

February 2013

User Manual for the Water Quality Benefits Spreadsheet

Prepared by

Daniel J. Phaneuf

University of Wisconsin

Roger H. von Haefen

North Carolina State University

Carol Mansfield, George Van Houtven and Ross Loomis

RTI International

CONTENTS

<u>Section</u>		<u>Page</u>
1	Introduction.....	1
2	Water Quality Benefits Spreadsheet Structure	3
3	Inputs.....	4
	Baseline Water Quality	4
	Target (Counterfactual) Water Quality	5
	Recreation Trips.....	5
	Timeframe and Discount Rate	5
4	Running the Water Quality Benefits Spreadsheet	6
	Single Input Model	6
	Multiple Input Model.....	6
5	Outputs.....	8
	Baseline and Counterfactual Water Quality Index	8
	Estimates for Annual and Total Benefits	9
	Uncertainty Assessment.....	9
6	Technical Details	10
	Imputation	10
	Predicting Index Values.....	11

	Predicting Economic Values.....	12
	Quantifying Uncertainty	12
7	Examples.....	13
	Example 1: Single Input Version.....	13
	Example 2: Multiple Input Version	15
8	Project Documents	18

SECTION 1 INTRODUCTION

The Water Quality Benefits Spreadsheet is the result of a project, funded by a grant from the U.S. Environmental Protection Agency Office of Water (Grant #X7-83381001-0), whose objective was to provide an integrated protocol for state water quality managers to use in setting numeric ambient nutrient pollution standards for surface water. The tool links measured nutrient pollution (e.g., ambient nitrogen, phosphorous) to a qualitative ranking of water quality and produces dollar-denominated benefits of nutrient reductions as they pertain to recreation services. Section 8 provides references for the two primary reports from the project that present details on the approach, the data, the analysis and the results. The Water Quality Benefits Spreadsheet uses the results from the project to create a tool that can be used to estimate the benefits of reducing nutrient pollution.

The study was conducted using water quality data from freshwater lakes in North Carolina and a survey of adults in Alabama, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee, and Virginia. Extrapolating the results from the Water Quality Benefits Spreadsheet beyond recreational use of freshwater lakes in the southeast is not recommended.

This document provides background information and instructions for using the Water Quality Benefits Spreadsheet to estimate the benefits of meeting a set of nutrient targets at a single lake undergoing policy analysis. Figure 1 outlines the general structure of the model. The user enters baseline water quality measures that are specific to the policy lake and sets the target or nutrient criteria, and the spreadsheet calculates the monetary values for the recreation benefits associated with the change from baseline water quality to the target water quality. The models underlying the spreadsheet calculations are described in the technical documents associated with the project (references are listed in Section 8). In this manual, Section 2 provides a description of the spreadsheet structure, Section 3 describes each of the necessary inputs, Section 4 explains how to run each model, and Section 5 explains the model outputs. In Sections 6 and 7, we provide more technical information on the computations that occur within the spreadsheet as well as example calculations.¹ Section 8 contains references for the project reports that provide the technical details underlying the Water Quality Benefits Spreadsheet.

¹ The workbook structure and underlying code are protected by a password. Users who wish access to the code should use the password “wq”.

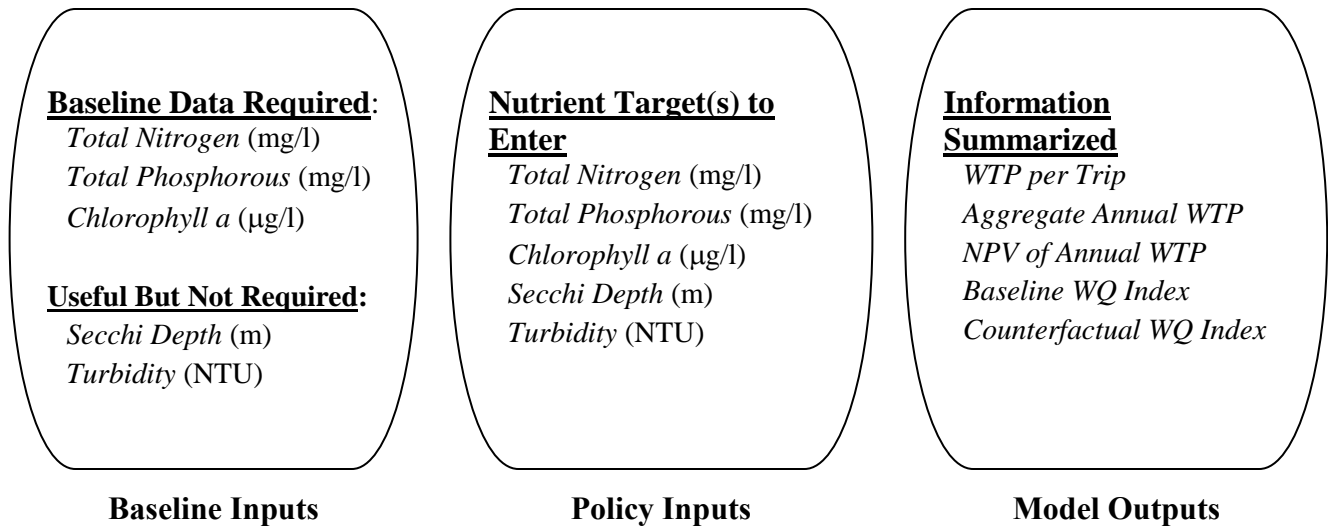


Figure 1. Water Quality Benefits Spreadsheet Overview

SECTION 2

WATER QUALITY BENEFITS SPREADSHEET STRUCTURE

The spreadsheet consists of six individual worksheets that together provide two ways of interacting with the model. The first three worksheets, labeled **Input Data**, **Output Table**, and **Chart**, comprise the *single input* version of the model. The single input version of the model uses mean values for the baseline water quality inputs to calculate the benefits of reaching the target over a designated length of time. The major assumptions used in the single input version of the model include the following:

- Baseline water quality is constant over the time period being evaluated.
- Trips to the lake are constant over the time period.
- Water quality improves to the target level immediately and stays at the target level for the entire time period.

The next three worksheets, labeled **Annual Input**, **Annual Output**, and **Annual Value Chart**, comprise the *multiple input* version of the model. The multiple input version of the model allows for more realism in how policies are defined. The user may vary the water quality baseline, targets, and other inputs annually over a designated number of years. With the multiple input version of the model, the user can

- enter new values for baseline water quality for each year (e.g., allowing baseline water quality to deteriorate over time),
- increase the number of trips to the lake over time as water quality improves, and
- enter intermediate targets for each year to account for interim benefits as water quality improves before reaching the final target.

SECTION 3 INPUTS

Both the single and multiple input versions of the model require similar inputs. In general, these inputs include

- water quality values that establish the baseline conditions at the lake;
- water quality values that establish the policy target—or counterfactual—conditions at the lake;
- an estimate of the annual number of recreation visits to the lake;
- the number of years over which the policy is to be evaluated; and
- a discount rate.

We describe each of these inputs in turn. Section 4 describes how to enter the inputs and run the model.

Baseline Water Quality

Our protocol defines baseline water quality using the ambient concentrations of five nutrient parameters: total nitrogen (TN, mg/l), total phosphorous (TP, mg/l), chlorophyll a (CLA, µg/l), Secchi depth (S, m), and turbidity (T, NTU). The user must have an estimate of baseline values for TN, TP, and CLA, measured in the units shown above. The model will impute values for S and T if needed, however measured values provided by the user will probably be more reliable.

The *single input* version of the model starts with the **Input Data** worksheet, where the user enters a single row of nutrient values according to the column headings. The single row might be based on the mean or median of several monitoring station readings or the output from a simulation model. The user must enter data for TN, TP, and CLA; entering data for S and T is optional but recommended. If data for S and/or T are not available, values will be imputed from the other parameters (see Section 6 of this manual for details on the imputation). After the model is executed, if there are imputed values for S and/or T, they are shown in red.

The *multiple input* version of the model allows the user to enter baseline data for multiple years, allowing the baseline to change (e.g., deteriorate or improve) in future years. Using the **Annual Input Data** worksheet, the user can enter different baseline values for TN, TP, and CLA (and S and T) for each year of the analysis. The row of values for each year is entered according

to the year index in the time column. For example, if the user wants to analyze the benefits of a policy over the next 10 years, s/he can enter different values for TN, TP, and CLA (and S and T) as they are expected to evolve without a policy intervention. As in the single input case, the data are entered according to the column headings, and values for S and T are imputed if not provided.

Target (Counterfactual) Water Quality

The model estimates the benefits of achieving a particular set of nutrient criteria targets, which we refer to as the counterfactual nutrient values, relative to baseline levels. For the counterfactual nutrient values, the user must enter criteria s/he wants to evaluate. For both the single and multiple input versions, criteria can be entered in one of two ways:

- Evaluating criteria based on a target for a single parameter (e.g., a target value for CLA): Any one of the five water quality measures can be selected.
- Evaluating criteria based on a combination of multiple parameters (e.g., targets for both TN and TP concentrations): Any combination of two or more of the water quality measures can be selected.

Section 4 provides details on how the counterfactual values are entered.

Recreation Trips

The model estimates the benefits accruing to recreational users of the lake. The benefits to recreational users can come from the enhanced value of existing trips or from new trips that occur due to the improvement. The user needs to enter an estimate of the total annual visits to the lake that will occur once the target quality level is in place. If the user is uncertain about future visitation under improved water quality conditions, current visitation provides a conservative approximation of future visitation in these circumstances.

Timeframe and Discount Rate

Many policies have costs and benefits that unfold over multiple years. Typically, policy analysis evaluates the benefits and costs of a water quality target over a set number of years. The model allows a user to enter the number of years over which the benefits are to be evaluated. To calculate the net present value (NPV) of the benefits over time, a discount rate must be specified. The discount rate deflates the value of future dollars to make them comparable to current dollars. If the user wants to calculate the undiscounted value of benefits, the discount rate can be set to 0%.

SECTION 4

RUNNING THE WATER QUALITY BENEFITS SPREADSHEET

The single and multiple input versions of the model run in slightly different ways. We describe each model below.

Single Input Model

1. Enter a single row of baseline data for TN, TP, and CLA (and if possible S and T) into the **Input Data** worksheet following the column headings.
2. Click on the button “Launch Model” on the right-hand side of the worksheet. A box called “**Model Options**” will appear.
3. In the first column, the user enters the expected number of recreational trips per year to the lake under the improved (or counterfactual) water quality conditions. The user enters a single number is provided, which is assumed to hold for the entire time frame of the analysis. Next the user enters the number of years over which benefits are to be computed (and discounted), and finally, the user enters a discount rate (e.g., 3%). It is possible to enter zero for the discount rate.
4. In the second column, the user enters the target (or counterfactual) nutrient value(s). The form prompts the user for information on nutrient targets to be evaluated. The user indicates via a checked box the parameter(s) for which explicit numeric criteria will be entered and then enters the target value(s), measured in the units defined above. Parameters that do not have an explicit target value are then imputed from those that do. The imputation strategy is described in Section 6 of this manual. Once the model is executed, any imputed target values are shown in light grey on the form and red on the input worksheet. To erase the nutrient values and enter new values, click on “Reset Defaults” (found at the bottom of the Model Options box). After all inputs have been provided, the user clicks “Run” (found at the bottom of the Model Options box). The model will run and the worksheet labeled **Output Table** will open.

Multiple Input Model

1. All the input data for the multiple input model are entered in the **Annual Input Data** worksheet. The user can type the values for each column directly into the worksheet or copy data from another spreadsheet organized according to the headings in the first row. Column A lists the years over which the analysis takes place. The values for columns B through L can vary by year. Column B contains the number of recreational trips expected in each year. Columns C to G contain the baseline water quality measures for TP, TN, CHA, S, and T. As described above, values for TP, TN, and CHA must be entered, but S and T are optional. Once the model is executed, the imputed values for S and/or T are shown in the worksheet if not specified in the data. Columns H to L contain the target (counterfactual) values for at least one of the five water quality measures or some combination of two or more of the measures. Again the imputed values will be shown in the worksheet when the model is executed. Note

that the user does not provide a discount rate. The NPVs of the benefits at four discount rates (0%, 3%, 5%, and 7%) are provided as part of the output.

2. After all inputs have been provided, the user clicks “Launch Annual Model” (found on the right side of the worksheet). The model will run and the worksheet labeled “Annual Output” will open.

SECTION 5 OUTPUTS

The spreadsheet model provides four pieces of output information:

- a prediction for the baseline water quality index;
- a prediction for the improvement in the water quality index arising if the target (counterfactual) is met;
- point estimates for the recreation-based benefits of improving water quality from baseline to the target (counterfactual) level (per-trip, aggregate annual, and NPV for the annual and aggregate); and
- summaries of uncertainty associated with the benefit estimates.

The *single input* version of the model provides details for all of these, while the *multiple input* version focuses only on the annual and total benefits. We describe each of the outputs in turn.

Baseline and Counterfactual Water Quality Index

The modeling framework takes readings of TN, TP, CLA, S, and T and converts them to a single dimension ordinal index of eutrophication (described in detail in the project documents listed in Section 8). We defined five categories of lake water quality based on their nutrient status: A, B, C, D, and E, where A is the best quality and E is the worst quality. These are assigned the numbers A = 1, B = 2, ... , E = 5. Because the actual level of eutrophication for a particular lake will depend on other factors in addition to the five nutrients, an underlying statistical model predicts the probability that a lake with a specific set of nutrient values might fall into each of the five eutrophication categories. The statistical model estimates a continuous number contained in the (1,5) interval that provides an index of the baseline level of eutrophication for the lake. Likewise, the model uses the nutrient concentration targets provided by the user to compute the same index of the potential improvement in the water quality of the lake.

For the *single input* version of the model, the **Output Table** worksheet contains a summary of the results along with measures to characterize the uncertainty in the results. For each output, the rows provide the mean estimate, the standard deviation, the minimum, the 1st quartile (the 25th percentile), the median (the 50th percentile), the 3rd quartile (the 75th percentile), and the maximum (labels appear in column A). Columns B to K [labeled prob(1), ... ,prob(5)] report the estimated probability that a lake with the baseline nutrient levels entered by the user would fall into each of the five eutrophication categories. Column L contains the

computed index of water quality for baseline conditions and, in column M, the index for the new, improved level arising from the nutrient criteria targets. Detailed summaries of the probabilities and indices are not provided in the output for the *multiple input* version of the model.

Estimates for Annual and Total Benefits

The Water Quality Benefits Spreadsheet uses an underlying economic model that computes the per-trip value of moving from the baseline to a proposed criteria-based value for the water quality index. The change in the water quality index, along with the numbers for the total annual trips feed into another statistical model that computes the annual aggregate benefits from the criteria under evaluation. The total benefits are computed for the user-defined benefits time frame and discount rate.

For the *single input* model, the **Output Table** worksheet contains a summary of the distributions for the per-trip value of the improvement (column N), as well as summaries for the annual aggregate benefits (column O) and total NPV of benefits (column P). The total NPV distribution is also shown graphically in the plot contained in the **Chart** worksheet.

For the *multiple input* model version, the worksheet **Annual Output** contains the benefit estimates. The distribution of the annual aggregate value of the benefits for each of the policy years is shown in columns B through H. Columns K to O show the distribution for the NPV using four different candidate discount rates.

Uncertainty Assessment

Estimates of water quality changes and economic benefits are subject to uncertainty from a number of sources including the baseline data, the functional form of the model, and the parameters. Some sources of uncertainty can be quantified, while others cannot. The uncertainty surrounding the underlying statistical and economic models that produce the water quality indices and per-trip values can be quantified to some degree. For the baseline probabilities, baseline and counterfactual water quality index, per trip value, annual value, and NPV, the standard deviations and order statistics (e.g., median, percentiles) shown in the **Output Table** and **Annual Output** worksheets reflect the uncertainty in the underlying statistical and economic models.

SECTION 6 TECHNICAL DETAILS

The spreadsheet has been programmed to implement a simple version of the Water Quality Benefits model in a way that does not require the user to engage with the technical details underlying the calculations. A full technical description of the protocol and its development can be found in the documents associated with the research project listed in Section 8. Here we provide a brief overview of the technical features of the spreadsheet.

Imputation

Computation of the baseline and target water quality indexes requires readings for TN, TP, CLA, S, and T. The baseline index computation uses the water quality data entered by the user. Because only TN, TP, and CLA are required, the program needs to be able to impute S and/or T when they are not provided. For this imputation, we use results from a collection of linear regressions. For S, the regressions are

$$\begin{aligned}\ln S &= \beta_0 + \beta_1 \ln TN + \beta_2 \ln TP + \beta_3 \ln CLA + \varepsilon \\ \ln S &= \beta_0 + \beta_1 \ln TN + \beta_2 \ln TP + \beta_3 \ln CLA + \beta_4 \ln T + \varepsilon\end{aligned}$$

For T, the regressions are

$$\begin{aligned}\ln T &= \delta_0 + \delta_1 \ln TN + \delta_2 \ln TP + \delta_3 \ln CLA + \varepsilon \\ \ln T &= \delta_0 + \delta_1 \ln TN + \delta_2 \ln TP + \delta_3 \ln CLA + \delta_4 \ln S + \varepsilon\end{aligned}$$

where β and δ are the estimated coefficients from the regressions and ε is the error term. We have estimated the β 's and δ 's in these four equations using a data set of water quality readings taken in reservoirs throughout the state of North Carolina. The equations are used to impute values for S and/or T using the values for the other water quality measures, with the particular equation(s) selected based on the configuration of data the user has provided. For example, if the user has provided measures for TN , TP , and CLA , imputations for S and T are computed as

$$\hat{S} = \exp\left(\hat{\beta}_0 + \hat{\beta}_1 \ln TN_u + \hat{\beta}_2 \ln TP_u + \hat{\beta}_3 \ln CLA_u + \sigma^2 / 2\right)$$

and

$$\hat{T} = \exp\left(\hat{\delta}_0 + \hat{\delta}_1 \ln TN_u + \hat{\delta}_2 \ln TP_u + \hat{\delta}_3 \ln CLA_u + \sigma^2 / 2\right)$$

respectively, where TN_u , TP_u , and CLA_u are the parameter values entered by the user, and σ is an estimate for the standard deviation of ε . Although this imputation capability is provided, we believe it will usually be best to use actual monitoring station readings (or a more lake-specific imputation approach) for specifying the baseline levels of turbidity and Secchi depth.

Similarly, target (or counterfactual) water quality criteria are imputed using the targets the user has entered. For this imputation, a large collection of regressions was estimated, which included all possible combinations of the water quality variables on the left- and right-hand sides:

$$\begin{aligned}
 \ln TN &= \gamma_0 + \gamma_1 \ln CLA + \varepsilon \\
 \ln TP &= \gamma_0 + \gamma_1 \ln CLA + \varepsilon \\
 \ln S &= \gamma_0 + \gamma_1 \ln CLA + \varepsilon \\
 \ln T &= \gamma_0 + \gamma_1 \ln CLA + \varepsilon \\
 \ln TP &= \gamma_0 + \gamma_1 \ln CLA + \gamma_2 TN + \varepsilon \\
 \ln S &= \gamma_0 + \gamma_1 \ln CLA + \gamma_2 TN + \varepsilon \\
 \ln T &= \gamma_0 + \gamma_1 \ln CLA + \gamma_2 TN + \varepsilon \\
 \ln S &= \gamma_0 + \gamma_1 \ln CLA + \gamma_2 TN + \gamma_3 TP + \varepsilon \\
 \ln T &= \gamma_0 + \gamma_1 \ln CLA + \gamma_2 TN + \gamma_3 TP + \varepsilon \\
 &\vdots
 \end{aligned}$$

The many γ s in these equations were estimated using the North Carolina water quality readings, and the results are coded into the model. Given the parameter(s) provided to define the counterfactual criteria and the baseline values, the program selects the appropriate equations and estimates, and uses them to impute the other counterfactual parameter values. For example, if the user provided values CLA_{cf} and TN_{cf} as the policy counterfactual, the remaining counterfactual pollution levels are computed as follows:

$$\begin{aligned}
 \hat{TP}_{cf} &= TP_b \times (CLA_{cf} / CLA_b)^{\gamma_1} \times (TN_{cf} / TN_b)^{\gamma_2} \\
 \hat{S}_{cf} &= S_b \times (CLA_{cf} / CLA_b)^{\gamma_1} \times (TN_{cf} / TN_b)^{\gamma_2} \\
 \hat{T}_{cf} &= T_b \times (CLA_{cf} / CLA_b)^{\gamma_1} \times (TN_{cf} / TN_b)^{\gamma_2},
 \end{aligned}$$

where the subscript bs are the baseline values for the pollutants. With these two steps all the water quality parameter values are available for use in the subsequent computations. Once again, it is preferable to use imputations for the missing criteria that are specific to the policy lake, if possible.

Predicting Index Values

The water quality index component of the spreadsheet uses the results of an expert elicitation framework to map values for TN, TP, CLA, S, and T into predictions for the water quality index.¹ In particular, as part of a larger project a sample of water quality experts reviewed different sets of readings for the five quality parameters and made a judgment on where a typical

¹ The expert elicitation method is summarized in the project documents.

lake producing these readings would fit in the qualitative A, ... ,E eutrophication scale. The resulting data were used to parameterize functions of the form $p_j = f(\text{TN}, \text{TP}, \text{CLA}, \text{S}, \text{T})$, where p_j is the probability that a lake with the given readings is of quality type j , for $j = \text{A}, \dots, \text{E}$. These functions are coded into the Water Quality Benefits Spreadsheet so that we can predict $p_{\text{A}}, \dots, p_{\text{E}}$ for any row of water quality parameter readings. With these, the index value is simply

$$I(\text{TN}, \text{TP}, \text{CLA}, \text{S}, \text{T}) = (1 \times p_{\text{A}}) + (2 \times p_{\text{B}}) + (3 \times p_{\text{C}}) + (4 \times p_{\text{D}}) + (5 \times p_{\text{E}}). \quad \square$$

Predicting Economic Values

The Water Quality Benefits Spreadsheet uses the results from an economic choice experiment survey to map values for I^0 and I^1 —the predicted index values at baseline and counterfactual water quality levels—to an estimate of the dollar-valued benefits a recreation visitor to the lake would receive from the improvement. This takes the form of a function $g(I^0, I^1)$, which is coded into the spreadsheet. Thus, we can predict the per-trip value of any improvement from the baseline to the user-provided counterfactual.

Define the per-trip value by PTV. The annual value (AV) is simply $\text{PTV} \times \text{T}$, where T is the number of trips to the lake expected per year. The total NPV of benefits for the counterfactual target is

$$TV = \sum_{t=1}^{\text{years}} \frac{AV}{(1+r)^t},$$

where r is a discount rate. Note that for $r > 0$ the contribution of AV to TV is smaller as we move further out in time. When $r = 0$ (i.e., we do not discount future benefits) the expression simplifies to $TV = AV \times \text{years}$.

Quantifying Uncertainty

The functions $f(\cdot)$ and $g(\cdot)$ referred to above were estimated using a sample of lakes and the sample of survey respondents rather than entire populations. Thus, in standard statistical parlance, our estimates contain sampling error. We account for this by examining distributions for our estimates using bootstrapping, which provides distributions for the functions $f(\cdot)$ and $g(\cdot)$. We quantify the sampling error uncertainty in our estimates by computing predictions using a range of estimates for $f(\cdot)$ and $g(\cdot)$, all drawn from their underlying distribution.

we expect the median CLA will be 30 µg/l and that it will reach its policy goal of 24 µg/l in Year 6.

To evaluate this scenario, we set the *baseline* columns of the **Annual Input Data** worksheet as shown here:

Year	Trips	Baseline				
		Total Nitrogen (mg/l)	Total Phosphorus (mg/l)	Chlorophyll a (ug/l)	Secchi Depth (m)	Turbidity (NTU)
1	500000	0.76	0.05	32.00	0.70	9.65
2	500000	0.77	0.05	32.32	0.69	9.75
3	500000	0.78	0.05	32.64	0.69	9.84
4	500000	0.78	0.05	32.97	0.68	9.94
5	500000	0.79	0.05	33.30	0.67	10.04
6	500000	0.80	0.05	33.63	0.67	10.14
7	500000	0.81	0.05	33.97	0.66	10.24
8	500000	0.81	0.05	34.31	0.65	10.35
9	500000	0.82	0.05	34.65	0.65	10.45
10	500000	0.83	0.05	35.00	0.64	10.55

We set the counterfactual columns as indicated below:

Counterfactual				
Total Nitrogen (mg/l)	Total Phosphorus (mg/l)	Chlorophyll a (ug/l)	Secchi Depth (m)	Turbidity (NTU)
		30		
		30		
		30		
		30		
		30		
		24		
		24		
		24		
		24		
		24		

To run the model, we click on the **Launch Annual Model** button. The **Annual Output** worksheet will appear. An excerpt from this page is shown here:

	NPV					
Discount Rate	Mean (Xbar)	Min	1st Quartile	Median	3rd Quartile	Max
0%	\$59,860,806	\$4,041,694	\$51,782,220	\$56,995,950	\$59,937,098	\$63,306,303
3%	\$48,648,881	\$3,286,466	\$42,082,567	\$46,317,401	\$48,711,483	\$51,450,398
5%	\$42,627,188	\$2,880,769	\$36,873,124	\$40,582,311	\$42,682,331	\$45,082,896
7%	\$37,527,646	\$2,537,141	\$32,461,474	\$35,725,584	\$37,576,408	\$39,690,531

The distribution of the total NPV is shown in the table, broken out by commonly used discount rates. For a 5% discount rate, the median estimate is approximately \$40.6 million. By returning to the **Annual Input Data** page, the user can view the imputed counterfactual values in red:

Counterfactual				
Total Nitrogen (mg/l)	Total Phosphorus (mg/l)	Chlorophyll a (ug/l)	Secchi Depth (m)	Turbidity (NTU)
0.75	0.05	30	0.72	9.4
0.75	0.05	30	0.71	9.45
0.76	0.05	30	0.71	9.51
0.76	0.05	30	0.7	9.57
0.77	0.05	30	0.7	9.62
0.72	0.05	24	0.75	8.84
0.73	0.05	24	0.74	8.89
0.73	0.05	24	0.74	8.94
0.74	0.05	24	0.73	9
0.74	0.05	24	0.73	9.05

SECTION 8 PROJECT DOCUMENTS

This project was funded by a grant from the U.S. Environmental Protection Agency Office of Water (Grant #X7-83381001-0). We produced two reports to document the research project and the results. The first report describes the water quality data, the expert elicitation process and the models used link the water quality readings to the qualitative eutrophication index. The second report describes the survey used to value changes in the water quality and the analysis of the survey data. The data and results contained in these two reports are the basis for the Water Quality Benefits Spreadsheet. The documents can be found on the EPA website (<http://www.epa.gov/nandppolicy/links.html>, click on the grants folder once on this webpage) or they are available from the lead author, Dr. Phaneuf.

Phaneuf, D. J., M. Kenney, and K. Reckhow. *Measuring Nutrient Reduction Benefits for Policy Analysis Using Linked Non-Market Valuation and Environmental Assessment Models—An Interim Report on Water Quality Modeling*, EPA Project Report, 2010.

Phaneuf, D. J., C. Mansfield, G. Van Houtven, and R. von Haefen. *Measuring Nutrient Reduction Benefits for Policy Analysis Using Linked Non-market Valuation and Environmental Assessment Models: Final Report on Stated Preference Surveys*, EPA Project Report, 2012.