2. DESIGN AND METHODS

2.1 Site Selection

The NJDEP has historically maintained a database of approved wetland mitigation sites including the location, size and type of mitigation proposed. The NJDEP database was reviewed to select sites for inclusion in this study. Given the limitations of study scope, and the need for evaluation consistency, the NJDEP project team recommended that only freshwater wetland mitigation sites be further evaluated.

A total of approximately 177 freshwater wetland mitigation sites were contained in the NJDEP database upon commencement of the study in July 1999. Based on database information, 135 mitigation sites had been constructed and were therefore selected for a file review and potential field evaluation. Study sites were selected from this group based on the availability of sufficient information regarding the size and type of mitigation to accommodate a thorough and consistent evaluation.

2.2 File/Plan Review

A review was conducted of the NJDEP files for each of the 135 constructed freshwater wetland mitigation sites. The files were reviewed to obtain and verify available information on the plans and specifications of the mitigation site including, when available, the type and amount of wetland disturbance authorized by the NJDEP permit and the type and amount of proposed mitigation approved by NJDEP. The file review included identification of the specified amount of proposed mitigation, mitigation type (i.e. forested, scrub/shrub, emergent or open water) and goals (creation, restoration, etc.).

Initially, files were reviewed to determine the level of completeness and details of mitigation plans and specifications. During initial review, determinations were made regarding suitability for subsequent field evaluation for each site. Based upon the review of mitigation files, the NJDEP recommended that the study concentrate on freshwater wetland creation. This recommendation was based upon the general inconsistency in mitigation details and

specifications provided for other wetland mitigation goals (i.e. restoration and enhancement), and difficulty in locating the field limits of the wetland restoration and enhancement sites to allow a consistent and complete evaluation. Sites for which the files did not contain sufficient details to accommodate a consistent and complete evaluation were omitted from further consideration. Examples of sites that were omitted from further consideration included large linear projects (e.g. utility projects with typically small mitigation areas distributed over several miles), sites that were comprised of numerous small mitigation areas that had poorly defined limits, and sites whose mitigation plans and specifications were incomplete and/or insufficient in detail to accommodate a complete field evaluation (e.g. no mitigation type or area specified on the plan, no indication of discernable site boundaries, no planting specifications, etc.). The results of the file review were recorded on standardized data sheets (Appendix B).

Of the 135 potential freshwater wetland mitigation sites that had been constructed, 90 sites (67%) were selected for inclusion in this study and subject to subsequent field evaluations (see Appendix A). These study sites represent approximately 326 acres of proposed freshwater wetlands mitigation.

2.3 Introduction to Study Indicators

The study included the development of three study indicators to measure attainment with NJDEP's NEPPS goals and monitor performance of New Jersey's wetland mitigation program. Field evaluations were conducted on each of the 90 study sites. Field evaluations consisted of measuring an individual site's attainment of the three (3) study indicators, including: Wetland Area Achieved, Concurrence Evaluation and Wetland Mitigation Quality Assessment (Table 1). The following sections provide an overview of the methods employed for each study indicator.

Wetland Area Achieved
A measure of the type and amount of wetlands provided through mitigation.

Concurrence Evaluation
A measure of the relative degree to which the mitigation achieved is consistent with the specifications of the mitigation plan approved by NJDEP.

Wetland Mitigation Quality Assessment (WMQA)
A measure of the relative quality of mitigated wetlands as it relates to their potential to provide desirable wetland functions and values.

Table 1: Introduction to Study Indicators

2.3.1 Wetland Area Achieved

The Wetland Area Achieved indicator was calculated based upon the results of a wetland delineation. The delineation was performed to determine if wetlands or open water were present and to establish the location of the wetland/open water boundary in the field. Wetland delineations were performed following the 1989 *Federal Manual for Identifying and Delineating Jurisdictional Wetlands* (Federal Interagency Committee) for a routine field determination based on examination of hydrology, soil and vegetation. In many of the mitigation wetlands it was not possible to rely on all three parameters (soils, hydrology, and vegetation) due to the disturbed nature of the sites and therefore the Disturbed Area Routine of the manual was often employed.

Documentation of typical hydrology, soils and vegetation characteristics of the wetland and upland communities of the site and photographs was collected as part of the wetland delineation. A visual areal estimate of the type of wetland communities present (i.e. forested, scrub/shrub, emergent, etc.) was made during the delineation and expressed as a percent.

The type and area of wetlands achieved were determined on 85 of the study sites. Some study sites were excluded from the area determination in cases where the boundaries of the mitigation area could not be readily determined in the field (n=5).

The location of the wetlands boundary and area of wetlands achieved expressed in acres were documented using a Global Positioning System (GPS) that complies with applicable NJDEP GIS/GPS standards. Upland inclusions or islands were delineated in the field using GPS and omitted from the calculation of total Wetland Area Achieved.

In instances where the total wetland mitigation area proposed on a particular site consisted of several distinct areas, only a portion of the proposed mitigation may have been included in the field delineation. Only the area included in the field delineation (Area Evaluated) was used to calculate the percent of Wetland Area achieved. For example, a particular site included a total of 2 acres of wetlands, including 1.8 acres of wetland creation and 0.2 acres of wetland restoration.

If the limits of the restoration areas were not clearly defined (i.e. distributed throughout a particular site with no discernable boundaries), they were not included in the field delineation. The Area Evaluated was therefore limited to the 1.8-acre creation site. To correct for this discrepancy, only the area of wetland creation was included in the calculation of percent area achieved. The Area Evaluated was based upon a review of the mitigation plans contained within the NJDEP file.

The Wetland Area Achieved indicator was expressed as a percent and calculated according to the following formula:

*Wetland Area Achieved (%) = (Area Achieved/Area Evaluated) * 100*

2.3.2 Concurrence Evaluation

The Concurrence Evaluation indicator consisted of a field inspection to verify and measure the extent to which the constructed mitigation site conforms and is consistent with NJDEP approved mitigation plans and specifications. A Concurrence Evaluation was performed on 88 sites. No Concurrence Evaluation was performed on two sites due to insufficient plan specifications.

The Concurrence Evaluation indicator assigned an overall concurrence score according to the degree to which a site was constructed consistent with approved plans, independent of the area of wetland achieved. Theoretically, a site may have been constructed in accordance with approved plans and specifications, and receive a relatively high concurrence score yet the site did not achieve any wetlands according to the field delineation. The Concurrence Evaluation was based upon several variables that could be readily observed in the field in relation to the plan specifications: Grading; Hydrology; Soil; Vegetation Cover; Vegetation Survival; and Design (Table 2).

Raw scores for each variable are expressed as a percent from 0-100 representing the relative degree to which the constructed mitigation site was consistent with approved plans and specifications. The raw score is assigned based on visual examination and collective best

Concurrence Evaluation Variables and (Weighting Factors)

A. Grading (4.1) – The degree to which topography is consistent with approved grading plans.

B. Hydrology (4.7) – The degree to which the duration and/or frequency of inundation or saturation is consistent with mitigation goals, type, and specifications. Includes a field determination of the source of hydrology and the status of monitoring devices and/or water control structures, if specified.

C. Soils (3.5) – The degree to which soil placement and stabilization conforms with specifications. Includes an evaluation of topsoil placement, soil stabilization, and acid soil specifications.

D. Vegetation Cover (2.9) – The extent to which the specified vegetation type was established. Includes percent cover of hydrophytes, seed mix specifications, presence of persistent grasses, such as fescue, and percent cover of invasive vegetation species.

E. Vegetation Survival (2.3) – The degree to which vegetation species planted in accordance with plans survived. Includes percent survival of trees, shrubs, and herbaceous vegetation specified in plans.

F. Design Characteristics (4.2) – The extent to which as-built conditions conform to approved plans. Includes an examination of the size and shape of the wetland transition (adjacent) area if specified, and the degree to which maintenance is required/provided.

Table 2: Description of Variables Included in the Concurrence Evaluation. Weighting Factors shown in parentheses (). **Note:** Weighting Factors were assigned a value from 1 (least important) to 5 (most important) and reflect the average values assigned by 15 independent wetland scientists in New Jersey.

professional judgment of at least two trained wetland scientists with practical experience in wetland mitigation design and plan interpretation.

In some cases, sufficient information was not available in the mitigation files to facilitate an accurate review of all variables. When there was not sufficient information available to make an informed evaluation of a specific variable, that variable was deemed not to be applicable and was not scored. The final score of the concurrence evaluation was based only on those variables deemed applicable based upon availability of information contained in the mitigation plans and specifications.

A weighting factor was assigned to differentiate the relative importance of each variable to the final score. Weighting factors reflect the input from 15 contributors. Each contributor assigned a relative score for each variable ranging from 1 (least important) to 5 (most important). The final weighting values are an average of all individual scores and are shown in parentheses in Table 2. Weighting of variables was used to help distinguish between those variables that are more important in achieving the stated goals in the approved plans. For example, it was generally felt by the research team that achieving the approved grade and hydrology of the mitigation site were more important than achieving the stated vegetation cover. This may have been in part a result of the recognition that vegetation cover would be more likely to be achieved over time given the proper growing conditions as determined by grading and hydrology.

The final Concurrence Evaluation indicator score is expressed as a percent. It is calculated by dividing the sum of the weighted values for all the applicable variables by the sum of the applicable weighting factors (Table 3).

Observations were also made during the Concurrence Evaluation to identify specific corrective action necessary to comply with approved plans and specifications, and that would serve to improve the status of the mitigation site. All field observations were recorded on standardized data forms (see Appendix B).

Concurrence Evaluation Weighted Values
(Weighted Value = Raw Score * Weighting Factor)

Grading
+ Hydrology
+ Soil
+ Vegetation Cover
+ Vegetation Survival
+ Design

= Sum of Applicable Weighted Values
÷ Sum of Applicable Weighting Factors

= Concurrence Evaluation Score (Percent)

Table 3: Method for calculating Concurrence Evaluation Score

2.3.3 Wetland Mitigation Quality Assessment (WMQA)

The Wetland Mitigation Quality Assessment (WMQA) indicator consisted of assigning a score based on readily observable field indicators of wetland variables, including hydrology, soils, and vegetation, using a standard rating index. The WMQA consists of qualitative field determinations of the presence or absence of designated field indicators that were selected to be representative of the relative probability that a constructed wetland will develop into a natural wetland system and provide desirable wetland functions over time (Appendix C). The WMQA was performed on only those sites that resulted in wetlands according to the wetland delineation (n=74). The procedure was not applied if wetlands were not present.

The WMQA was developed as a qualitative, results-based evaluation procedure to measure status and monitor changes in the relative quality of mitigation sites following construction. The method is intended to accomplish several objectives: 1) establish a simple, consistent and timely assessment tool based on readily observable field indicators; 2) be applicable to a wide range of wetland community types and field conditions; and 3) offer consistency and guidance in evaluating NJDEP's NEPPS goal.

The WMQA assigns a standardized rating index from 0 to 1 based upon the use of professional judgment to provide a consistent and practical measure of relative mitigation quality. It is probable that a constructed wetland that receives a high rating index score of 1 will have a greater potential to function as a natural system over time.

The procedure relies on observation of field indicators and use of best professional judgment to identify the relative value that best describes the variable being measured. This method relies on the basic assumption that function will follow form. For example, if observable indicators of hydrology are present such as drift lines, hummocks, and/or plant morphological adaptations, it is assumed that the wetland has the potential to perform hydrologic functions analogous to a natural wetland of the same type. For examples of predictors of wetland function, see Adamus and Stockwell (1983) and Keddy (1999 and 2000).

The WMQA assigns a score for each of six (6) variables including: Hydrology, Soils, Vegetation Composition/Diversity, Wildlife Suitability, Site Characteristics and Landscape Characteristics. A description of the variables included in the WMQA is provided in Table 4.

The WMQA procedure assigns a value (V) on a scale from 0 to 3 for each variable being evaluated. A value of 3 is used if the variable is thought to have the greatest probability of simulating a natural wetland system over time. A value of 0 is assigned if the variables are severely impeded or not present. The Vegetation and Landscape variables include two or more sub-categories (see Table 4) that are each assigned an individual score. The average of the sub-category scores is used to assign a raw score for the applicable variable.

The raw score for each wetland variable is multiplied by a weighting factor to differentiate the relative importance of each variable's contribution to the final score. Weighting factors reflect input from 15 contributors. Each contributor assigned a relative score for each variable ranging from 1 (least important) to 5 (most important). The final weighting factors are an average of all individual scores and are shown in Table 4.

The method for calculating the WMQA index score is provided in Table 5. An index score from 0 to 1 is calculated based on the sum of the weighted values for all applicable variables (VTOTAL). VTOTAL is divided by the sum of the weighting factors to provide the WMQA score. The WMQA score is then divided by 3 (the maximum score achievable for each variable) to express the total WMQA Index score as a relative value from 0-1. All WMQA scores were recorded on standardized data sheets (see Appendix B).

The WMQA is a rapid assessment tool that is useful for monitoring attainment with NJDEP's NEPPS goals. It is practical, allowing for an assessment based on a single site visit during the growing season and provides enough flexibility to be applicable to multiple wetland habitat types and field conditions. Rapid assessment methodologies have been reported in other studies and reviews (e.g. Maguire, 1985; Redmond, 1991; USFWS, 1994; Bartoldus, 1999) for use in determining relative wetland quality and ecological success; however, none provided the

Wetland Mitigation Quality Assessment (WMQA) Variables
and Weighting Factors

A. **Hydrology (4.8) --** Provides a measure of the degree to which wetland hydrology is present through observation of field evidence of surface inundation or saturation.

B. **Soils (3.6) --** Evaluates whether existing conditions are favorable for the establishment/development of hydrophytic vegetation.

C. **Vegetation Composition/Diversity (3.7) --** Assesses the presence, abundance, composition and condition of plant species within the mitigation site. Also measures the extent of colonization by undesirable (i.e. invasive) plant species. This variable includes two sub-categories: **C.1 - Overstory Layer (plants >3' in height) and C.2 - Ground Cover (plants <3' in height)**.

D. **Wildlife Suitability (2.1) --** Provides an indication of the extent to which the wetland provides suitable wildlife habitat.

E. **Site Characteristics (3.0) --** Evaluates the degree to which the location and design of the mitigation site affects its capacity to perform wetland functions. Includes an evaluation of design factors such as shape and size.

F. **Landscape Characteristics (3.6) --** Evaluates the nature of surrounding land use as it affects the functional capacity of the mitigation site including transition area quality and quantity, and contiguity with adjacent habitats. This variable includes three sub-categories:

F.1 - Adjacent Buffer
Provides a description of the vegetation characteristics of uplands within 50 feet of the wetland boundary.

F.2 - Contiguity
The extent to which the site adjoins other wetlands or open space

F.3 - Land Use
Describes the predominant type of land use within proximity of the wetland.

Table 4: Description of the Variables Included in the Wetland Mitigation Quality Assessment (WMQA). See Appendix C (WMQA Procedure Manual) for details on each parameter. Weighting Factors are shown in parentheses (). **Note:** Weighting Factors were assigned a value from 1 (least important) to 5 (most important) and reflect the average values assigned by 15 independent wetland scientists in New Jersey.

Wetland Mitigation Quality Assessment (WMQA) Weighted Values (V)
(Weighted Value = Raw Score * Weighting Factor)

Hydrology
+ Soils
+ Vegetation Composition/Diversity Total =
(Overstory + Ground Cover) / 2
+ Wildlife Suitability
+ Site Characteristics
+ Landscape Characteristics Total =
(Adjacent Buffer + Contiguity + Land Use) / 3

= Sum of Weighted Values (VTOTAL)
÷ Sum of Weighting Factors

= WMQA Score
÷ 3

= WMQA Index Score (0 - 1)

Table 5: Method for Calculating the Wetland Mitigation Quality Assessment (WMQA) Index Score

comprehensive tool developed here in concert with simultaneous field delineations of acreage achieved, including relationship to permit requirements.

The WMQA procedure does not allow for direct quantitative measurement of wetland functions and it is not intended to provide a numerical value that can be used to establish absolute quality of an individual wetland mitigation project or be a surrogate for more quantitative procedures that may be necessary to evaluate mitigation success.

A more precise index of quality would be based on the use of "reference sets" of sites that provide some indication of the range of conditions normally encountered in particular types of wetlands. This type of index would allow for a more precise measurement of the performance of a range of wetland functions. Efforts are underway in New Jersey and in other states to develop such an assessment technique. This type of assessment is time-consuming to develop (on the order of years for one wetland type, such as "riverine depressional") and none were completed at the time this study was conducted. Therefore, use of such a procedure was considered to be impractical for the purposes of this study.

Due to the large spatial and temporal variations that are characteristic of wetland systems, an extended study period would be required to develop a more predictive wetland mitigation quality assessment procedure (Zedler and Calloway, 1999). After conducting a seven-year study on an estuarine wetland in the State of Washington, Simenstad and Thom (1996) suggested that time series in excess of 10 years would be required. Another study (NRC, 2001), suggests that as many as 20 years may be needed for some wetland restoration or creation sites to achieve functional goals. Additionally, there is an increased level of difficulty and associated cost in accurately measuring wetland functions (Bedford, 1996; Mitsch and Wilson, 1996; Race and Fonseca, 1996) using more predictive or quantitative assessment tools.

The science of evaluating wetland quality and function is evolving, especially in relation to constructed wetland mitigation projects. When placed in the context of regulatory review, a rapid assessment procedure that provides NJDEP with a relative and consistent indicator of the

potential of a wetland to achieve functional goals is considered a practical approach. The NJDEP is currently sponsoring companion research to test the WMQA method at reference wetlands in New Jersey, and compare it with other functional assessment tools.

Although the results of the assessment technique are represented in numerical form, it should be noted that these numbers do not reflect a quantitative representation of actual processes. At the current time, this procedure is not intended for regulatory evaluation and does not replace performance criteria that NJDEP may use to determine mitigation status in accordance with permit requirements.

2.4 Data Collection and Management Techniques

2.4.1 Global Positioning System (GPS)

All field data were collected using a Trimble Pathfinder Pro XRS unit. Trimble reports sub-meter accuracy for the Pathfinder Pro XRS (Trimble 1998). The use of GPS has the benefit of providing a geographic reference and date stamp for all data points. The GPS unit was also used as a portable data collection tool. With all data fields pre-programmed into the GPS unit, sampling procedures were easily standardized and streamlined. Drop-down menus provided a fixed number of available responses, reduced the potential for sampling error and unintentional omissions, and assured compatibility of data. All field data were entered into and stored in the GPS unit in the field and later downloaded to a PC running Trimble Pathfinder Office software.

2.4.2 Geographic Information System (GIS) Application

This study was designed to be compatible with NJDEP GIS standards. GIS allows the data and results generated to be integrated with other GIS data presently available at NJDEP such as digital aerial photographs and land use data. ESRI ArcView GIS 3.2© software was used in order to be compatible with the Department's GIS. All field data obtained from the GPS unit were converted into ArcView GIS shapefiles. This information can ultimately be integrated into any NJDEP database application and the NJDEP's GIS.

Using GIS, a particular mitigation site can be digitally linked to an aerial photograph showing the location of the site and the boundary of the wetland created or restored. Information available in other GIS coverages can be linked to the results of this study including the study indicators and other supporting documentation. GIS can also be used to illustrate performance measures by using graphs or charts generated from the results of this study. Figure 1 provides an illustration of these capabilities.

2.4.3 Wetland Mitigation Database

The NJDEP mitigation database has been expanded to include all data generated as part of this study. The new wetland mitigation database includes all raw data and supporting information generated during file reviews and field evaluations such as the wetland delineation, concurrence evaluation, and quality assessment. Wetland indicators were calculated for each mitigation site. The wetland mitigation database was designed to automatically apply weighting factors and calculate study indicator values including Area Achieved, Concurrence Evaluation score and WMQA Index score. All data were summarized for analysis using Lotus 123©. Each mitigation site was assigned a unique four-digit number. All data were summarized using these unique mitigation site number references. Statistical analyses were performed using Lotus 123© and SAS©.

Currently, NJDEP maintains its mitigation database in a Paradox© 3.5 format. The database contains fields for the date mitigation was authorized, the type of mitigation, proposed acreage, and other pertinent data. The database was copied for use in the study. The data remained in Paradox© 3.5 format. ASGECI exported the field data from the GPS unit as ArcView shapefiles. Shapefiles are actually comprised of multiple files, some of which contain geographic information, and one which contains attribute data in Dbase4© format.

The database program used in the study was specifically chosen to be compatible with both existing NJDEP database information and NJDEP GIS standards. Lotus Approach 9.5© (a database management software program) was picked because it allowed the NJDEP mitigation

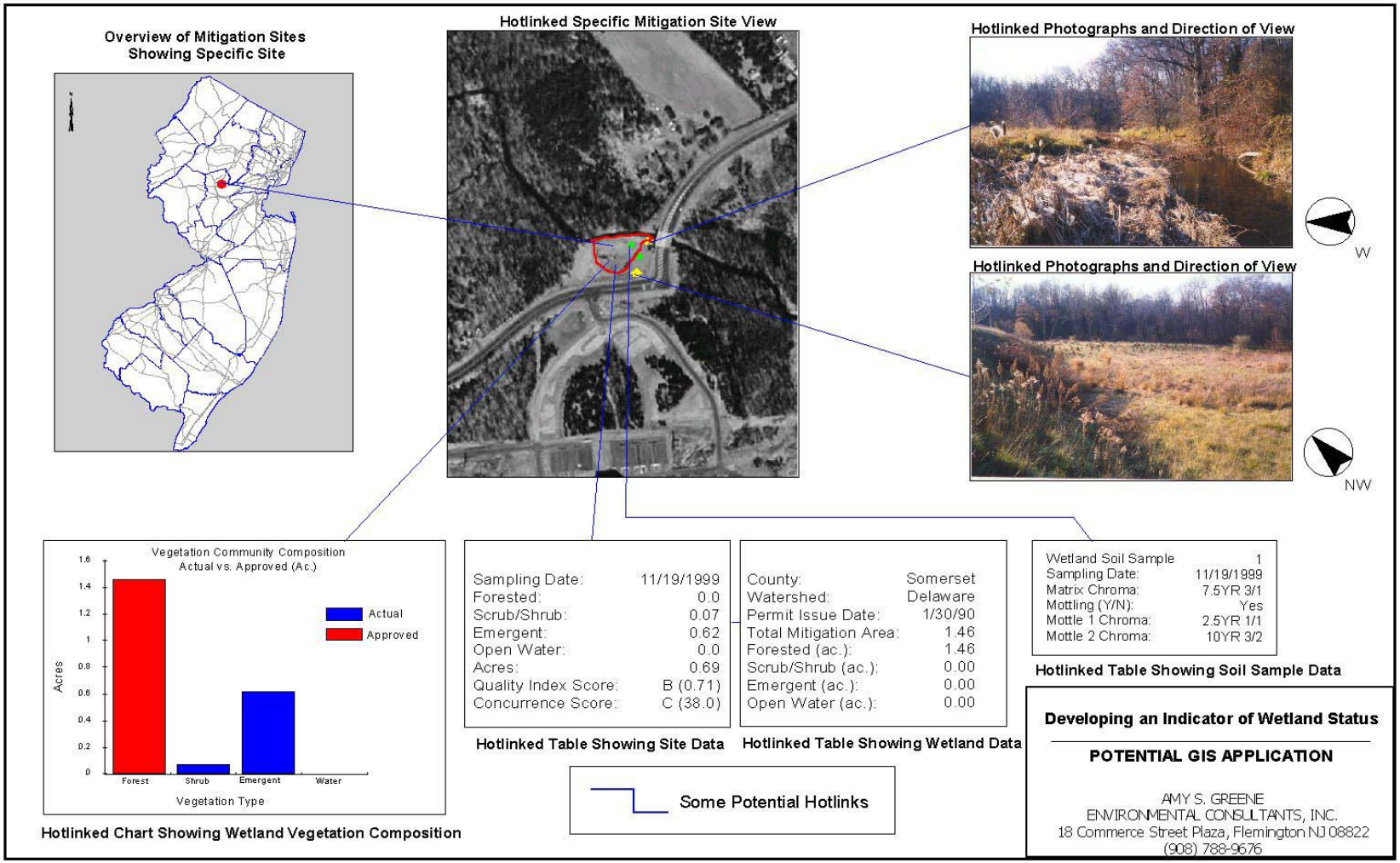

Figure 1: Illustration Showing a Potential Geographic Information System GIS) Application

database to remain in its native Paradox© format, while simultaneously using ArcView© shapefile attribute tables in their native Dbase© format.

The Lotus Approach© application joined together NJDEP mitigation data with information obtained from the field investigations in a multi-table relational database system. Joins were performed based on the unique mitigation site number field.

The updated database and GIS/GPS meta data descriptions for all added fields will be provided to NJDEP as a deliverable separate from this report.