used to estimate various chemograph metrics such as annual maximum peak concentration, maximum 30-day rolling average, etc. The Panel recommended using multiple regression with standardized concentrations (e.g., observed concentration/estimated mass applied in up-stream watershed, log(max) observed standardized concentration/yr, used in Schriever et al. 2007), if possible. If not, then the Panel suggests considering a logistic regression approach. Either approach has the advantage of using all of the available data.

The Panel provided the Agency with several recommendations to improve these predictions. Other possibilities included trying to use crop type, watershed and pesticide use statistics to predict vulnerability to atrazine. Another suggestion was to examine the approach NOAA has used for predicting coastal area vulnerability to oil/hazardous material as a model for developing an atrazine watershed vulnerability index tool.

G. Watershed/Hydrograph Signature

The Agency mentioned that one of the reasons for exceeding the LOCs at the Missouri sites is the combination of surface runoff and subsurface through flow (i.e., water flow below the surface and above the impervious shallow layer). The Panel suggested that the chemograph/hydrograph provides a signature of watershed hydrologic and management features. They recommended that the Agency focus on the hydrograph from April through June, and investigate the fraction of total flow that is both base or event flow, and further relate these features to storm intensity and duration, and the other explanatory factors discussed previously. Subsurface lateral flow may result in relatively higher base flow contributions and, as EPA noted, this flow appears to be related to elevated atrazine concentrations during base flow periods. In particular, perhaps the temporal correlations in flow and atrazine concentration can be related to local watershed features such as the mechanism of subsurface lateral flow.

H. Improved Precipitation Records/Planting Date Estimation

The Agency pointed out the importance of rainfall timing relative to planting date. The Panel agreed that this may be a critically important factor. Distinctions were made during the Panel's deliberations between corn and sorghum planting dates, with the latter typically occurring several weeks after corn planting. The Panel discussed possible improvements in developing watershed average rainfall data rather than that recorded by a single gauge at the flow monitoring stations such as the National Weather Service Quantitative Precipitation Rainfall Forecast (QPRF) and NOAA radar data (NEXRAD). Finally, the Panel noted several options for estimating corn planting date, including examining historic weather data such as soil temperature at 4-inch depth and daily rainfall to identify "windows" of opportunity for growers to plant corn. One panel member indicated that local/regional farm news websites and or state/county extension service databases provide daily or weekly estimates of the fraction of a county (or region or state) that has been planted. The Panel determined that acquiring more accurate weather and planting date information was reasonable since yield is usually influenced by planting date, and thus farmers are striving to plant as soon as weather and field conditions allow.

I. SSURGO Uncertainty

The SSURGO county-level soils data consists of soil polygons or delineations with multiple components; typically, a maximum of three soils composed of dominant or major soils, and minor soils. EPA conducted their GIS analysis of SSURGO using the dominant soils components to reduce the complexity of the preprocessing steps. Syngenta reported at the SAP that their analysis of SSURGO used both the major soils and minor soils components. The Panel recommended that EPA either re-analyze their SSURGO data using both major and minor components or work with Syngenta to acquire their dataset of the pre-processed SSURGO data for analysis. This recommendation is based on the field observation that small field areas of minor soils, although present in a smaller spatial extent than the dominant soils, may serve as the area of a watershed which generates the greatest amount of surface runoff.

This potential high runoff condition might be missed using only the dominant components data.

Finally, neither Syngenta nor EPA has discussed and/or evaluated the uncertainty in various SSURGO data values (i.e., vertical distribution of K_{sat}, dominant vs. minor soil classes, etc.) and this uncertainty influences the analysis. The Panel pointed out that USDA-NRCS publishes their scientific information and technical references on the Internet. The National Engineering Handbook, Part 630 Hydrology, Chapter 7 Hydrologic Soil Groups (HSGs) contains detailed information in Table 7-1 on the rule sets as a decision matrix for using soil properties to assign the various HSGs. This chapter is available at http://policy.nrcs.usda.gov/RollupViewer.aspx?hid=17092. This report provides the most up-to-date criteria for determining the assignment of a soil to HSG classes. The HSG criteria are (1) depth to an impermeable layer, (2) depth to high water table, (3) K_{sat} of the least transmissive layer in a depth range, and (4) K_{sat} depth range. Dual classes are also possible in some soils. One panel member recommended that the Agency review these classification criteria.

J. Applications of PRZM for Vulnerability Assessment

The soil properties used for modeling vulnerable watersheds serve as a proxy for soil hydrology on a spatial scale. The soil attributes in SSURGO are reported as static, intrinsic properties that do not vary in time but do vary in space. However, soil hydrology is a dynamic condition with intrinsic variables that vary spatially and temporally (e.g., saturated hydraulic conductivity) and extrinsic variables which also vary in time and space (e.g., rainfall, timing pesticide application). The variation of soil hydrology can be augmented using model simulations from (PRZM) (a Pesticide Transport Model) or SWAT (a Soil and Water Assessment Tool) in combination with either historic climate data or, ideally, by using NOAA NEXRAD weather data or similar dynamic weather data.

Along these lines, an initial effort has been made by Syngenta in the application of the PRZM model. PRZM has been applied to estimate a relative vulnerability index for numerous soil and NHDPlus catchment polygons using climate data assembled over a 30-year time period. However, PRZM is actually a one-dimensional pesticide transport model which is not capable of addressing watershed issues. For a given area (field or watershed), it is assumed that all inputs (e.g., rainfall, pesticide application, etc.) are uniformly distributed. The Panel noted that while this has apparently not been done yet, Syngenta proposes to use the PRZM output for each polygon and couple this output via overland flow routing to estimate the associated atrazine runoff across the area or sub-basin, and to thereby develop a relative metric for assessing vulnerability.

PRZM is a physically-based pesticide transport model; therefore, it requires extensive and detailed input data at a daily time interval (e.g., rainfall, antecedent soil moisture, atrazine application, etc.). For example, users need to provide specific application dates, application methods, and quantities for atrazine applications. The Panel expressed concerns about the accuracy and availability of such intensive data/information for all polygons for the 30-year simulation period for the modeling. Any model should be calibrated and validated. The Panel noted that considerable atrazine concentration data are available for the selected watersheds and recommended that the Agency select some typical sub-basins for model calibration and validation.

Even if concerns regarding data limitations and overland flow routing are adequately addressed, this approach ignores a primary impact of shallow impermeable soil layers on sloping topography. In such situations, impermeable layers will produce significant horizontal subsurface flows. This 2-D flow and transport across an area, polygon, or sub-basin cannot be simulated with the 1-D PRZM model as the latter does not have the capability of simulating such interflow across an area/polygon/sub-basin. The Panel indicated that the Agency may want to consider this issue further.

K. Retrospective Assessment of Potential Long-Term Ecological Impacts of Atrazine in MO-02.

Prior to this SAP meeting, one panel member provided the Agency with atrazine concentration data for Goodwater Creek, Missouri (MO-02) as part of EPA's overall efforts to assess other atrazine monitoring data sets (EPA's issue paper, Section VI. D.) EPA's issue paper incorrectly states that the USDA-ARS Goodwater Creek data represents a different sub-watershed than MO-02, but the monitoring stations for ARS and the AEEMP are co-located on opposite sides of Goodwater Creek, near its outlet to Young's Creek.

The Panel presented the 15-year ARS atrazine dataset for Goodwater Creek (MO-02) to illustrate the importance of identifying watersheds vulnerable to atrazine transport in surface runoff. The ARS long-term monitoring results provided a more accurate characterization of the frequency with which atrazine may have exceeded a calculated LOC estimated from CASM, PATI, or other MEI in a vulnerable watershed. This assessment also addresses the assertion by Syngenta that vulnerable watersheds would not necessarily consistently exceed the LOC because of the effects of agronomic practices and rainfall timing on variation in atrazine transport. Goodwater Creek has been monitored by the USDA-ARS since 1992. **Table 2** below shows the number of days that a given running average trigger was exceeded in a given year, and the maximum running average concentrations based on the ARS data from 1992 to2006.

In 10 of 15 years, at least one of the running average criteria was exceeded in Goodwater Creek, and in eight of those years, multiple running averages were exceeded **(Table 2**). In four years (1992, 1996, 1997, and 2006) all four running averages were exceeded for multiple days. The 14- and 60-day criteria were exceeded least frequently (six of 15 years), and the 90-day criterion was exceeded most frequently (nine of 15 years). The years with three or more criteria exceeded shared common patterns with respect to their flow-weighted concentrations, with >30 consecutive days per year exceeding 10 $\mu g\ L^{-1}$ and peak concentrations >50 $\mu g\ L^{-1}$ for at least one day per year. For example, in 1992 flow-weighted atrazine concentrations reached a peak of 106 $\mu g\ L^{-1}$, and atrazine concentrations exceeded 10 $\mu g\ L^{-1}$ for 53 days. In the five years with no exceedance (1994, 1998, 1999, 2000, and 2003), high concentrations occurred in two or more discontinuous periods over shorter time intervals (<20 days), and peak concentrations were generally <40 $\mu g\ L^{-1}$ and always <50 $\mu g\ L^{-1}$. There was one period of consecutive years, from 1998 to 2000, without an exceedance of the screening criteria.

Thus, short-term monitoring studies, such as the AEEMP, in relatively small watersheds like Goodwater Creek, may result in underestimation of the potential ecological impact of atrazine. Because of the annual variation in conditions that cause high atrazine concentrations, the ARS long-term monitoring results provided a more accurate characterization of the frequency with which atrazine impacted the aquatic ecosystem in Goodwater Creek. In considering the probability that a vulnerable watershed would exceed the LOC, the Panel recommended that EPA take into consideration that the short duration of the AEEMP monitoring study could result in underestimation of the ecological impacts of atrazine, and this is a potentially important source of uncertainty in the AEEMP study.

Table 2. Days per year in which the running average atrazine concentrations exceeded the screening criteria established by the USEPA 2003 interim re-registration eligibility decision (IRED)[†].

Year	14-Day	30-Day	60-Day	90-Day
1992	35 (86.4)[‡]	44 (71.1)	68 (47.1)	105 (32.3)
1993	0	6 (29.2)	34 (23.3)	66 (16.9)
1994	0	0	0	0
1995	8 (44.9)	5 (27.6)	0	0
1996	14 (62.1)	25 (38.7)	44 (26.4)	93 (23.4)
1997	18 (65.3)	30 (47.1)	56 (30.5)	89 (22.3)
1998	0	0	0	0
1999	0	0	0	0
2000	0	0	0	0
2001	5 (43.0)	2 (27.3)	0	24 (12.9)
2002	0	0	0	16 (13.1)
2003	0	0	0	0
2004	0	9 (29.4)	7 (18.4)	40 (13.2)
2005	0	0	0	59 (13.5)
2006	2 (38.3)	15 (34.5)	35 (19.5)	69 (14.8)

[†] Running average concentration screening criteria established by the IRED:
14-day = 38 µg L^{-1}; 30-day = 27 µg L^{-1}; 60-day = 18 µg L^{-1}; 90-day = 12 µg L^{-1}.

[‡] Numbers in parentheses indicate the maximum running average for the year, in µg L^{-}

Question 5: Neither atrazine use intensity or rainfall data (annual or monthly) correlate positively with watersheds that exceed the LOC. The Agency noted that the monitoring site selection already focused on areas with sufficient atrazine use to potentially result in high atrazine exposures in streams. **Please comment on the Agency's proposed approach to establish a minimum criteria for atrazine use intensity (> 0.1 lb ai/A) and rainfall (>23 inches annually).**

Panel Response

A. General Response

The Panel indicated that the Agency should pay careful attention to temporal scale when identifying correlations that can be used to identify watersheds likely to be vulnerable to have high atrazine exposures. The two minimum criteria suggested by the Agency, atrazine use intensity (> 0.10 lb ai/A) and rainfall (> 23 inches annually), are annual measures. Rainfall timing and intensity related to atrazine application are important factors that greatly influence atrazine runoff potential; however, additional factors such as land use, land cover, soil conditions, crop management practices and other variables should also be evaluated. These runoff events generally occur during three months each year. The Panel, therefore, suggested that the Agency use a shorter, more appropriate time interval, such as days, weeks or months (Pappas et al. 2008). The Panel expressed doubt that these criteria, even at a shorter time scale, would be able to adequately identify vulnerable watersheds. The Panel recommended that a multiple regression approach be used instead of the proposed indicators of rainfall and atrazine use intensity. The Panel also considered a logistic regression approach as another alternative. Each of these regression approaches was discussed including an example of how to use a multiple regression approach.

B. Multiple Regression Approach

Currently, each study site is categorized as being above or below the LOC. Yet, some sites are well above the LOC and others are borderline LOC. This information about a site's relationship to the LOC is lost when forming categories, especially during an early phase of the analysis. Assuming that the raw MEI, concentration duration, or some other response variable can be calibrated to the cosm studies, multiple regression can be used to predict the response for a given set of environmental, agricultural, and anthropogenic variables, such as rainfall, soil, topography, land cover, agricultural management, pesticide use, percent land in corn, percent land in sorghum, and atrazine application per hectare. In this approach, variables should only be treated as categorical if that is appropriate. As an example, soil type is categorical, but atrazine use is not and should be treated as a continuous variable.

The Panel noted that the Agency has acquired a good scientific understanding of the primary factors influencing atrazine runoff. This knowledge can be used in a science-driven approach to select the variables. This latter process is more time intensive than automatic methods such as forward selection and backward elimination but may result in a model that is more meaningful to users.

Although the study is data rich, only 40 sites have been studied. The Panel appreciated the effort that EPA has made to identify additional sites that can potentially be used in this phase of the study. The Panel indicated that the Agency will need to ensure that each of the sites has enough information of the requisite quality to determine the value of the response variable, whether it be raw MEI or some other measure. If sufficient data are not available for independent validation, cross validation and other model assessment tools should be used.

The Panel indicated that care should be taken in evaluating the fit of the model. The model should be evaluated on a data set that was not used to develop the model. If additional sites can be identified as mentioned above, then some or all of these could be used as the validation set. The Panel indicated that once a model(s) is/are developed and validated, the response variable (e.g., raw MEI) could be predicted and used in the overall risk assessment and risk characterization of atrazine.

C. Logistic Regression Approach

If an appropriate response variable cannot be properly calibrated to the cosm studies, it may be necessary to categorize each site as being above or below the LOC. This represents a loss of information compared to the preceding approach because it would no longer be evident whether a site was well above the LOC or borderline to the LOC. However, if this is the best that can be done, then a logistic regression approach could be used. In this approach, the goal is to model the probability that a site exceeds the LOC given its environmental, agricultural, and anthropogenic characteristics. The basic approach of identifying potential explanatory variables, fitting the model, and assessing the fit is the same as in multiple regression. The difference lies in the result of the predicted probability of exceeding the LOC instead of raw MEI or some other response variable. As an example, a site may have a probability of 0.5 of exceeding the LOC in a given year. In that case, about half the years the site would be expected to exceed the LOC and half the years it would not exceed the LOC. The Agency would have to decide the probability of exceeding the LOC that would warrant further study.

D. Revision to Current Approach

If a multiple regression approach is used, specific criteria for atrazine use intensity or land use should not be necessary. However, if such criteria are deemed necessary, the Panel agreed that the Agency's proposal to establish a minimum use criterion of >0.1 lbs ai/acre is reasonable as a first-tier criterion for identification of vulnerable watersheds. Given that atrazine use intensity data are more difficult to acquire than land use information, the Panel recommended that a land use criterion based on the fraction of the watershed in corn and sorghum be used instead of atrazine use. Some threshold in the range of 10% of the watershed drainage area might be sufficient.

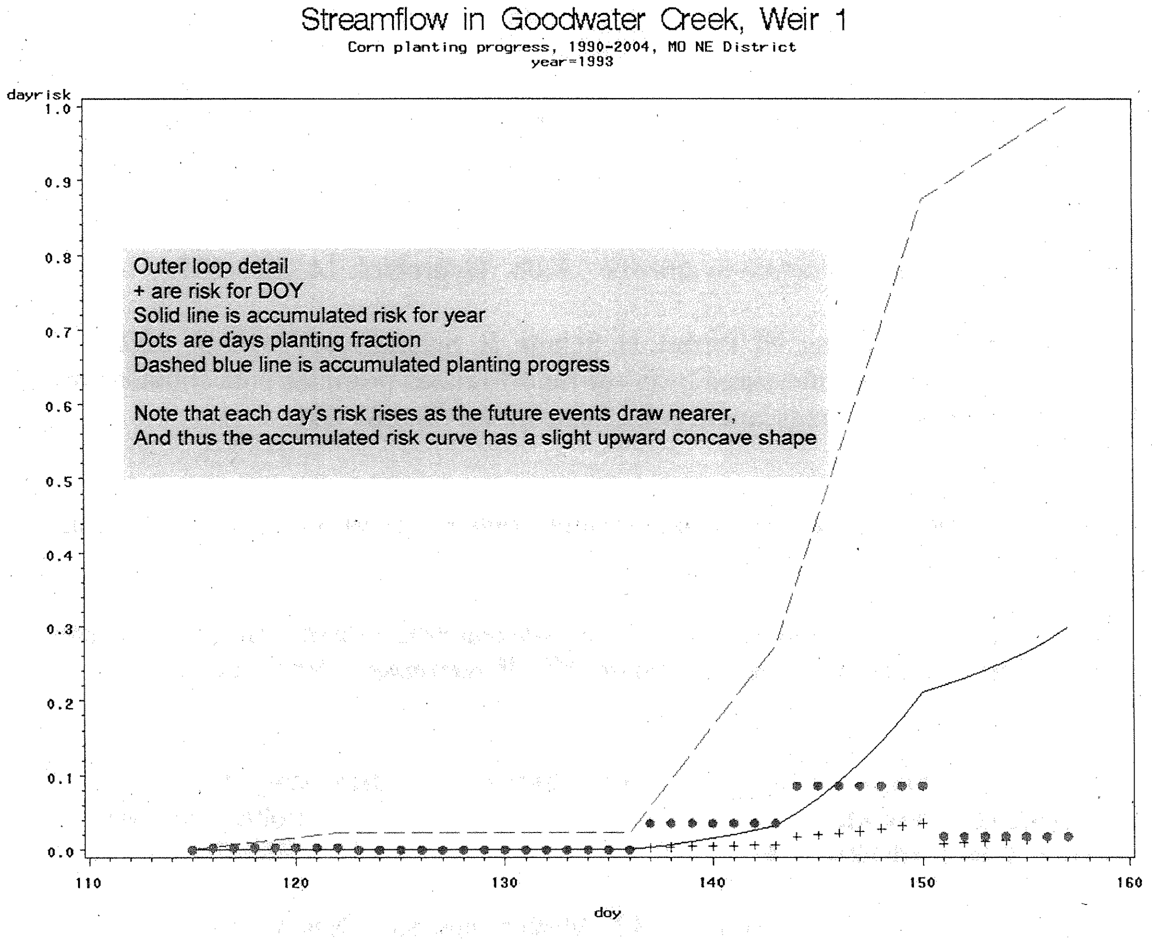
The Panel thought that the rainfall criteria of >23 inches annually was not useful as an indicator of vulnerability. Instead, they stated that what is really needed is the development of an index of herbicide loss vulnerability that takes into account the risk associated with rainfall timing relative to atrazine application in a given watershed. This factor is the single largest source of variation in annual atrazine transport for HUC-10 and smaller watersheds. An ancillary risk factor to rainfall timing is the antecedent moisture conditions at the time of the first runoff event following application. The development of an index of herbicide loss vulnerability can be accomplished using stream discharge data and crop district reports for corn planting progress, which is used as a surrogate for atrazine application progress within the watershed. This type of index is independent of discharge magnitude and only a minimum threshold for designating a runoff event is required. The USDA-ARS is in the process of developing such an index for Goodwater Creek (MO-02; see the discussion below), but the development of this index on an annual basis for specific watersheds at the HUC-10 (or AEEMP) scale may be impractical. If that is the case, the Panel suggested that the R factor (rainfall intensity) currently used in WARP might sufficiently capture the risks associated with rainfall at the scale of the AEEMP.

Creating an annual index of herbicide loss vulnerability

The discharge hydrograph can be reduced to a sequence of binary event indicators; thus, this will account for timing after application without involving quantitative discharge data. For Goodwater Creek (MO-02), atrazine dissipation rate was considered constant in space and time, and a field-based derivation (Ghidey et al. 2005) of the first-order rate constant (k) was used. Weekly planting progress data for the northeastern crop reporting district of Missouri were used as the surrogate for herbicide application timing (USDA-NASS 1992-2006). In addition, the first reported value for planting progress is the first non-zero value observed. Thus, a zero is pre-pended one week ahead of the first non-zero value, and all values are scaled to the maximum planting progress, making a range of weekly values from 0 to 1. This series of weekly values was expanded to daily values by linear interpolation, and the daily planting values (DP_i) were found by difference from the day before. The first day, last day, and length of the planting season (LS) were also obtained here. Since discharge rarely returns to zero during the herbicide loss periods, some method to separate runoff events was required. The series of event indicators (Ev_i) was developed by setting a value of 0 for all daily discharge less than an arbitrary threshold (T), set here to a daily average discharge of 10 mm d^{-1}. The value is 1 for all daily flows greater than or equal to the threshold. This series of event indicators starts the first day of planting and extended 100 days beyond the last day of planting. For a given day of planting, the daily weight (DW_i) was the weighted accumulation of the product of the event indicator and the dissipation residual (e^{-kt}), where t is time between the day of planting and the day of the event. This accumulation needs to run for a length of time (LA) defined by the steepness of the dissipation curve. For initial purposes, we used an arbitrary duration of 100 days. This corresponds to a minimum weight of 0.000335 for a k=0.0625 as found by Ghidey et al (2005).

$$DW_i = \sum_{i=1}^{LA} Ev_i * e^{(-kt)}$$

For a season, the annual weight (AW) is the accumulation of the daily weights multiplied by the daily planting progress fraction (DP_i). **Figure 1** below shows an example for Goodwater Creek (MO-02) for 1993. The accumulated risk for 1993 was about 0.3 (on a scale of 0 to 1). This process was repeated for our 15-year dataset (1992 to 2006) to acquire annual risks for each year. The vulnerability index showed a strong correlation to annual atrazine load (r^2 ~0.70) in Goodwater Creek, demonstrating that the index can explain a large portion of the annual variability in atrazine transport for a specific watershed.



Outer loop detail
+ are risk for DOY
Solid line is accumulated risk for year
Dots are days planting fraction
Dashed blue line is accumulated planting progress

Note that each day's risk rises as the future events draw nearer,
And thus the accumulated risk curve has a slight upward concave shape

Figure 1. Streamflow in Goodwater Creek, Weir 1, 1993

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Appendix 1
Sediment Quality Guidelines

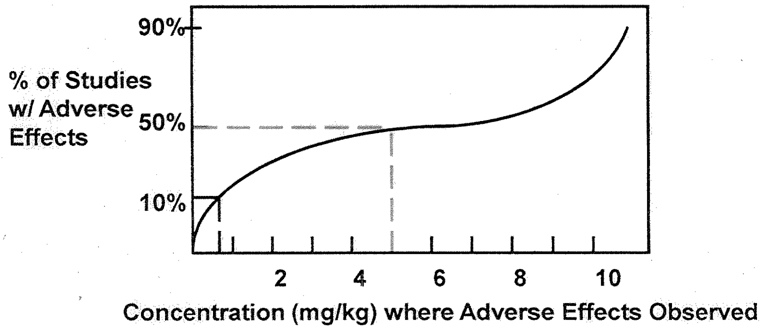
Presented by Dr. Geoffrey Scott,
Member of the FQPA Science Review Board

- The paper by Long & Morgan (1990) set in motion attempts to develop Sediment Quality Guidelines (SQGs).
- Long et al. (1995. Env. Management 19:81-97) published SQGs for trace metals, pesticides, PAHs & PCBs using all published QA/QC data from estuarine, marine & freshwater.
- For each compound a cumulative frequency distribution curve was developed ranking data from the lowest to highest concentration causing effects. Two terms are derived:

  - Effects Range Low (ERLs = 10% of the cumulative frequency distribution of published data)

  -Effects Range Median (ERMs = 50%)

Apparent Effects Threshold (AET) Methodology
10% = Effects Range Low (ERL)
50% = Effects Range Median (ERM)
Cum. ERM Quotient = Combined Effects



Sediment Quality Guidelines

- MacDonald et al. (1993). Development of an approach to the assessment of sediment quality in Florida coastal waters. FL Dept. of Env. Protection: 133pp) developed a different approach to SQGs using a more limited data set for the SE U.S.
- Data was divided into a "no effects" & "effects" data set which was ranked from low to highest concentration for each data set using a cumulative frequency distribution

Sediment Quality Guidelines

- MacDonald et al. (1993) calculated 2 terms:

-Threshold Effects Levels (TELs) = the geometric mean of the 50th % of the No Effects Data and the 15% % of the Effects Data distributions

- Probable Effects Levels (PELs) = the geometric mean of the 85th % of the No Effects Data and the 50% % of the Effects Data distributions

Sediment Quality Guidelines

- TELs and ERLs are usually quite similar

- PELs and ERMs are usually quite similar

- Example As
  -TEL = 7.24 ppm vs. ERL = 8.2 ppm
  - PEL = 41.6 ppm vs ERM = 70 ppm

ERLs and TELs: Trace Metals

Contaminant	*TEL (ppm)*	*ERL (ppm)*
As	7.24	8.2
Cd	0.68	1.2
Cr	52.3	81.0
Cu	18.7	34
Pb	30.2	46.7
Hg	0.13	0.15
Ni	15.9	20.9
Ag	0.73	1.0
Zn	124	150

Contaminant: PAHs	**TEL (ppb)**	**ERL (ppb)**
Acenapthene	6.71	16
Acenpathylene	5.87	44
Anthracene	46.9	85.3
Fluorene	21.2	19
Napthalene	34.6	160
2-methylnapthalene	20.2	70
Phenanthrene	86.7	240
Total Low MW PAHs	312	552
Benzo(a)anthracene	74.8	261
Benzo(a)pyrene	88.8	430
Chrysene	108	384
Diben(a,h)antrhacene	6.22	63.4
Fluoranthene	113	600
Pyrene	153	665
Total High MW PAHs	655	1,700
Total PAHs	1684	4022

APPENDIX 2

Search terms used in Web of Science

Atrazine and mesocosm* and phytoplankton
Atrazine and mesocosm* and periphyton
Atrazine and mesocosm* and macrophyte*
Atrazine and mesocosm* and chlorophyll
Atrazine and microcosm* and phytoplankton
Atrazine and microcosm* and periphyton
Atrazine and microcosm* and macrophyte*
Atrazine and microcosm* and chlorophyll
Atrazine and community and phytoplankton
Atrazine and community and periphyton
Atrazine and community and macrophyte*
Atrazine and community and chlorophyll

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