Santa Rosa County
Development Services

Beckie Cato, AICP
Planning and Zoning Director

Tony Gomillion
Public Service Director

Rhonda C. Royals
Building Official

MEMORANDUM

TO: Zoning Board

FROM: Beckie Cato

DATE: June 1, 2012

RE: Agenda Package for Wellfield Protection Project Public Hearing

Enclosed please find the agenda package for your June 14, 2012, 5:00 p.m. public hearing regarding the Wellfield Protection Project.

The draft ordinance has been revised to reflect feedback received at your May meeting. At that meeting, a number of you indicated a desire for more specificity in the ordinance. The current draft provides that, with new sections mirroring ordinances from other Florida communities.

The revised draft is written to address two protection area options: (1) the Wellfield Protection District recommended by the consultant and (2) Wellhead Protection Areas that emulate the Escambia County travel time model of protection.

Additional information in the package are the background reports that support the vulnerability map: *Florida Aquifer Vulnerability Assessment (FAVA): Contamination potential of Florida's principal aquifer systems*, 2005; *Florida Aquifer Vulnerability Assessment (FAVA II)*, 2009; and *Assessment of the extent and Effectiveness of the Wellfield Protection Area and Ordinance*, 2011. We have only included those sections of the reports that apply to Santa Rosa County. The three reports build upon each other and provide the scientific support for the aquifer vulnerability map.

As requested, we have also provided examples from Escambia and Pinellas Counties. The Northwest Florida Water Management District 1999 report, *Susceptibiilty of Public Supply Wells to Ground Water Contimination in Southern Excambia County, Florida* is provided along with Escambia County's wellhead protection ordinance. The wellhead protection ordinance for Pinellas County is also included.

And finally, we have included a copy of a map titled "Sand and Gravel Aquifer – Relative Vulnerability Map with Active Well Locations" which shows the vulnerability for the entire county along with active wells and utility districts. This map helps to demonstrate the uniqueness of the East Milton area with regard to the aquifer and potable water wells. Although other utility franchise districts have wells located in vulnerable areas, the East Milton area differs

in that all of the wells for the East Milton and Fairpoint Utility Systems are located within an area of increased vulnerability.

As you review the package, please feel free to call me with any questions you may have. I can be reached at the office at 981-7077 or on my cell phone at 393-9802.

Note: If the Zoning Board chooses the proposed Wellfield Protection District as the area to be regulated, then the term "District" will apply in this ordinance. If the Zoning Board chooses a more specific area surrounding each well for added regulation, the term "Area" will apply.

DRAFT

ORDINANCE 2012 - ____

AN ORDINANCE RELATING TO SANTA ROSA COUNTY, FLORIDA; AMENDING ORDINANCE 91-24 AS AMENDED; AMENDING ARTICLE 6.05.25 (FAIRPOINT REGIONAL UTILITY SYSTEM WELLFIELD PROTECTION AREA OVERLAY DISTRICT) AS SHOWN IN THE ATTACHED MAP; PROVIDING FOR CHANGES TO THE DISTRICT NAME AND THE DISTRICT BOUNDARIES; DEFINING ALLOWABLE, RESTRICTED, AND PROHIBITED USES AND ADDING PERFORMANCE STANDARDS FOR THOSE USES; PROVIDING FOR CODIFICATION; PROVIDING FOR SEVERABILITY; AND PROVIDING FOR AN EFFECTIVE DATE.

6.05.25 East Milton Area Wellfield Protection Overlay District **(OR "AREA")**

A. Purpose: This overlay district is to provide an added degree of protection for the aquifer recharge area in the vicinity of the Fairpoint Regional Utility System and East Milton Water System wellfield which is an important resource in providing potable water for the Fairpoint peninsula and the East Milton Area. It is the intent of this overlay district to protect present and future public potable water supply wells and wellfields from degradation by contamination from regulated substances.

B. District Boundaries: **(OR "AREA BOUNDARIES")**

(WELLFIELD "DISTRICT" OPTION) The East Milton Area Wellfield Protection Overlay District is defined as beginning at the intersection of Highway 90 and the Santa Rosa-Okaloosa County line follow the County line south to the Yellow River; follow the Yellow River in a generally southwesterly direction to State Highway 87 South; then follow State Highway 87 South northwesterly to Hickory Hammock Road; then follow Hickory Hammock Road westerly to the western boundary of section 17-1N-27; then follow the western boundary of Sections 17-1N-27, 8-1N-27, 5-1N-27, and 32-2N-27, then commencing at the southwest corner of section 29-2N-27 continue N0°for 2302.06 feet to the northern edge of the Gulf Power easement then N79°on the northern right-of-way for 1184.7 feet to the western edge of a Gulf Power easement, then proceed N23°03"30"W along the right-of-way for 143.6 feet to the southern boundary of the northern ½ of section 29-2N-27, then continue East along the southern half section line to the eastern boundary of section 29-2N-27, then north to the northeast corner of section 29-2N-27, then follow the northern section line of sections 28-2N-27, 27-2N-27, 26-2N-27, 25-2N-27 and 30-2N-26 easterly to the intersection with Highway 90; then follow Highway 90 easterly to the point of beginning. The Wellfield Protection Area Map in Appendix "A" is a graphic depiction of the district.

(WELLFIELD "AREA" OPTION) The East Milton Area Wellfield Protection Overlay Areas are defined as the area within a 2,000 foot radius of public supply potable water wells, as measured from the center of the wellhead; or the 5-year travel time area when known.

C. Definitions

Regulated substances. **(Note: This definition is taken from the Escambia County Wellhead Protection Ordinance)**

1. Those deleterious substances and contaminants, including degradation and interaction products which, because of quality, concentration, or physical, chemical (including ignitability, corrosivity, reactiveness and toxicity), or infectious characteristics, radioactivity, mutagenicity, carcinogenicity, teratogenicity, bioaccumulative effect, persistence (nondegradability) in nature, or any other characteristic, may cause significant harm to human health and the environment (including surface water and groundwater, plants, and animals).

2. Regulated substances shall include, but are not limited to, those substances set forth in the lists, as amended from time to time, entitled Lists of Hazardous Wastes (40 CFR Part 261, Subpart D), 40 CFR, Part 261, Appendix VII – Hazardous constituents, and EPA designation Reportable Quantities and Notification Requirements for Hazardous Substances Under Circular (40 CFR 302, effective July 3, 1986); provided, however, that this article shall only apply whenever the aggregate sum of all quantities at any one time exceeds five gallons where said substance is a liquid, or 25 pounds where said substance is a solid.

3. These regulations shall also apply if no single substance exceeds the above-referenced limits but the aggregate sum of all regulated substances present at one facility/building at any one time exceeds 100 gallons if said substances are liquids, or 500 pounds if said substances are solids.

4. These regulations shall apply to all underground storage facilities.

5. A generic list of Regulated Substances is provided in Appendix "B".

D. Applicability:

1. The provisions of this chapter shall apply to all new, non-residential development within the East Milton Area Wellfield Protection Overlay District. **(or "Areas")**

2. In addition, the provisions of Section 12.13.02 shall apply to all new development within Wellhead Protection Zones, which are the 500 foot radius around public supply potable water wells, measured from the center of the wellhead. Where there is a conflict, the more restrictive provisions apply.

E. Permitted uses: The uses allowed within the overlay district are those listed as permitted and conditional uses in the underlying zoning districts with the exception of those listed as prohibited in Section 6.05.25.F.

F. Prohibited uses:

1. Solid Waste Disposal and Solid Waste Management Facilities as defined in Rule 62-701, F.A.C.;

2. Underground storage facilities located within 2,000 feet of a public supply water well;

3. Any use that qualifies as a Large Quantity Generator according to US Resource Conservation and Recovery Act.

(Note: Additional prohibited uses have been proposed by the consultant and project workgroup members. Those are provided as an attachment should the board decide to consider them.)

G. Permitting Requirements: An applicant for any permitted non-residential use that involves the use, storage, handling or disposal of regulated substances is required to obtain an Operating Permit, a General Exemption approval, or a Special Exemption approval from the County. The closure of such facilities will require a closure permit.

1. Operating Permits will be granted concurrent with Site Plan approval upon demonstration of compliance with Section 6.05.25.H.

2. General Exception approval will be granted concurrent with Site Plan approval upon demonstration of compliance with Section 6.05.25.I.

3. Special Exception approval may be granted by the Zoning Board upon demonstration of compliance with Section 6.05.25.J.

4. Closure Permit approval will be granted consistent with Section 6.05.25.I

H. Operating Permit Requirements: An operating permit application must be submitted as part of a site plan application and must meet the following regulations as applicable:

1. The use of secondary containment is required for all liquid storage and distribution of regulated substances. Such containment systems must be easily inspected and designed to intercept any leak or release from the primary containment vessel or structure. Secondary containment must be sized to accommodate 110% of the substance volume.

2. No nonresidential facility shall discharge any regulated substance into groundwater, either directly or indirectly, into the soil or groundwater.

3. New underground storage facilities within the Wellfield Protection District **(or Areas)** shall meet the following requirements:

a. Double-walled tank and piping with continuous leak detection system in between the walls; or

b. An impervious secondary containment having monitoring well(s) or detector located therein; and

c. For each of the above options, it is required that the facility install, maintain, and monitor a groundwater testing system.

4. New underground facilities for transportation of regulated substances within the Wellfield Protection District **(or Areas)** shall be constructed to ensure no leakage into the soil or groundwater.

5. New discharge to groundwater of treated domestic waste effluent meeting domestic wastewater plant class I reliability, daily monitoring to assure proper treatment plant process control, and 24-hour-a-day attendance by a wastewater operator as required by the Florida Department of Environmental Protection (FDEP) and under the general supervision of a class A certified wastewater operator, shall be allowed to operate provided that the discharge from such plant shall meet the groundwater criteria specified by FDEP prior to contact with groundwater. Treated domestic waste effluent discharge employing land application shall be restricted to slow-rate infiltration methods.

6. All permitted facilities must adhere to appropriate federal and state standards for storage, handling and disposal of any hazardous materials.

7. A contingency plan for all permitted facilities must be prepared for preventing hazardous materials from contaminating the surficial aquifer should fire or other natural catastrophes, equipment failure, or releases occur.

8. Areas where hazardous materials are stored shall not drain to the soil, a stormwater system, water body, or a sewage disposal system. The Planning Director or his/her designee, with input from the Engineering and Environmental Departments, may require that a sump or other device, as appropriate to address the contaminants of concern, be used to ensure protection of ground water quality.

9. All vehicle and equipment washing must be done in a self contained area (e.g. with recycling system) designed to ensure that hazardous materials do not reach the soil, a water body or a sewage disposal system. This does not apply to discharges to a sewer that were approved by the sewer utility, consistent with Chapter 62-625, F.A.C and Chapter 403, F.S.. Water used in wash down areas shall be treated to remove contaminants prior to discharge consistent with Rule 62-660, F.A.C.

10. All new commercial and industrial land uses that involve the use, handling, storage or disposal of hazardous materials or dangerous/extremely dangerous wastes, as defined in Table 302.4 of 40 CFR and Appendix A to 40 CFR part 355, shall be required to prevent contact between the aforementioned materials and stormwater. Secondary containment may not apply to materials applied in an outdoor setting as part of an approved activity's landscaping maintenance plan. This includes, but is not limited to, gas stations, fuel distributors, car/truck washes, trucking companies, asphalt plants and paint shops.

11. Fuel dispensing. - Sites where fuel is dispensed shall be designed to contain fuel spills on site without contaminating stormwater systems, sewage disposal systems, soil, surface water or groundwater.

12. Gasoline and diesel powered generators. - Gasoline and diesel powered backup generators in a wellfield protection area shall be placed in a secondary containment device such that a fuel spill or leak will not reach the soil or a water body.

13. All new wastewater treatment facilities must be constructed and operated to advanced wastewater treatment (AWT) standards.

I. General Exceptions: Facilities qualifying for General Exception approval are exempt from the permitting requirements of Section 6.05.25.H.

a. Facilities and activities qualifying for a general exemption include residential uses, public utilities, commercial lawn maintenance businesses, parks, maintenance of office facilities, retail sales and the like.

b. A general exemption application shall be required for any nonresidential activity claiming a general exemption under this section.

c. Such application shall be submitted as part of a Site Plan application and must contain a concise statement by the applicant detailing the circumstances upon which the applicant believes he would be entitled to a General Exception.

J. Special Exceptions: Exemption from the requirements of Section 6.05.25.H may be granted by Special Exception, subject to the following requirements:

a. Special Exceptions will be process as outlined in Section 2.04.00.C.

b. The applicant must provide substantial scientific evidence that special or unusual circumstances and adequate technology exist to isolate the facility or activity from the potable water supply.

c. In granting the special exception, the Zoning Board may prescribe any additional appropriate conditions and safeguards which are necessary to protect the wellfield.

K. Closure Permit: Closure permit applications shall include a schedule of events to complete the closure of a facility that does or did store, handle, use, dispose, or produce regulated substances. At a minimum, the following actions shall be address:

a. Disposition of all regulated substances and contaminated containers.

b. Cleanup of the activity and environs to preclude leaching of unacceptable levels or residual regulated substances into the aquifer.

c. Certification by a professionally registered engineer or a geologist certified by the State that disposal and cleanup have been completed in a technically acceptable manner.

d. An agreement to indemnify and hold the County harmless from any and all claims, liabilities, causes of action, or damages arising out of the issuance of the permit.

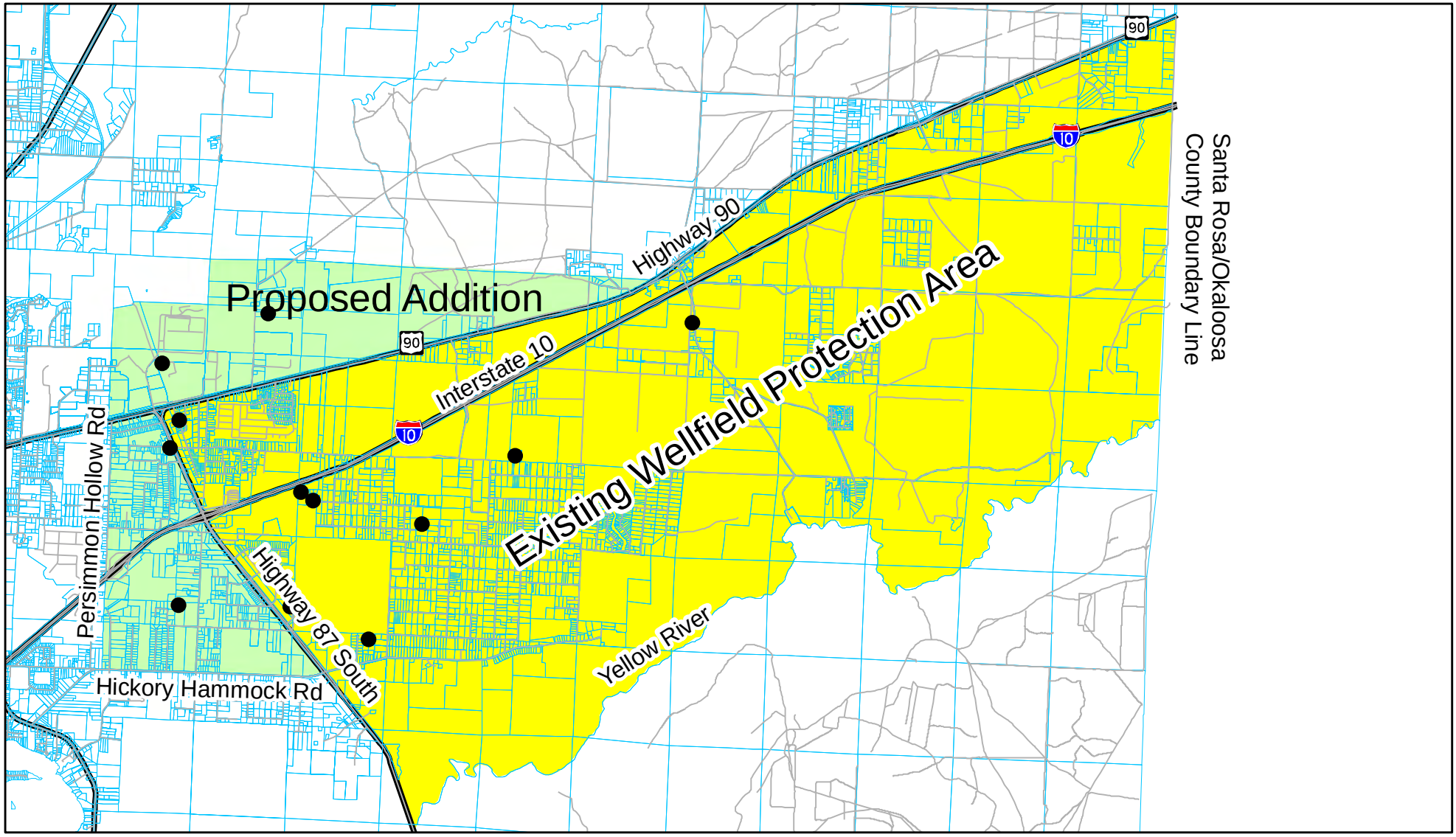
L. Non-Conforming Sites or Facilities: Any expansion, modification or alteration which would increase the storage, handling, use or production of regulated substances at an existing non-conforming site or facility shall require approval of an Operating Permit, General Exception, or Special Exception as described above.

M. Non-conforming uses: Non-conforming uses in operation at the time of adoption of this ordinance may be allowed to continue operation. Expansion of such uses that would increase the storage, handling, use or production of regulated substances is prohibited.

N. Variances: The Board of County Commissioners may grant a variance from one or more of the above requirements upon finding that the proposed facility would not create a risk to ground water quality. Variances will be processed consistent with Section 2.04.00.A.

O. Trade Secrets: The County shall not disclose any trade secrets of the permittee under this article that are exempted from such disclosure by federal or state law; provided, however, that the burden shall be on the permittee to demonstrate entitlement to such nondisclosure.

Proposed Wellfield Protection Area and Recommended Revision
Santa Rosa County, Florida - Revised May 31, 2012



Appendix A

Appendix A

Legend

- SRC Wells
- Streets
- Parcel Lines
- Existing Wellfield Protection Area
- Proposed Expansion of Wellfield Protection Area (Rev 1)

N W E S

1 in equals 1.5 miles

Map Document: (C:\mav's-d-drive\mav\work\Wellfield ProtectionAArea\Proposed Wellfield Changes May 31 2012.mxd)
5/31/2012 -- 2:55:00 PM

Community Planning, Zoning and Development Division
January 23, 2012
Map Revised May 31, 2012

Appendix “B”

Generic Regulated Substances List

Acid and basic cleaning solutions	Medical, pharmaceutical, dental, veterinary and hospital solutions
Antifreeze and coolants	Mercury and mercury compounds
Arsenic and arsenic compounds	Metal finishing solutions
Bleaches and peroxides	Oils
Brake and transmission fluids	Paints, primers, thinners, dyes, stains wood preservatives, varnishing and cleaning compounds
Brine solution	Painting solvents
Casting and Foundry chemicals	PCB’s
Caulking agents and sealants	Pesticides and herbicides
Cleaning Solvents	Plastic resins, plasticizers and catalysts
Corrosion and rust prevention solutions	Photo development chemicals
Cutting fluids	Poisons
Degreasing and parts cleaning solvents	Polishes
Disinfectants	Pool Chemicals
Electroplating solutions	Processed dust and particulates
Explosives	Radioactive sources
Fertilizers	Reagents and standards
Fire extinguishing chemicals	Refrigerants
Food processing wastes	Roofing chemicals and sealers
Formaldehyde	Sanitizers, disinfectant bactericides and algaecides
Fuels and fuel additives	Soaps, detergents and surfactants
Glues, adhesives and resins	Solders and fluxes
Greases	Stripping compounds
Hazardous waste	Tanning industry chemicals
Hydraulic Fluid	Transformer and capacitor oils/fluids
Indicators	Waste oils and antifreeze
Industrial and commercial janitorial supplies	Water and wastewater treatment chemicals
Industrial process chemicals	
Industrial sludges and stillbottoms	
Inks, printing and photocopying chemicals	
Laboratory chemicals	
Liquid storage batteries	

Appendix “C”

Additional Uses Suggested for Prohibition by the Consultant and the Public

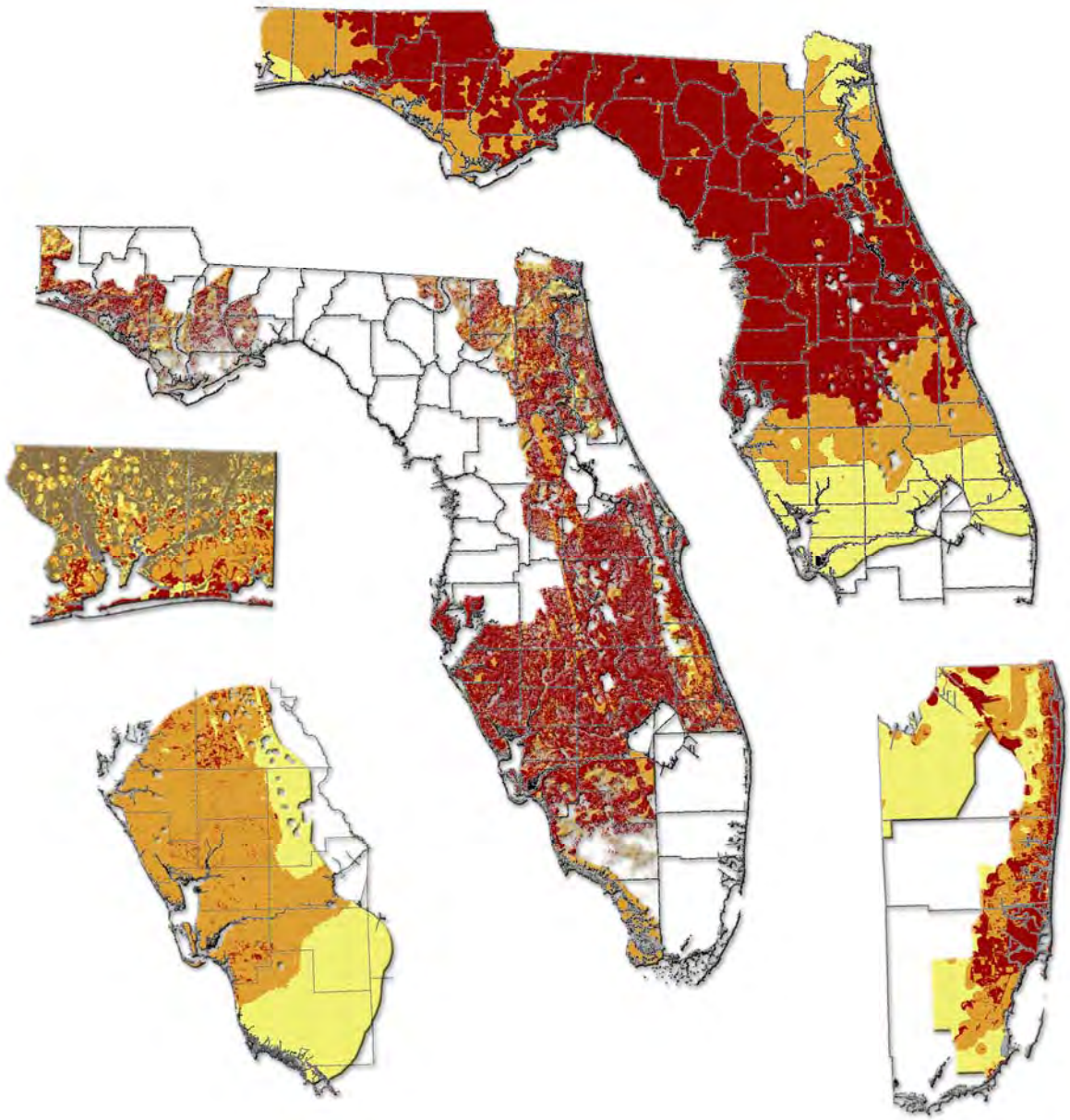
1. Underground fuel storage facilities
2. Project with impervious cover of 50% or more
3. Wastewater/reclaimed water sprayfields, land application sites, percolation ponds, and similar facilities
4. Mines or mining activities
5. Excavation of waterways or drainage facilities which intersect the water table
6. Onsite septic systems for residential developments with greater thatn 100 planned housing units
7. Drilling oil and gas wells
8. Underground storage of hazardous materials
9. Land divisions resulting in residential density greater than one unit per acre.
10. Hazardous Waste Transporter (TRA) facility
11. Used Oil Processor (UOP) facility
12. Used Oil Transporter (UOT) facility
13. Treatment, Storage or Disposal facility for hazardous waste (TSD)
14. Pharmaceutical and Medical waste transfer/transport facility
15. Transporter/Handler/Transfer Facility mercury containing lamps and devices
16. Asphalt plants
17. Wood preserving/treating facility
18. Junk yard, scrap yard, salvage yard and solid waste recycling facility
19. Dry cleaning facilities
20. Large and Medium Concentrated Animal Feeding Operation (CAFO). As defined in Title 40: Protection of Environment § 122.23 Concentrated animal feeding operations
21. Concentrated Aquatic Animal Production (CAAP), or farm raised fish facilities
22 Injection wells and dry wells. Exception geothermal heat exchange systems that do not use chemicals or antifreeze and roof gutter downspouts to a drywell.
23. Waste holding pond, percolation ponds, and similar facilities. Exception stormwater holding ponds.
24. Spreading of sewer sludge or septic tank waste on the land
25. Industrial ash spreading

Link to FAVA I Report

http://publicfiles.dep.state.fl.us/FGS/WEB/fava/fava_final_dep_report/FAVA_REPORT_MASTER_DOC_3-21-05.pdf

FLORIDA AQUIFER VULNERABILITY ASSESSMENT (FAVA II)

A Ground-Water Protection and Management Tool



Prepared for the Florida Department of Environmental Protection by Advanced GeoSpatial Inc.

FLORIDA AQUIFER VULNERABILITY ASSESSMENT

Prepared For:

The Department of Environmental Protection as part of the Florida Aquifer Vulnerability Assessment (FAVA) Phase II Project, Contract No.RM-059

Prepared by

Alan E. Baker, P.G. 2324 and James R. Cichon of
Advanced GeoSpatial Inc., 1949 Raymond Diehl Rd., Ste. D, Tallahassee, FL 32308

September 2009

PROFESSIONAL GEOLOGIST CERTIFICATION

I, Alan E. Baker, P.G., no. 2324, have read and agree with the findings in this report titled FLORIDA AQUIFER VULNERABILITY ASSESSMENT (FAV II) and do hereby certify that I currently hold an active professional geology license in the state of Florida. The model and report were prepared by Advanced GeoSpatial Inc., a State of Florida Licensed Geology Business (GB491), and have been reviewed by me and found to be in conformance with currently accepted geologic practices, pursuant to Chapter 492 of the Florida Statutes.

Alan E. Baker, P.G.
Florida License No. 2324

September 14, 2009
Date

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For additional information regarding this project, please refer to the associated 24” x 36” interpretive poster of the same title as this report, and/or the GIS project data and associated metadata. At the time of this report, these GIS files may be accessed using ArcMap™, version 9.x.

FLORIDA AQUIFER VULNERABILITY ASSESSMENT

Alan E. Baker, P.G. 2324 and James R. Cichon
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INTRODUCTION

During FAVA version 1.0 it was recognized that additional data could improve the predictive capabilities of the model. FAVA phase II was developed to address this need. Training point and evidential theme improvements were the main focus of phase II. The changes that were made are described in the paragraphs that follow. New models were also created to account for important potable groundwater sources. The surficial aquifer system (SAS) was divided into three models; the sand-and-gravel aquifer, the Biscayne/Surficial aquifer and the SAS. The sand-and-gravel and Biscayne/Surficial models where cut out of the original SAS model because they represent important potable water sources. Modeling these SAS aquifers separately will help identify the relative vulnerability of these systems in their regional context rather than on a statewide scale.

Data Improvements

Training Points

The FDEP Background Groundwater Quality Monitoring Network has now been incorporated into a new database known as the STAUS Network. The STATUS network has removed some wells from the Background Network and added new monitoring well locations. All wells that were sampled for dissolved oxygen and dissolved nitrogen (nitrate + nitrite, dissolved as N), were possible training point locations from this database. All models had training point locations developed for them using the procedure in the FAVA version 1.0 model. The major difference was that all wells had water quality parameters that were measured through the 2006 calendar year. In addition to the STATUS network, all water management district water quality databases were examined to see if it was suitable to use any of their wells in the training point process. Again, all the wells had water quality parameters that were measured through the 2006 calendar year. The result was a water quality database with more well locations and more water quality measurements. Information on each models training points can be found in the project results section of this report.

Intermediate Confining Unit/ Overburden Thickness

Improved resolution of the Intermediate Confining Unit (ICU) was developed by the Florida Geological Survey of the Florida Department of Environmental Protection. Using the most recent well cuttings and core data, Florida Geological Survey staff developed a surface for the top of the IAS. To create an ICU thickness surface, the top of Floridan aquifer system (FAS) surface developed during FAVA version 1.0 was subtracted from the top of IAS surface. Likewise, overburden thickness was calculated by subtracting the top of the IAS surface from the latest Digital Elevation model (DEM). These layers were used in the modeling of the Floridan aquifer system and the intermediate aquifer system.

Depth to Water

In FAVA version 1.0 one depth to water layer was created for the entire State and the SAS was modeled on a statewide scale. For this project, the SAS was divided into three models; the sand-and-gravel, the Biscayne/Surficial and the SAS for the remainder of the State. As a result, three separate depth to water layers were created. The sand-and-gravel depth to water layer used the same methodology as version 1.0 of the FAVA model, but incorporated new data. The National Hydrography Dataset 1:24000 was used to develop the minimum water table layer and new water level data from the Northwest Florida Water Management District (NWFWMD) aided in the creation

of a new linear regression equation. The results of this new data decreased the range of error by as much as 50%.

Two methods were utilized to create a depth to water coverage for the Biscayne/Surficial aquifer. The first was the same as the method described above (linear regression method) and incorporated the National Hydrography Dataset 1:24000 and water level data from the South Florida Water Management District (SFWMD). The second method used surficial aquifer system water level measurements from SFWMD databases and used kriging to create a surface. After comparing both surfaces, the surface that relied strictly on water level measurements had a smaller range of errors and correlated better with the actual measurements.

For the remainder of the State, the DEM was used to assess potential elevation discrepancies near water bodies and correct significant errors. The depth to water surface for this layer included the statewide surficial aquifer system minus the Biscayne/Surficial aquifer and the sand-and-gravel aquifer. Based on the new improvements the range of errors was reduced by 50% and the correlation between measured and regressed values was increased.

Soil Hydraulic Conductivity/ Soil Pedality

FAVA version 1.0 did not include Soil Survey Geographic (SSURGO) soil data for four counties (Holmes Washington, Taylor and Liberty) at the time of its completion. Since then the National Resource Conservation Service (NRCS) has improved the county soil data by digitally mapping every county in Florida and placing these GIS datasets in geodatabase format. They also improved the tabular data for soil hydraulic conductivity. As a result, the entire soil hydraulic conductivity data layer was reproduced rather then just updating the four missing counties.

During the modeling process for the Sand-and-gravel aquifer system, a large discrepancy in soil hydraulic conductivity values was noticed along the Santa Rosa/ Okaloosa County line. The Lakeland soil polygons on the Santa Rosa County side had a soil hydraulic conductivity value of 423 micrometers/sec, while the Lakeland soil polygons on the Okaloosa County side had a soil hydraulic conductivity value of 92 micrometers/sec. To remedy this situation, data from the Florida Soil Characterization Data Retrieval System was used. Based on this information, a median soil hydraulic conductivity value of 225 micrometers/sec was assigned to the polygons in the area that represent Lakeland soils.

Topography

The digital elevation model (DEM) currently in use by FDEP/FGS has minor problems that were recognized during FAVA version 1.0 of the process. These included the omission of hilltop attributes for the peninsula, providing curvature for flat areas where depressions and hilltops occur and updating two quadrangle maps.

Hilltops were attributed using an automated process in ArcView. All (topographic) polygons that touched more than two polygons were selected. The unselected polygons were either depressions or hilltops. Since depressions are already attributed a simple query was constructed to select all polygons that were not depressions. These remaining polygons were then attributed as hilltops.

Flat areas in the DEM are the result of closed contour lines. Since these features contain one elevation value, a centroid had to be established to add ½ contour intervals and provide curvature to these features. Centroids were developed based on the automated selection of hilltops/depressions described above. Elevation values were assigned to each centroid by extracting values from the original DEM grid. One-half the contour interval (rounded to 3 feet because it's an integer grid) was added to each centroid value to provide needed curvature in the DEM.

Two quadrangles in the St. Johns River Water Management District (Bostwick and Green Cove Springs) were based on the 1949 topographic survey. A later survey done in 1991 revealed that these contour lines were inaccurate. To fix this problem AGI scanned and digitized the two newer quad sheets for Bostwick and Green Cove Springs. Hilltops and depressions were attributed and then the new lines were edge matched with the surrounding quad sheets. Unfortunately edge matching issues were not exclusive to the new contours that were added. Significant errors were located just north of the Bay/Washington County due to a substantial number of two-meter interval quadrangle maps. To make matters worse this is an area that is characterized by intense karst. The contour lines associated with closed depressions along this border were matched with the nearest equivalent across the boundary. While this is not an accurate way to characterize elevation it did allow for the inclusion of many closed depressions that straddle the border of the two different quadrangle maps that had been missing from previous analyses.

Karst and Closed Topographic Depressions

Karst features are a very important part of the FAS model and it is in this model that the term is used. In the other models, IAS, SAS, SNG and Biscayne/Surficial models closed topographic depressions are used as an evidential theme. While developing the proximity to karst feature dataset for the FAVA version 1.0 project several problems were encountered. First of all not every closed depression is a karst feature. Second, the FGS sinkhole database was not used in the phase I vulnerability analysis because of its strong bias towards land use.

To address the issue of excluding non-karst features from the FAS model, AGI developed a filtering process based on index of circularity or circular index (Denizman, 2003). Closed depressions are filtered based on the ratio of circularity of a polygon to the circularity of a circle where 1 is a perfect circle and 0 is a line that never forms a polygon. Values for ratios ranged from of 0.9967 to 0.0003 the mean was 0.7665. Several evidential themes were generated based on circular index scores. These values were; 0.90, 0.85, 0.80, 0.75, 0.70 and 0.65. Each was evaluated individually for inclusion into the model based on the evidential theme's association with the training point set. More information on the circularity index method and the potential karst features evidential theme can be found in the FAS model section.

The FGS sinkhole database which indicates areas of the state where recent karst activity has occurred was investigated for inclusion into the model. The sinkhole database was originally excluded from the model because of its inherent bias towards land use. The sinkhole database is more of a predictor of where structures are built and not a predictor of aquifer vulnerability. A thorough review of the latest sinkhole database reveals that of the reported 2,939 sinkholes less than 7% fall in the land use categories of forest or wetland. All of the other land use codes are urban or agricultural land. Further, there is no way to perform a circularity index calculation on the features and 98% of the reported sinkholes were within the 3,000 meter buffer of existing features and therefore did not add to the analysis.

Aquifer Vulnerability

All groundwater and therefore all aquifer systems are vulnerable to contamination to some degree (National Research Council, 1993) and, as a result, different areas overlying an aquifer system require different levels of protection. An aquifer vulnerability assessment provides for the identification of areas which, based on predictive spatial analysis, are more vulnerable to contamination from land surface. AGI uses a definition of aquifer vulnerability similar to that of the FDEP in the version 1.0 of the FAVA report which is: the tendency or likelihood for a contaminant to reach the top of a specified aquifer system after introduction at land surface based on best available data representing the natural hydrogeologic system (Arthur et al., 2005). As a result, model output is considered an estimate of

intrinsic vulnerability because it relies only on physical hydrogeologic factors and does not include natural and human sources of contamination or behavior of specific contaminants.

APPROACH

FAVA Technical Advisory Committee

An advisory committee was formed to provide technical review and support during the development of the FAVA Phase II project. This committee consists of professionals in the water resource, planning, engineering, hydrogeology and other environmental fields. Members, listed below, participated in workshop meetings, provided technical review of model progress and final results.

Table 1. FAVA Technical Advisory Committee members.

Name	Organization
Jonathan Arthur, Ph.D., P.G.	Florida Geological Survey of FDEP
Rodney Dehan, D.V.M.	Florida Geological Survey of FDEP
Allan Stodghill, P.G.	Florida Department of Environmental Protection
Gary Maddox, P.G.	Florida Department of Environmental Protection
Eberhard Roeder, Ph.D., P.E.	Florida Department of Health
Richard Deadman	Florida Department of Community Affairs
Tony Countryman, P.G.	Northwest Florida Water Management District
Chris Richards, P.G.	Northwest Florida Water Management District
Dave Dewitt, P.G.	Southwest Florida Water Management District
Jeff Davis	St. Johns Water Management District
Carlos Herd	Suwannee River Water Management District
Sam Upchurch, Ph.D., P.G.	SDII Global, Inc.
Timothy Hazlett, Ph.D.	Hazlett-Kincaid Inc.
Harley Means, P.G.	Florida Geological Survey of FDEP
John Lockwood	South Florida Water Management District
Keith Wilkins	Escambia County

Weights of evidence methodology, and weighted logistic regression methodology, were employed in FDEP's FAVA project (refer to Arthur et al., 2005). Use of these methods involves combination of diverse spatial data that are used to describe and analyze interactions and generate predictive models (Raines et al., 2000). This section provides an overview of the methodology.

Weights of Evidence

Weights of evidence was used in the FAVA phase II project to develop aquifer vulnerability assessment models of the SAS (Biscayne/Surficial and sand-and-gravel), IAS and FAS. These modeling techniques are based in a geographic information system (GIS) and executed using Arc Spatial Data Modeler (Arc-SDM), an extension to ESRI's ArcGIS software package (available for ArcView 3.x, and ArcGIS 8.x and 9.x). For more information on these methods please refer to Arthur et al. (2007), Kemp et al. (2001), Raines et al. (2000), and Bonham-Carter (1994). Primary benefits of applying these techniques to the FAVA project are that they are data-driven methods, rather than expert-driven, and model generation is dependent upon a training dataset resulting in a self-validated model output.

Weights of evidence involves the combination of diverse spatial data used to describe and analyze interactions and generate predictive models. Weights of evidence utilizes known occurrences (*training points)* to create maps from weighted continuous input data layers (*evidential themes*), which are in turn combined to yield an output data layer, or *response theme* (Raines, 1999).

Data Acquisition and Development

The initial phase of an aquifer vulnerability assessment project comprises acquisition, development and attribution of various GIS data representing natural hydrogeologic conditions for use as input into the model. The input data chosen during this phase determines the level of detail, accuracy, and

confidence of final model output, i.e., vulnerability maps. Examples of data typically used in an aquifer vulnerability assessment include:

- Digital Elevation Data
- Aquifer Confinement or Overburden Thickness
- Karst Features/Topographic Depressions
- Water-Quality Data
- Soil Hydraulic Conductivity/Soil Pedality

Vulnerability Modeling

Upon completion of the development and adaptation of the necessary data coverages for the vulnerability assessment, the modeling phase using weights of evidence is initiated to generate aquifer vulnerability response themes, which, for the FAVA project, are expressed as probability maps.

Study Area and Training Points

The initial step in the vulnerability modeling phase is the identification and delineation of a study area extent. The study areas for each separate aquifer system are described below. Training points are locations of known occurrences of an event. In an aquifer vulnerability assessment, groundwater wells with water quality indicative of high recharge are selected as known occurrences. Dissolved oxygen or dissolved nitrogen analytical concentrations from ambient monitor well networks were used to develop training point datasets. The occurrence of a training point does not directly correspond to a site of aquifer system contamination, but is indicative of aquifer vulnerability.

Evidential Themes (Model Input)

Evidential themes are defined as sets of continuous spatial data that are associated with the location of training points and are analogous to data layers listed and described above, such as soil hydraulic conductivity or thickness of confinement. Weights are calculated for each evidential theme based on the location of training points with respect to the study area and spatial associations between training points and evidential themes are established. Themes are then generalized to determine the threshold or thresholds that maximize the spatial association between the evidential theme and the training points (Bonham-Carter, 1994).

Response Theme (Vulnerability Maps)

Following generalization of evidential themes, output results (response themes) are generated and display the probability that a unit area contains a training point based on the evidential themes provided (for more on generalization of evidential themes, see Arthur et al., 2005). The response theme generated in this project is a probability map displayed in classes of relative vulnerability.

Sensitivity Analysis and Validation of Model Results

Sensitivity analysis and validation are a significant component of any modeling project as they allow evaluation of the accuracy of results. Sensitivity analysis is applied during development of each evidential theme and validation exercises are applied to assess model strength and confidence.

PROJECT RESULTS

SURFICIAL AQUIFER SYSTEM

SAND-AND-GRAVEL AQUIFER SYSTEM

Study Area

The Counties of Escambia, Santa Rosa and Okaloosa were used as the sand-and-gravel aquifer system (SNG) model study area extent (Figure 1). Because of the sizes of some polygons representing soil data, a grid cell size of approximately 30 meter squares (or 900 m^2) was selected for evidential theme development. This grid cell size, while necessary to capture resolution available in some input data layers, does not reflect appropriate resolution of final model output. Appropriate scale of use of model results is discussed in *Model Implementation and Limitations*.

Training Point Theme

In the SNG analysis, training points are groundwater wells tapping the SAS with water quality data indicative of high recharge. Dissolved nitrogen analytical values served as training point data for the SNG model. Dissolved oxygen concentrations could not be used as a training point set because too many outliers were removed during statistical analysis to provide a viable training point theme. These extremely high dissolved oxygen values may be the result of where the samples were taken (at the tank rather than the wellhead). Naturally occurring oxygen and nitrogen are generally considered ubiquitous at land surface as primary components of the atmosphere; moreover, relatively low concentrations of these analytes occur in well protected – or less vulnerable – aquifer systems. Accordingly, where these analytes occur in elevated concentrations in groundwater, yet are not attributable to human activity, they are good indicators of aquifer vulnerability (Arthur et al., 2007).

Water quality data sources explored include the FDEP background water quality network, FDEP STATUS network and NWFWMD databases. From these data sources, 57 wells measured for dissolved nitrogen were identified as being potential candidates for training points. Statistical analyses revealed 5 samples were considered statistical outliers. The upper 25th percentile of this set – or all wells with median dissolved nitrogen values greater than or equal to 0.655 milligrams per liter (mg/L) – served as the training point theme and consists of thirteen wells. Figure 2 displays the distribution of water wells used to derive training points and the resulting training point theme across the study area. Training points are used to calculate prior probability, weights for each evidential theme, and posterior probability of the response theme (see *Glossary*). Prior probability (training point unit area divided by total study area) is the probability that a training point will occupy a defined unit area within the study area, independent of any evidential theme data. The prior probability value, a unitless parameter, for the SNG model is 0.0019 ([1 km^2 model unit area * 13 training points] / 6813.9 km^2 = 0.0019). Posterior probability values generated during response theme development are interpreted relative to the value of prior probability with higher values generally indicating areas with higher probability of containing a training point.

Figure 1. Sand-and-Gravel Aquifer Vulnerability Assessment project study area corresponds to the County's political boundaries.

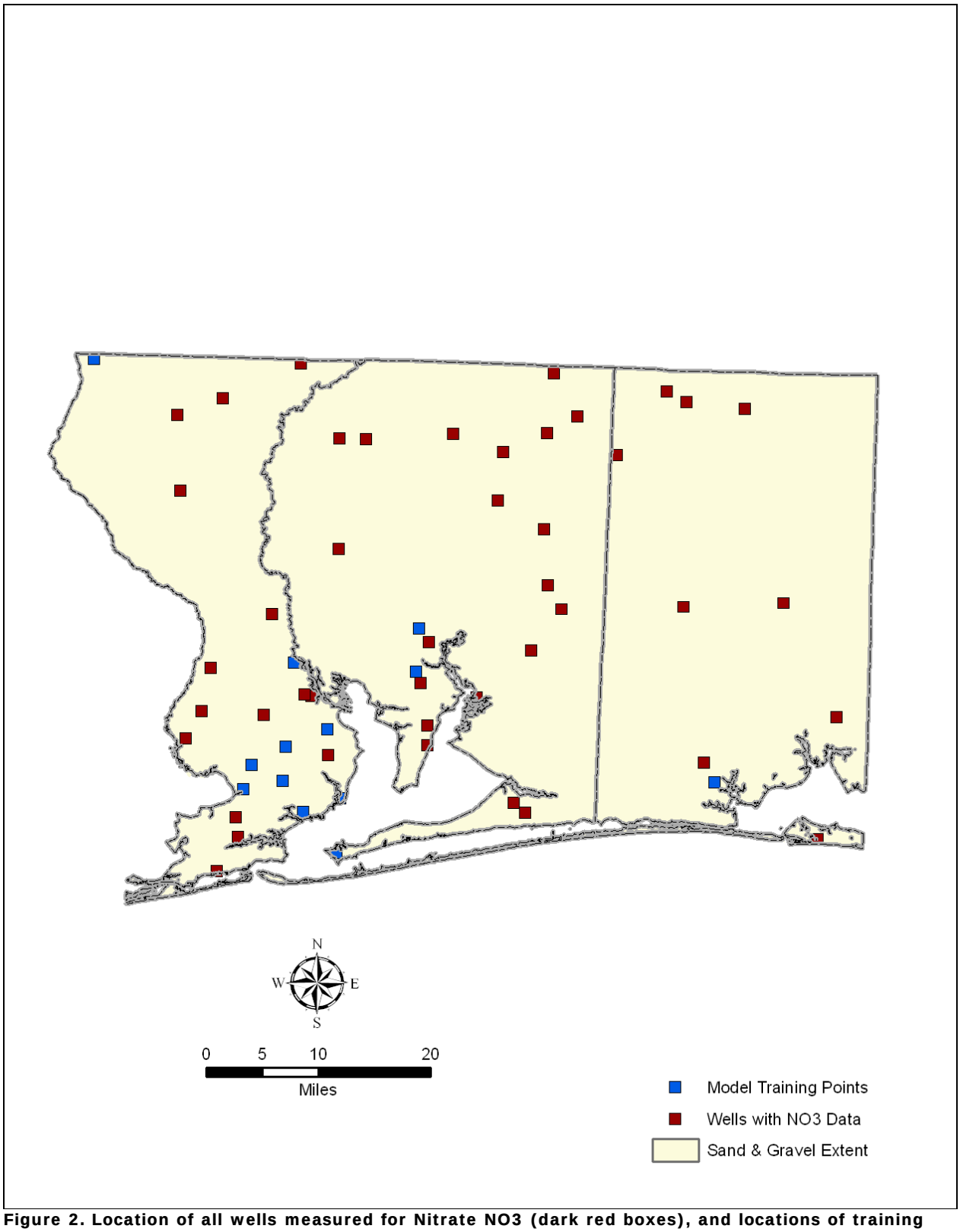

Figure 2. Location of all wells measured for Nitrate NO3 (dark red boxes), and locations of training point wells with median nitrate values greater than 0.655 mg/L (blue boxes).

Evidential Themes – Model Input Layers

Input data layers, or evidential themes, representing hydrogeologic factors controlling the location of training points, and thereby vulnerability, were developed for model input. Because of the local scale nature of the SNG project and the availability of new data, all model inputs represent previously unavailable datasets. The factors considered for the SNG project include closed topographic depressions, depth to water, soil pedality, and soil hydraulic conductivity.

Soil Hydraulic Conductivity and Soil Pedality Themes

The rate that water moves through soil is a critical component of any aquifer vulnerability analysis, as soil is literally an aquifer system's first line of defense against potential contamination (Arthur et al., 2005). Two parameters of soils were evaluated for input into the SNG model: *soil hydraulic conductivity*, which is the "amount of water that would move vertically through a unit area of saturated soil in unit time under unit hydraulic gradient" (U.S. Department of Agriculture, 2005); and *soil pedality*, which is calculated based on soil type, soil grade, and soil pedon size, and is a unitless parameter. Soil pedality is a relatively new concept used to estimate the hydrologic parameter of soil and is generated for SNG using the pedality point method developed by Lin et al. (1999).

Countywide datasets representing soil hydraulic conductivity and soil pedality were developed for use as input into the SNG model. Multiple empirical values are reported in soil surveys representing various zones in each soil column underlying a particular soil polygon. Representative values for each horizon in a column are combined using a sum of the weighted mean. This is completed for both hydraulic conductivity and soil pedality. Figure 4 displays values of soil hydraulic conductivity.

Depth to Water Theme

Depth to water is another critical layer in determining aquifer vulnerability. Where the depth to water is greatest (larger vadose zone), aquifer vulnerability is generally lower, whereas in areas where the depth to water is nearer to the surface, the vulnerability of the aquifer is generally higher.

To estimate the water-table elevation, and thus be able to derive depth to the water table, a multiple linear regression equation was generated based on the following datasets:

- Land surface altitude
- Monitor well water-level data
- Minimum water-table elevation

Land surface altitude (LSA) was based on the FDEP DEM. Elevations from 1:24,000 USGS maps for water bodies including streams, lakes and shorelines were used to interpolate a minimum water table (MINWT). Water-level data were compiled from NWFWMD and FDEP for the period of record between 1990 and 2006. The water table was calculated based on the following equation from Sepulveda (2002):

$$WT_i = \beta_1 \, MINWT_i + \beta_2 \, (LSA_i - MINWT_i)$$

Where:

WT_i	is water-table measurement for the period of record at well i, in feet
$MINWT_i$	is the minimum water table interpolated at well i, in feet
LSA_i	is the land surface altitude interpolated at well i, in feet
$\beta 1$ and $\beta 2$	are dimensionless regression coefficients of the multiple linear regression.

The water table grid for the study area was calculated from the equation:

$$WT = 1.01MINWT + 0.253(LSA - MINWT)$$

The root-mean-square residual between the regressed and measured water-table elevation resulted in a weighted mean of 4.82 feet and exhibited a strong correlation coefficient of 0.99 (Figure 3). The final depth to water evidential theme was calculated by subtracting the water table elevation values from the FDEP DEM values (Figure 5).

Table 2. Linear regression coefficients for MINWT and difference between DEM and MINWT.

Number of sand and gravel wells	Regression coefficient of minimum water table (β_1)	Regression coefficient of difference between LSA & MINWT (β_2)	Root mean square residual (ft)	Value range for difference between regressed & measured water table (ft)	Correlation coefficient
103	1.01	0.253	4.82	[-10.13, 9.05]	0.99

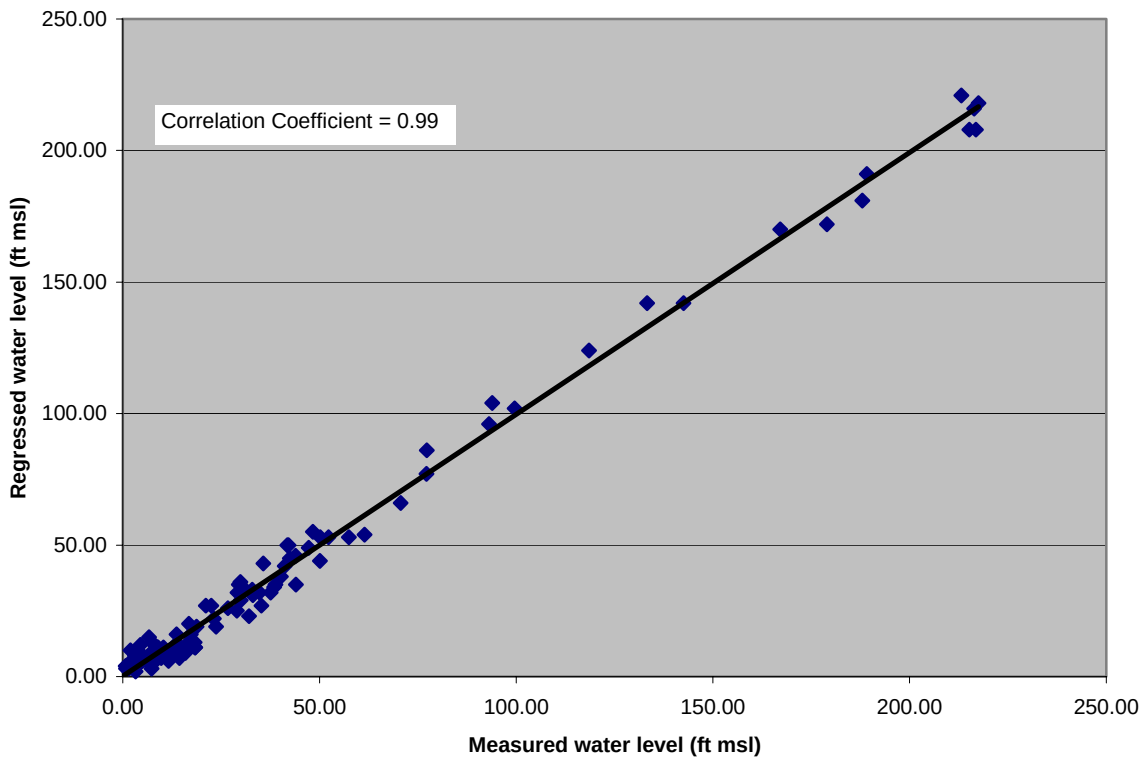

Figure 3. Regressed and measured water level for sand-and-gravel aquifer.

Closed Topographic Depressions

Karst features, or sinkholes and depressions, can provide preferential pathways for movement of surface water into the underlying aquifer system and enhance an area's aquifer vulnerability where present. The closer an area is to a karst feature, the more vulnerable it may be considered. Closed topographic depressions extracted from U.S. Geological Survey 7.5-minute quadrangle maps served as the dataset from which to estimate closed topographic depressions in the study area (Figure 6).

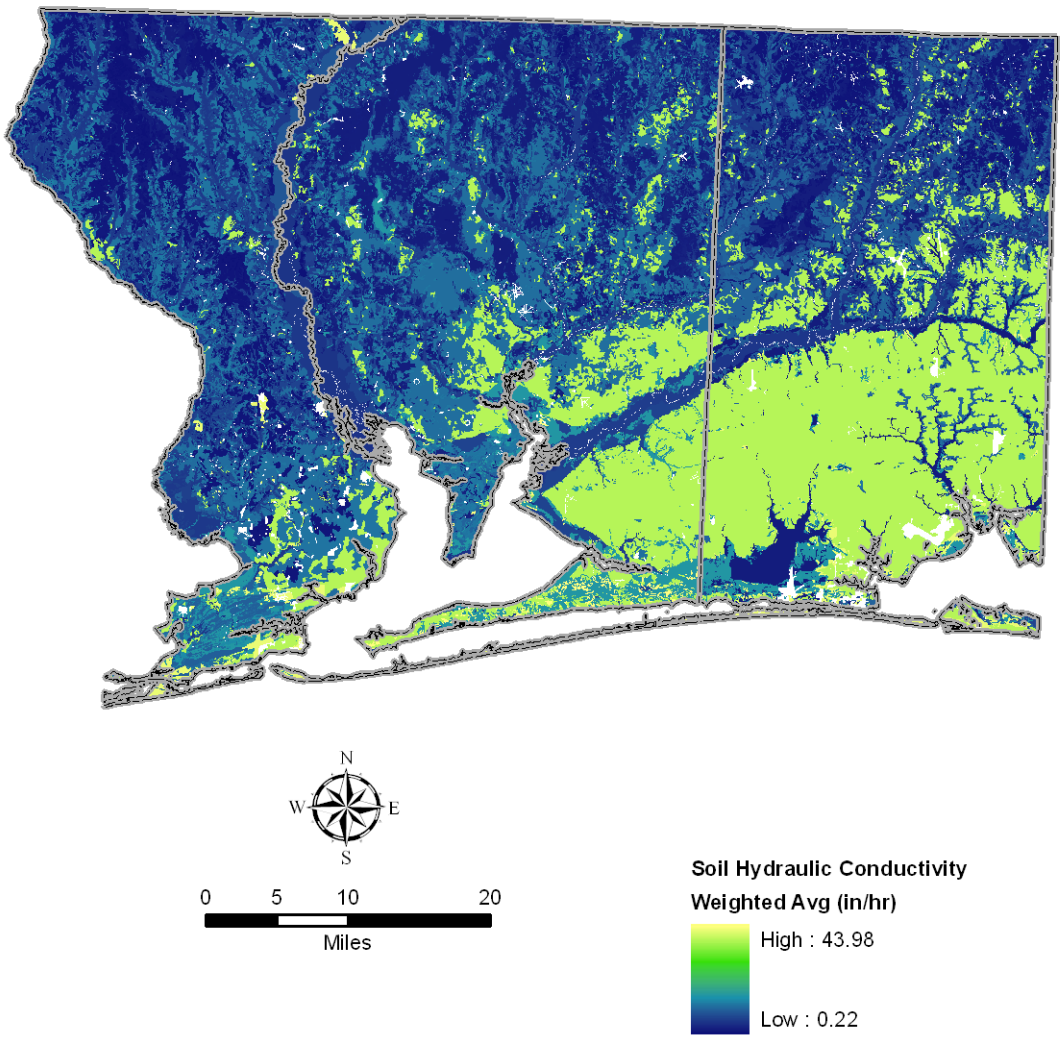

Figure 4. Distribution of soil hydraulic conductivity values across the SNG study area. White areas represent 'no data' areas in the soil survey data or locations of water bodies.

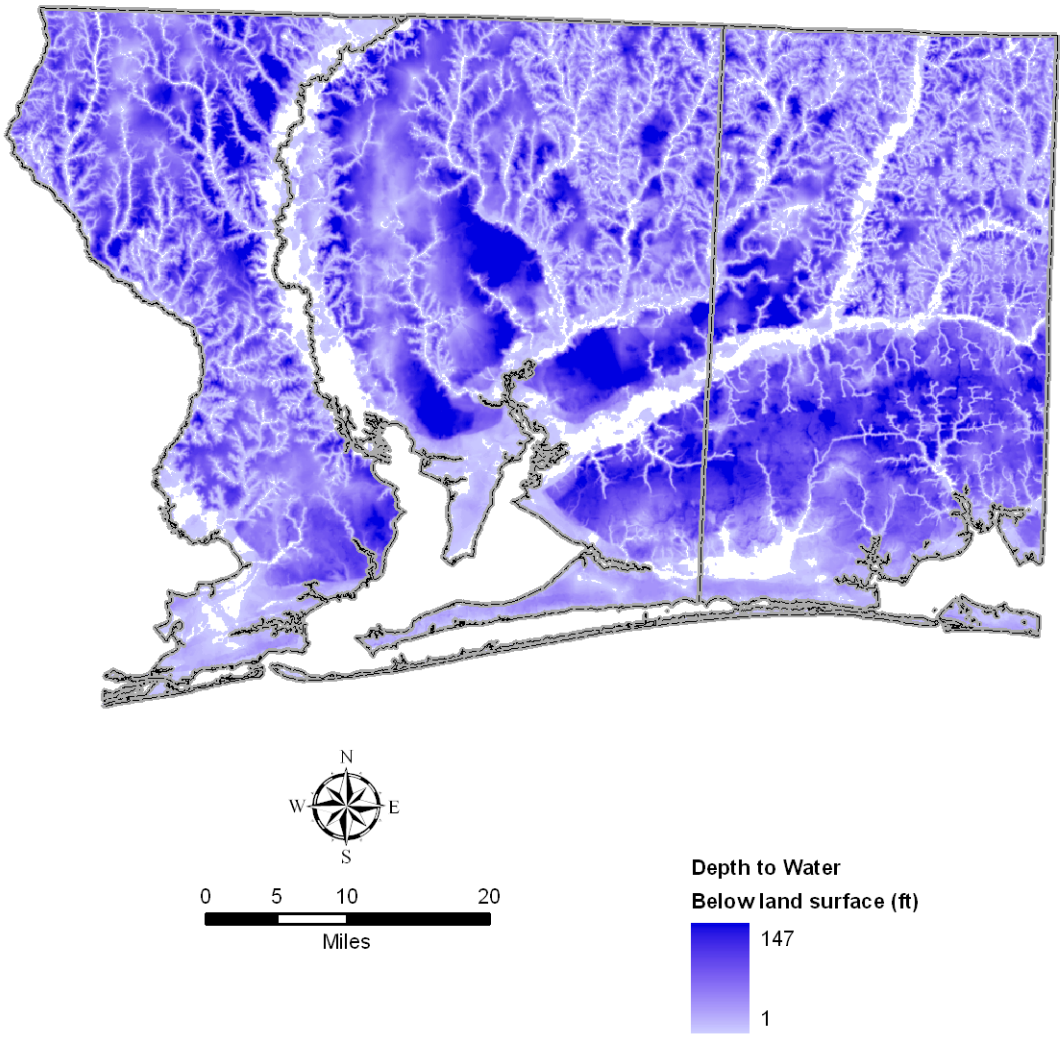

Figure 5. Distribution of depth to water values across the SNG study area. White areas represent 'no data' areas (where depth to water equals zero) or locations of water bodies.

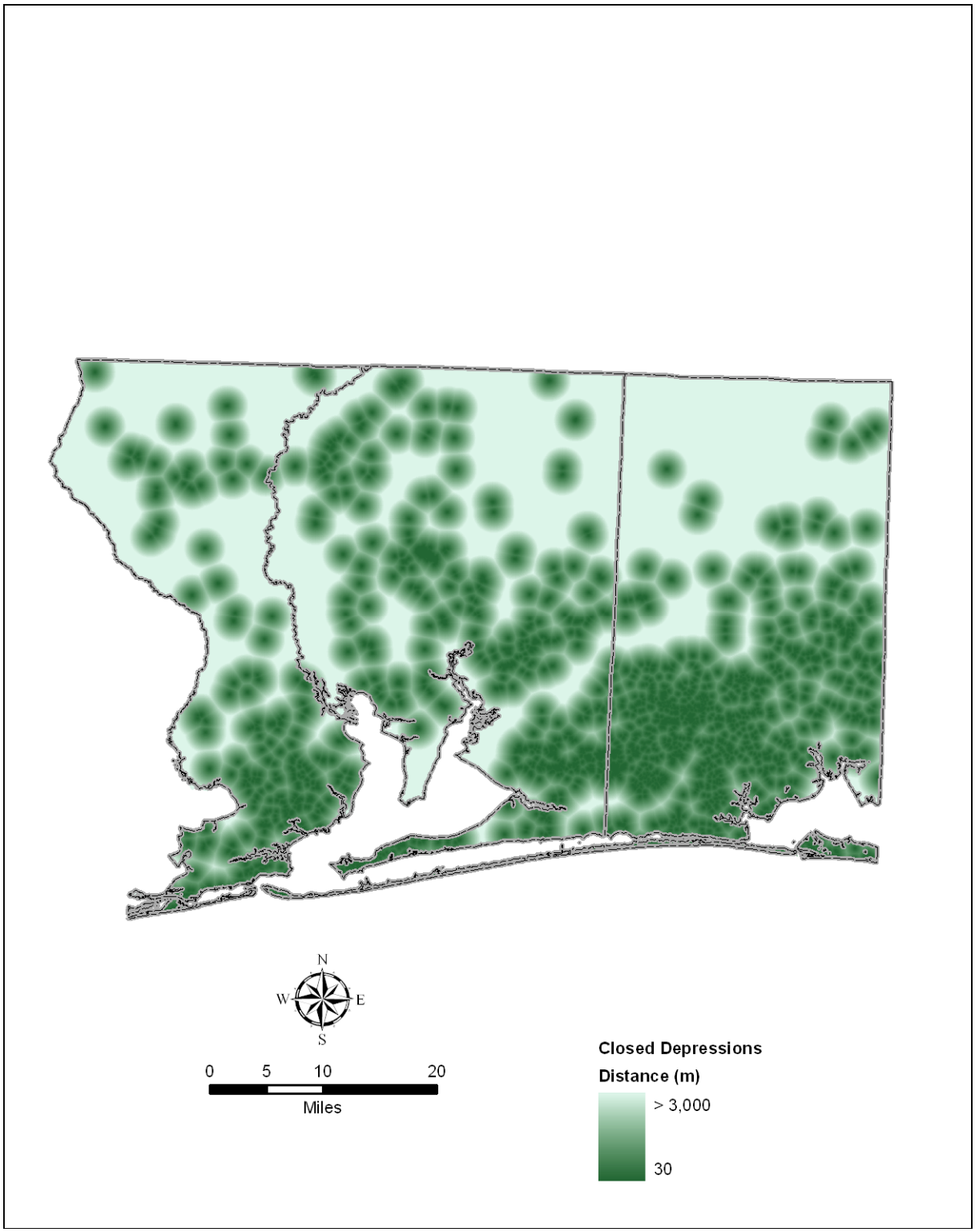

Figure 6. Proximity to closed topographic depressions extracted from U.S. Geological Survey 7.5-minute topographical contour lines.

Sensitivity Analysis/Evidential Theme Generalization

Sensitivity analysis allows decisions to be made about proposed evidential themes by evaluating each theme's association with training points – or aquifer vulnerability – and ultimately helps determine model input. For example, soil hydraulic conductivity and soil pedality were both developed to represent soil properties; sensitivity analysis allows, through statistical analysis, determination of which of these two layers served as the most appropriate input representing soil properties for the final SNG analysis. Results of this process indicate that soil hydraulic conductivity, depth to water, and closed topographic depressions were the best suited evidential themes for use in final modeling.

Following sensitivity analysis and selection of evidential themes to be input into the SNG model, themes were generalized to assess which areas of the evidence share a greater association with locations of training points. During calculation of weights for each theme, a contrast value was calculated for each class of the theme by combining the positive and negative weights. Contrast is a measure of a theme's significance in predicting the location of training points and helps to determine the threshold or thresholds that maximize the spatial association between the evidential theme map pattern and the training point theme pattern (Bonham-Carter, 1994). Contrast and weights are described in more detail below in *Discussion*.

Contrast values were used to determine where to sub-divide evidential themes into generalized categories prior to final modeling. The simplest and most accepted method used to subdivide an evidential theme is to select the maximum contrast value as a threshold value to create binary generalized evidential themes. In other models, categorization of more than two classes may be justified (Arthur et al., 2005). For the SNG project, a binary break was typically defined by the weights of evidence analysis for each evidential theme creating two spatial categories: one with stronger association with the training point theme and one with weaker association.

Soil Hydraulic Conductivity/ Soil Pedality

Weights calculated during sensitivity analysis for soil hydraulic conductivity were stronger (i.e., had higher absolute value) than weights calculated for soil pedality. As a result, soil hydraulic conductivity was chosen as the better predictor of aquifer vulnerability because it shared the best association with training points.

Soil hydraulic conductivity, ranges from 0.22 to 43.98 in/hr across the study area. Test modeling indicated that areas greater than or equal to 9.20 in/hr were more associated with the training points, and therefore associated with higher aquifer vulnerability. Conversely, areas less than 9.20 in/hr were less associated with the training points, and therefore lower aquifer vulnerability. Based on this analysis, the evidential theme was generalized into two classes as displayed in Figure 7.

Depth to Water

The depth to water ranges from zero to 147 feet deep across the study area. The analysis revealed that areas less than or equal to 33 feet deep were more associated with the training points, and therefore associated with higher aquifer vulnerability. Areas with a depth to water greater than 33 feet were less associated with the training points, and therefore lower aquifer vulnerability. Based on this analysis, the evidential theme was generalized into two classes as displayed in Figure 8.

Closed Topographic Depressions

As mentioned above, areas closer to a depression are normally associated with higher aquifer vulnerability. Based on this, features were buffered into 30 meter zones to allow for a proximity analysis. The analysis indicated that areas within 1,470 meters of a closed topographic depression were more associated with the training points, and therefore with higher aquifer vulnerability.

Conversely, areas greater than 1,470 meters from a closed topographic depression were less associated with the training points, and therefore lower aquifer vulnerability. Based on this analysis, the evidential theme was generalized into two classes as displayed in Figure 9.

Response Theme

Using evidential themes representing soil hydraulic conductivity, depth to water, and closed topographic depressions, weights of evidence was applied to generate a response theme, which is a GIS raster consisting of *posterior probability* values ranging from 0.00003 to 0.0099 across the study area. These probability values describe the relative probability that a unit area of the model will contain a training point – i.e., a point of aquifer vulnerability as defined above in *Training Points* – with respect to the prior probability value of 0.0019 or ([1.0 km^2 model unit area * 13 training points] / 6813.9 km^2 = 0.0019). Prior probability is the probability that a training point will occupy a defined unit area within the study area, independent of evidential theme data. Probability values at the locations of twelve of the thirteen training points are above the prior probability, indicating that this model is a strong predictor of training point locations.

The response theme was broken into classes of relative vulnerability based on the prior probability value and on inflections in a chart in which cumulative study area was plotted against posterior probability (Figure 10). Higher posterior probability values correspond with more vulnerable areas, as they essentially have a higher chance of containing vulnerability based on the definition of a training point. Conversely, lower posterior probability values correspond to less vulnerable areas as they essentially have a lower chance of containing vulnerability based on the definition of a training point.

As described in *Introduction*, the SNG model was based on the modeling technique used in the FAVA project. The FAVA project identified relative vulnerability of Florida's principal aquifer systems broken into three classes: more vulnerable, vulnerable and less vulnerable zones. This naming technique was applied to the SNG results, along with addition of an extra vulnerability class, to define the relative vulnerability classes as displayed in Figure 11.

As expected, the SNG response theme indicates that areas of highest vulnerability are associated with areas where the depth to water is lowest, in areas of dense closed topographic depressions, and areas of higher soil hydraulic conductivity. Conversely, areas of lowest vulnerability are determined by high depth to water values, sparse closed topographic depression distribution, and lower soil hydraulic conductivity values.

Discussion

Prior to discussion of weights calculations during model execution, two components of a weights of evidence analysis are described to assist in interpretation of SNG model results: *Conditional Independence* and *Model Confidence*.

Conditional Independence

Conditional independence is a measure of the degree that evidential themes are affecting each other due to similarities between themes. Evidential themes are considered independent of each other if the conditional independence value is around 1.00, and conditional independence values within the range of 1.00 ± 0.15 generally indicate limited to no dependence among evidential themes (Bonham-Carter, 1994). Values significantly outside this range can inflate posterior probabilities resulting in unreliable response themes.

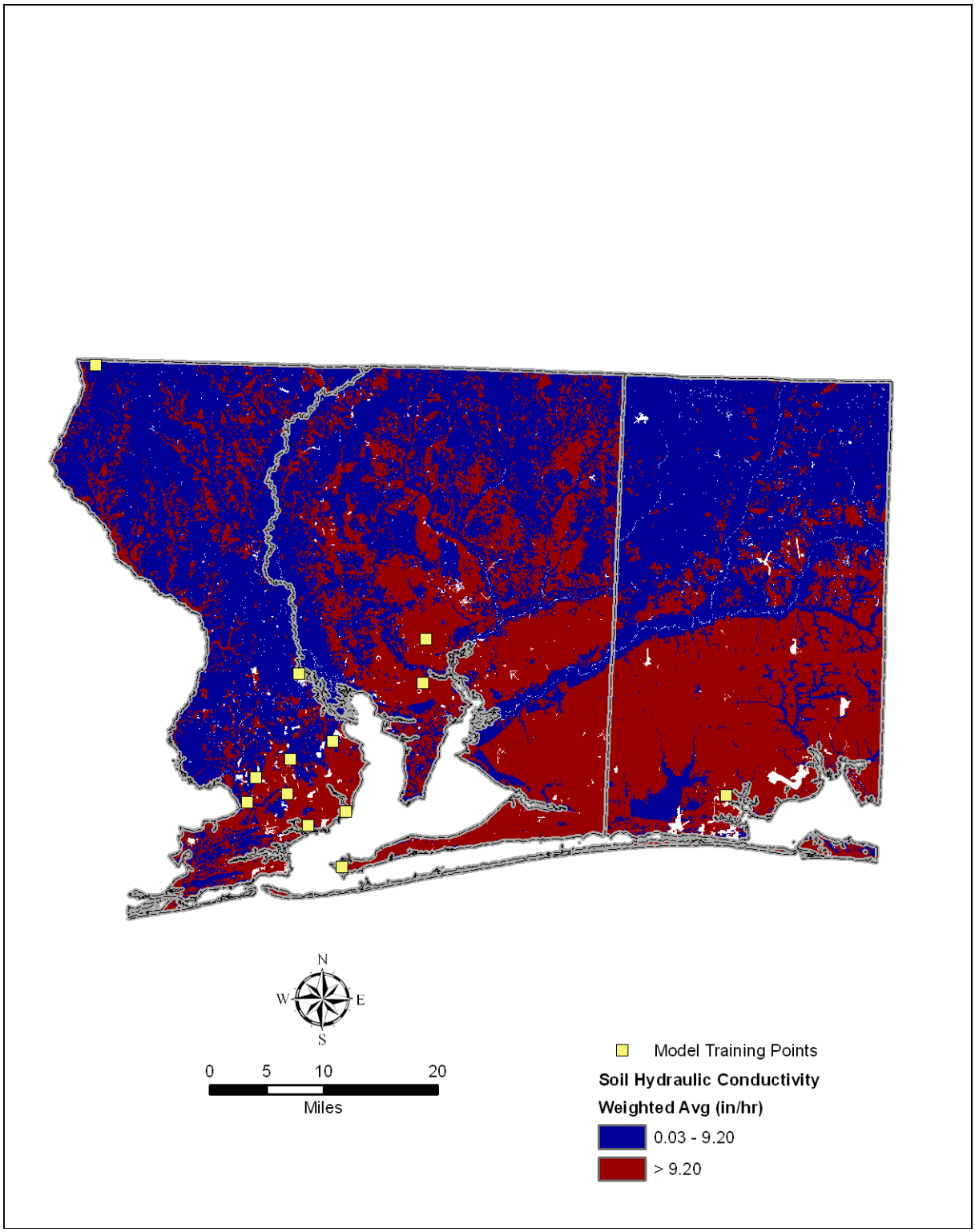

Figure 7. Generalized soil hydraulic conductivity evidential theme; based on calculated weights analysis blue areas share a weaker association with training points and thereby relatively lower aquifer vulnerability, whereas red areas share a stronger association with training points.

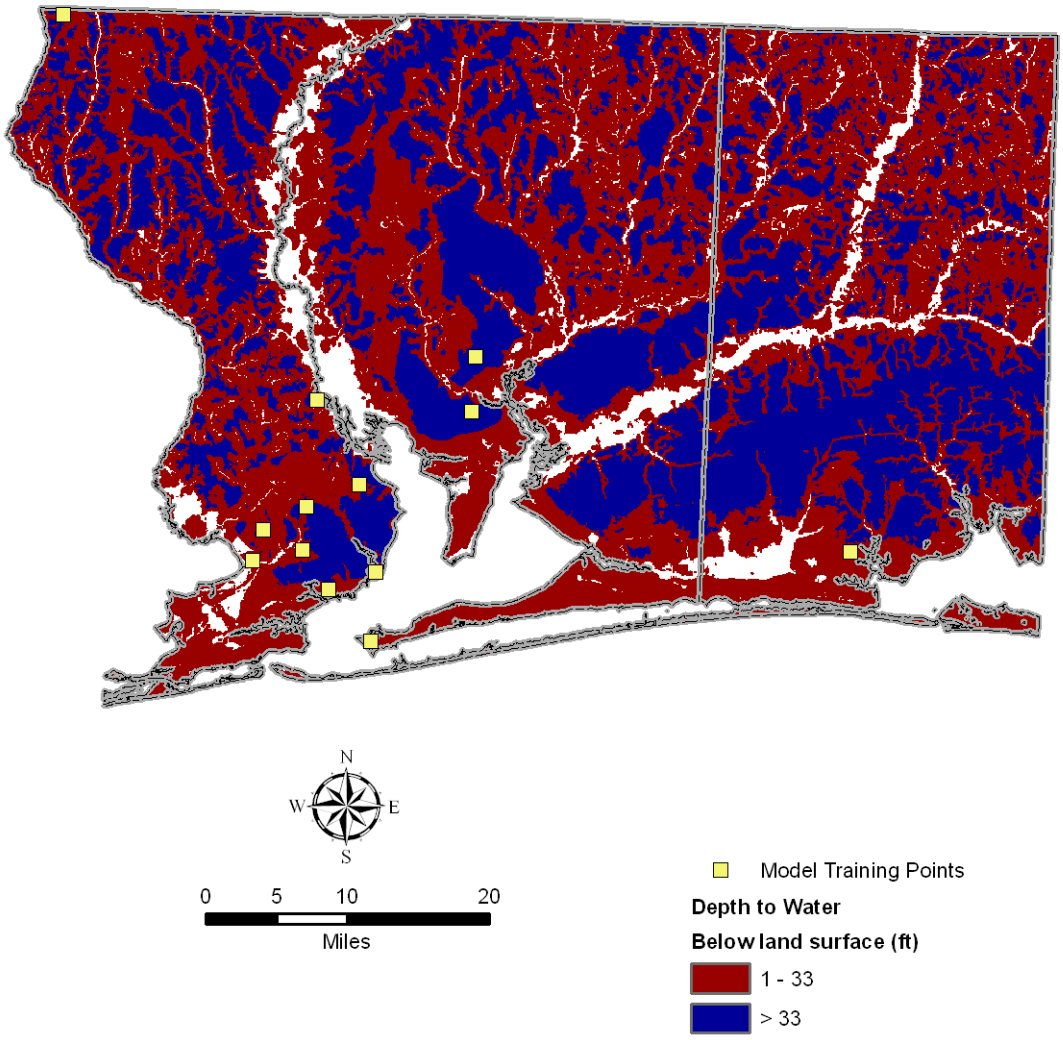

Figure 8. Generalized depth to water evidential theme; based on calculated weights analysis blue areas share a weaker association with training points and thereby relatively lower aquifer vulnerability, whereas red areas share a stronger association with training points.

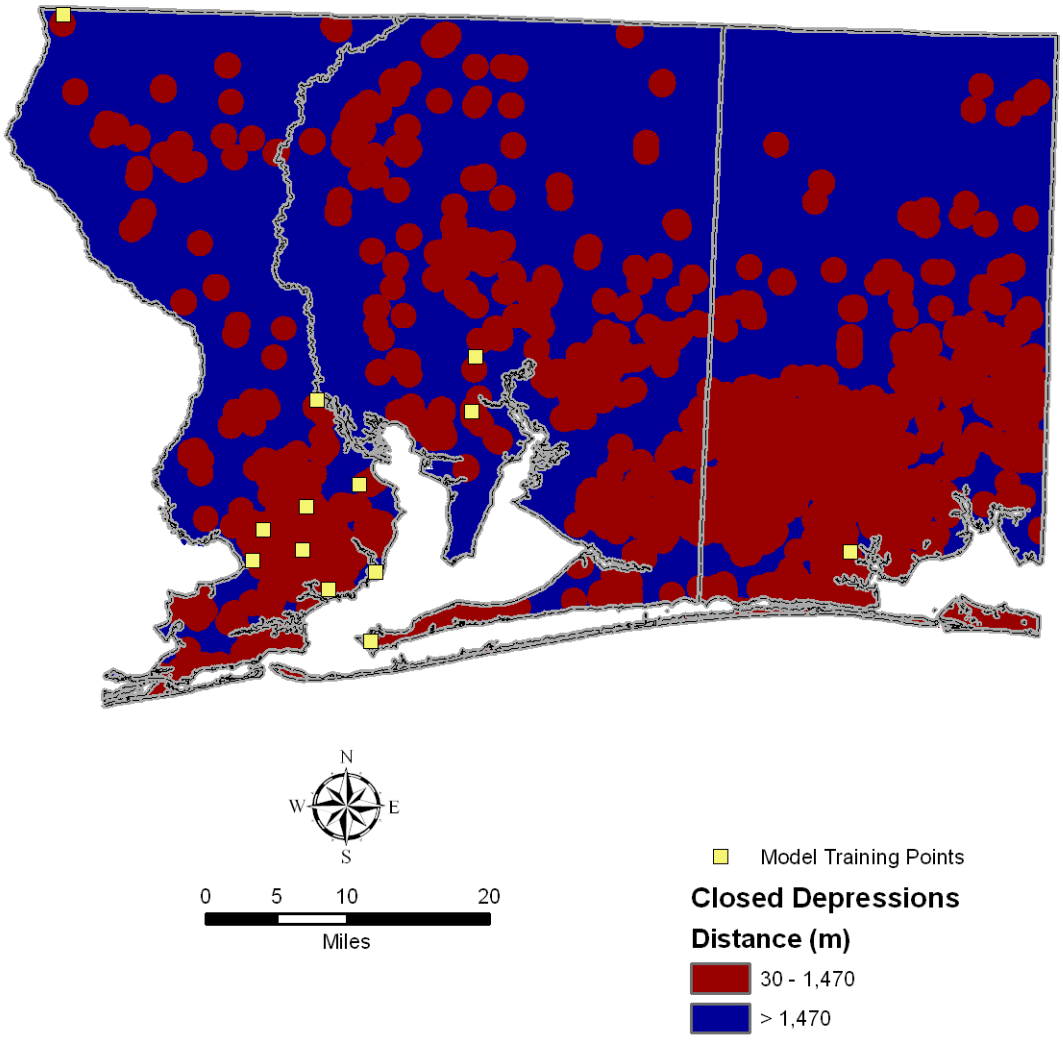

Figure 9. Generalized closed topographic depressions evidential theme; based on calculated weights analysis blue areas share a weaker association with training points and thereby relatively lower aquifer vulnerability, whereas red areas share a stronger association with training points.

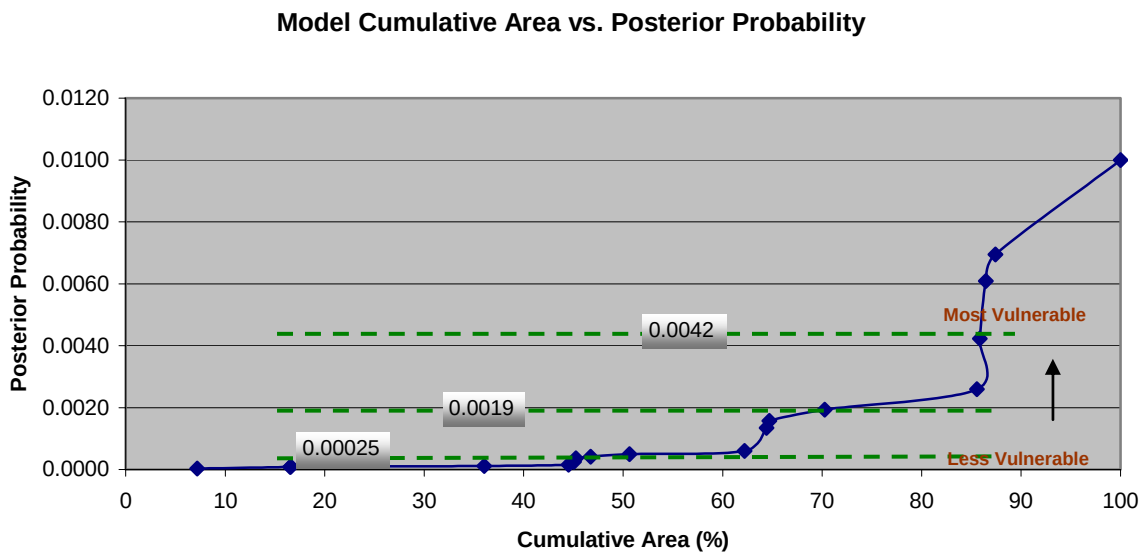

Figure 10. Vulnerability class breaks are defined by selecting where a significant increase in probability and area are observed.

Conditional independence was calculated at 0.93 for the SNG project indicating that evidential themes had virtually no conditional dependence.

Model Confidence

During model execution, confidence values are calculated both for each generalized evidential theme and for the final response theme. Confidence values approximately correspond to the statistical levels of significance listed in Table 3.

Table 3. Test values calculated in weights of evidence and their respective studentized T values expressed as level of significance in percentages.

Studentized T Value	Test Value
99.5%	2.576
99%	2.326
97.5%	1.960
95%	1.645
90%	1.282
80%	0.842
75%	0.674
70%	0.542
60%	0.253

Confidence of the evidential theme equals the contrast divided by the standard deviation (a student T-test) for a given evidential theme and provides a useful measure of significance of the contrast due to the uncertainties of the weights and areas of possible missing data (Raines, 1999). A test value of 1.7644 corresponds to a greater than 95% confidence – or level of significance – and was the minimum calculated confidence level for the SNG project evidential themes (see Table 4 below for evidential theme confidence values).

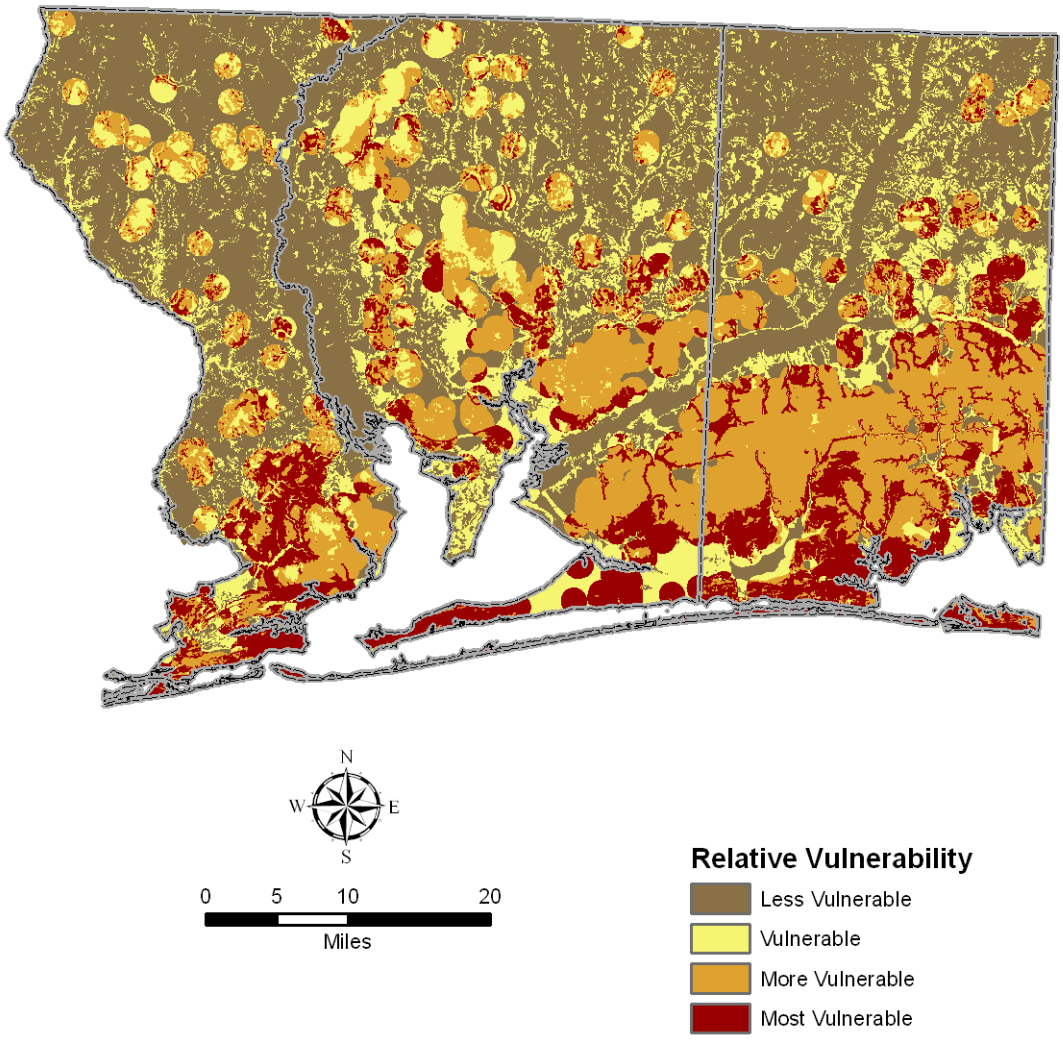

Figure 11. Relative vulnerability map for the Sand-and-Gravel Aquifer Vulnerability Assessment project. Classes of vulnerability are based on calculated probabilities of a unit area containing a training point, or a monitor well with water quality sample results indicative of vulnerability.

A confidence map is also calculated for a response theme by normalizing the theme's posterior probability by its total uncertainty (standard deviation). A confidence map can be generated based on these calculations. The confidence map for the SNG response theme is displayed in Figure 12. Areas with high posterior probability values typically correspond to higher confidence values and as a result have a higher level of certainty with respect to predicting aquifer vulnerability.

Weights Calculations

Table 4 displays evidential themes used in the SNG model, weights calculated for each theme, along with contrast and confidence values. Positive weights indicate areas where training points are likely to occur, while negative weights indicate areas where training points are not likely to occur. The contrast column is a combination of the highest and lowest weights (positive weight - negative weight) and is a measure of how well the generalized evidential themes predict training points. Confidence of the evidential theme is also calculated and is equal to the contrast divided by its standard deviation (a student T test). Confidence is a measure of significance due to uncertainties of the weights and missing data (Raines, 1999). A positive contrast that is significant, based on its confidence, suggests that a generalized evidential theme is a useful predictor.

Table 4. Weights of evidence final output table listing weights calculated for each evidential theme and their associated contrast and confidence values of the evidential themes.

Evidential Theme	W1	W2	Contrast	Confidence
Soil Hydraulic Conductivity	0.4997	-1.1516	1.6513	2.147
Depth to Water	0.3673	-0.9898	1.3571	1.7644
Closed Topographic Depressions	0.7972	-2.0272	2.8244	2.7128

Because negative weights (W2) values for all evidential themes are stronger (have greater absolute values) than the positive weights (W1), they are better predictors of where training points were *less* likely to occur. Based on contrast values, closed topographic depressions theme has the strongest (highest absolute value) weight and is the primary determinant in predicting areas of vulnerability in the SNG model.

Validation

The weights of evidence approach, because it relies on a set of training points, which by definition are known sites of vulnerability, is essentially self-validated. Twelve of Thirteen training points were predicted in zones of posterior probability greater than the prior probability (in other words, classified accurately). Further strengthening the results were the evaluation of a minimum confidence threshold for evidential themes, and generation of a confidence map of the response theme. In addition to these exercises, and in the style of previous aquifer vulnerability assessments (Cichon et al., 2005; Baker et al., 2005; Arthur et al., 2005), additional validation techniques were applied to the SNG model to further strengthen its defensibility, and, ultimately, its utility: (1) comparison of dissolved nitrogen values to posterior probability and evaluation of an associated trend; and (2) generation of a test response theme based on a subset of training points and comparison of points not used in subset to model results.

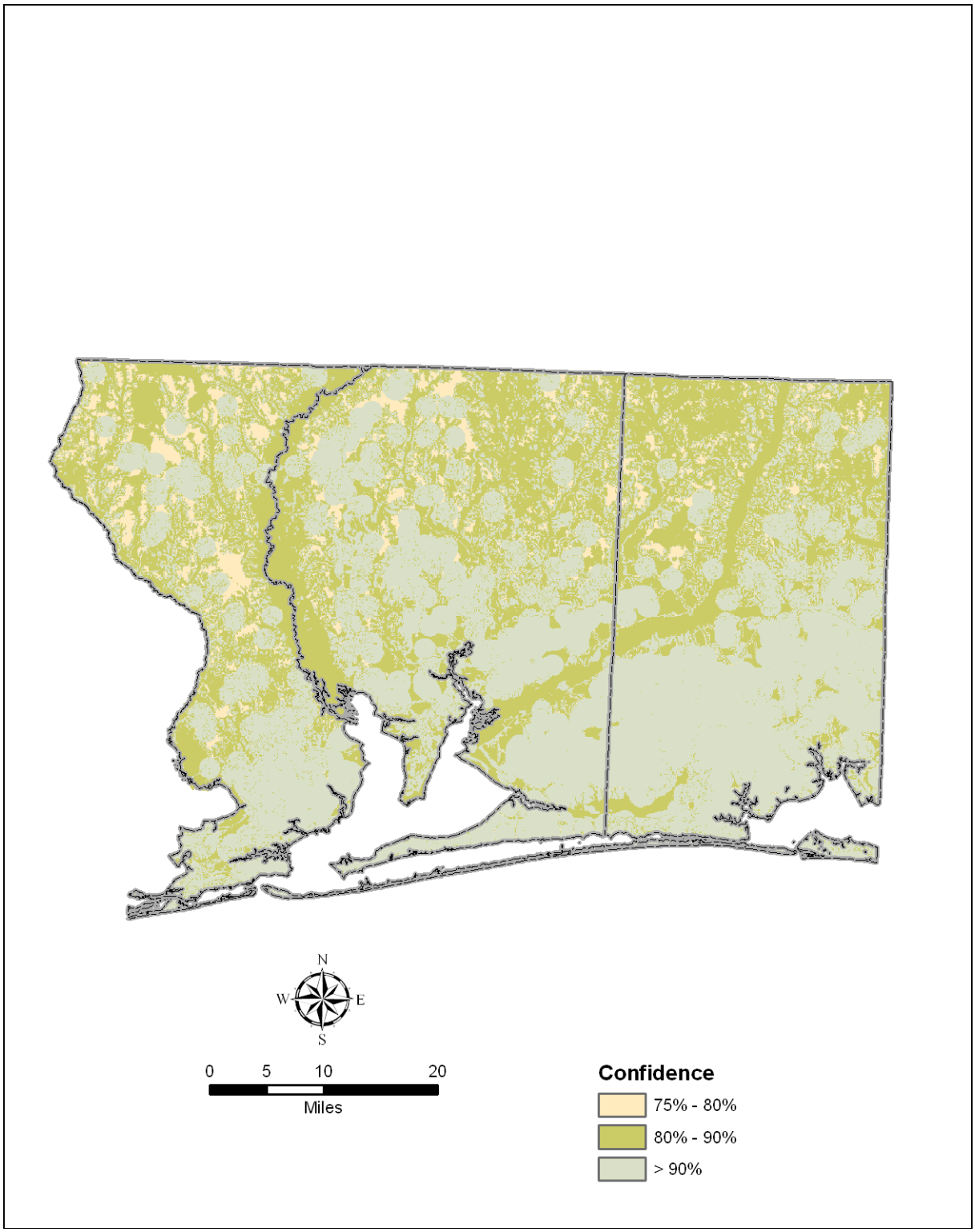

Figure 12. Confidence map for the SNG model calculated by dividing the posterior probability values by the total uncertainty for each class to give an estimate of how well specific areas of the model are predicted.

Dissolved Nitrogen Data vs. Posterior Probability

It was expected that comparison of posterior probability values to the dissolved nitrogen dataset from which the training point theme was extracted would reveal a proportional trend, in other words, as dissolved nitrogen values increase, so should posterior probability values. Dissolved nitrogen median concentrations were binned and averaged for each posterior probability value calculated in model output. The average values were plotted in a chart against posterior probability values (Figure 13) and a positive trend was observed.

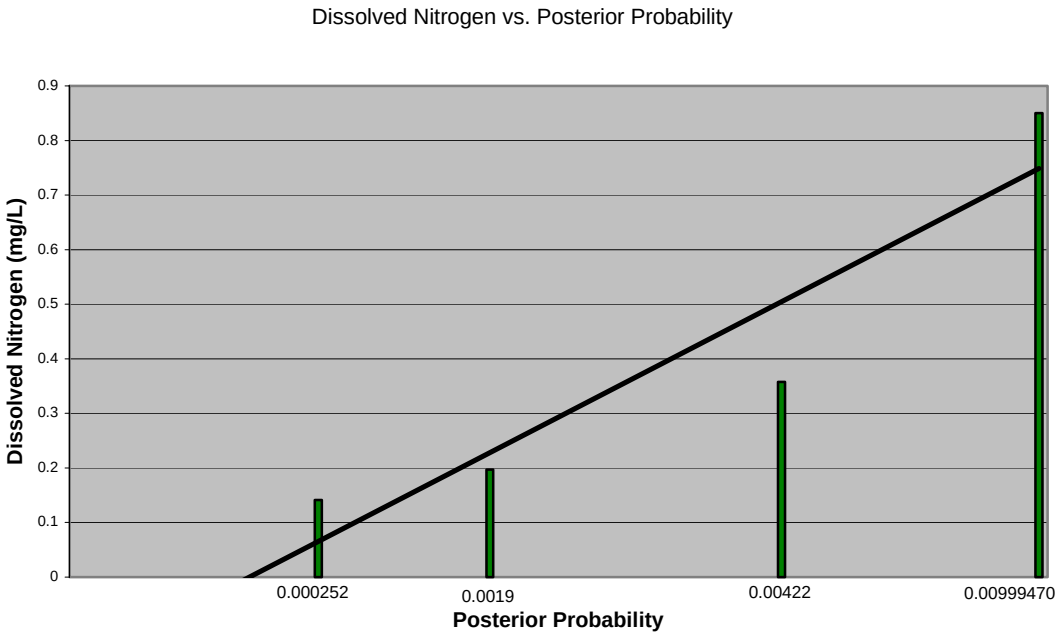

Figure 13. Dissolved nitrogen values (averaged per posterior probability class) versus probability values to reveal trend between increasing dissolved nitrogen concentrations and posterior probability.

An additional test involved applying a Pearson's correlation coefficient (r) test to all dissolved nitrogen values versus posterior probability values. This test revealed a value of 0.60 indicating more than a 99% degree of statistical significance between the response theme values and the dissolved nitrogen data.

Subset Response Theme

Another meaningful validation exercise similar to the exercise above is to use the existing training point dataset to develop two subsets: one to generate a test response theme, and one to validate output from this test response theme. Results from this exercise helped to further assess whether the dissolved nitrogen training points are reasonable predictors of aquifer vulnerability.

From the SNG training point theme, a subset of 75% (ten wells) were randomly selected and used to develop a test response theme; the remaining 25% (three wells) of the training points were used as the validation dataset for the test response theme. This comparison revealed that the three test wells in the validation subset, or 100%, occur in areas of the test response theme with predicted probability values higher than the prior probability value. In other words, 100% of the validation subset of training points were located in areas predicted to have a greater than chance probability of containing a training point in the test response theme (Figure 14). This further supports the conclusion that the SNG model response theme is a reasonable estimator of vulnerability.

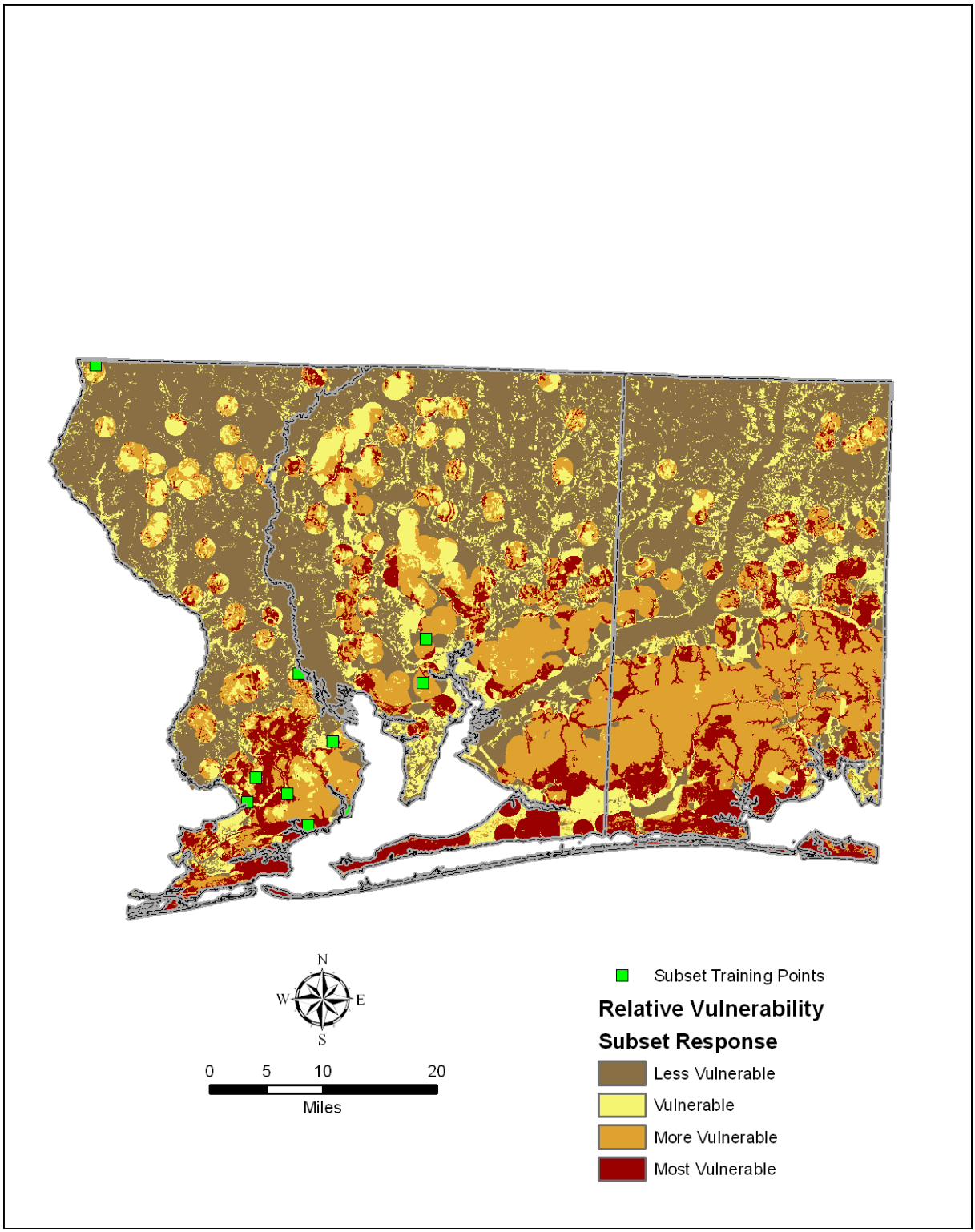

Figure 14. Subset response training points plotted in the dissolved nitrogen response theme.

BISCAYNE/SURFICIAL AQUIFER

Study Area

The Counties of Miami-Dade, Broward and Palm Beach were used as the Biscayne/Surficial aquifer system model study area extent (Figure 15). This boundary extends slightly outside the range of the Biscayne aquifer but does represent a valuable surficial aquifer system potable water source and conforms to political boundaries similar to the way the SNG boundary was developed. Because of the sizes of some polygons representing soil data, a grid cell size of approximately 30 meter squares (or 900 m^2) was selected for evidential theme development. This grid cell size, while necessary to capture resolution available in some input data layers, does not reflect appropriate resolution of final model output. Appropriate scale of use of model results is discussed in *Model Implementation and Limitations*.

Water bodies were omitted from the model extent for two main reasons: first, the main goal of this project is to estimate vulnerability of the surficial aquifer system (SAS) and not vulnerability of surface water features, and second, data for water bodies is typically not available – i.e., Everglades or wells are not drilled in water bodies. Also, soil surveys normally don't contain information regarding lake and stream bottoms.

Training Point Theme

In the model analysis, training points are groundwater wells tapping the SAS with water quality data indicative of high recharge. Dissolved nitrogen (ammonia plus total dissolved nitrogen) analytical values served as training point data for the Biscayne/Surficial model. Ammonia concentrations were incorporated into the Biscayne/Surficial training point data set to account for areas of the State with a high water table. In these areas, nitrogen in the form of ammonia can be more prevalent where the high water table and organic soils create a reducing environment. Naturally occurring oxygen and nitrogen are generally considered ubiquitous at land surface as primary components of the atmosphere; moreover, relatively low concentrations of these analytes occur in well protected – or less vulnerable – aquifer systems. Accordingly, where these analytes occur in elevated concentrations in groundwater, yet are not attributable to human activity, they are good indicators of aquifer vulnerability (Arthur et al., 2007).

Water quality data sources explored include the FDEP background water quality network, FDEP STATUS network and SFWMD databases. From these data sources, 115 wells measured for dissolved nitrogen were identified as being potential candidates for training points. Statistical analyses revealed 14 samples were considered statistical outliers. The upper 25th percentile of this set – or all wells with median dissolved nitrogen values greater than or equal to 0.955 milligrams per liter (mg/L) – served as the training point theme and consists of 24 wells. Figure 16 displays the distribution of water wells used to derive training points and the resulting training point theme across the study area.

Training points are used to calculate prior probability, weights for each evidential theme, and posterior probability of the response theme (see *Glossary*). Prior probability (training point unit area divided by total study area) is the probability that a training point will occupy a defined unit area within the study area, independent of any evidential theme data. The prior probability value, a unitless parameter, for the Biscayne/Surficial model is 0.003 ([1 km^2 model unit area * 24 training points] / 8841.9 km^2 = 0.003). Posterior probability values generated during response theme development are interpreted relative to the value of prior probability with higher values generally indicating areas with higher probability of containing a training point.

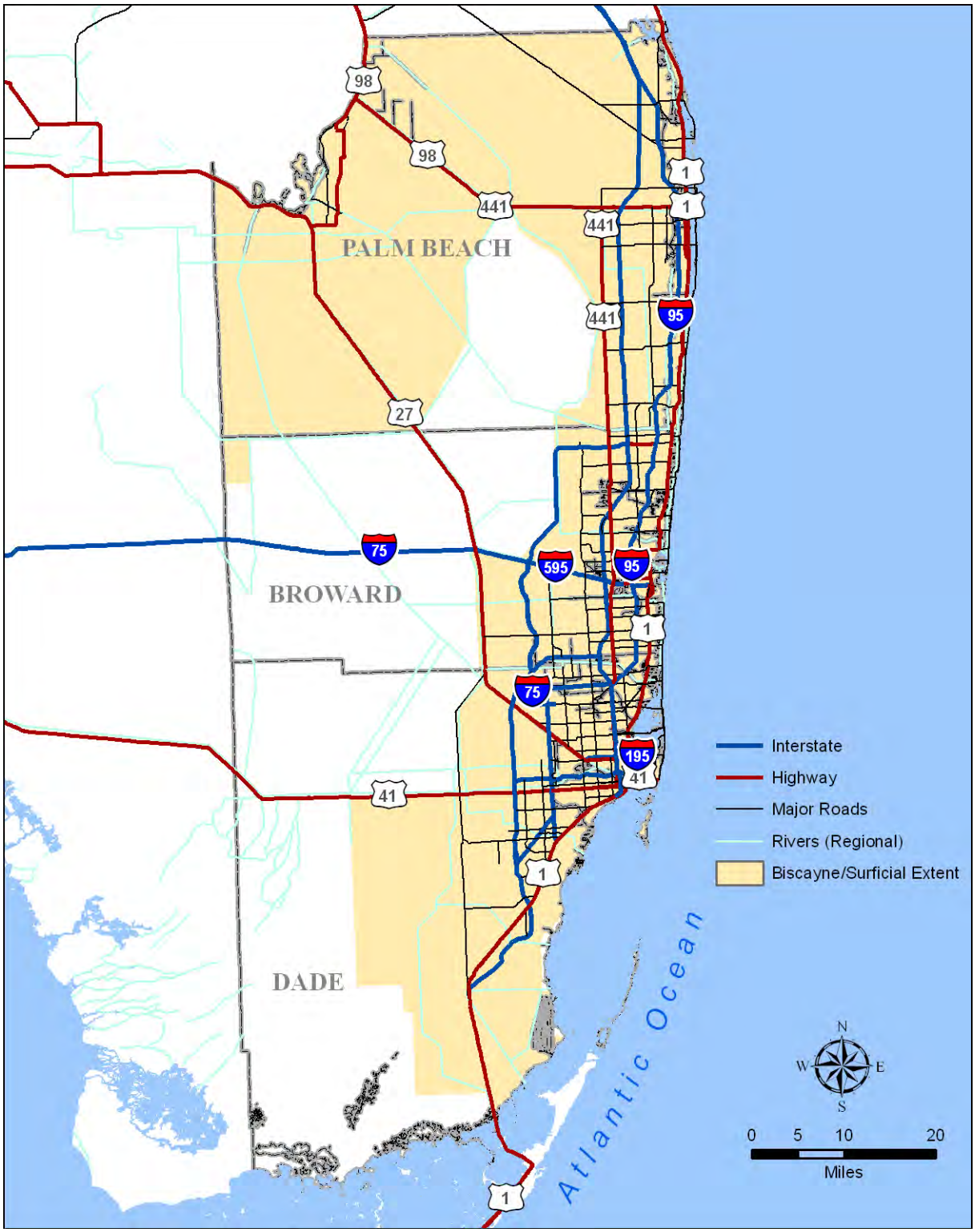

Figure 15. Biscayne / Surficial Aquifer Vulnerability Assessment project study area extent.

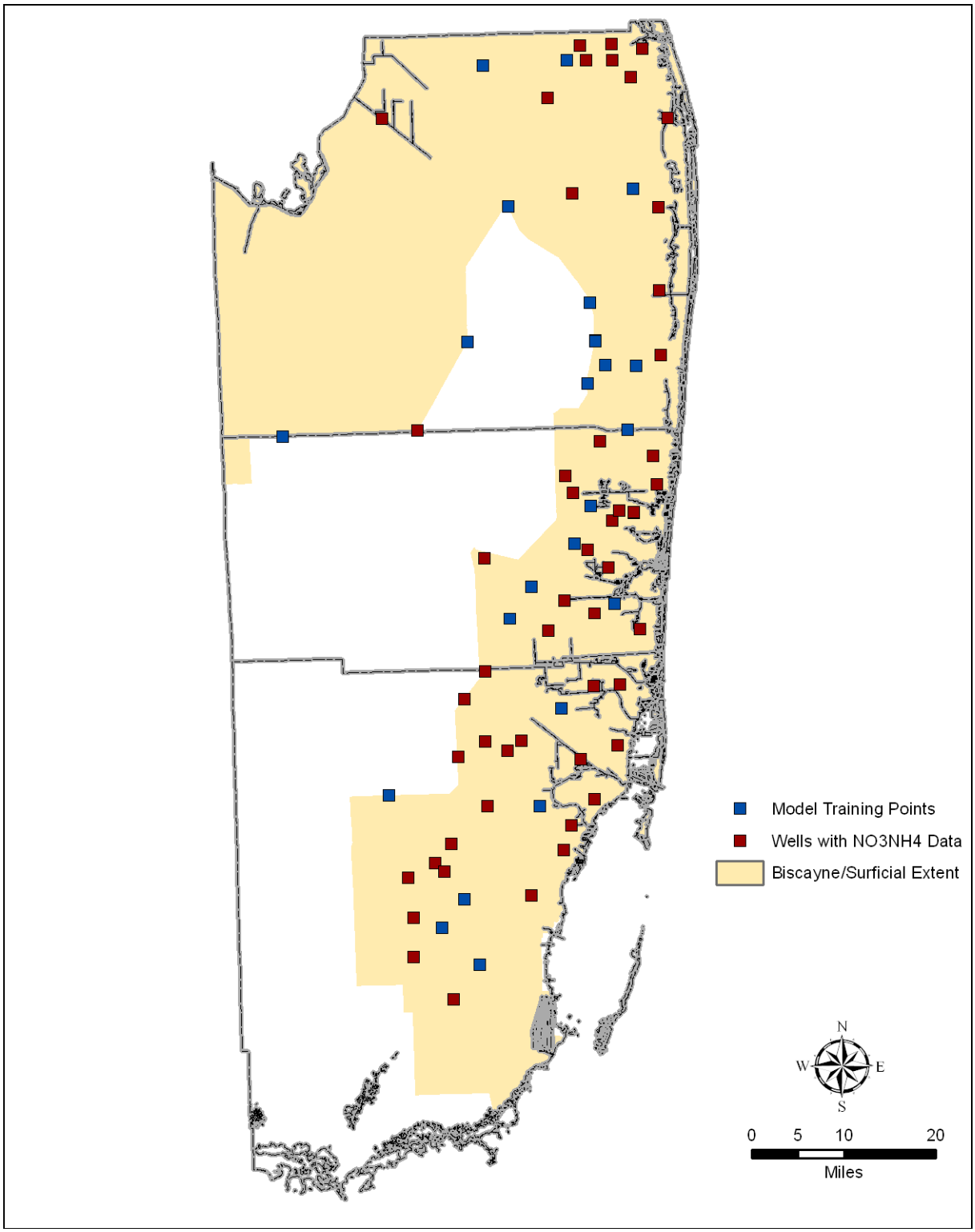

Figure 16. Location of all wells measured for ammonia + nitrate (dark red boxes), and locations of training point wells with median ammonia + nitrate values greater than 0.955 mg/L (blue boxes).

Evidential Themes – Model Input Layers

Input data layers, or evidential themes, representing hydrogeologic factors controlling the location of training points, and thereby vulnerability, were developed for model input. Because of the local scale nature of the Biscayne/Surficial project and the availability of new data, all model inputs represent previously unavailable datasets. The factors considered for the Biscayne/Surficial project include closed topographic depressions, depth to water, soil pedality, and soil hydraulic conductivity.

Soil Hydraulic Conductivity and Soil Pedality Themes

The rate that water moves through soil is a critical component of any aquifer vulnerability analysis, as soil is literally an aquifer system's first line of defense against potential contamination (Arthur et al., 2005). Two parameters of soils were evaluated for input into the Biscayne/Surficial model: *soil hydraulic conductivity*, which is the "amount of water that would move vertically through a unit area of saturated soil in unit time under unit hydraulic gradient" (U.S. Department of Agriculture, 2005); and *soil pedality*, which is calculated based on soil type, soil grade, and soil pedon size, and is a unitless parameter. Soil pedality is a relatively new concept used to estimate the hydrologic parameter of soil and is generated for the Biscayne/Surficial aquifer system using the pedality point method developed by Lin et al. (1999).

Countywide datasets representing soil hydraulic conductivity and soil pedality were developed for use as input into the Biscayne/Surficial model. Multiple empirical values are reported in soil surveys representing various zones in each soil column underlying a particular soil polygon. Representative values for each horizon in a column are combined using a sum of the weighted mean. This is completed for both hydraulic conductivity and soil pedality. Figure 18 displays values of soil hydraulic conductivity.

Depth to Water Theme

Depth to water is another critical layer in determining aquifer vulnerability. Where the depth to water is greatest (larger vadose zone), aquifer vulnerability is generally lower, whereas in areas where the depth to water is nearer to the surface, the vulnerability of the aquifer is generally higher.

The multiple linear regression equation method was not used to create the depth to water for the Biscayne/Surficial aquifer system. During testing of this method, the lack of good topographic data enhanced errors making the use of well data a more viable option. The SFWMD has a multitude of wells that measure water level of the surficial aquifer system. After examining all wells and removing outliers, 308 wells were used to create a water table elevation layer that was generated using the kriging interpolation technique.

The root-mean-square residual between the regressed and measured water-table elevation resulted in a weighted mean of 0.63 feet and exhibited a strong correlation coefficient of 0.99 (Figure 17). The final depth to water evidential theme was calculated by subtracting the water table elevation values from the FDEP DEM values (Figure 19).

Table 5. Linear regression coefficients for MINWT and difference between DEM and MINWT.

Number of surficial wells	Root mean square residual (ft)	Value range for difference between interpolated & measured water table (ft)	Correlation coefficient
308	0.626	[-3.65, 3.11]	0.99

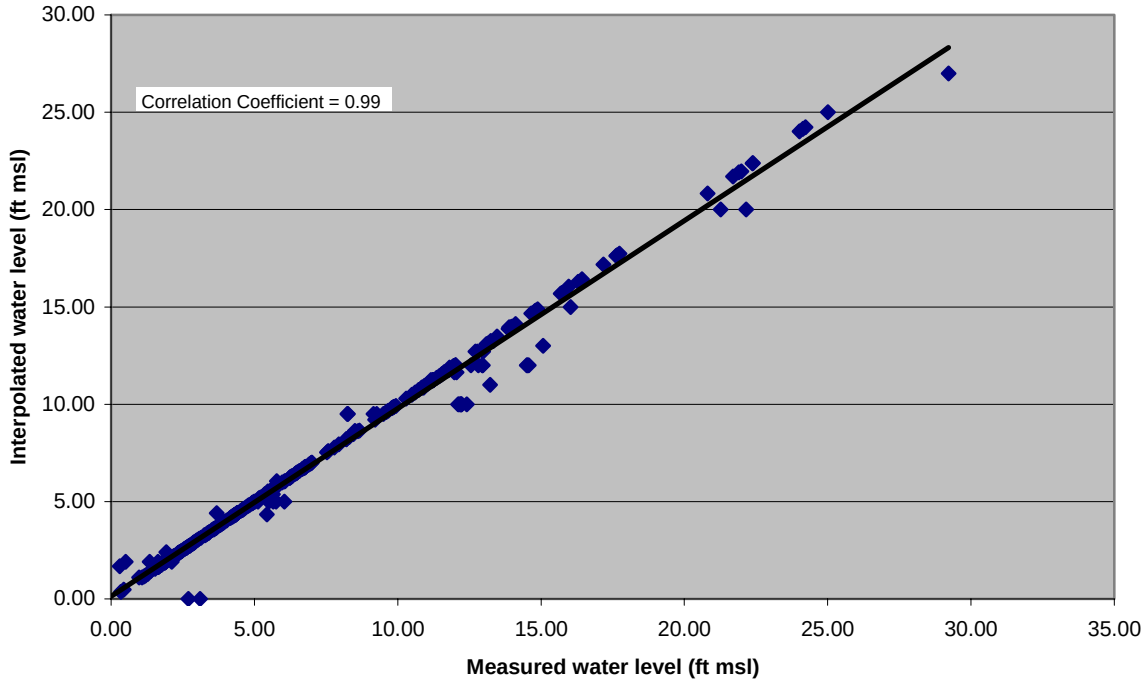

Figure 17. Regressed and measured water level for Biscayne/Surficial Aquifer.

Closed Topographic Depressions

Karst features, or sinkholes and depressions, can provide preferential pathways for movement of surface water into the underlying aquifer system and enhance an area's aquifer vulnerability where present. The closer an area is to a karst feature, the more vulnerable it may be considered. Closed topographic depressions extracted from U.S. Geological Survey 7.5-minute quadrangle maps served as the dataset from which to estimate closed topographic depressions in the study area (Figure 20).

Sensitivity Analysis/Evidential Theme Generalization

Sensitivity analysis allows decisions to be made about proposed evidential themes by evaluating each theme's association with training points – or aquifer vulnerability – and ultimately helps determine model input. For example, soil hydraulic conductivity and soil pedality were both developed to represent soil properties; sensitivity analysis allows, through statistical analysis, determination of which of these two layers served as the most appropriate input representing soil properties for the final Biscayne/Surficial analysis. Results of this process indicate that soil hydraulic conductivity, depth to water, and closed topographic depressions were the best suited evidential themes for use in final modeling.

Following sensitivity analysis and selection of evidential themes to be input into the Biscayne/Surficial model, themes were generalized to assess which areas of the evidence share a greater association with locations of training points. During calculation of weights for each theme, a contrast value was calculated for each class of the theme by combining the positive and negative weights. Contrast is a measure of a theme's significance in predicting the location of training points and helps to determine the threshold or thresholds that maximize the spatial association between the evidential theme map pattern and the training point theme pattern (Bonham-Carter, 1994). Contrast and weights are described in more detail below in *Discussion*.

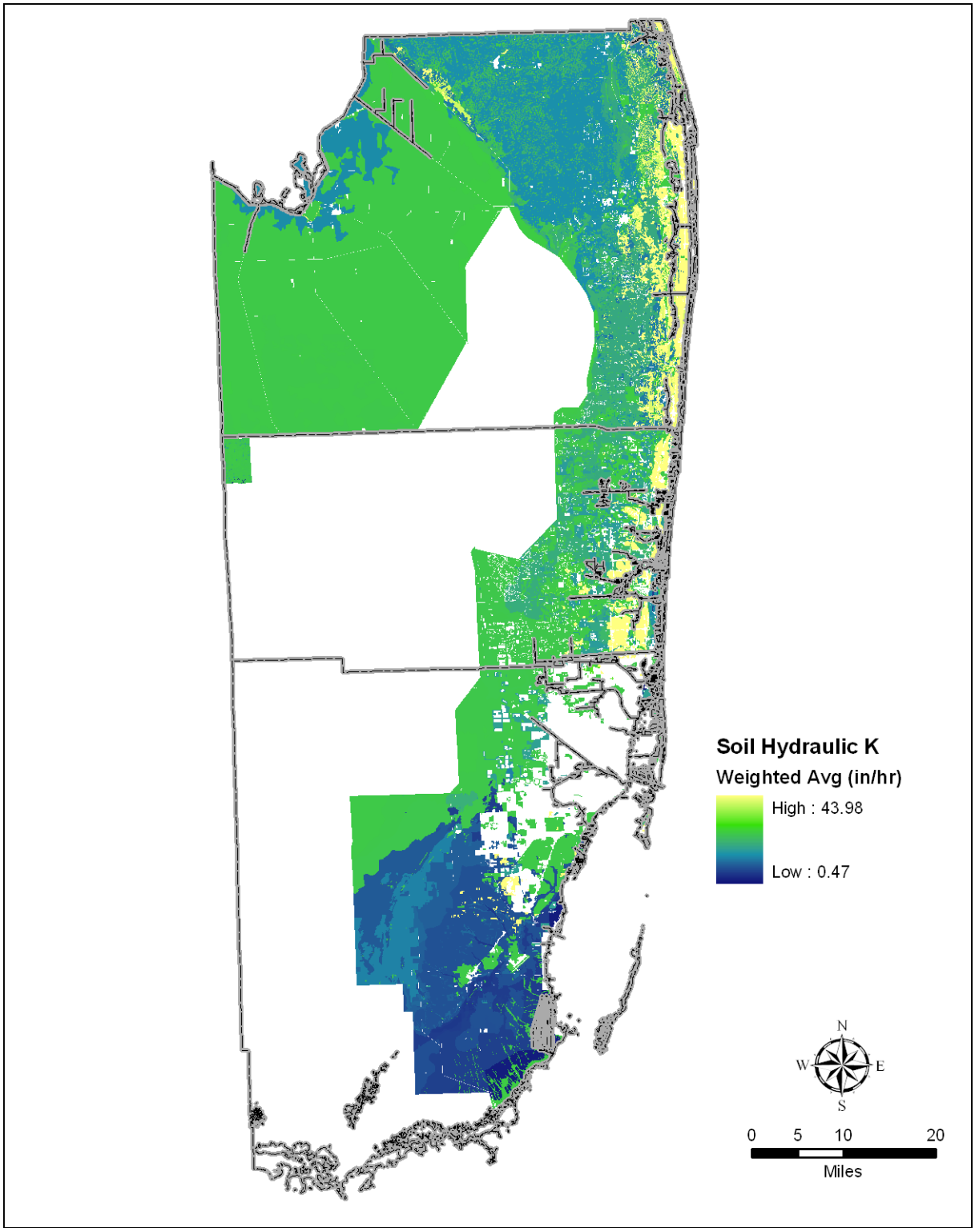

Figure 18. Distribution of soil hydraulic conductivity values across the Biscayne/Surficial study area. White areas represent 'no data' areas in the soil survey data or locations of water bodies.

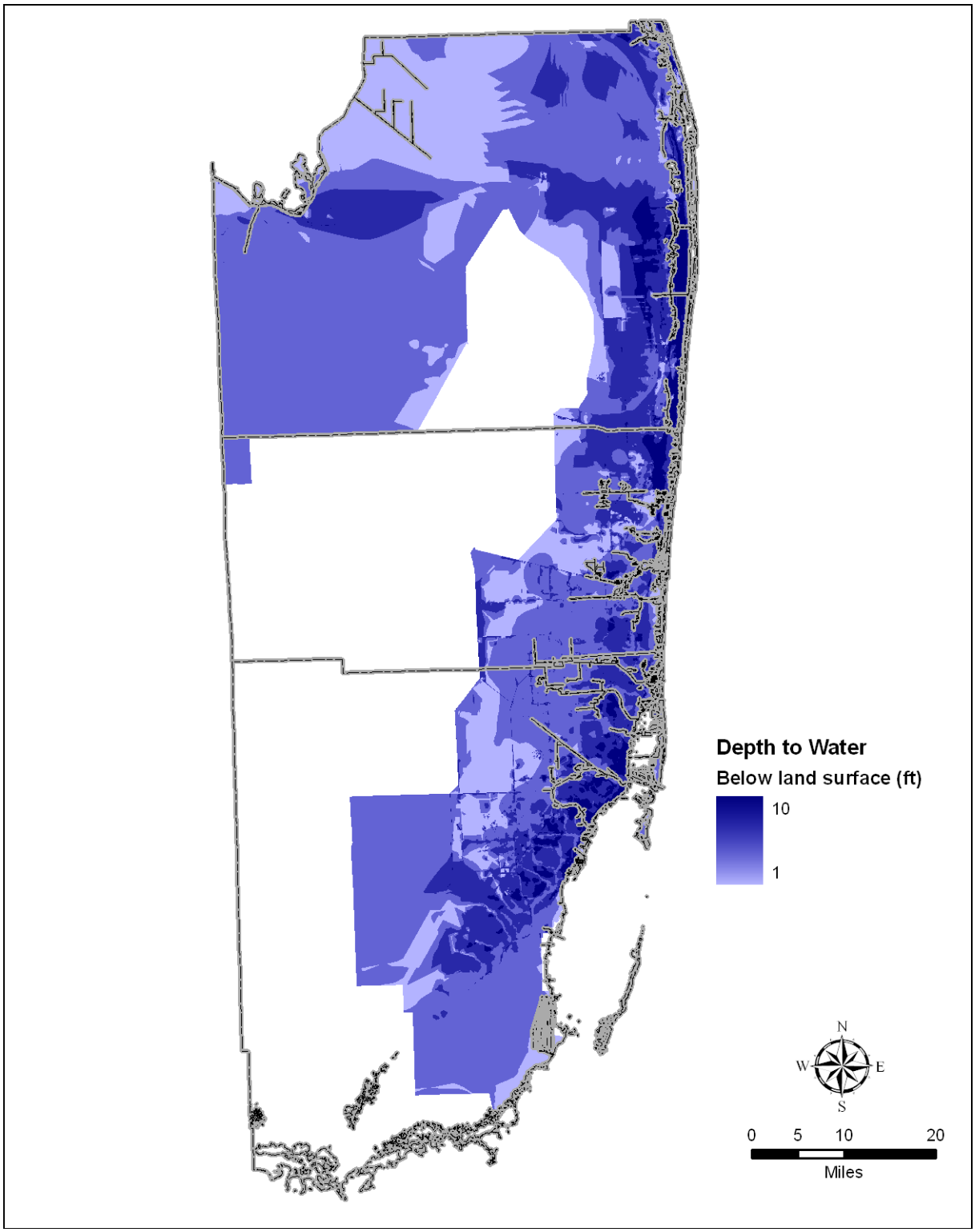

Figure 19. Distribution of depth to water values across the Biscayne/Surficial study area. White areas represent 'no data' areas or locations of water bodies.

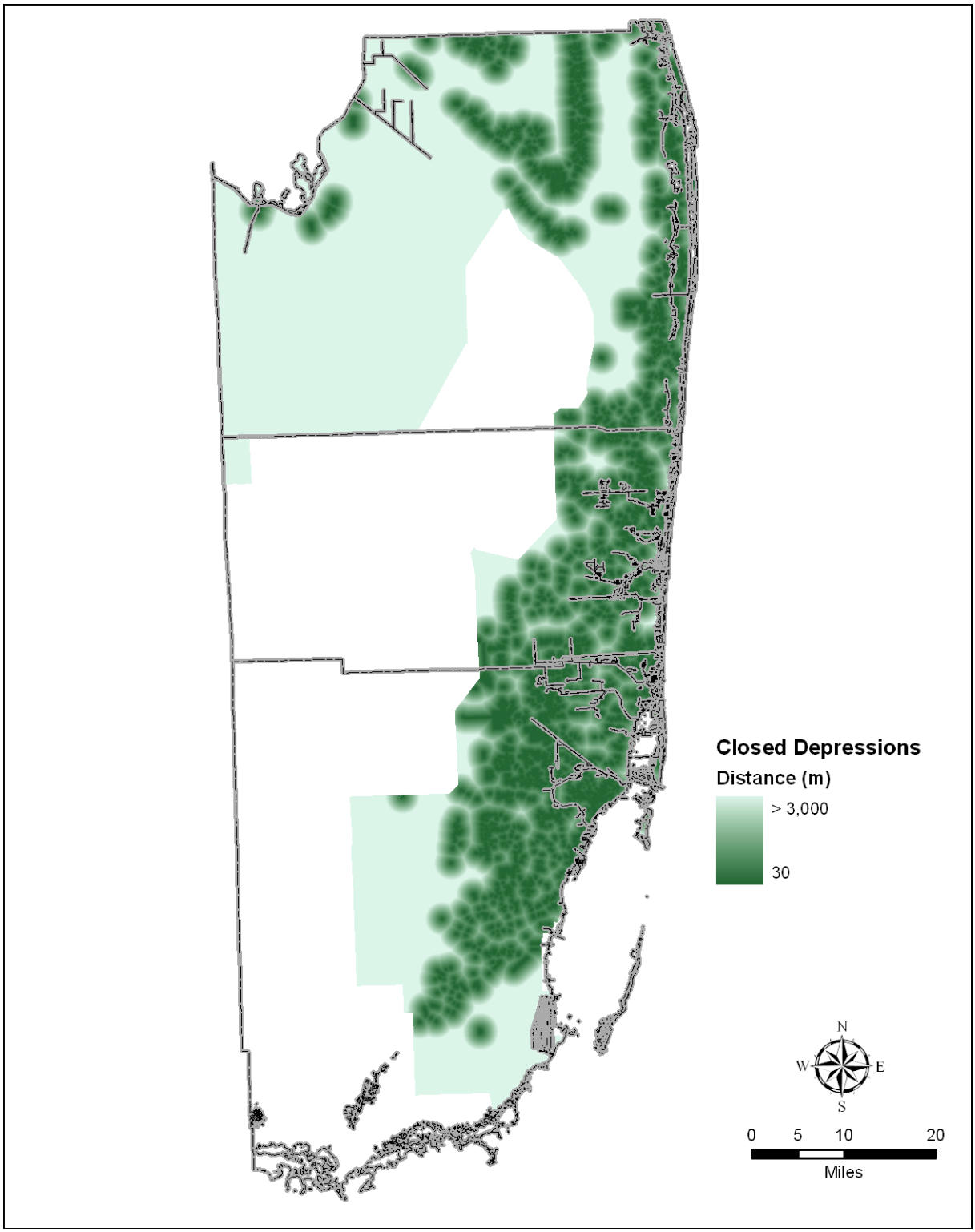

Figure 20. Proximity to closed topographic depressions extracted from U.S. Geological Survey 7.5-minute topographical contour lines.

Contrast values were used to determine where to sub-divide evidential themes into generalized categories prior to final modeling. The simplest and most accepted method used to subdivide an evidential theme is to select the maximum contrast value as a threshold value to create binary generalized evidential themes. In other models, categorization of more than two classes may be justified (Arthur et al., 2005). For the Biscayne/Surficial project, a binary break was typically defined by the weights of evidence analysis for each evidential theme creating two spatial categories: one with stronger association with the training point theme and one with weaker association.

Soil Hydraulic Conductivity/ Soil Pedality

Weights calculated during sensitivity analysis for soil hydraulic conductivity were stronger (i.e., had higher absolute value) than weights calculated for soil pedality. As a result, soil hydraulic conductivity was chosen as the better predictor of aquifer vulnerability because it shared the best association with training points.

Soil hydraulic conductivity, ranges from 0.47 to 29.71 in/hr across the study area. Test modeling indicated that areas greater than or equal to 13.02 in/hr were more associated with the training points, and therefore associated with higher aquifer vulnerability. Conversely, areas less than 13.02 in/hr were less associated with the training points, and therefore lower aquifer vulnerability. Based on this analysis, the evidential theme was generalized into two classes as displayed in Figure 21.

Depth to Water

The depth to water ranges from zero to 83 feet deep across the study area. The analysis revealed that areas less than or equal to one foot deep were more associated with the training points, and therefore associated with higher aquifer vulnerability. Areas with a depth to water greater than one foot were less associated with the training points, and therefore lower aquifer vulnerability. Based on this analysis, the evidential theme was generalized into two classes as displayed in Figure 22.

Closed Topographic Depressions

As mentioned above, areas closer to a depression are normally associated with higher aquifer vulnerability. Based on this, features were buffered into 30 meter zones to allow for a proximity analysis. The analysis indicated that areas within 2,430 meters of a closed topographic depression were more associated with the training points, and therefore with higher aquifer vulnerability. Conversely, areas greater than 2,430 meters from a closed topographic depression were less associated with the training points, and therefore lower aquifer vulnerability. Based on this analysis, the evidential theme was generalized into two classes as displayed in Figure 23.

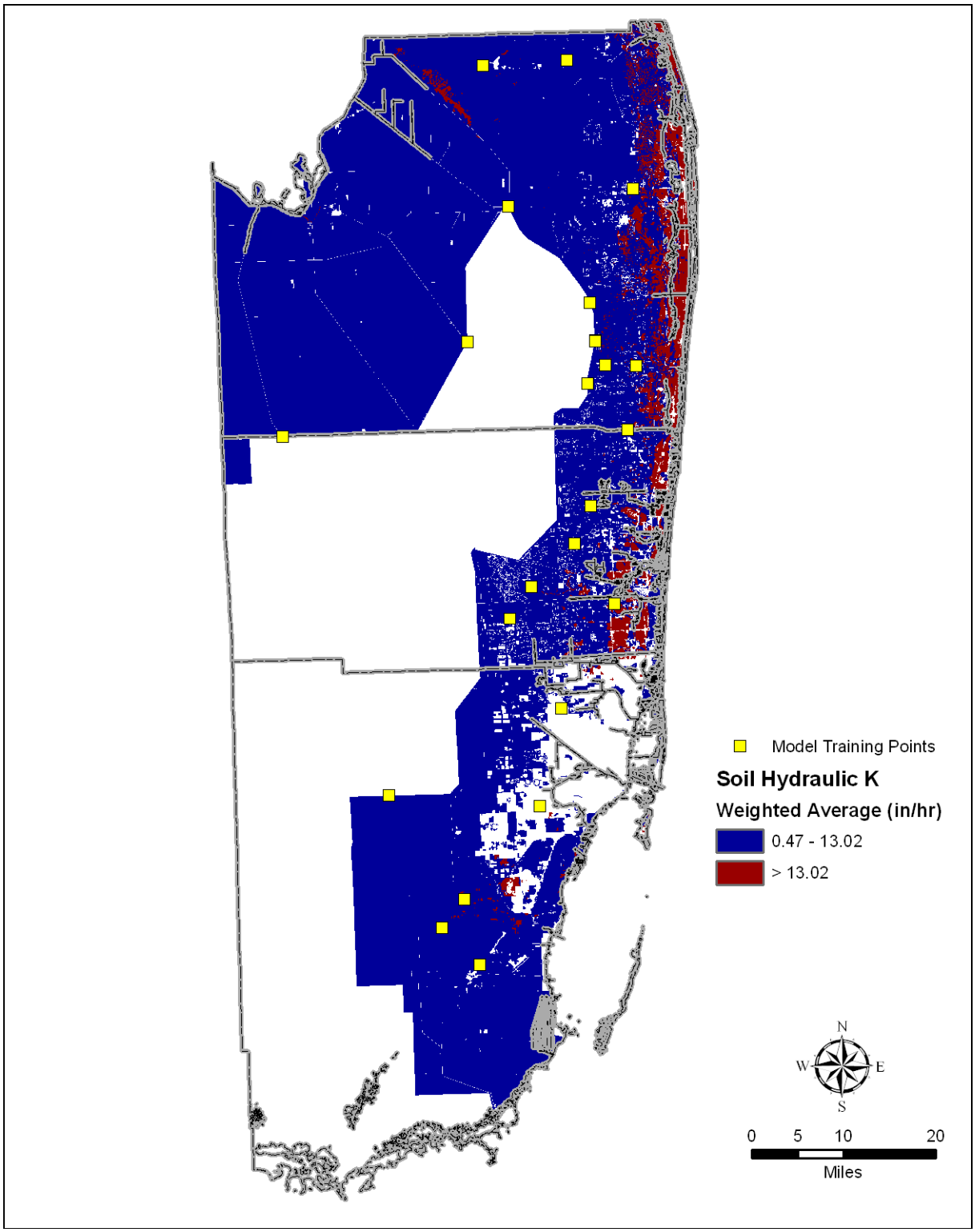

Figure 21. Generalized soil hydraulic conductivity evidential theme; based on calculated weights analysis blue areas share a weaker association with training points and thereby relatively lower aquifer vulnerability, whereas red areas share a stronger association with training points.

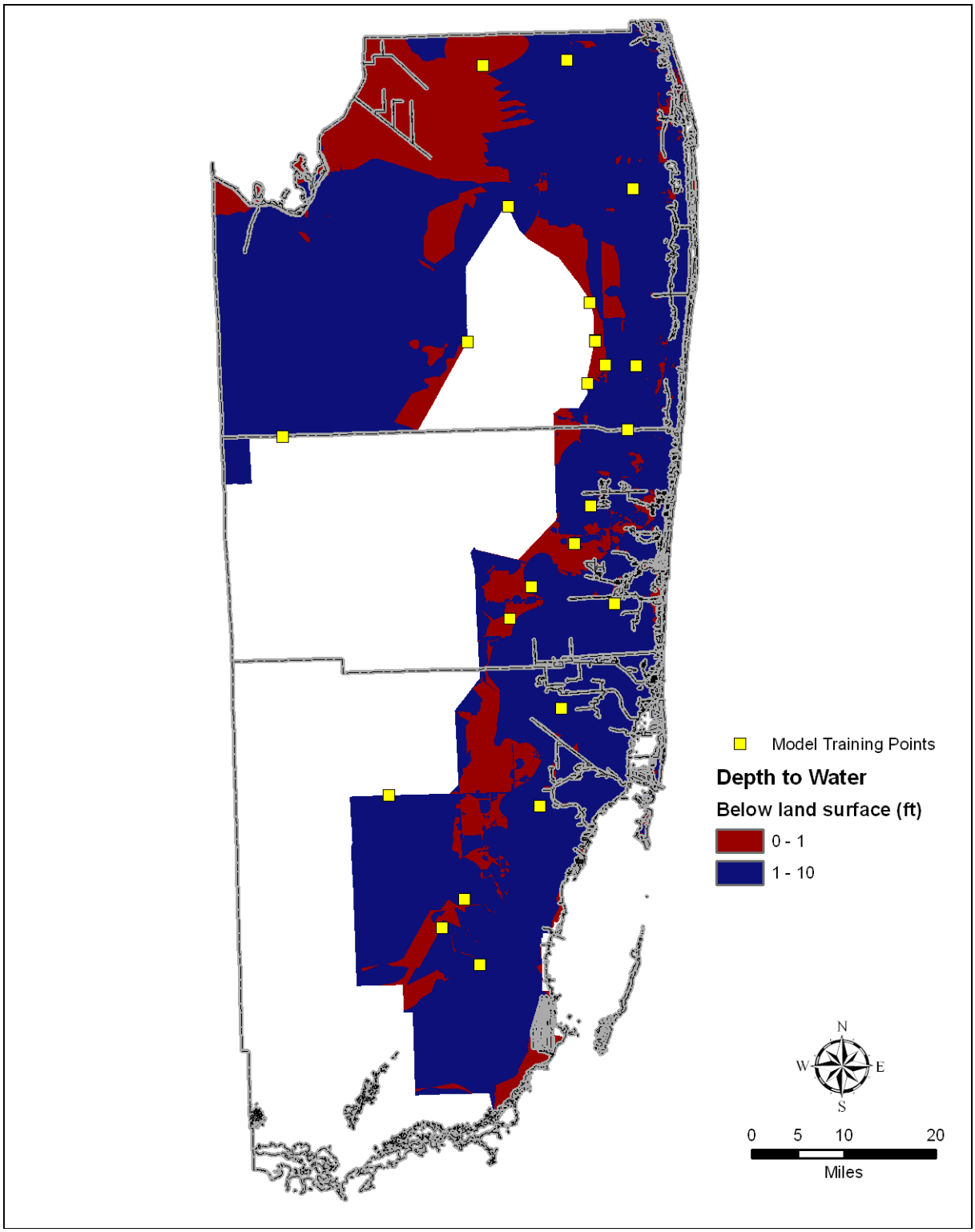

Figure 22. Generalized depth to water evidential theme; based on calculated weights analysis blue areas share a weaker association with training points and thereby relatively lower aquifer vulnerability, whereas red areas share a stronger association with training points.

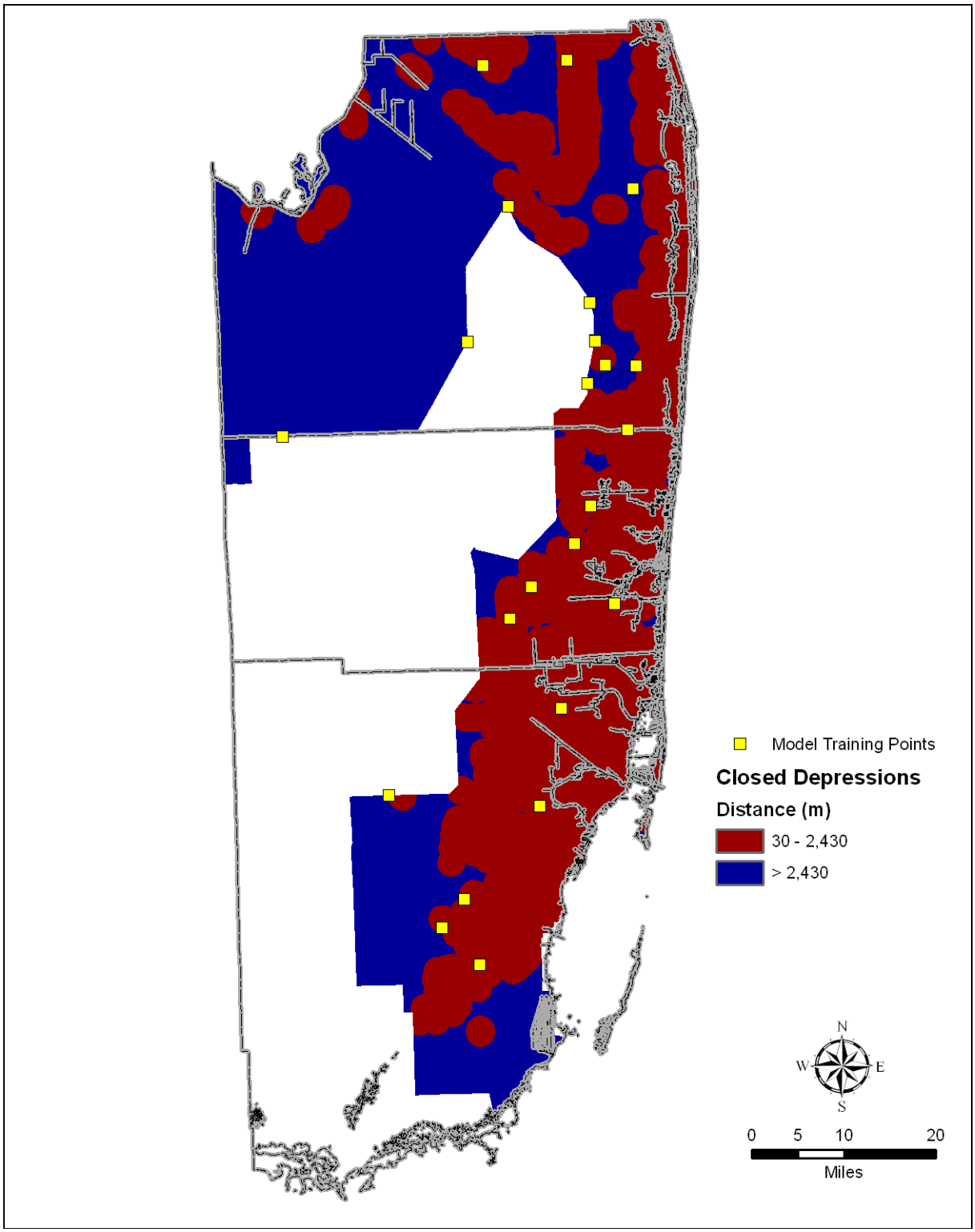

Figure 23. Generalized closed topographic depressions evidential theme; based on calculated weights analysis blue areas share a weaker association with training points and thereby relatively lower aquifer vulnerability, whereas red areas share a stronger association with training points.

Response Theme

Using evidential themes representing soil hydraulic conductivity, depth to water, and closed topographic depressions, weights of evidence was applied to generate a response theme, which is a GIS raster consisting of *posterior probability* values ranging from 0.0011 to 0.0146 across the study area. These probability values describe the relative probability that a unit area of the model will contain a training point – i.e., a point of aquifer vulnerability as defined above in *Training Points* – with respect to the prior probability value of 0.003 or ([1.0 km^2 model unit area * 24 training points] / 8841.9 km^2 = 0.003). Prior probability is the probability that a training point will occupy a defined unit area within the study area, independent of evidential theme data. Probability values at the locations of 22 of the 24 training points are above the prior probability, indicating that this model is a strong predictor of training point locations.

The response theme was broken into classes of relative vulnerability based on the prior probability value and on inflections in a chart in which cumulative study area was plotted against posterior probability (Figure 24). Higher posterior probability values correspond with more vulnerable areas, as they essentially have a higher chance of containing vulnerability based on the definition of a training point. Conversely, lower posterior probability values correspond to less vulnerable areas as they essentially have a lower chance of containing vulnerability based on the definition of a training point.

As described in *Introduction*, the Biscayne/Surficial model was based on the modeling technique used in the FAVA project. The FAVA project identified relative vulnerability of Florida's principal aquifer systems broken into three classes: more vulnerable, vulnerable and less vulnerable zones. This naming technique was applied to the Biscayne/Surficial results, to define the relative vulnerability classes as displayed in Figure 25.

As expected, the Biscayne/Surficial response theme indicates that areas of highest vulnerability are associated with areas where the depth to water is lowest, in areas of dense closed topographic depressions, and areas of higher soil hydraulic conductivity. Conversely, areas of lowest vulnerability are determined by high depth to water values, sparse closed topographic depression distribution, and lower soil hydraulic conductivity values.

Discussion

Prior to discussion of weights calculations during model execution, two components of a weights of evidence analysis are described to assist in interpretation of Biscayne/Surficial model results: *Conditional Independence* and *Model Confidence*.

Conditional Independence

Conditional independence is a measure of the degree that evidential themes are affecting each other due to similarities between themes. Evidential themes are considered independent of each other if the conditional independence value is around 1.00, and conditional independence values within the range of 1.00 ± 0.15 generally indicate limited to no dependence among evidential themes (Bonham-Carter, 1994). Values significantly outside this range can inflate posterior probabilities resulting in unreliable response themes.

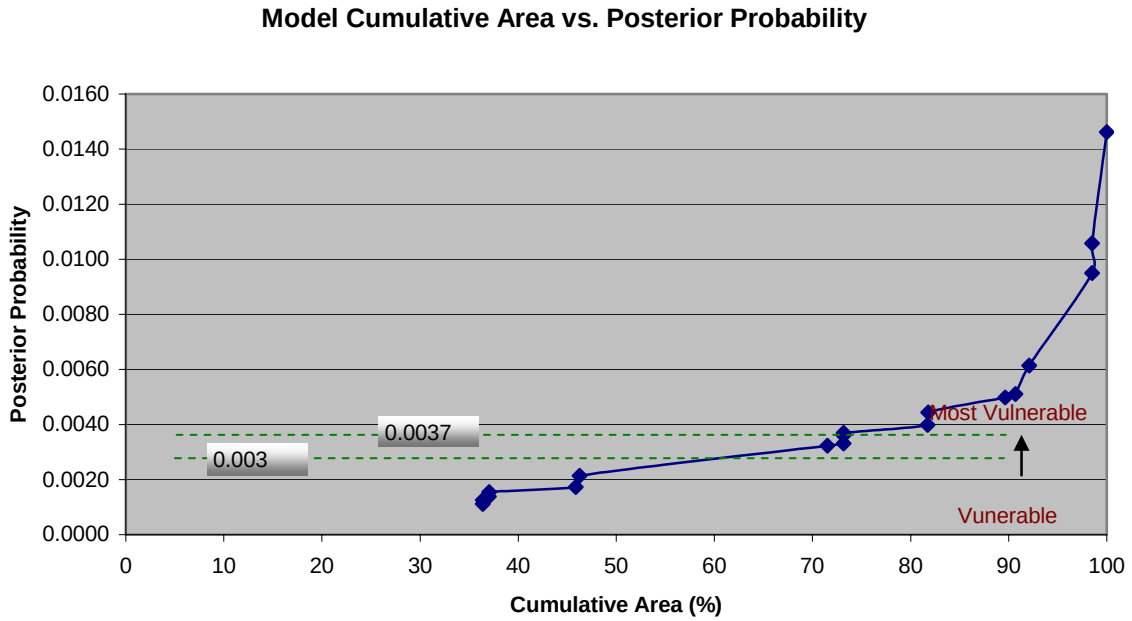

Figure 24. Vulnerability class breaks are defined by selecting where a significant increase in probability and area are observed.

Conditional independence was calculated at 0.96 for the Biscayne/Surficial project indicating that evidential themes had virtually no conditional dependence.

Model Confidence

During model execution, confidence values are calculated both for each generalized evidential theme and for the final response theme. Confidence values approximately correspond to the statistical levels of significance listed in Table 3.

Confidence of the evidential theme equals the contrast divided by the standard deviation (a student T-test) for a given evidential theme and provides a useful measure of significance of the contrast due to the uncertainties of the weights and areas of possible missing data (Raines, 1999). A test value of 0.9691 corresponds to approximately 85% confidence – or level of significance – and was the minimum calculated confidence level for the Biscayne/Surficial project evidential themes (see Table 6 below for evidential theme confidence values).

A confidence map is also calculated for a response theme by normalizing the theme's posterior probability by its total uncertainty (standard deviation). A confidence map can be generated based on these calculations. The confidence map for the Biscayne/Surficial response theme is displayed in Figure 26. Areas with high posterior probability values typically correspond to higher confidence values and as a result have a higher level of certainty with respect to predicting aquifer vulnerability.

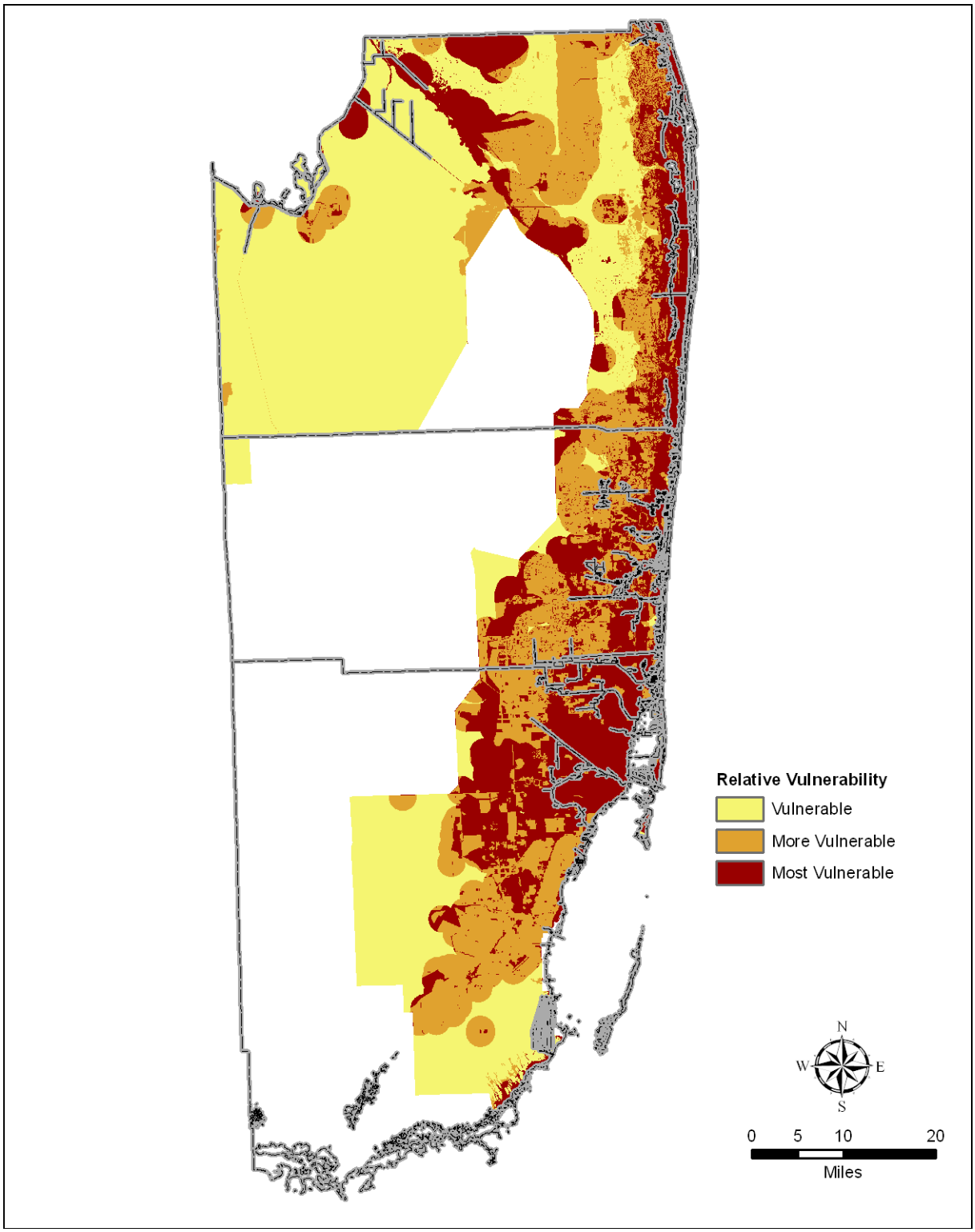

Figure 25. Relative vulnerability map for the Biscayne/Surficial Vulnerability Assessment project. Classes of vulnerability are based on calculated probabilities of a unit area containing a training point, or a monitor well with water quality sample results indicative of vulnerability.

Weights Calculations

Table 6 displays evidential themes used in the Biscayne/Surficial model, weights calculated for each theme, along with contrast and confidence values. Positive weights indicate areas where training points are likely to occur, while negative weights indicate areas where training points are not likely to occur. The contrast column is a combination of the highest and lowest weights (positive weight – negative weight) and is a measure of how well the generalized evidential themes predict training points. Confidence of the evidential theme is also calculated and is equal to the contrast divided by its standard deviation (a student T test). Confidence is a measure of significance due to uncertainties of the weights and missing data (Raines, 1999). A positive contrast that is significant, based on its confidence, suggests that a generalized evidential theme is a useful predictor.

Table 6. Weights of evidence final output table listing weights calculated for each evidential theme and their associated contrast and confidence values of the evidential themes.

Evidential Theme	W1	W2	Contrast	Confidence
Soil Hydraulic Conductivity	0.8763	-0.2098	1.0861	2.2420
Depth to Water	0.3273	-0.1088	0.4360	0.9691
Closed Topographic Depressions	0.3866	-0.6740	1.0606	2.2473

Because positive weights (W1) values for soil hydraulic conductivity and depth to water are stronger (have greater absolute values) than the negative weights (W2), they are better predictors of where training points are likely to occur, whereas the closed topographic depression theme is a better indicator of where training points are less likely to occur. Based on contrast values, the soil hydraulic conductivity theme has the strongest (highest absolute value) weight and is the primary determinant in predicting areas of vulnerability in the Biscayne/Surficial model.

Validation

The weights of evidence approach, because it relies on a set of training points, which by definition are known sites of vulnerability, is essentially self-validated. Twenty-two of twenty-four training points were predicted in zones of posterior probability greater than the prior probability (in other words, classified accurately). Further strengthening the results were the evaluation of a minimum confidence threshold for evidential themes, and generation of a confidence map of the response theme. In addition to these exercises, and in the style of previous aquifer vulnerability assessments (Cichon et al., 2005; Baker et al., 2005; Arthur et al., 2005), additional validation techniques were applied to the Biscayne/Surficial model to further strengthen its defensibility, and, ultimately, its utility: (1) comparison of dissolved nitrogen values to posterior probability and evaluation of an associated trend; (2) generation of a test response theme based on a subset of training points and comparison of points not used in subset to model results and (3) comparison of dissolved oxygen values with vulnerable zones of the response theme.

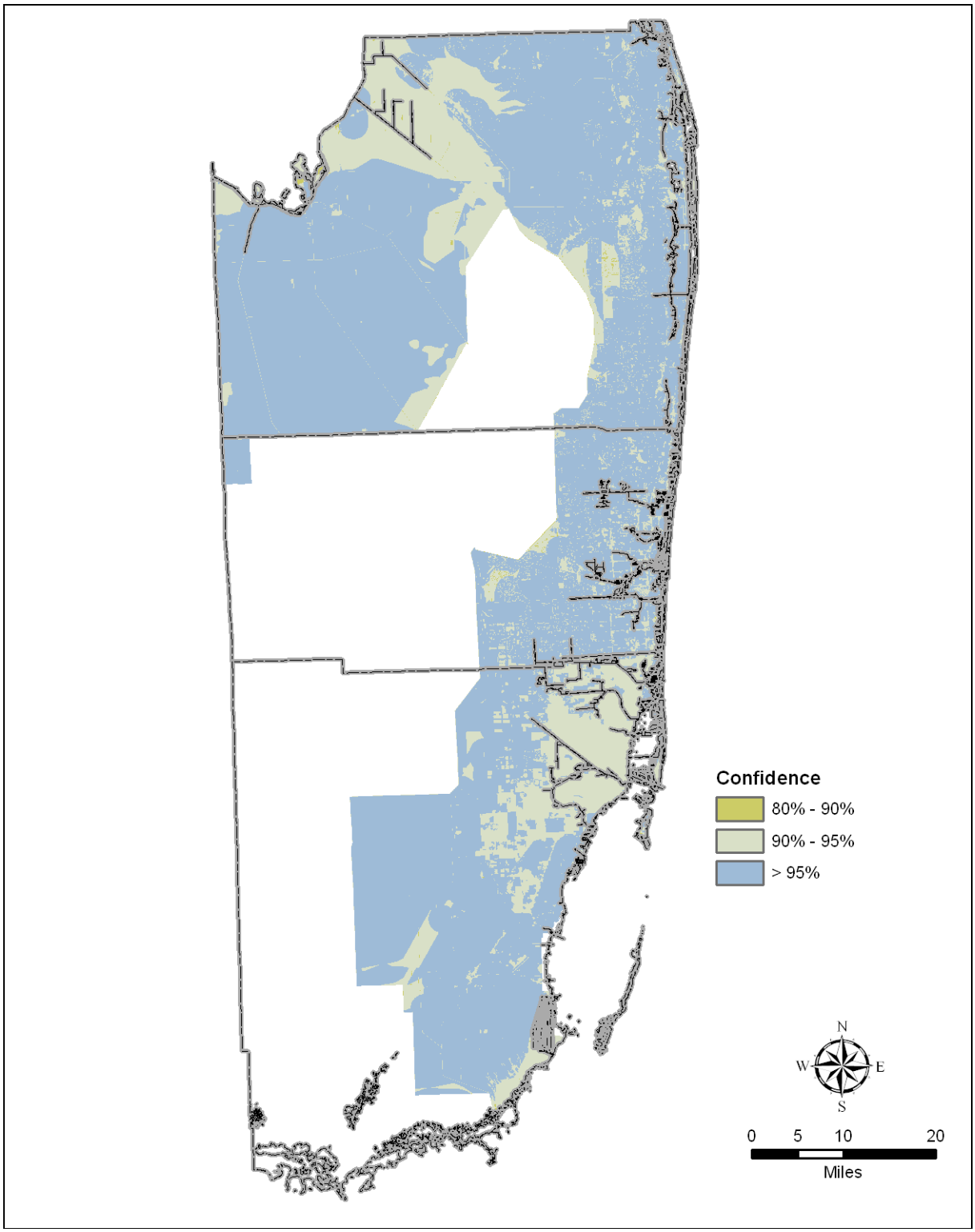

Figure 26. Confidence map for the Biscayne/Surficial model calculated by dividing the posterior probability values by the total uncertainty for each class to give an estimate of how well specific areas of the model are predicted.

Dissolved Nitrogen Data vs. Posterior Probability

It was expected that comparison of posterior probability values to the dissolved nitrogen dataset from which the training point theme was extracted would reveal a proportional trend, in other words, as dissolved nitrogen values increase, so should posterior probability values. Dissolved nitrogen median concentrations were binned and averaged for each posterior probability value calculated in model output. The average values were plotted in a chart against posterior probability values (Figure 27) and a slight positive trend was observed.

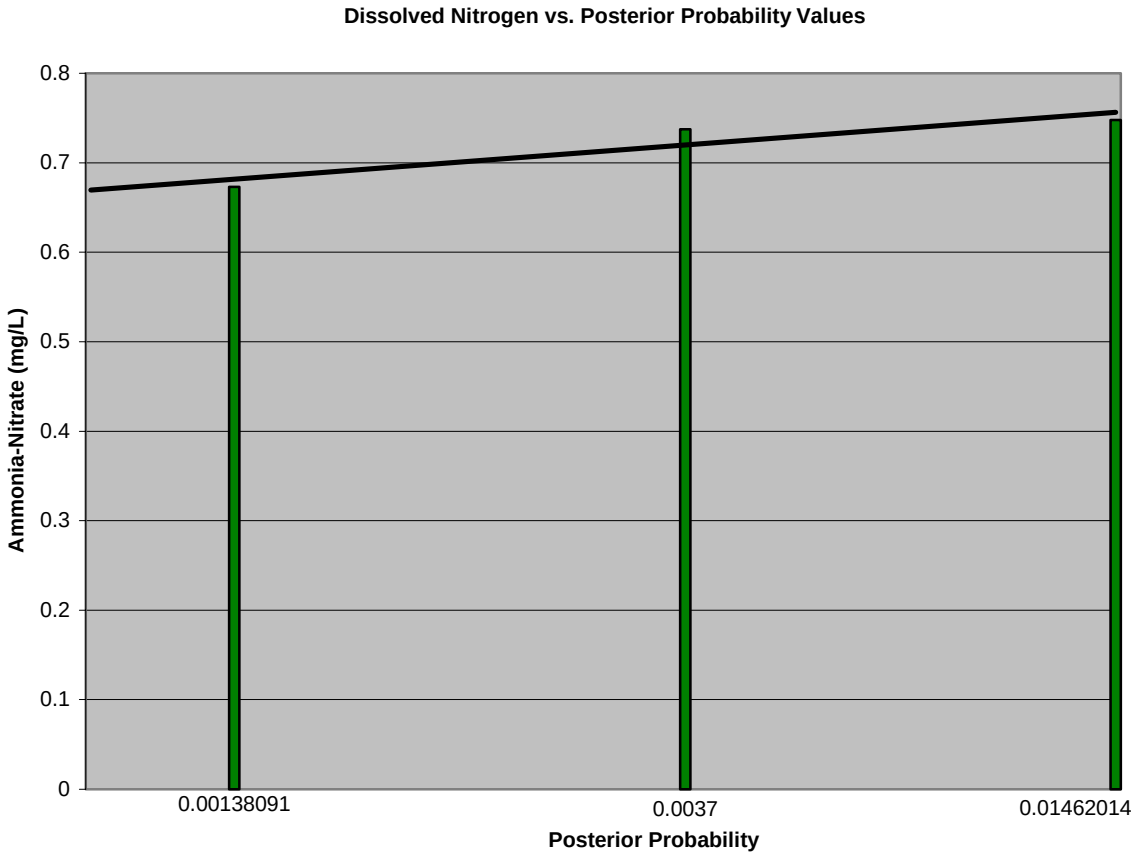

Figure 27. Dissolved nitrogen values (averaged per posterior probability class) versus probability values to reveal trend between increasing dissolved nitrogen concentrations and posterior probability.

Subset Response Theme

Another meaningful validation exercise similar to the exercise above is to use the existing training point dataset to develop two subsets: one to generate a test response theme, and one to validate output from this test response theme. Results from this exercise helped to further assess whether the dissolved nitrogen training points are reasonable predictors of aquifer vulnerability.

From the Biscayne/Surficial training point theme, a subset of 75% (18 wells) were randomly selected and used to develop a test response theme; the remaining 25% (6 wells) of the training points were used as the validation dataset for the test response theme. This comparison revealed that four of the six test wells in the validation subset, or 67%, occur in areas of the test response theme with predicted probability values higher than the prior probability value. The other two wells were within four meters of an area with predicted probability values higher than the prior probability. This further supports the conclusion that the Biscayne/Surficial model response theme is a reasonable estimator of vulnerability.

Dissolved Oxygen Data

Perhaps the most rigorous validation exercise used to evaluate quality of model-generated output is to compare predicted model values with independent test values not used in the model. For the Biscayne/Surficial model, this was accomplished by comparison of a separate well dataset based on dissolved oxygen. As mentioned above in *Training Point Theme*, dissolved oxygen is indicative of aquifer vulnerability, but is independent of dissolved nitrogen. Applying the methodology described in *Training Point Theme* to dissolved oxygen data (obtained from the same data sources as dissolved nitrogen data) resulted in a dissolved oxygen dataset of 32 wells each indicative of aquifer vulnerability.

These 32 points were evaluated against posterior probability values of the Biscayne/Surficial model output. Extracting the value of posterior probability from the dissolved nitrogen response theme for the location of each of the 32 dissolved oxygen training points revealed that 28 of the 32 dissolved oxygen training points occur in areas of the dissolved nitrogen model with predicted probability values higher than the prior probability value. In other words, 87.5% of the dissolved oxygen wells were located in areas predicted to have a greater than chance probability of containing a training point. Based on this test, the dissolved nitrogen model is not only a good predictor of vulnerability as defined by the training point theme, it is also a good predictor of the location of an independent parameter also representing aquifer vulnerability. Figure 29 displays dissolved oxygen data points plotted on the dissolved nitrogen response theme.

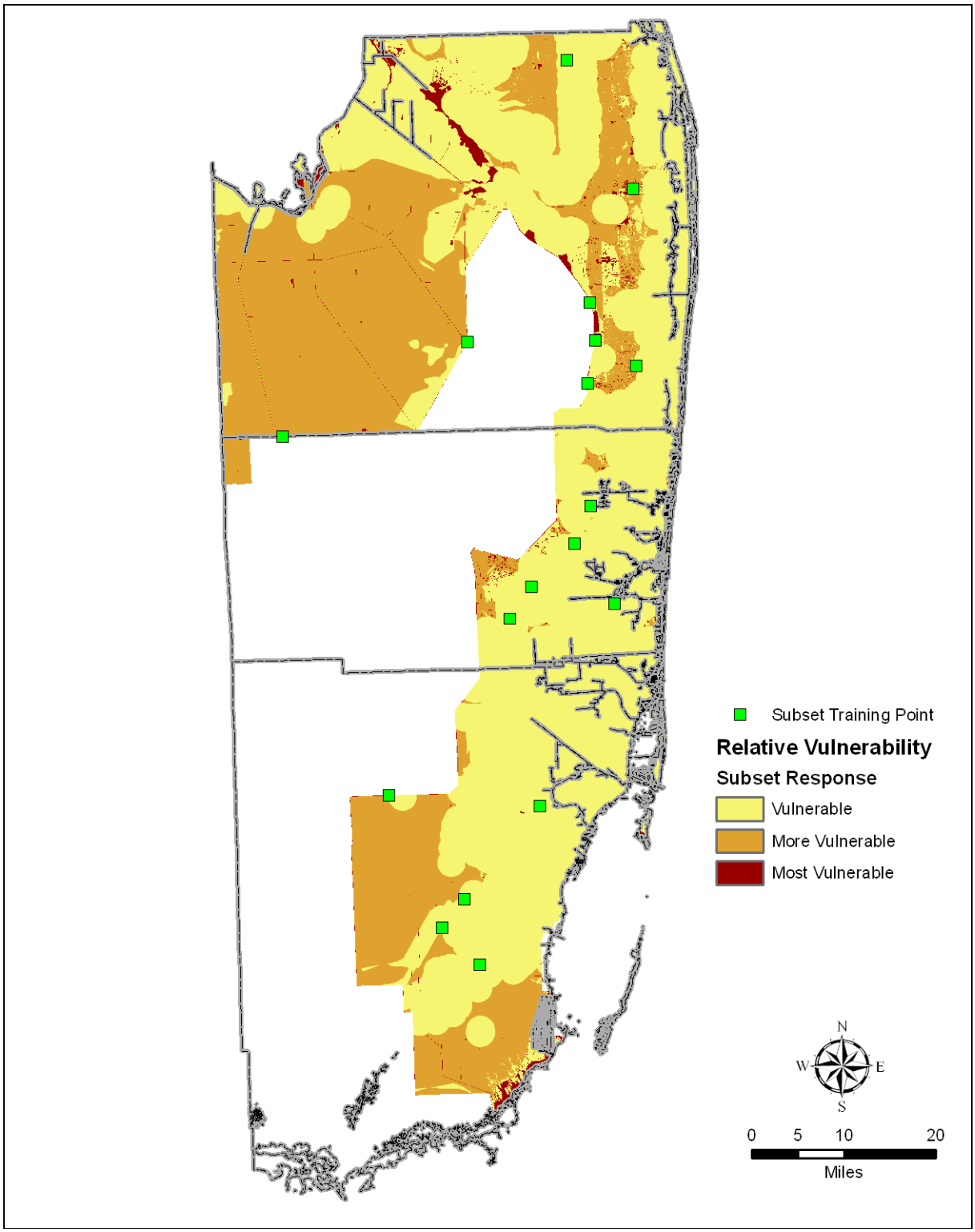

Figure 28. Subset response training points plotted in the dissolved nitrogen response theme.

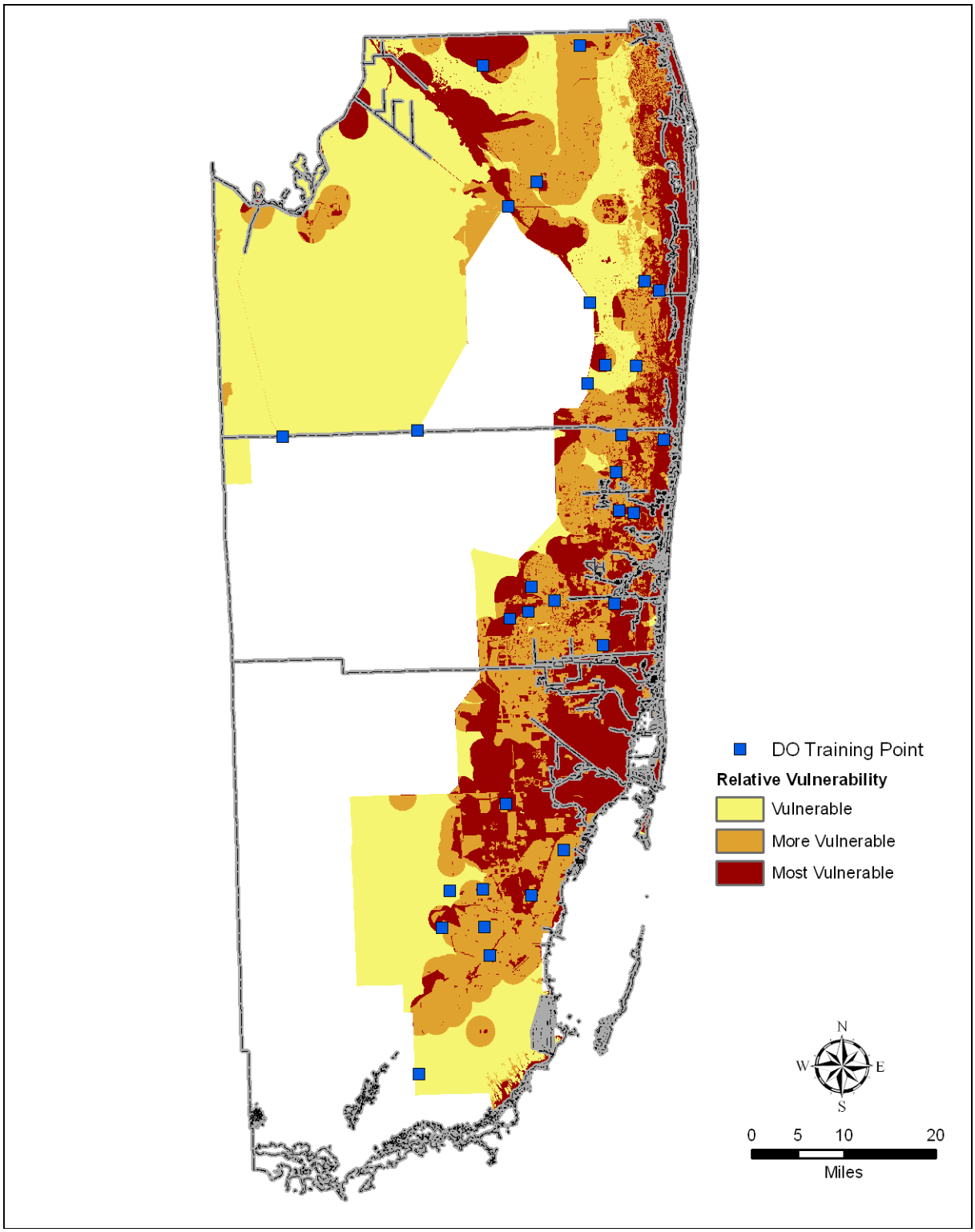

Figure 29. Dissolved oxygen validation training points plotted in the dissolved nitrogen response theme. Comparison reveals 28 of 32 wells (87.5%) of the independent water quality dataset are located in areas with predicted probability values higher than the prior probability value.

SURFICIAL AQUIFER SYSTEM

Study Area

The study area is the same as the FAVA version 1.0 model extent except that the Biscayne/Surficial and SNG model extents have been removed (Figure 30). Because of the sizes of some polygons representing soil data, a grid cell size of approximately 30 meter squares (or 900 m^2) was selected for evidential theme development. This grid cell size, while necessary to capture resolution available in some input data layers, does not reflect appropriate resolution of final model output. Appropriate scale of use of model results is discussed in *Model Implementation and Limitations*.

Water bodies were omitted from the model extent for two main reasons: first, the main goal of this project is to estimate vulnerability of the SAS and not vulnerability of surface water features, and second, data for water bodies is typically not available – i.e., wells are not drilled in water bodies, nor do soil surveys normally contain information regarding lake and stream bottoms.

Training Point Theme

In the model analysis, training points are groundwater wells tapping the surficial aquifer system (SAS) with water quality data indicative of high recharge. Dissolved oxygen analytical values served as training point data for the SAS model. Naturally occurring oxygen and nitrogen are generally considered ubiquitous at land surface as primary components of the atmosphere; moreover, relatively low concentrations of these analytes occur in well protected – or less vulnerable – aquifer systems. Accordingly, where these analytes occur in elevated concentrations in groundwater, yet are not attributable to human activity, they are good indicators of aquifer vulnerability (Arthur et al., 2007).

Water quality data sources explored include the FDEP background water quality network and FDEP STATUS network. From these data sources, 474 wells measured for dissolved oxygen were identified as being potential candidates for training points. Statistical analyses revealed 62 samples were considered statistical outliers. The upper 25th percentile of this set – or all wells with median dissolved oxygen values greater than or equal to 0.655 milligrams per liter (mg/L) – served as the training point theme and consists of 99 wells. Figure 31 displays the distribution of water wells used to derive training points and the resulting training point theme across the study area.

Training points are used to calculate prior probability, weights for each evidential theme, and posterior probability of the response theme (see *Glossary*). Prior probability (training point unit area divided by total study area) is the probability that a training point will occupy a defined unit area within the study area, independent of any evidential theme data. The prior probability value, a unitless parameter, for the SAS model is 0.0019 ([1 km^2 model unit area * 99 training points] / 52919.2 km^2 = 0.0019). Posterior probability values generated during response theme development are interpreted relative to the value of prior probability with higher values generally indicating areas with higher probability of containing a training point.

Figure 30. Surficial Aquifer System Vulnerability Assessment project study area extent.

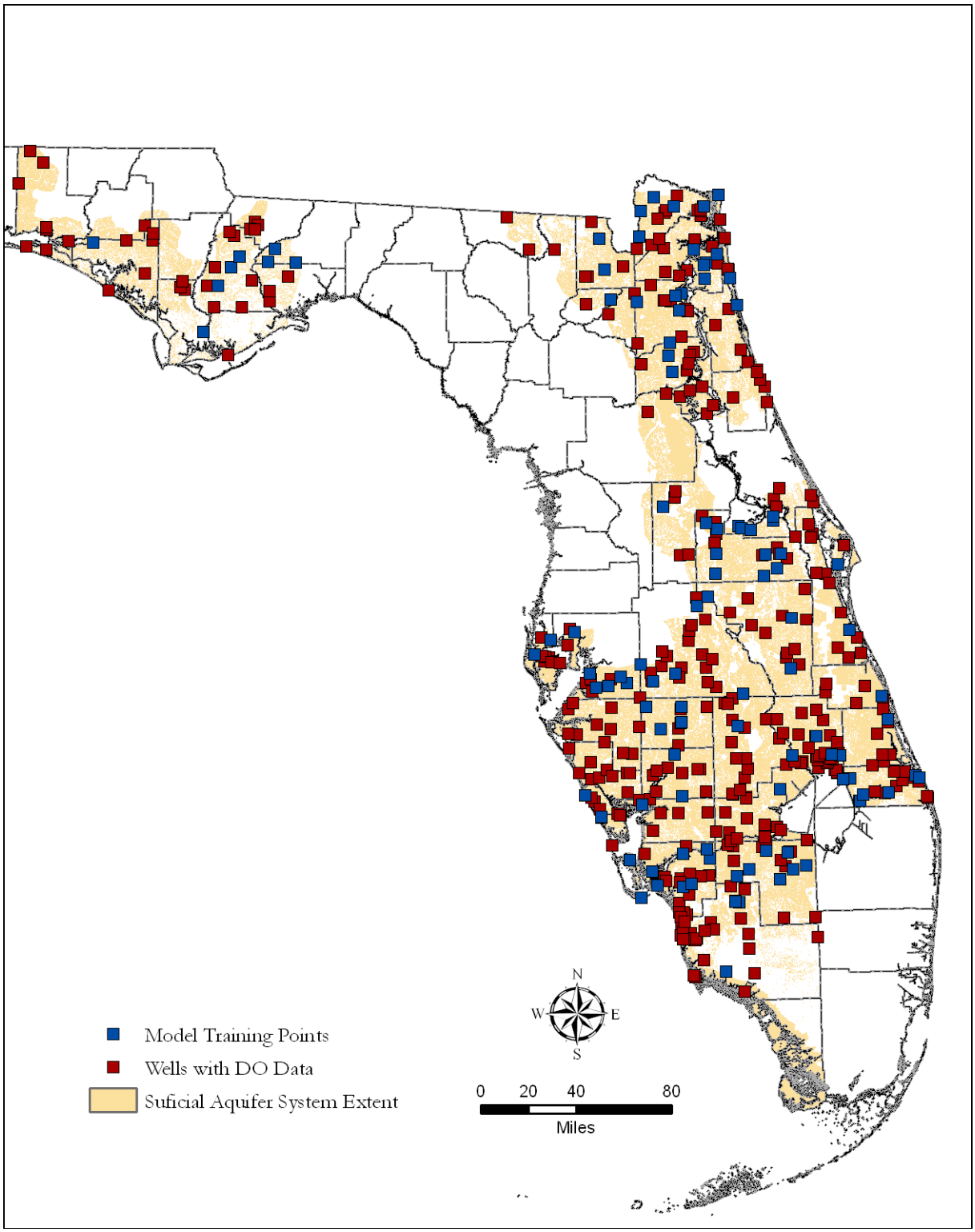

Figure 31. Location of all wells measured for dissolved oxygen (dark red boxes), and locations of training point wells with median dissolved oxygen values greater than 0.655 mg/L (blue boxes).

Evidential Themes – Model Input Layers

Input data layers, or evidential themes, representing hydrogeologic factors controlling the location of training points, and thereby vulnerability, were developed for model input. The factors considered for the SAS project include closed topographic depressions, depth to water, soil pedality, and soil hydraulic conductivity.

Soil Hydraulic Conductivity and Soil Pedality Themes

The rate that water moves through soil is a critical component of any aquifer vulnerability analysis, as soil is literally an aquifer system's first line of defense against potential contamination (Arthur et al., 2005). Two parameters of soils were evaluated for input into the SAS model: *soil hydraulic conductivity*, which is the "amount of water that would move vertically through a unit area of saturated soil in unit time under unit hydraulic gradient" (U.S. Department of Agriculture, 2005); and *soil pedality*, which is calculated based on soil type, soil grade, and soil pedon size, and is a unitless parameter. Soil pedality is a relatively new concept used to estimate the hydrologic parameter of soil and is generated for the SAS using the pedality point method developed by Lin et al. (1999).

Countywide datasets representing soil hydraulic conductivity and soil pedality were developed for use as input into the SAS model. Multiple empirical values are reported in soil surveys representing various zones in each soil column underlying a particular soil polygon. Representative values for each horizon in a column are combined using a sum of the weighted mean. This is completed for both hydraulic conductivity and soil pedality. Figure 33 displays values of soil hydraulic conductivity.

Depth to Water Theme

Depth to water is another critical layer in determining aquifer vulnerability. Where the depth to water is greatest (larger vadose zone), aquifer vulnerability is generally lower, whereas in areas where the depth to water is nearer to the surface, the vulnerability of the aquifer is generally higher.

Using the newly corrected DEM, errors in the SAS water table surface were corrected to produce a more accurate evidential theme layer. The original water table surface had an average error of 6.58 feet and an error range between regressed and measured values of -33.96 to 30.70. The newly created water able surface has an average error of 4.82 feet and an error range between regressed and measured values of -15.82 to 16.72 (Table 7). A strong correlation coefficient of 0.99 was exhibited between the regressed and measured water-table elevation (Figure 32). The final depth to water evidential theme was calculated by subtracting the water table elevation values from the FDEP DEM values (Figure 34).

Table 7. Linear regression coefficients for MINWT and difference between DEM and MINWT.

Number of surficial wells	Root mean square residual (ft)	Value range for difference between interpolated & measured water table (ft)	Correlation coefficient
656	4.82	[-15.82, 16.72]	0.99

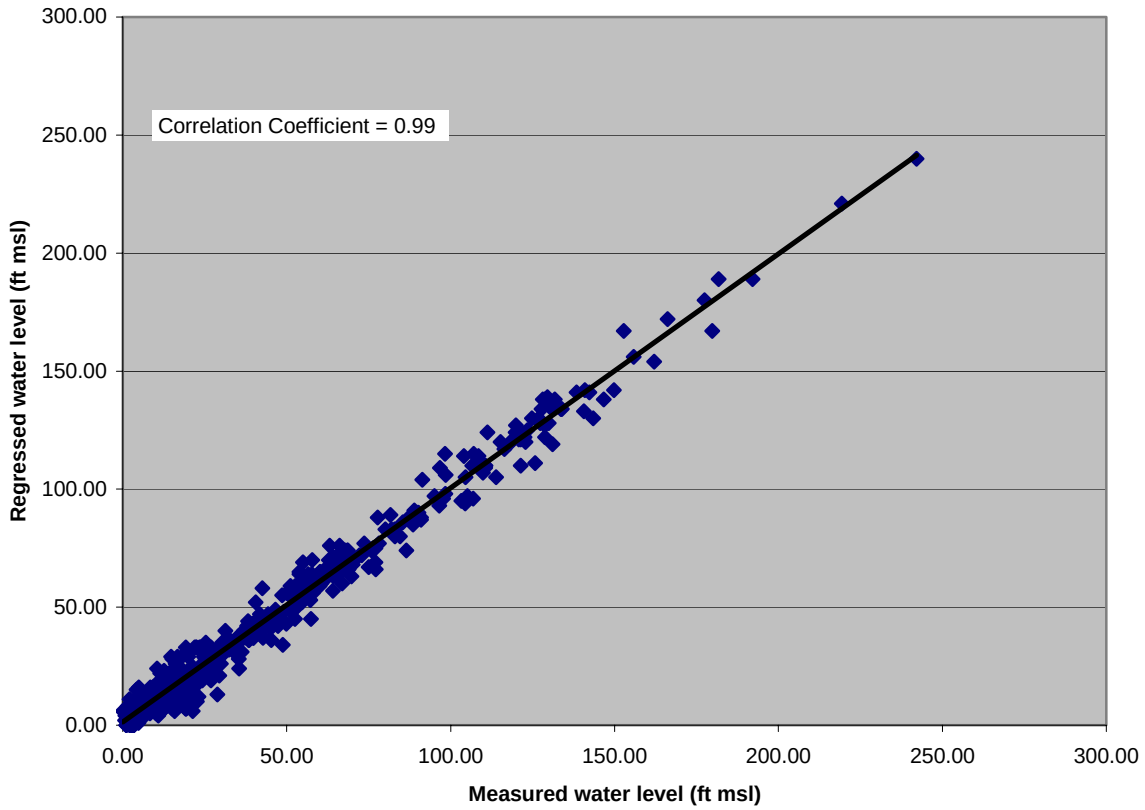

Figure 32. Regressed and measured water level for Surficial Aquifer.

Closed Topographic Depressions

Karst features, or sinkholes and depressions, can provide preferential pathways for movement of surface water into the underlying aquifer system and enhance an area's aquifer vulnerability where present. The closer an area is to a karst feature, the more vulnerable it may be considered. Closed topographic depressions extracted from U.S. Geological Survey 7.5-minute quadrangle maps served as the dataset from which to estimate closed topographic depressions in the study area (Figure 35).

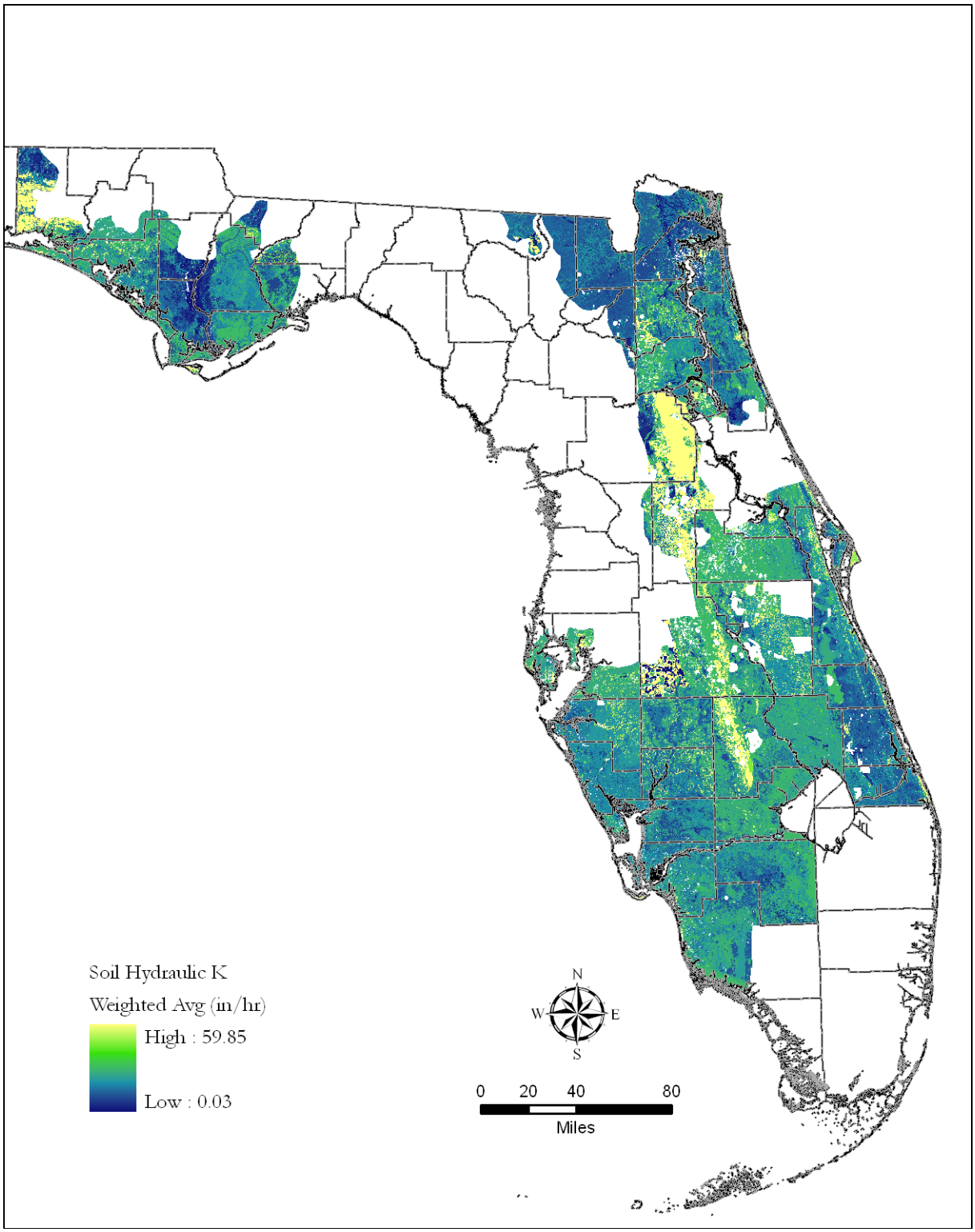

Figure 33. Distribution of soil hydraulic conductivity values across the Surficial Aquifer study area. White areas represent 'no data' areas in the soil survey data or locations of water bodies.

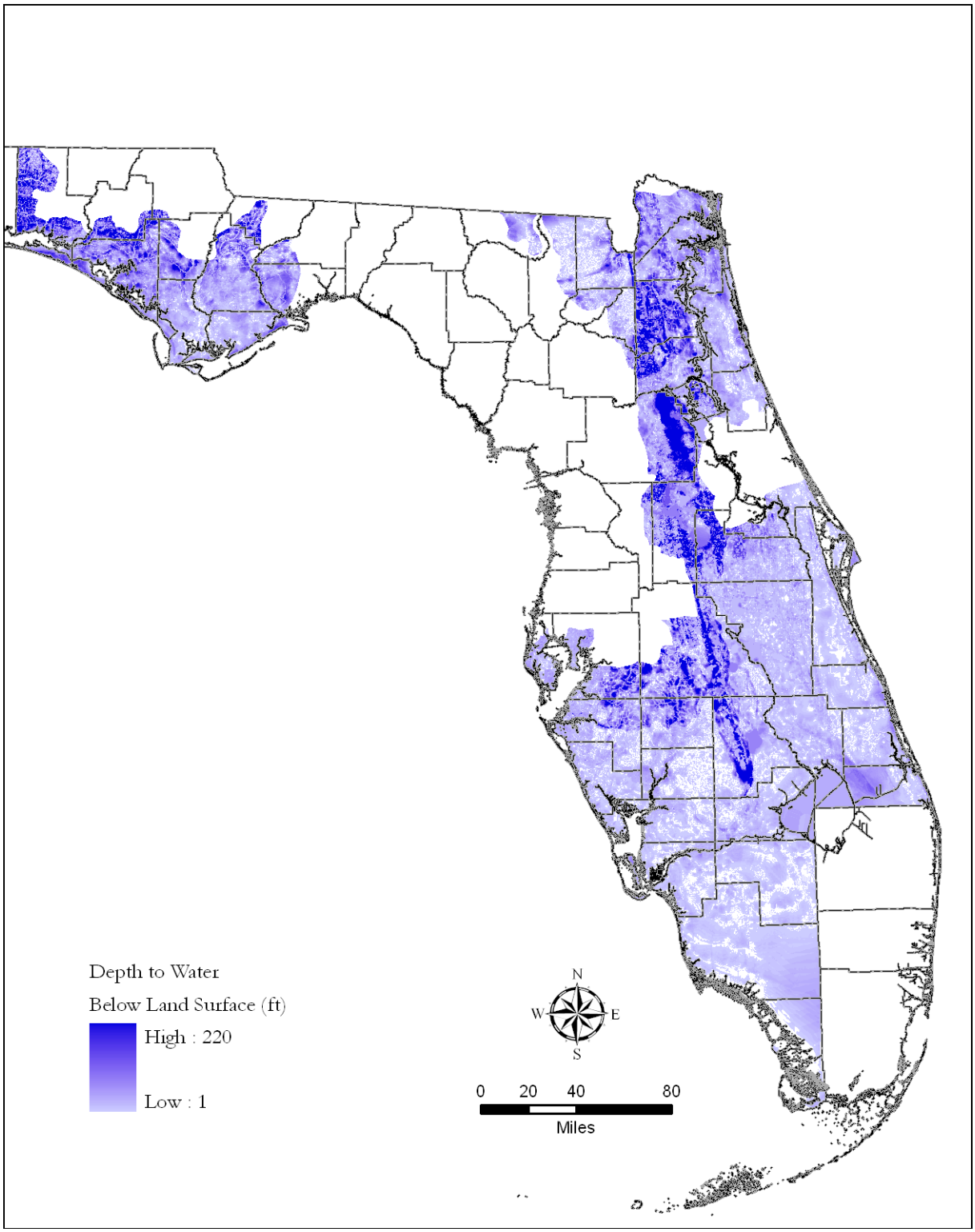

Figure 34. Distribution of depth to water values across the Surficial Aquifer study area. White areas represent 'no data' areas or locations of water bodies.

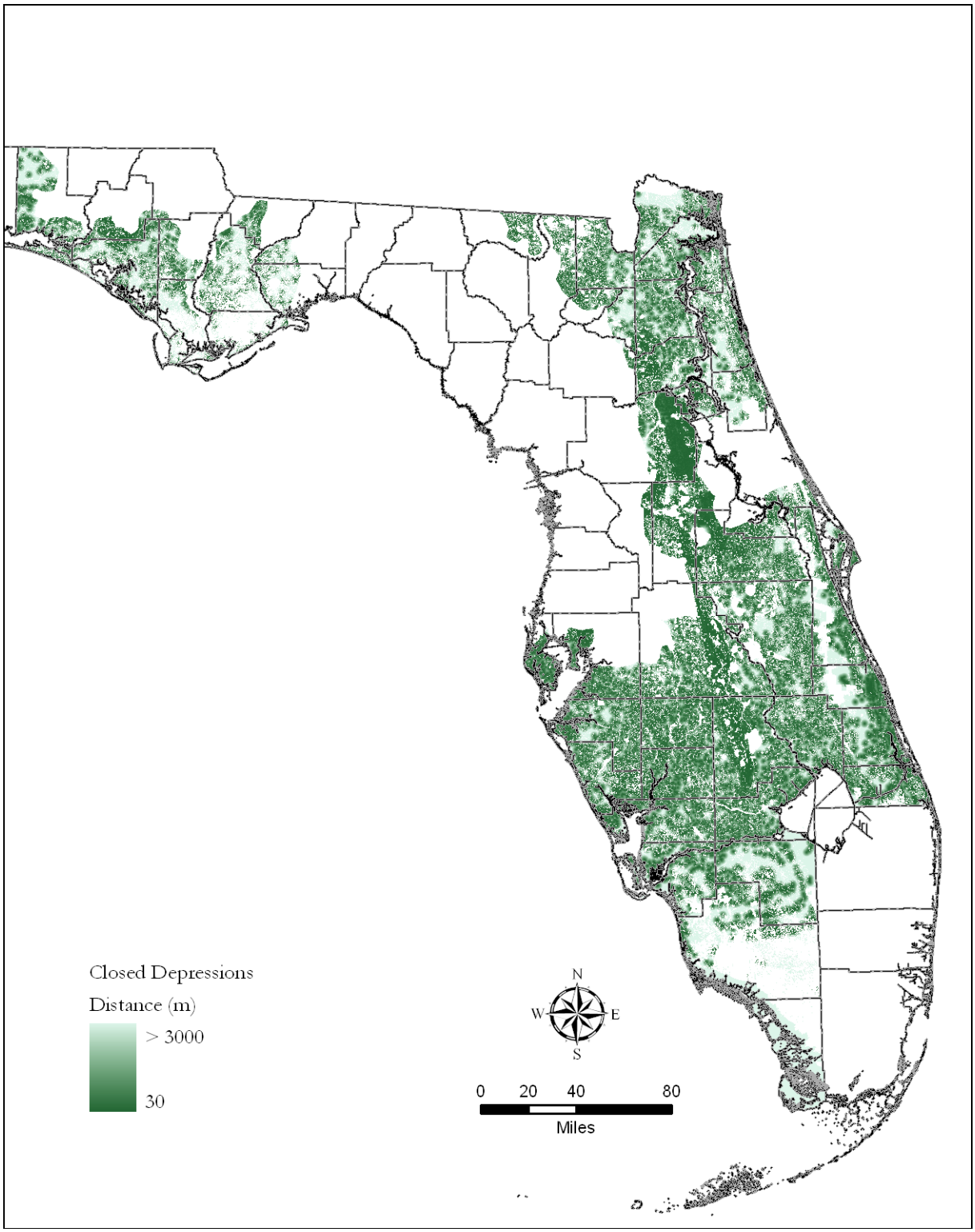

Figure 35. Proximity to closed topographic depressions extracted from U.S. Geological Survey 7.5-minute topographical contour lines.

Sensitivity Analysis/Evidential Theme Generalization

Sensitivity analysis allows decisions to be made about proposed evidential themes by evaluating each theme's association with training points – or aquifer vulnerability – and ultimately helps determine model input. For example, soil hydraulic conductivity and soil pedality were both developed to represent soil properties; sensitivity analysis allows, through statistical analysis, determination of which of these two layers served as the most appropriate input representing soil properties for the final SAS analysis. Results of this process indicate that soil hydraulic conductivity, depth to water, and closed topographic depressions were the best suited evidential themes for use in final modeling.

Following sensitivity analysis and selection of evidential themes to be input into the SAS model, themes were generalized to assess which areas of the evidence share a greater association with locations of training points. During calculation of weights for each theme, a contrast value was calculated for each class of the theme by combining the positive and negative weights. Contrast is a measure of a theme's significance in predicting the location of training points and helps to determine the threshold or thresholds that maximize the spatial association between the evidential theme map pattern and the training point theme pattern (Bonham-Carter, 1994). Contrast and weights are described in more detail below in *Discussion*.

Contrast values were used to determine where to sub-divide evidential themes into generalized categories prior to final modeling. The simplest and most accepted method used to subdivide an evidential theme is to select the maximum contrast value as a threshold value to create binary generalized evidential themes. In other models, categorization of more than two classes may be justified (Arthur et al., 2005). For the SAS project, a binary break was typically defined by the weights of evidence analysis for each evidential theme creating two spatial categories: one with stronger association with the training point theme and one with weaker association.

Soil Hydraulic Conductivity/ Soil Pedality

Weights calculated during sensitivity analysis for soil hydraulic conductivity were stronger (i.e., had higher absolute value) than weights calculated for soil pedality. As a result, soil hydraulic conductivity was chosen as the better predictor of aquifer vulnerability because it shared the best association with training points.

Soil hydraulic conductivity, ranges from 0.03 to 59.85 in/hr across the study area. Based on calculated weights, this theme had justification for a multiple class generalization. Test modeling indicated that areas greater than or equal to 36.43 in/hr were most associated with the training points, areas that are greater than or equal to 6.17 in/hr and less than 36.43 in/hr were less associated with training points and areas less than 6.17 in/hr were least associated with the training points. Based on this analysis, the evidential theme was generalized into three classes as displayed in Figure 36.

Depth to Water

The depth to water ranges from zero to 220 feet deep across the study area. The analysis revealed that areas less than or equal to 34 feet deep were more associated with the training points, and therefore associated with higher aquifer vulnerability. Areas with a depth to water greater than 34 feet were less associated with the training points, and therefore lower aquifer vulnerability. Based on this analysis, the evidential theme was generalized into two classes as displayed in Figure 37.

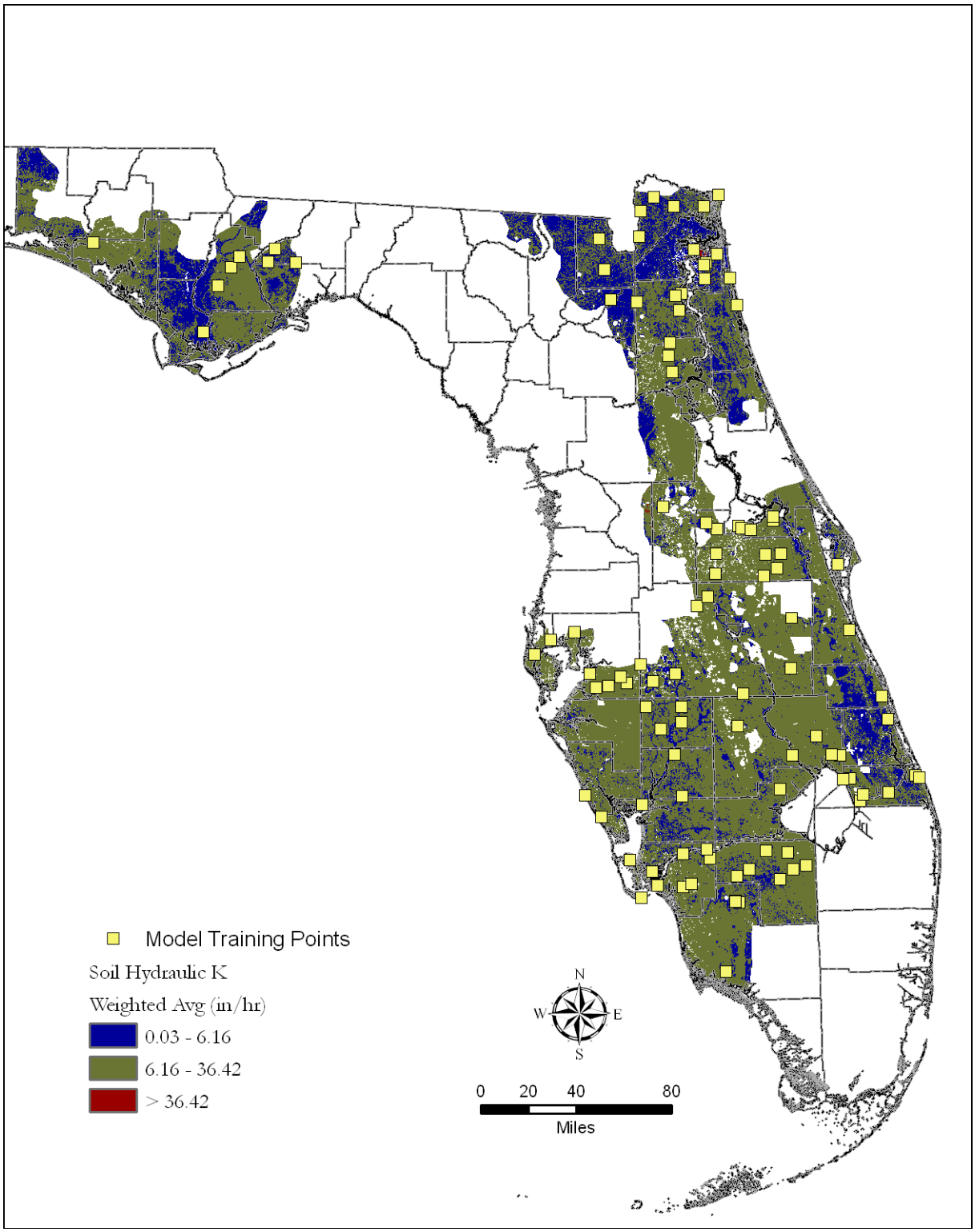

Figure 36. Generalized soil hydraulic conductivity evidential theme; based on calculated weights, a multi-class generalization with a break at a value of 6.16 and 36.42 in/hr was defined by the analysis. Based on the location of training points, blue areas share a weaker association with training points and thereby relatively lower aquifer vulnerability, whereas red areas share a stronger association with training points.

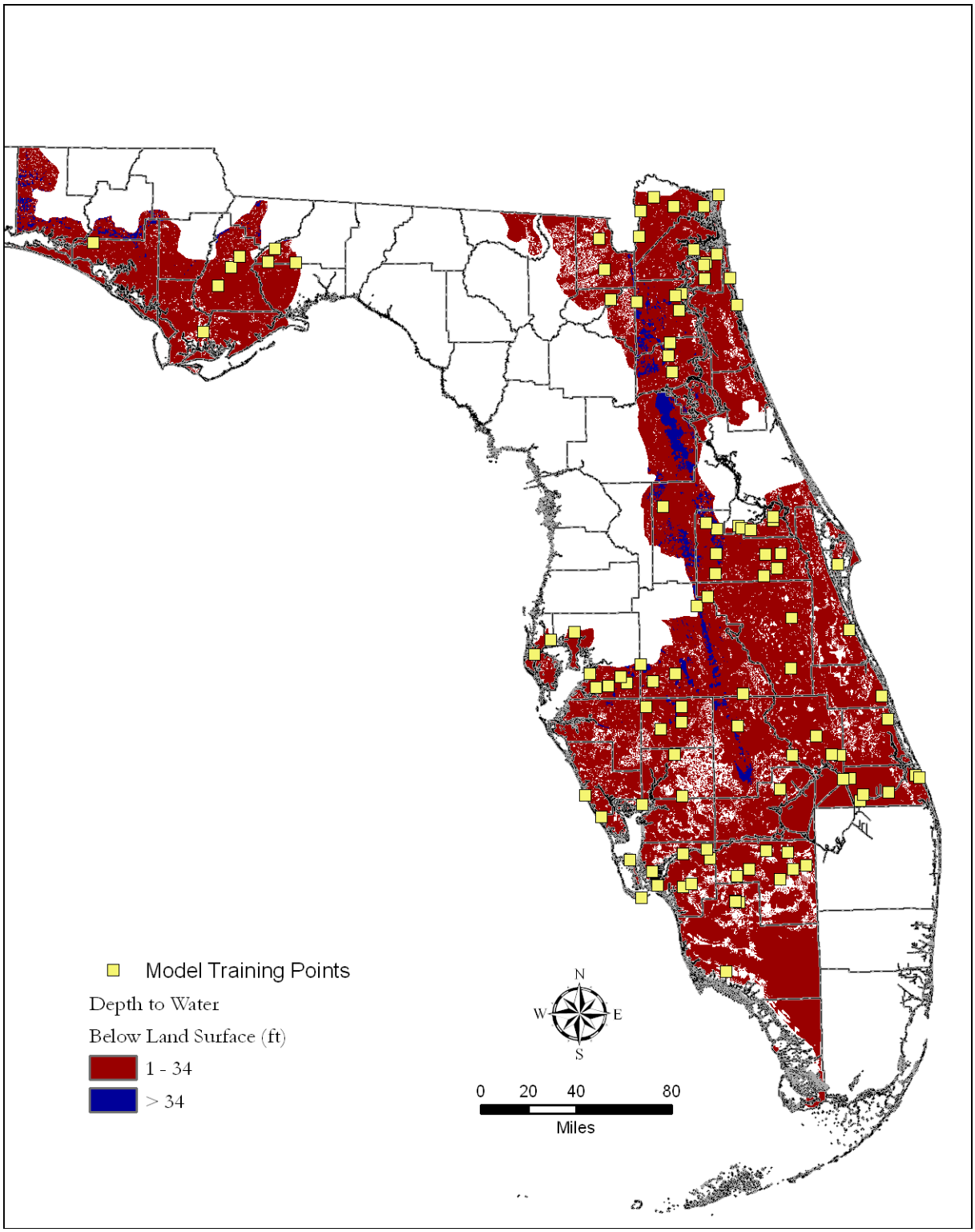

Figure 37. Generalized depth to water evidential theme; based on calculated weights analysis blue areas share a weaker association with training points and thereby relatively lower aquifer vulnerability, whereas red areas share a stronger association with training points.

Closed Topographic Depressions

As mentioned above, areas closer to a depression are normally associated with higher aquifer vulnerability. Based on this, features were buffered into 30 meter zones to allow for a proximity analysis. The analysis indicated that areas within 2,760 meters of a closed topographic depression were more associated with the training points, and therefore with higher aquifer vulnerability. Conversely, areas greater than 2,760 meters from a closed topographic depression were less associated with the training points, and therefore lower aquifer vulnerability. Based on this analysis, the evidential theme was generalized into two classes as displayed in Figure 38.

Response Theme

Using evidential themes representing soil hydraulic conductivity, depth to water, and closed topographic depressions, weights of evidence was applied to generate a response theme, which is a GIS raster consisting of *posterior probability* values ranging from 0.00019 to 0.0166 across the study area. These probability values describe the relative probability that a unit area of the model will contain a training point – i.e., a point of aquifer vulnerability as defined above in *Training Points* – with respect to the prior probability value of 0.0019 or ([1.0 km^2 model unit area * 99 training points] / 52919.2 km^2 = 0.0019). Prior probability is the probability that a training point will occupy a defined unit area within the study area, independent of evidential theme data. Probability values at the locations of 83 of the 99 training points are above the prior probability, indicating that this model is a strong predictor of training point locations.

The response theme was broken into classes of relative vulnerability based on the prior probability value and on inflections in a chart in which cumulative study area was plotted against posterior probability (Figure 39). Higher posterior probability values correspond with more vulnerable areas, as they essentially have a higher chance of containing vulnerability based on the definition of a training point. Conversely, lower posterior probability values correspond to less vulnerable areas as they essentially have a lower chance of containing vulnerability based on the definition of a training point.

As described in *Introduction*, the SAS model was based on the modeling technique used in the FAVA project. The FAVA project identified relative vulnerability of Florida's principal aquifer systems broken into three classes: more vulnerable, vulnerable and less vulnerable zones. This naming technique was applied to the SAS results to define the relative vulnerability classes as displayed in Figure 40.

As expected, the SAS response theme indicates that areas of highest vulnerability are associated with areas where the depth to water is lowest, in areas of dense closed topographic depressions, and areas of higher soil hydraulic conductivity. Conversely, areas of lowest vulnerability are determined by high depth to water values, sparse closed topographic depression distribution, and lower soil hydraulic conductivity values.

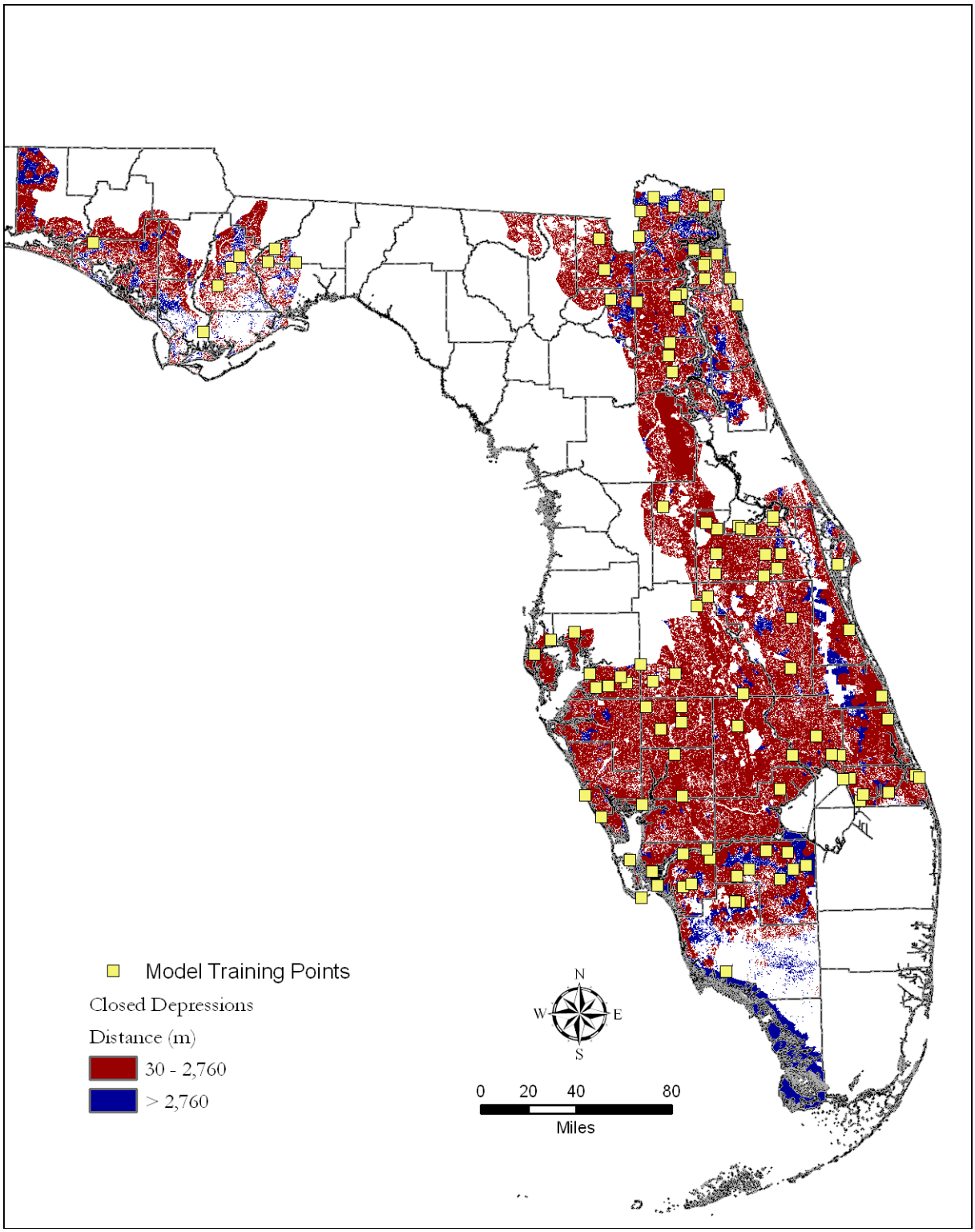

Figure 38. Generalized closed topographic depressions evidential theme; based on calculated weights analysis blue areas share a weaker association with training points and thereby relatively lower aquifer vulnerability, whereas red areas share a stronger association with training points.

Discussion

Prior to discussion of weights calculations during model execution, two components of a weights of evidence analysis are described to assist in interpretation of SAS model results: *Conditional Independence* and *Model Confidence*.

Conditional Independence

Conditional independence is a measure of the degree that evidential themes are affecting each other due to similarities between themes. Evidential themes are considered independent of each other if the conditional independence value is around 1.00, and conditional independence values within the range of 1.00 ± 0.15 generally indicate limited to no dependence among evidential themes (Bonham-Carter, 1994). Values significantly outside this range can inflate posterior probabilities resulting in unreliable response themes.

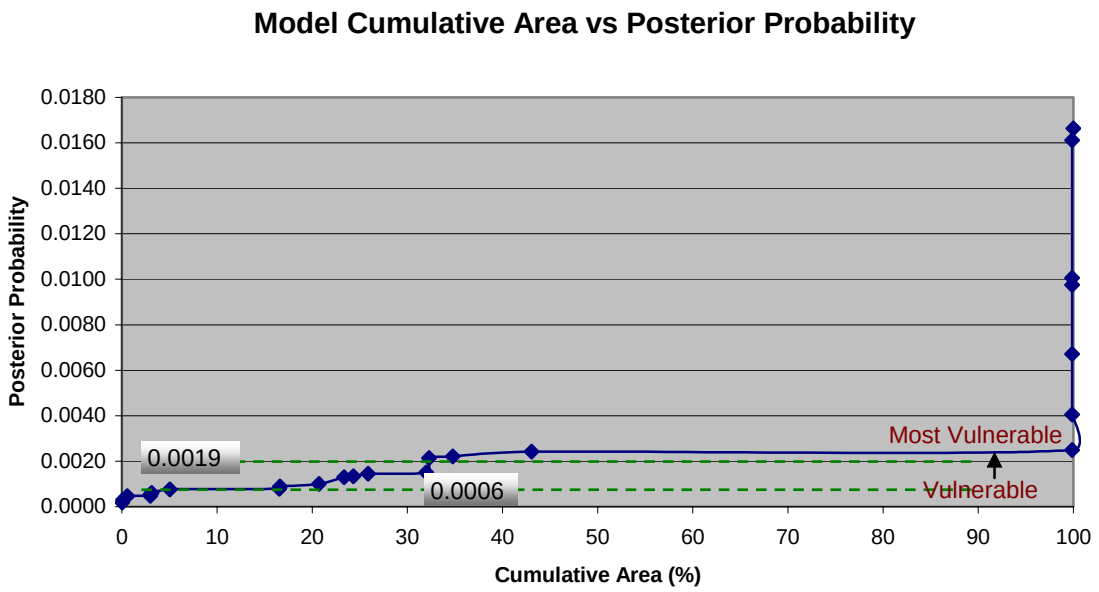

Figure 39. Vulnerability class breaks are defined by selecting where a significant increase in probability and area are observed.

Conditional independence was calculated at 1.00 for the SAS project indicating that evidential themes had virtually no conditional dependence.

Model Confidence

During model execution, confidence values are calculated both for each generalized evidential theme and for the final response theme. Confidence values approximately correspond to the statistical levels of significance listed in Table 3.

Confidence of the evidential theme equals the contrast divided by the standard deviation (a student T-test) for a given evidential theme and provides a useful measure of significance of the contrast due to the uncertainties of the weights and areas of possible missing data (Raines, 1999). A test value of 1.2814 corresponds to approximately 90% confidence – or level of significance – and was the minimum calculated confidence level for the SAS project evidential themes (see Table 8 below for evidential theme confidence values).

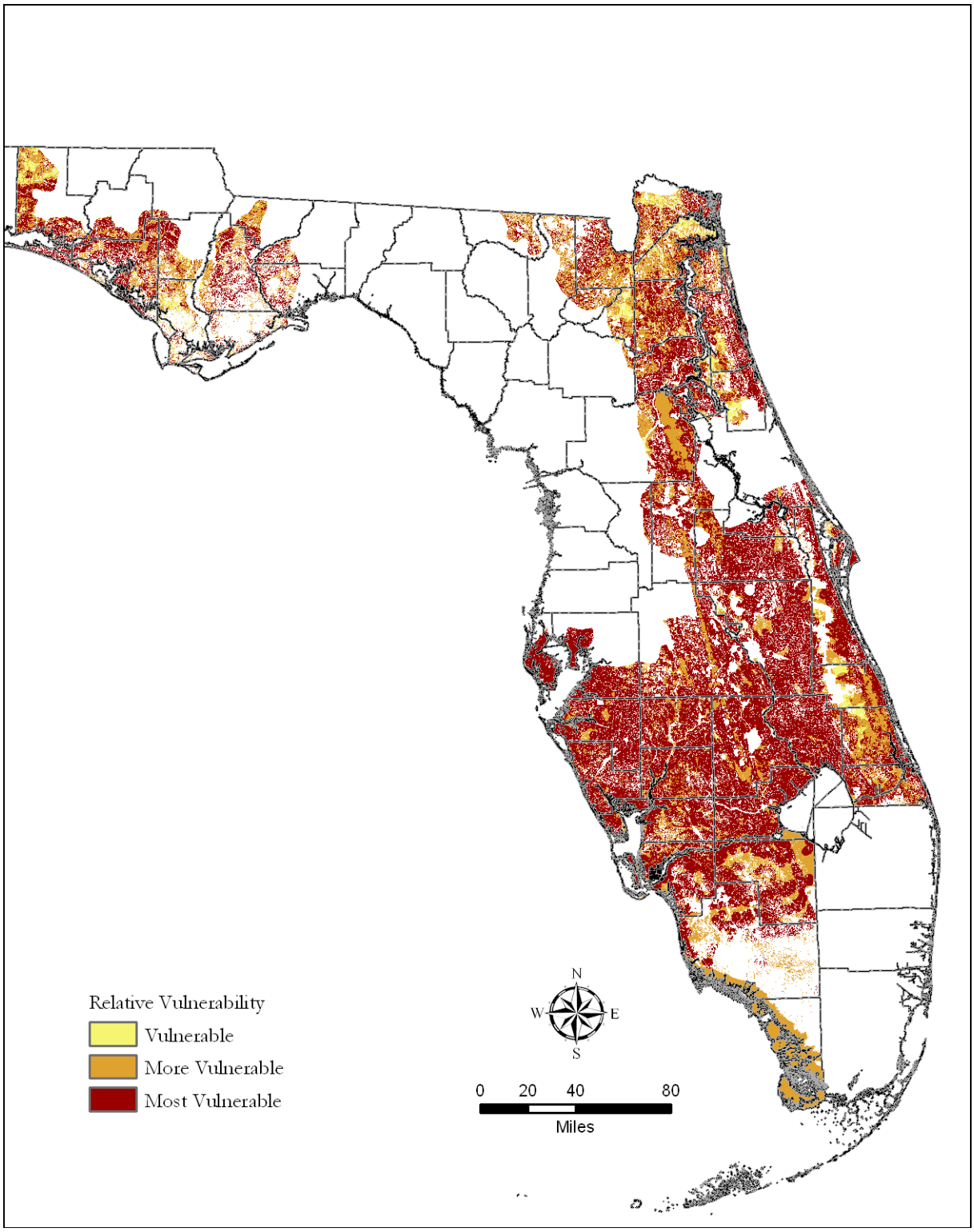

Figure 40. Relative vulnerability map for the Surficial Aquifer Vulnerability Assessment project. Classes of vulnerability are based on calculated probabilities of a unit area containing a training point, or a monitor well with water quality sample results indicative of vulnerability.

A confidence map is also calculated for a response theme by normalizing the theme's posterior probability by its total uncertainty (standard deviation). A confidence map can be generated based on these calculations. The confidence map for the SAS response theme is displayed in Figure 41. Areas with high posterior probability values typically correspond to higher confidence values and as a result have a higher level of certainty with respect to predicting aquifer vulnerability.

Weights Calculations

Table 8 displays evidential themes used in the SAS model, weights calculated for each theme, along with contrast and confidence values. Positive weights indicate areas where training points are likely to occur, while negative weights indicate areas where training points are not likely to occur. The contrast column is a combination of the highest and lowest weights (positive weight – negative weight) and is a measure of how well the generalized evidential themes predict training points. Confidence of the evidential theme is also calculated and is equal to the contrast divided by its standard deviation (a student T test). Confidence is a measure of significance due to uncertainties of the weights and missing data (Raines, 1999). A positive contrast that is significant, based on its confidence, suggests that a generalized evidential theme is a useful predictor.

Table 8. Weights of evidence final output table listing weights calculated for each evidential theme and their associated contrast and confidence values of the evidential themes.

Evidential Theme	W1	W2	W3	Contrast	Confidence
Soil Hydraulic Conductivity	2.0316	0.1195	-1.0353	3.0669	2.8214
Depth to Water	0.0318	-0.8847		0.9164	1.2814
Closed Topographic Depressions	0.0586	-0.4507		0.5094	1.456

Because positive weights (W1) values for soil hydraulic conductivity are stronger (have greater absolute values) than the negative weights (W3), they are better predictors of where training points are likely to occur, whereas the depth to water and closed topographic depression themes are better indicators of where training points are less likely to occur. Based on contrast values, the soil hydraulic conductivity theme has the strongest (highest absolute value) weight and is the primary determinant in predicting areas of vulnerability in the SAS model.

Validation

The weights of evidence approach, because it relies on a set of training points, which by definition are known sites of vulnerability, is essentially self-validated. Eighty-three of ninety-nine training points were predicted in zones of posterior probability greater than the prior probability (in other words, classified accurately). Further strengthening the results were the evaluation of a minimum confidence threshold for evidential themes, and generation of a confidence map of the response theme. In addition to these exercises, and in the style of previous aquifer vulnerability assessments (Cichon et al., 2005; Baker et al., 2005; Arthur et al., 2005), additional validation techniques were applied to the SAS model to further strengthen its defensibility, and, ultimately, its utility: (1) comparison of dissolved oxygen values to posterior probability and evaluation of an associated trend; and (2) generation of a test response theme based on a subset of training points and comparison of points not used in subset to model results and (3) comparison of dissolved nitrogen values with vulnerable zones of the response theme.

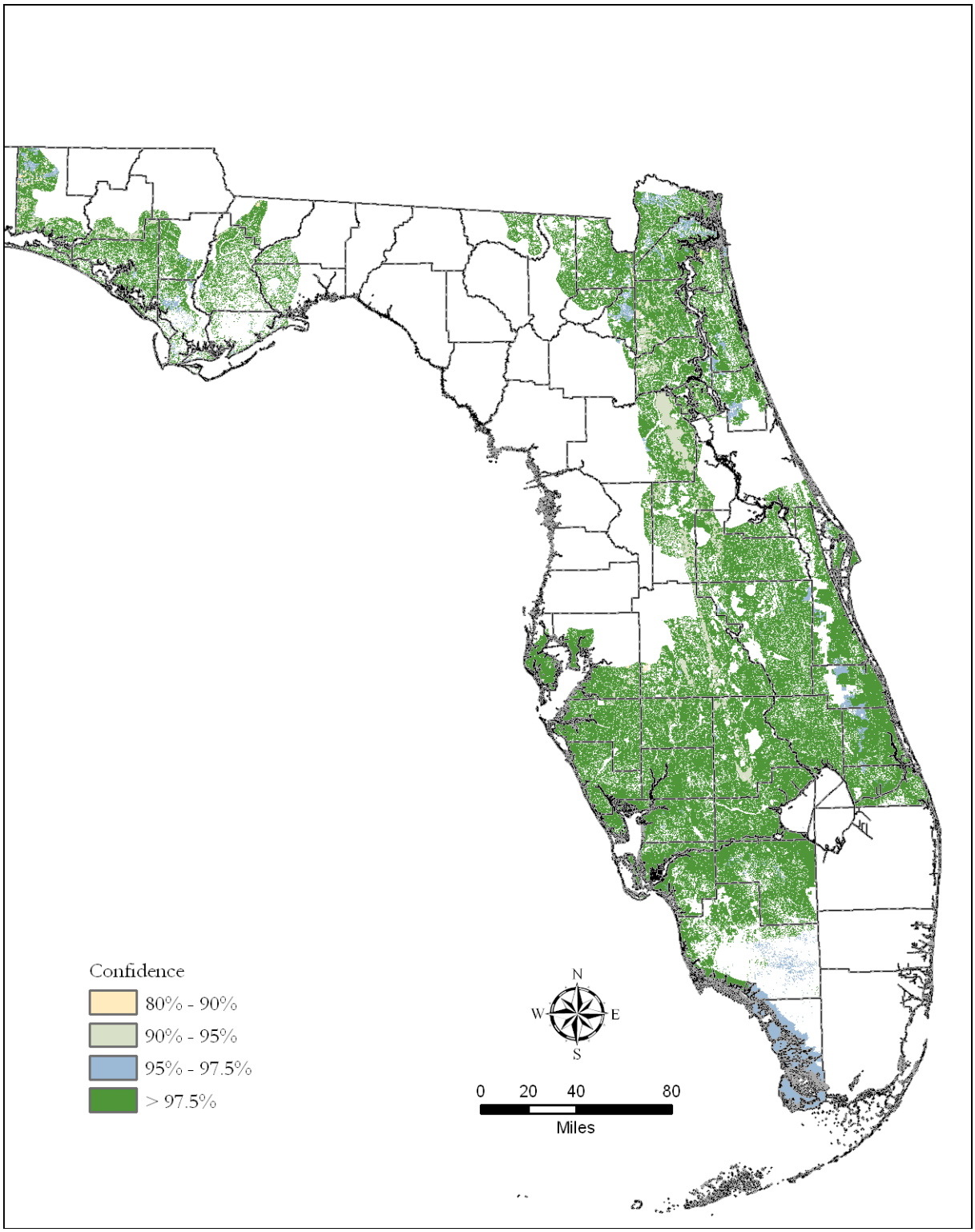

Figure 41. Confidence map for the Surficial Aquifer model calculated by dividing the posterior probability values by the total uncertainty for each class to give an estimate of how well specific areas of the model are predicted.

Dissolved Oxygen Data vs. Posterior Probability

It was expected that comparison of posterior probability values to the dissolved oxygen dataset from which the training point theme was extracted would reveal a proportional trend, in other words, as dissolved oxygen values increase, so should posterior probability values. Dissolved oxygen median concentrations were binned and averaged for each posterior probability value calculated in model output. The average values were plotted in a chart against posterior probability values (Figure 42) and a slight positive trend was observed. Only one well was observed in the first class so it was averaged into the next higher class.

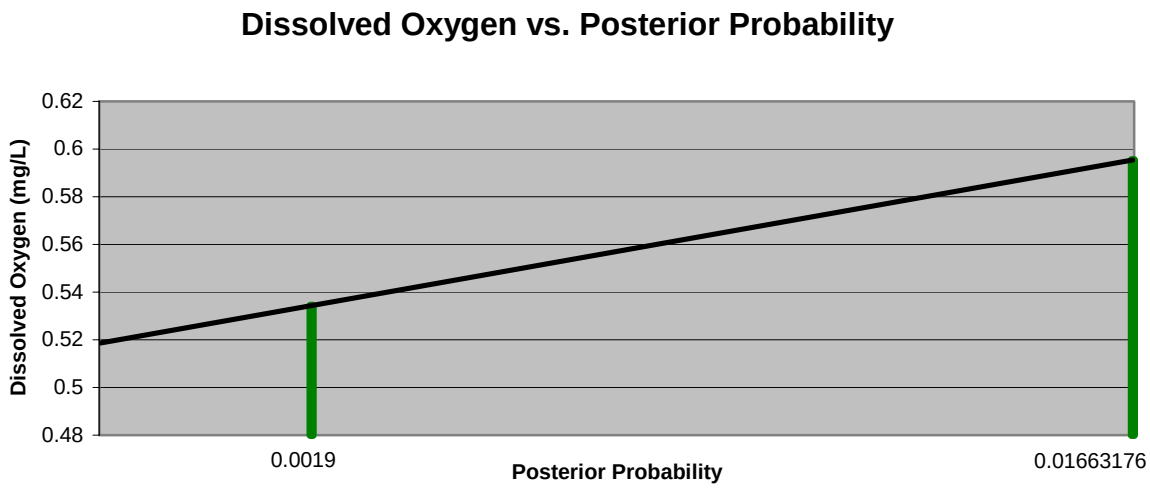

Figure 42. Dissolved oxygen values (averaged per posterior probability class) versus probability values to reveal trend between increasing dissolved oxygen concentrations and posterior probability.

Subset Response Theme

Another meaningful validation exercise similar to the exercise above is to use the existing training point dataset to develop two subsets: one to generate a test response theme, and one to validate output from this test response theme. Results from this exercise helped to further assess whether the dissolved oxygen training points are reasonable predictors of aquifer vulnerability.

From the SAS training point theme, a subset of 75% (81 wells) were randomly selected and used to develop a test response theme; the remaining 25% (26 wells) of the training points were used as the validation dataset for the test response theme. This comparison revealed that twenty-three of the twenty-six test wells in the validation subset, or 88.5%, occur in areas of the test response theme with predicted probability values higher than the prior probability value (Figure 43). This further supports the conclusion that the SAS model response theme is a reasonable estimator of vulnerability.

Dissolved Nitrogen Data

Perhaps the most rigorous validation exercise used to evaluate quality of model-generated output is to compare predicted model values with independent test values not used in the model. For the SAS model, this was accomplished by comparison of a separate well dataset based on dissolved nitrogen. As mentioned above in *Training Point Theme*, dissolved nitrogen is indicative of aquifer vulnerability,

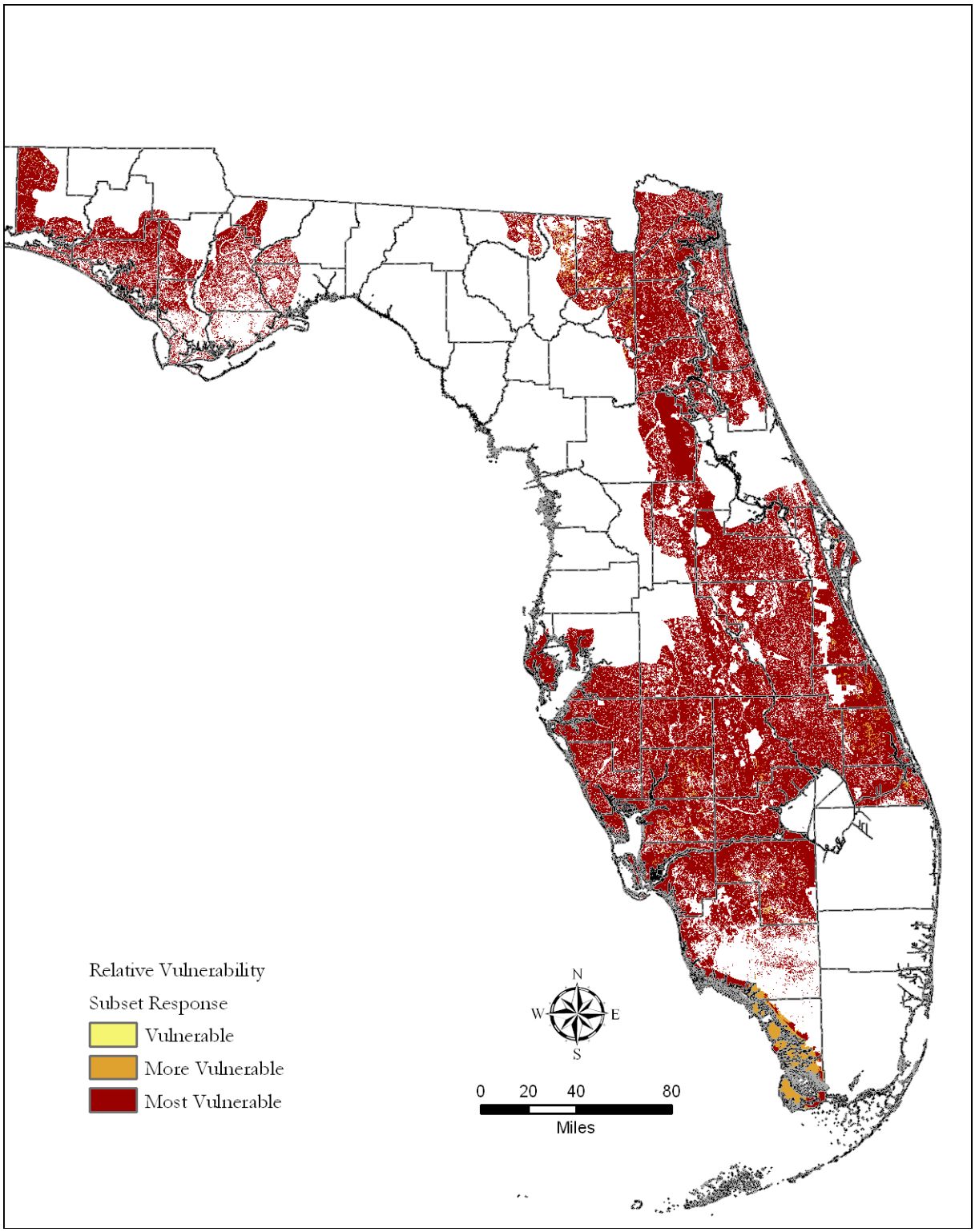

Figure 43. Subset response training points plotted in the dissolved oxygen response theme.

but is independent of dissolved oxygen. Applying the methodology described in *Training Point Theme* to dissolved nitrogen data (obtained from the same data sources as dissolved oxygen data) resulted in a dissolved nitrogen dataset of 63 wells each indicative of aquifer vulnerability.

These 63 points were evaluated against posterior probability values of the SAS model output. Extracting the value of posterior probability from the dissolved oxygen response theme for the location of each of the 63 dissolved nitrogen training points revealed that 53 of the 63 dissolved nitrogen training points occur in areas of the dissolved oxygen model with predicted probability values higher than the prior probability value. In other words, 84% of the dissolved nitrogen wells were located in areas predicted to have a greater than chance probability of containing a training point. Based on this test, the dissolved oxygen model is not only a good predictor of vulnerability as defined by the training point theme, it is also a good predictor of the location of an independent parameter also representing aquifer vulnerability. Figure 44 displays dissolved nitrogen data points plotted on the dissolved oxygen response theme.

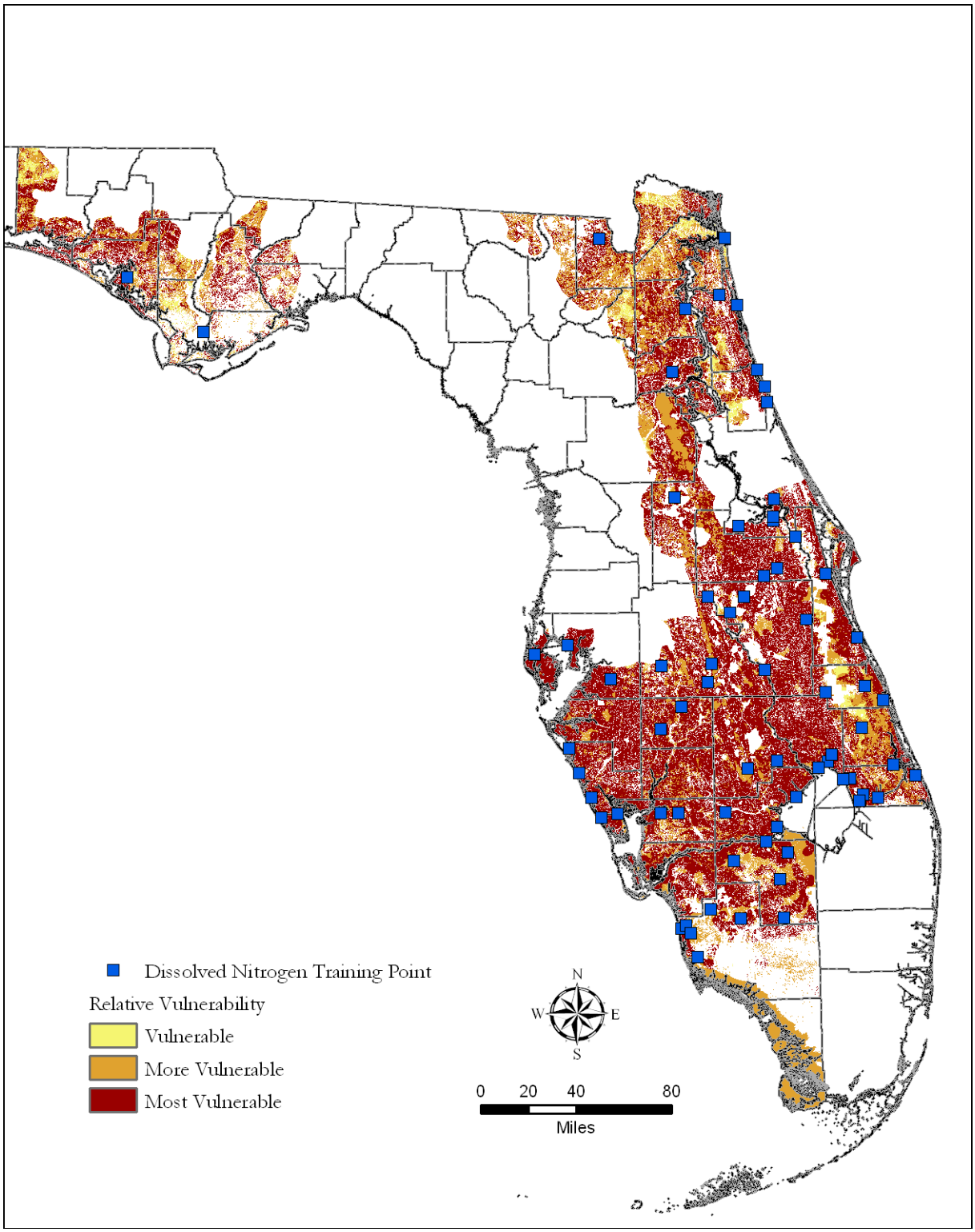

Figure 44. Dissolved nitrogen validation training points plotted in the dissolved oxygen response theme. Comparison reveals 53 of 63 wells (84%) of the independent water quality dataset are located in areas with predicted probability values higher than the prior probability.

INTERMEDIATE AQUIFER SYSTEM

Study Area

The study area is the same as the original FAVA model extent (Figure 45). Because of the sizes of some polygons representing soil data, a grid cell size of approximately 30 meter squares (or 900 m^2) was selected for evidential theme development. This grid cell size, while necessary to capture resolution available in some input data layers, does not reflect appropriate resolution of final model output. Appropriate scale of use of model results is discussed in *Model Implementation and Limitations*.

Water bodies were omitted from the model extent for two main reasons: first, the main goal of this project is to estimate vulnerability of the intermediate aquifer system (IAS) and not vulnerability of surface water features, and second, data for water bodies is typically not available – i.e., wells are not drilled in water bodies, nor do soil surveys normally contain information regarding lake and stream bottoms.

Training Point Theme

In the model analysis, training points are groundwater wells tapping the IAS with water quality data indicative of high recharge. Dissolved nitrogen (ammonia plus total dissolved nitrogen) analytical values served as training point data for the IAS model. Ammonia concentrations were incorporated into the IAS training point data set to account for areas of the State with a high water table. In these areas, nitrogen in the form of ammonia can be more prevalent where the high water table and organic soils create a reducing environment. Naturally occurring oxygen and nitrogen are generally considered ubiquitous at land surface as primary components of the atmosphere; moreover, relatively low concentrations of these analytes occur in well protected – or less vulnerable – aquifer systems. Accordingly, where these analytes occur in elevated concentrations in groundwater, yet are not attributable to human activity, they are good indicators of aquifer vulnerability (Arthur et al., 2007).

Water quality data sources explored include the FDEP background water quality network and FDEP STATUS network. From these data sources, 120 wells measured for dissolved nitrogen were identified as being potential candidates for training points. Statistical analyses revealed 4 samples were considered statistical outliers. The upper 25th percentile of this set – or all wells with median dissolved nitrogen values greater than or equal to 0.477 milligrams per liter (mg/L) – served as the training point theme and consists of 29 wells. Figure 46 displays the distribution of water wells used to derive training points and the resulting training point theme across the study area.

Training points are used to calculate prior probability, weights for each evidential theme, and posterior probability of the response theme (see *Glossary*). Prior probability (training point unit area divided by total study area) is the probability that a training point will occupy a defined unit area within the study area, independent of any evidential theme data. The prior probability value, a unitless parameter, for the IAS model is 0.0011 ([1 km^2 model unit area * 29 training points] / 27,458.4 km^2 = 0.0011). Posterior probability values generated during response theme development are interpreted relative to the value of prior probability with higher values generally indicating areas with higher probability of containing a training point.

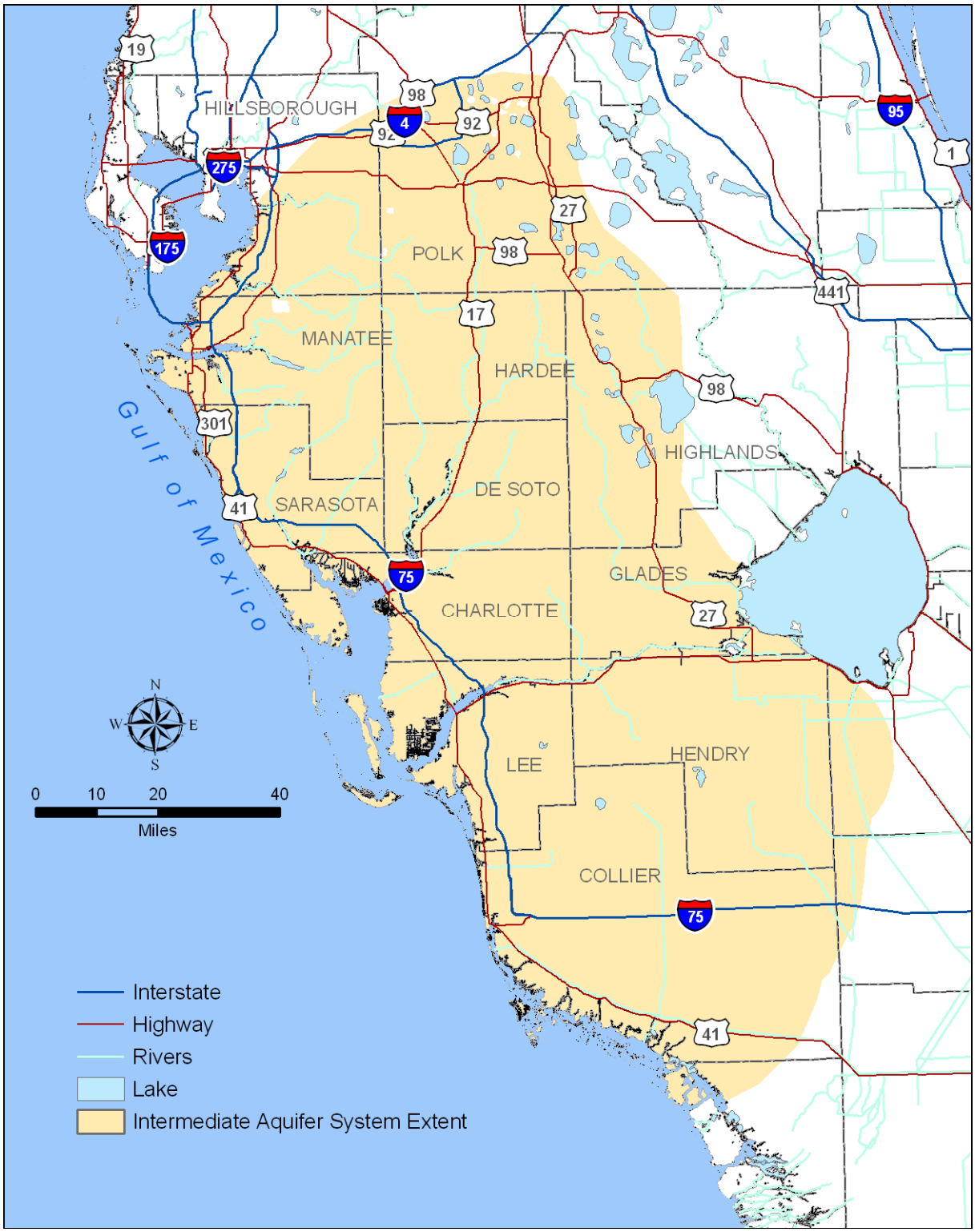

Figure 45. Intermediate Aquifer System Vulnerability Assessment project study area extent.

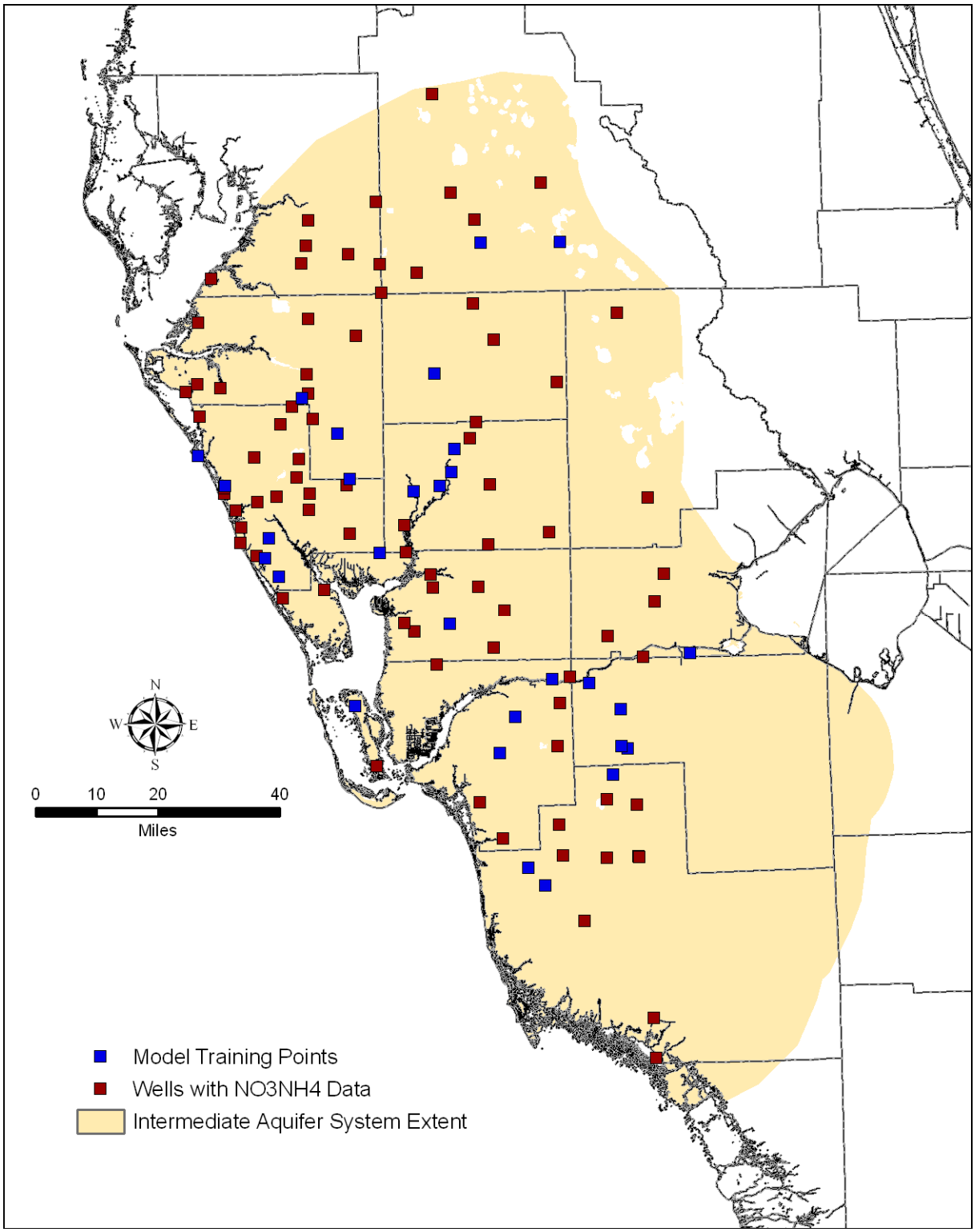

Figure 46. Location of all wells measured for ammonia + nitrate (dark red boxes), and locations of training point wells with median ammonia + nitrate values greater than 0.477 mg/L (blue boxes).

Evidential Themes – Model Input Layers

Input data layers, or evidential themes, representing hydrogeologic factors controlling the location of training points, and thereby vulnerability, were developed for model input. The factors considered for the IAS project include closed topographic depressions, IAS overburden, soil pedality, and soil hydraulic conductivity.

Soil Hydraulic Conductivity and Soil Pedality Themes

The rate that water moves through soil is a critical component of any aquifer vulnerability analysis, as soil is literally an aquifer system's first line of defense against potential contamination (Arthur et al., 2005). Two parameters of soils were evaluated for input into the IAS model: *soil hydraulic conductivity*, which is the "amount of water that would move vertically through a unit area of saturated soil in unit time under unit hydraulic gradient" (U.S. Department of Agriculture, 2005); and *soil pedality*, which is calculated based on soil type, soil grade, and soil pedon size, and is a unitless parameter. Soil pedality is a relatively new concept used to estimate the hydrologic parameter of soil and is generated for the IAS using the pedality point method developed by Lin et al. (1999).

Countywide datasets representing soil hydraulic conductivity and soil pedality were developed for use as input into the IAS model. Multiple empirical values are reported in soil surveys representing various zones in each soil column underlying a particular soil polygon. Representative values for each horizon in a column are combined using a sum of the weighted mean. This is completed for both hydraulic conductivity and soil pedality. Figure 47 displays values of soil pedality.

Intermediate Aquifer System Overburden Thickness Theme

Aquifer confinement – in the form of overburden overlying the IAS – is another critical layer in determining aquifer vulnerability. Where aquifer overburden is thick and the IAS is deeply buried, aquifer vulnerability is generally lower, whereas in areas of thin to absent confinement, the vulnerability of the IAS is generally higher.

A GIS model was developed of the surface of the IAS. The intent of this model was to allow the calculation of aquifer confinement thickness in various study areas. The surface model was developed using a dataset of borehole records from the Florida Geological Survey. The surface was used to calculate thickness of overburden overlying the IAS (Figure 48) in the study area.

Closed Topographic Depressions

Karst features, or sinkholes and depressions, can provide preferential pathways for movement of surface water into the underlying aquifer system and enhance an area's aquifer vulnerability where present. The closer an area is to a karst feature, the more vulnerable it may be considered. Closed topographic depressions extracted from U.S. Geological Survey 7.5-minute quadrangle maps served as the dataset from which to estimate closed topographic depressions in the study area (Figure 49).

Sensitivity Analysis/Evidential Theme Generalization

Sensitivity analysis allows decisions to be made about proposed evidential themes by evaluating each theme's association with training points – or aquifer vulnerability – and ultimately helps determine model input. For example, soil hydraulic conductivity and soil pedality were both developed to represent soil properties; sensitivity analysis allows, through statistical analysis, determination of which of these two layers served as the most appropriate input representing soil properties for the final IAS analysis. Results of this process indicate that soil pedality, IAS overburden, and closed topographic depressions were the best suited evidential themes for use in final modeling.

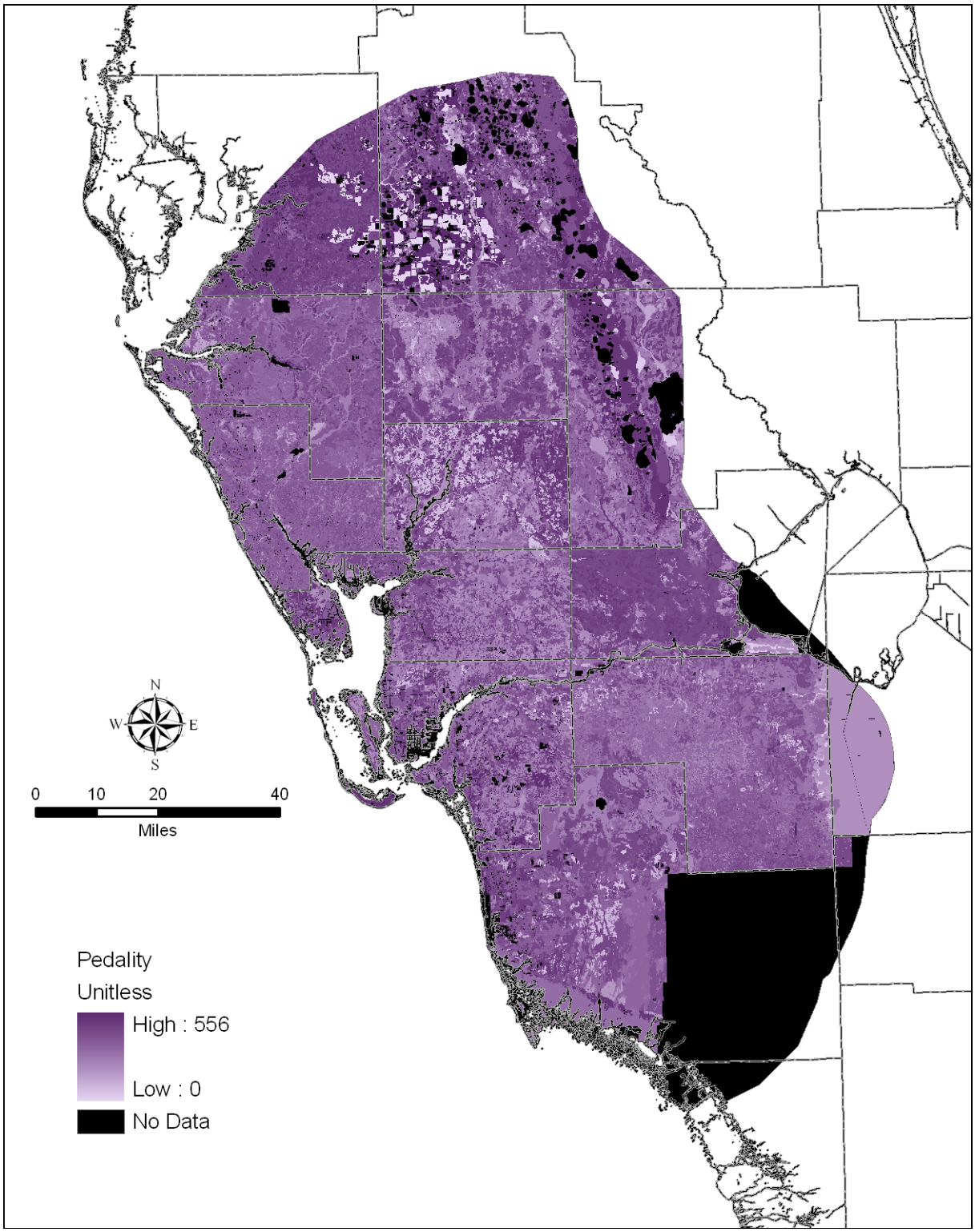

Figure 47. Distribution of soil pedality values across the Intermediate Aquifer study area. Black areas represent 'no data' areas in the soil survey data or locations of water bodies.

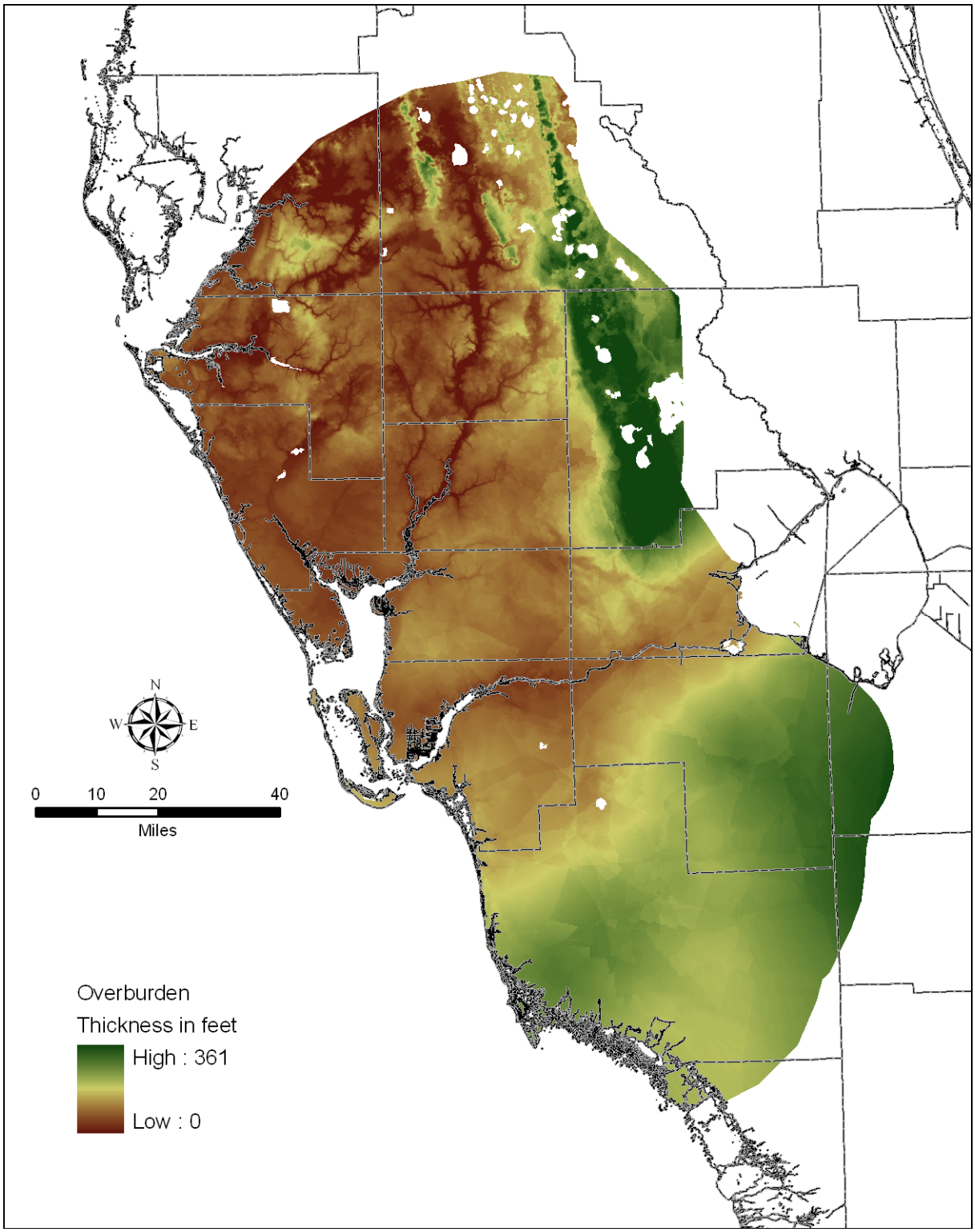

Figure 48. Thickness of IAS overburden calculated by subtracting predicted top of IAS surface (generated by FGS/FDEP) from digital elevation model.

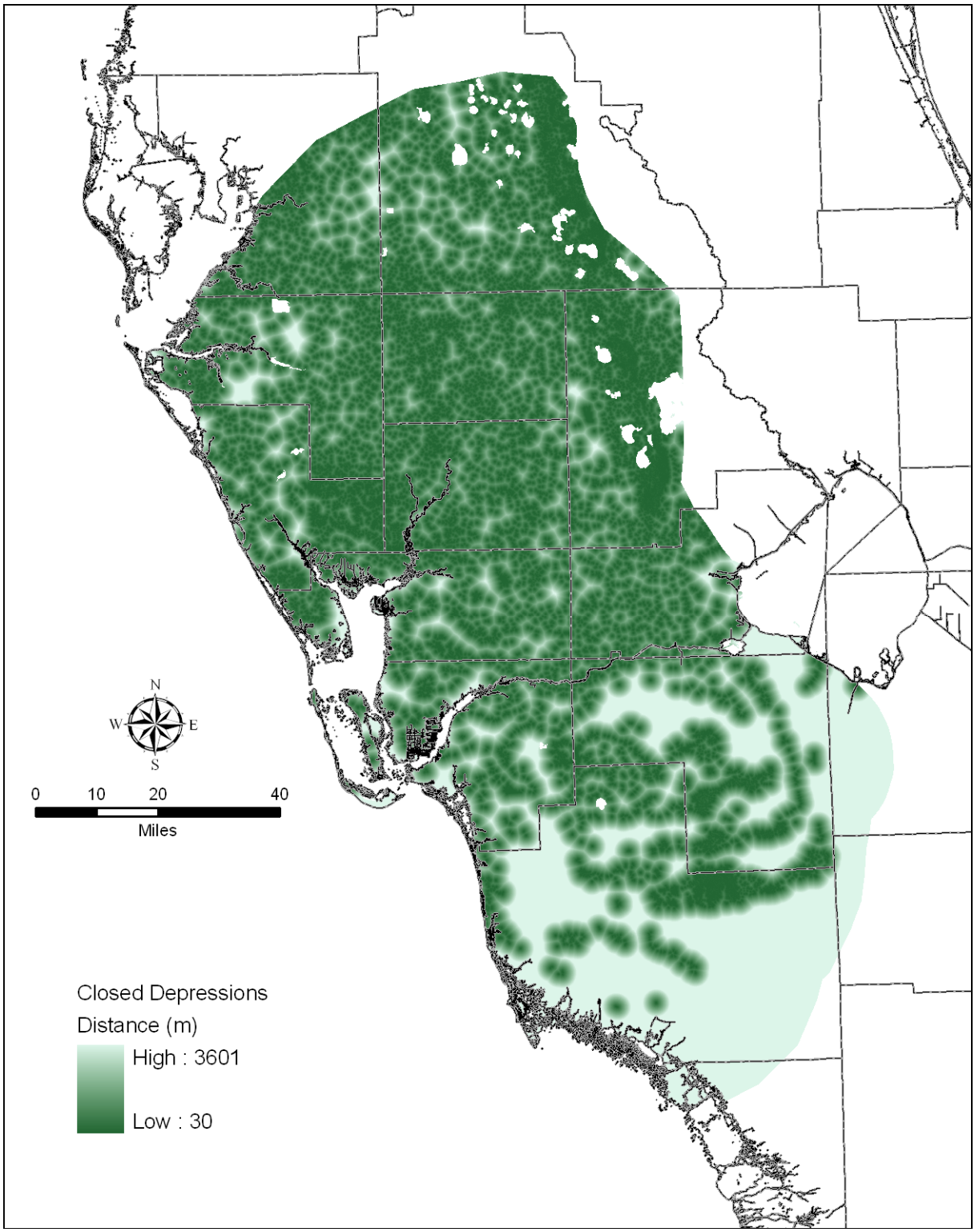

Figure 49. Proximity to closed topographic depressions extracted from U.S. Geological Survey 7.5-minute topographical contour lines.

Following sensitivity analysis and selection of evidential themes to be input into the IAS model, themes were generalized to assess which areas of the evidence share a greater association with locations of training points. During calculation of weights for each theme, a contrast value was calculated for each class of the theme by combining the positive and negative weights. Contrast is a measure of a theme's significance in predicting the location of training points and helps to determine the threshold or thresholds that maximize the spatial association between the evidential theme map pattern and the training point theme pattern (Bonham-Carter, 1994). Contrast and weights are described in more detail below in *Discussion*.

Contrast values were used to determine where to sub-divide evidential themes into generalized categories prior to final modeling. The simplest and most accepted method used to subdivide an evidential theme is to select the maximum contrast value as a threshold value to create binary generalized evidential themes. In other models, categorization of more than two classes may be justified (Arthur et al., 2005). For the IAS project, a binary break was typically defined by the weights of evidence analysis for each evidential theme creating two spatial categories: one with stronger association with the training point theme and one with weaker association.

Soil Hydraulic Conductivity/ Soil Pedality

Weights calculated during sensitivity analysis for soil pedality were stronger (i.e., had higher absolute value) than weights calculated for soil hydraulic conductivity. As a result, soil pedality was chosen as the better predictor of aquifer vulnerability because it shared the best association with training points.

Soil pedality, ranges from 0 to 556 across the study area. Test modeling indicated that areas greater than or equal to 538 were most associated with the training points, and therefore associated with higher aquifer vulnerability. Conversely, areas less than 538 were less associated with the training points, and therefore lower aquifer vulnerability. Based on this analysis, the evidential theme was generalized into two classes as displayed in Figure 50.

Intermediate Aquifer System Overburden Thickness Theme

The overburden thickness ranges from absent to 361 feet thick across the study area. The analysis revealed that areas underlain by 86 feet or less of overburden thickness were more associated with the training points, and therefore associated with higher aquifer vulnerability. Areas underlain by greater than 86 feet of overburden thickness were less associated with the training points, and therefore lower aquifer vulnerability. Based on this analysis, the evidential theme was generalized into two classes as displayed in Figure 51.

Closed Topographic Depressions

As mentioned above, areas closer to a depression are normally associated with higher aquifer vulnerability. Based on this, features were buffered into 30 meter zones to allow for a proximity analysis. The analysis indicated that areas within 30 meters of a closed topographic depression were more associated with the training points, and therefore with higher aquifer vulnerability. Conversely, areas greater than 30 meters from a closed topographic depression were less associated with the training points, and therefore lower aquifer vulnerability. Based on this analysis, the evidential theme was generalized into two classes as displayed in Figure 52.

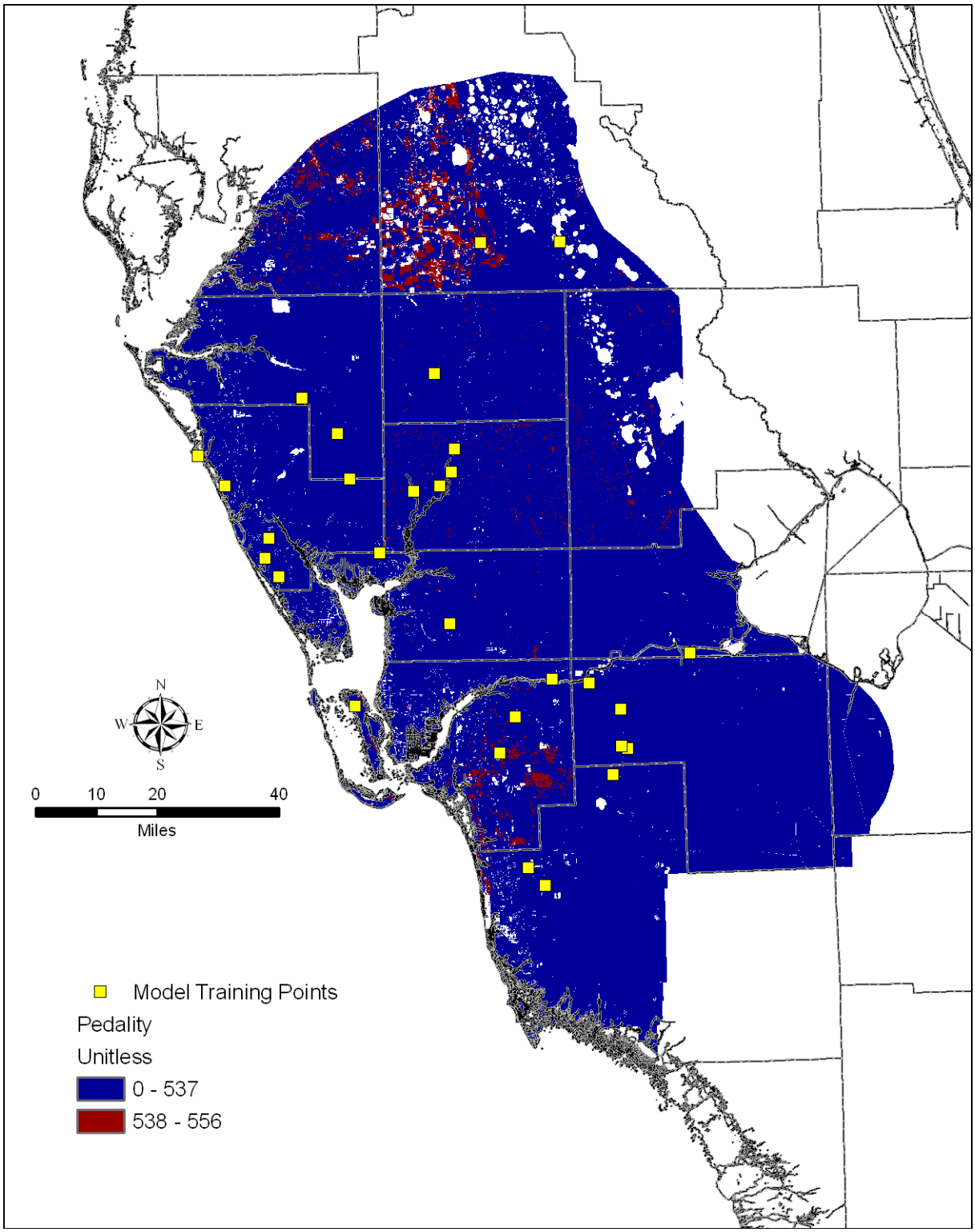

Figure 50. Generalized soil pedality evidential theme; based on calculated weights analysis blue areas share a weaker association with training points and thereby relatively lower aquifer vulnerability, whereas red areas share a stronger association with training points.

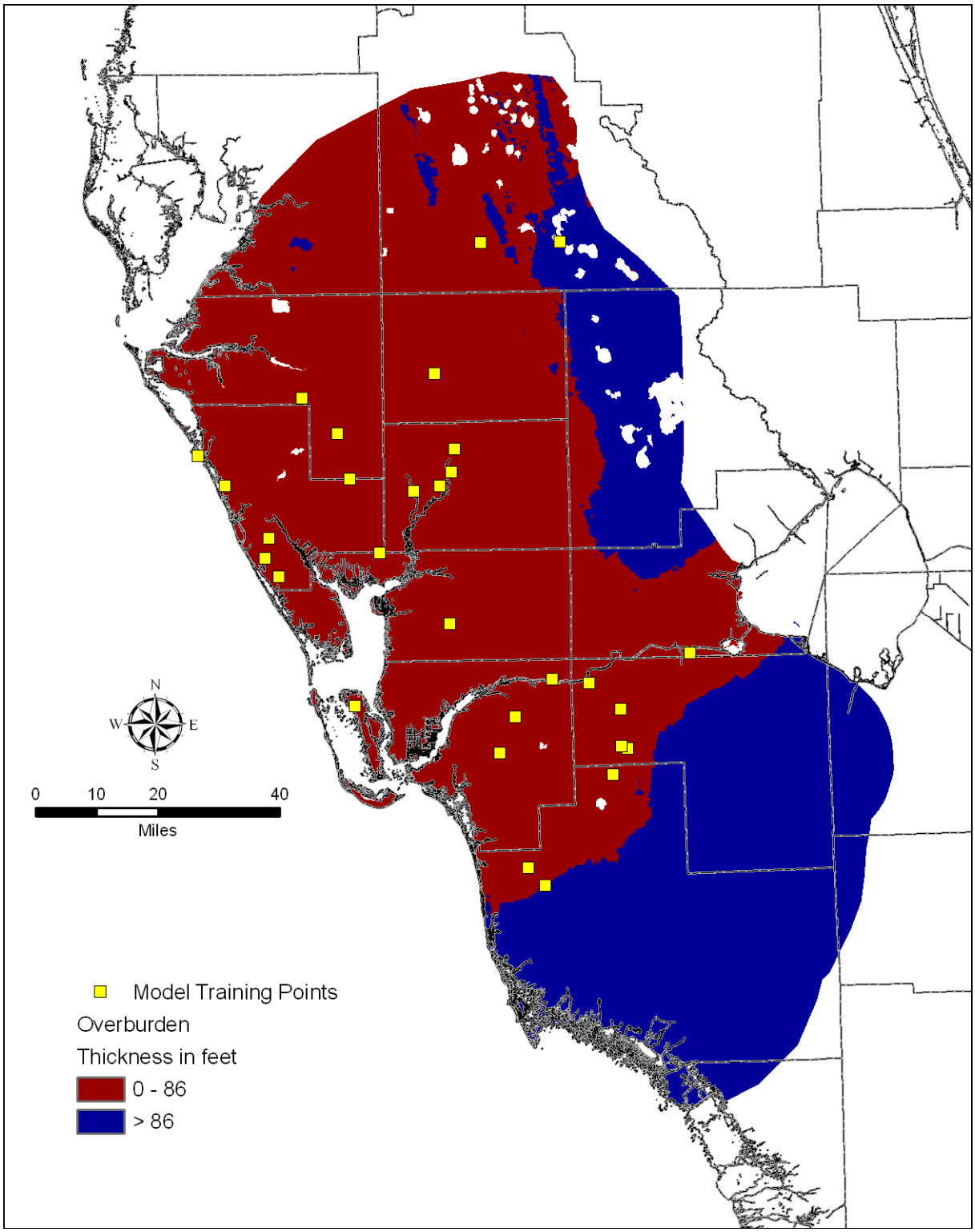

Figure 51. Generalized IAS overburden evidential theme; based on calculated weights analysis blue areas share a weaker association with training points and thereby relatively lower aquifer vulnerability, whereas red areas share a stronger association with training points.

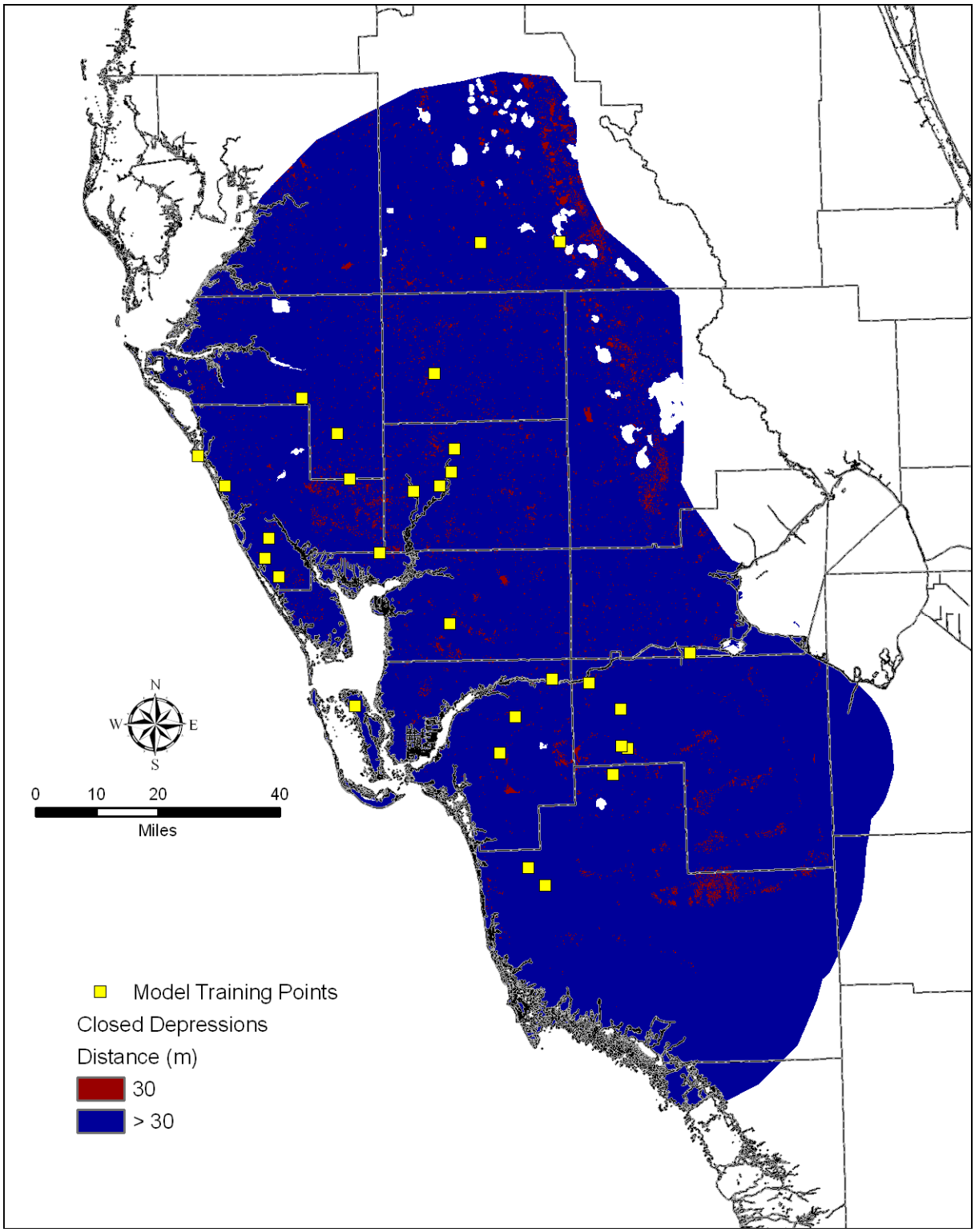

Figure 52. Generalized closed topographic depressions evidential theme; based on calculated weights analysis blue areas share a weaker association with training points and thereby relatively lower aquifer vulnerability, whereas red areas share a stronger association with training points.

Response Theme

Using evidential themes representing soil pedality, IAS overburden thickness, and closed topographic depressions weights of evidence was applied to generate a response theme, which is a GIS raster consisting of *posterior probability* values ranging from 0.000088 to 0.016892 across the study area. These probability values describe the relative probability that a unit area of the model will contain a training point – i.e., a point of aquifer vulnerability as defined above in *Training Points* – with respect to the prior probability value of 0.0011 ([1 km^2 model unit area * 29 training points] / 27,458.4 km^2 = 0.0011). Prior probability is the probability that a training point will occupy a defined unit area within the study area, independent of evidential theme data. Probability values at the locations of 28 of the 29 training points are above the prior probability, indicating that this model is a strong predictor of training point locations.

The response theme was broken into classes of relative vulnerability based on the prior probability value and on inflections in a chart in which cumulative study area was plotted against posterior probability (Figure 53). Higher posterior probability values correspond with more vulnerable areas, as they essentially have a higher chance of containing vulnerability based on the definition of a training point. Conversely, lower posterior probability values correspond to less vulnerable areas as they essentially have a lower chance of containing vulnerability based on the definition of a training point.

As expected, the IAS response theme indicates that areas of highest vulnerability are associated with areas where the IAS overburden is thinnest, in areas of dense closed topographic depressions, and areas of higher soil pedality. Conversely, areas of lowest vulnerability are determined by thick IAS overburden values, sparse closed topographic depression distribution, and lower soil pedality values. Relative vulnerability classes are displayed in Figure 54.

Discussion

Prior to discussion of weights calculations during model execution, two components of a weights of evidence analysis are described to assist in interpretation of IAS model results: *Conditional Independence* and *Model Confidence*.

Conditional Independence

Conditional independence is a measure of the degree that evidential themes are affecting each other due to similarities between themes. Evidential themes are considered independent of each other if the conditional independence value is around 1.00, and conditional independence values within the range of 1.00 ± 0.15 generally indicate limited to no dependence among evidential themes (Bonham-Carter, 1994). Values significantly outside this range can inflate posterior probabilities resulting in unreliable response themes.

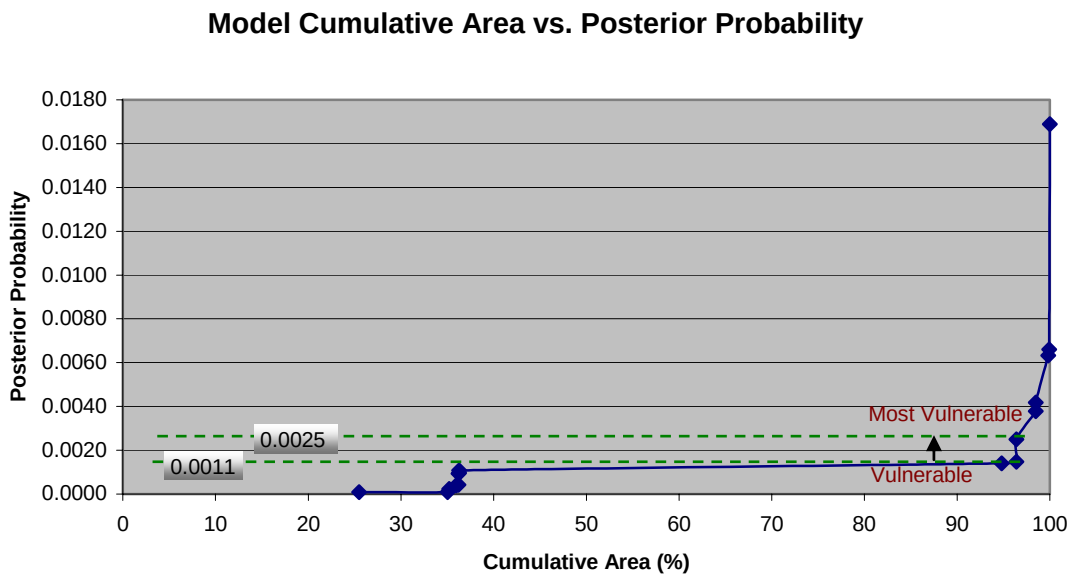

Figure 53. Vulnerability class breaks are defined by selecting where a significant increase in probability and area are observed.

Conditional independence was calculated at 0.98 for the IAS project indicating that evidential themes had virtually no conditional dependence.

Model Confidence

During model execution, confidence values are calculated both for each generalized evidential theme and for the final response theme. Confidence values approximately correspond to the statistical levels of significance listed in Table 3.

Confidence of the evidential theme equals the contrast divided by the standard deviation (a student T-test) for a given evidential theme and provides a useful measure of significance of the contrast due to the uncertainties of the weights and areas of possible missing data (Raines, 1999). A test value of 1.3537 corresponds to approximately 90% confidence – or level of significance – and was the minimum calculated confidence level for the IAS project evidential themes (see Table 9 below for evidential theme confidence values). A confidence map is also calculated for a response theme by normalizing the theme's posterior probability by its total uncertainty (standard deviation). A confidence map can be generated based on these calculations. The confidence map for the IAS response theme is displayed in Figure 55. Areas with high posterior probability values typically correspond to higher confidence values and as a result have a higher level of certainty with respect to predicting aquifer vulnerability.

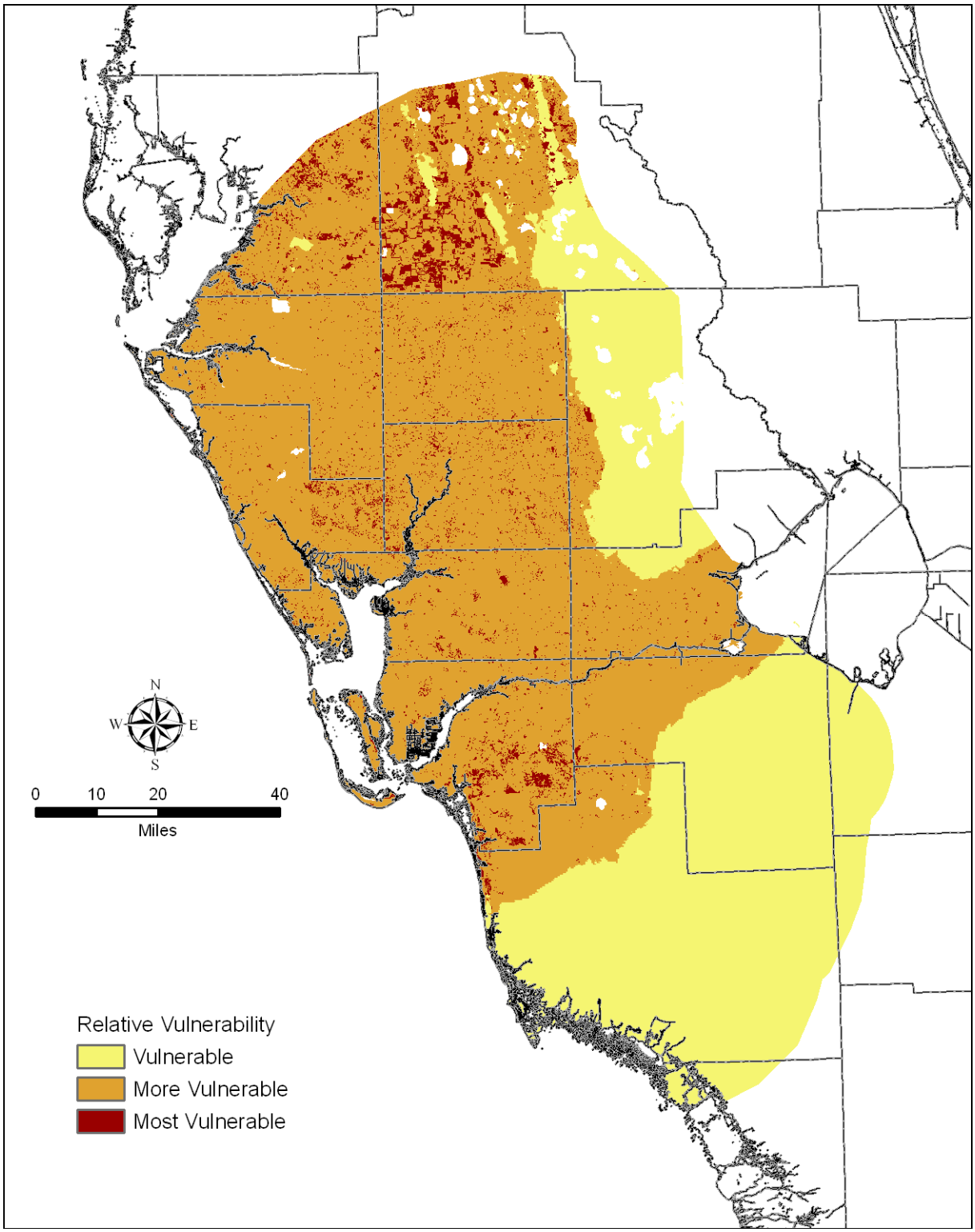

Figure 54. Relative vulnerability map for the Intermediate Aquifer Vulnerability Assessment project. Classes of vulnerability are based on calculated probabilities of a unit area containing a training point, or a monitor well with water quality sample results indicative of vulnerability.

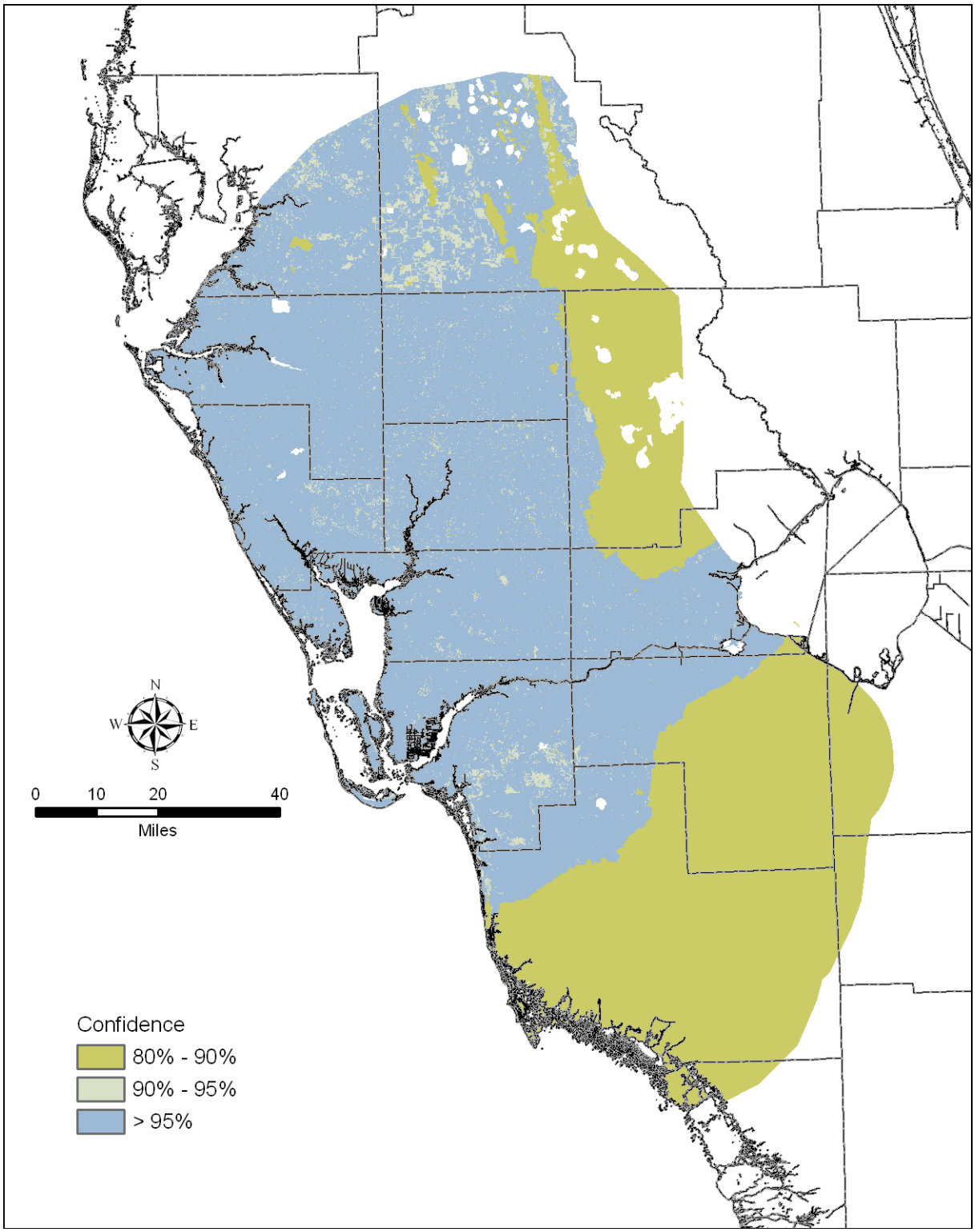

Figure 55. Confidence map for the Intermediate Aquifer model calculated by dividing the posterior probability values by the total uncertainty for each class to give an estimate of how well specific areas of the model are predicted.

Weights Calculations

Table 9 displays evidential themes used in the IAS model, weights calculated for each theme, along with contrast and confidence values. Positive weights indicate areas where training points are likely to occur, while negative weights indicate areas where training points are not likely to occur. The contrast column is a combination of the highest and lowest weights (positive weight – negative weight) and is a measure of how well the generalized evidential themes predict training points. Confidence of the evidential theme is also calculated and is equal to the contrast divided by its standard deviation (a student T test). Confidence is a measure of significance due to uncertainties of the weights and missing data (Raines, 1999). A positive contrast that is significant, based on its confidence, suggests that a generalized evidential theme is a useful predictor.

Table 9. Weights of evidence final output table listing weights calculated for each evidential theme and their associated contrast and confidence values of the evidential themes.

Evidential Theme	W1	W2	Contrast	Confidence
Soil Pedality	0.9491	-0.0444	0.9935	1.3537
IAS Overburden	0.4154	-2.353	2.7684	2.72
Closed Topographic Depressions	1.4237	-0.084	1.5077	2.4677

Because positive weights (W1) values for soil pedality and closed topographic depressions are stronger (have greater absolute values) than the negative weights (W2), they are better predictors of where training points are likely to occur, whereas the IAS overburden theme is a better indicator of where training points are less likely to occur. Based on contrast values, the IAS overburden theme has the strongest (highest absolute value) weight and is the primary determinant in predicting areas of vulnerability in the IAS model.

Validation

The weights of evidence approach, because it relies on a set of training points, which by definition are known sites of vulnerability, is essentially self-validated. Twenty-eight of twenty-nine training points were predicted in zones of posterior probability greater than the prior probability (in other words, classified accurately). Further strengthening the results were the evaluation of a minimum confidence threshold for evidential themes, and generation of a confidence map of the response theme. In addition to these exercises, and in the style of previous aquifer vulnerability assessments (Cichon et al., 2005; Baker et al., 2005; Arthur et al., 2005), additional validation techniques were applied to the IAS model to further strengthen its defensibility, and, ultimately, its utility: (1) comparison of dissolved nitrogen values to posterior probability and evaluation of an associated trend; and (2) generation of a test response theme based on a subset of training points and comparison of points not used in subset to model results and (3) comparison of dissolved oxygen values with vulnerable zones of the response theme.

Dissolved Nitrogen Data vs. Posterior Probability

It was expected that comparison of posterior probability values to the dissolved nitrogen dataset from which the training point theme was extracted would reveal a proportional trend, in other words, as dissolved nitrogen values increase, so should posterior probability values. Dissolved nitrogen median concentrations were binned and averaged for each posterior probability value calculated in model output. The average values were plotted in a chart against posterior probability values (Figure 56) and a positive trend was observed.

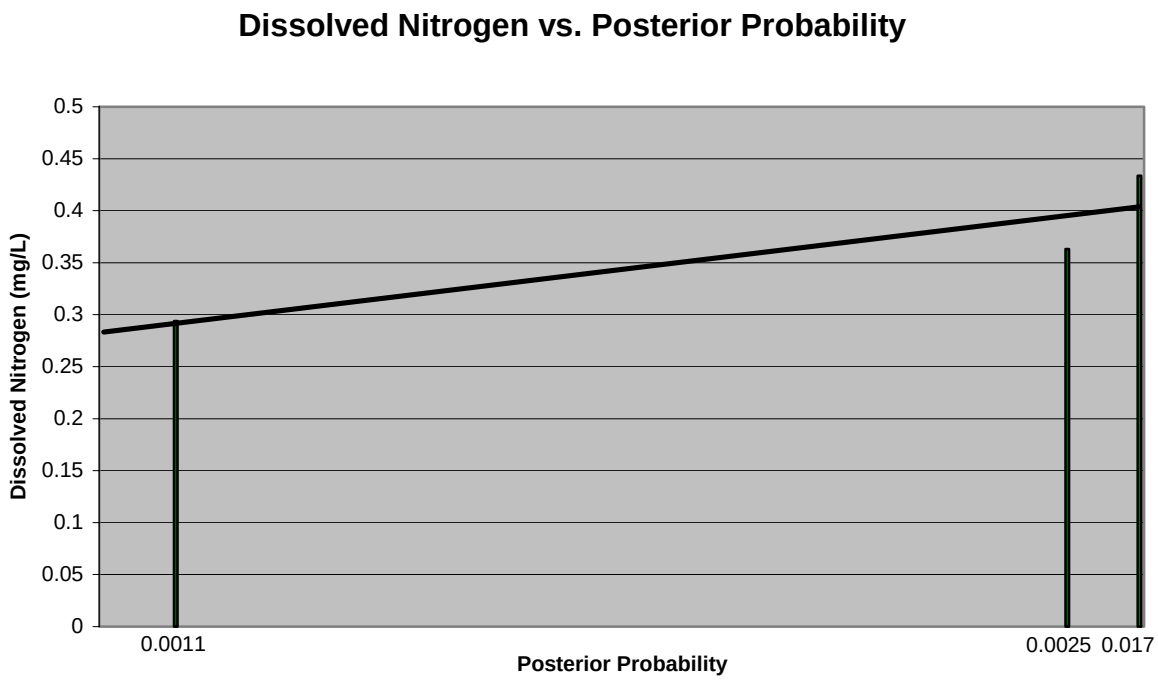

Figure 56. Dissolved nitrogen values (averaged per posterior probability class) versus probability values to reveal trend between increasing dissolved nitrogen concentrations and posterior probability.

Subset Response Theme

Another meaningful validation exercise similar to the exercise above is to use the existing training point dataset to develop two subsets: one to generate a test response theme, and one to validate output from this test response theme. Results from this exercise helped to further assess whether the dissolved nitrogen training points are reasonable predictors of aquifer vulnerability.

From the IAS training point theme, a subset of 75% (22 wells) were randomly selected and used to develop a test response theme (Figure 57); the remaining 25% (7 wells) of the training points were used as the validation dataset for the test response theme. This comparison revealed that seven of the seven test wells in the validation subset, or 100%, occur in areas of the test response theme with predicted probability values higher than the prior probability value. This further supports the conclusion that the IAS model response theme is a reasonable estimator of vulnerability.

Dissolved Oxygen Data

Perhaps the most rigorous validation exercise used to evaluate quality of model-generated output is to compare predicted model values with independent test values not used in the model. For the IAS model, this was accomplished by comparison of a separate well dataset based on dissolved oxygen. As mentioned above in *Training Point Theme*, dissolved oxygen is indicative of aquifer vulnerability, but is independent of dissolved nitrogen. Applying the methodology described in *Training Point Theme* to dissolved oxygen data (obtained from the same data sources as dissolved nitrogen data) resulted in a dissolved oxygen dataset of 35 wells each indicative of aquifer vulnerability.

These 35 points were evaluated against posterior probability values of the IAS model output. Extracting the value of posterior probability from the dissolved nitrogen response theme for the location of each of the 35 dissolved oxygen training points revealed that 32 of the 35 dissolved oxygen training points occur in areas of the dissolved nitrogen model with predicted probability values higher than the prior probability value. In other words, 91.4% of the dissolved oxygen wells were located in areas predicted to have a greater than chance probability of containing a training point. Based on this test, the dissolved nitrogen model is not only a good predictor of vulnerability as defined by the training point theme; it is also a good predictor of the location of an independent parameter also representing aquifer vulnerability. Figure 58 displays dissolved oxygen data points plotted on the dissolved nitrogen response theme.

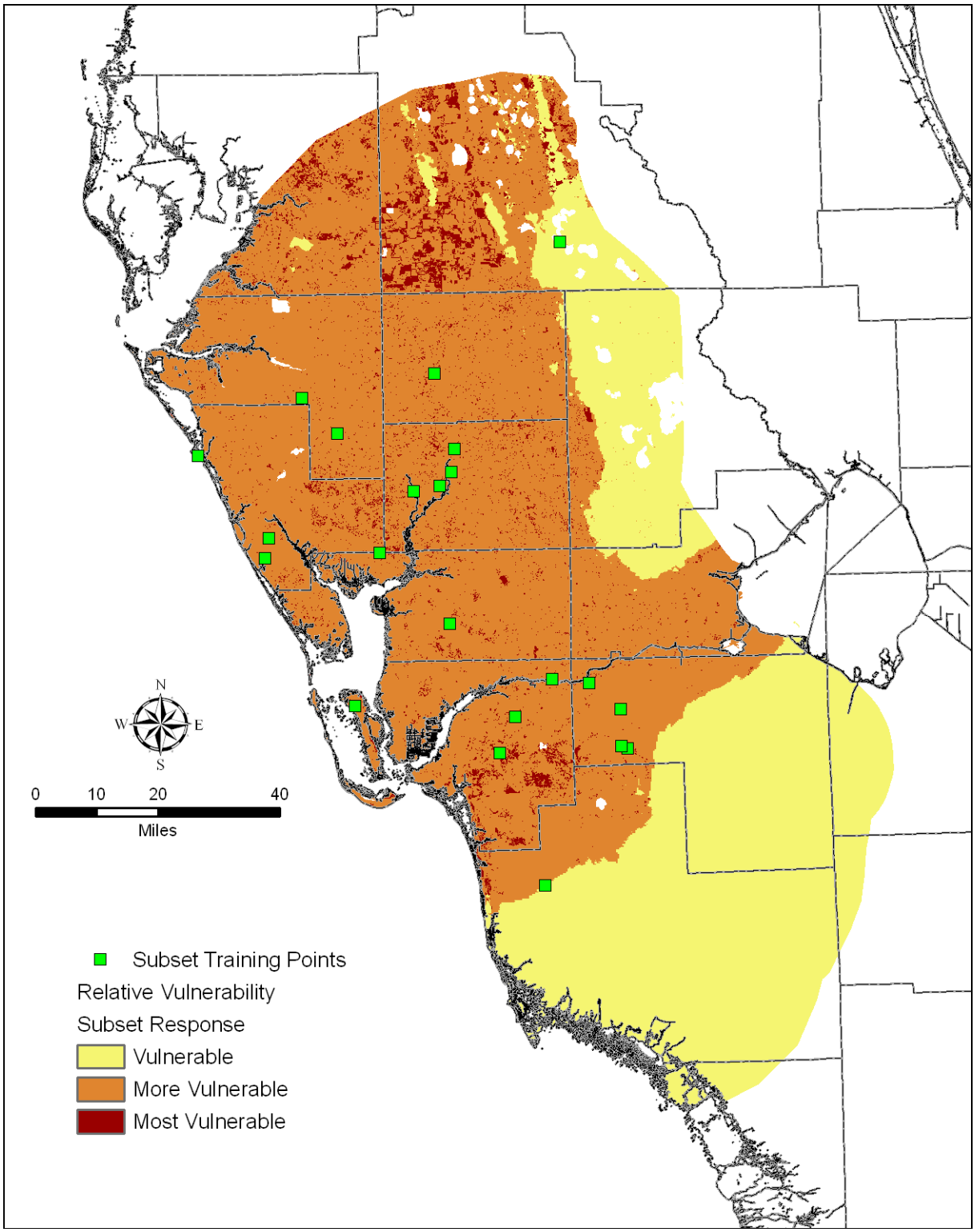

Figure 57. Subset response training points plotted in the dissolved oxygen response theme.

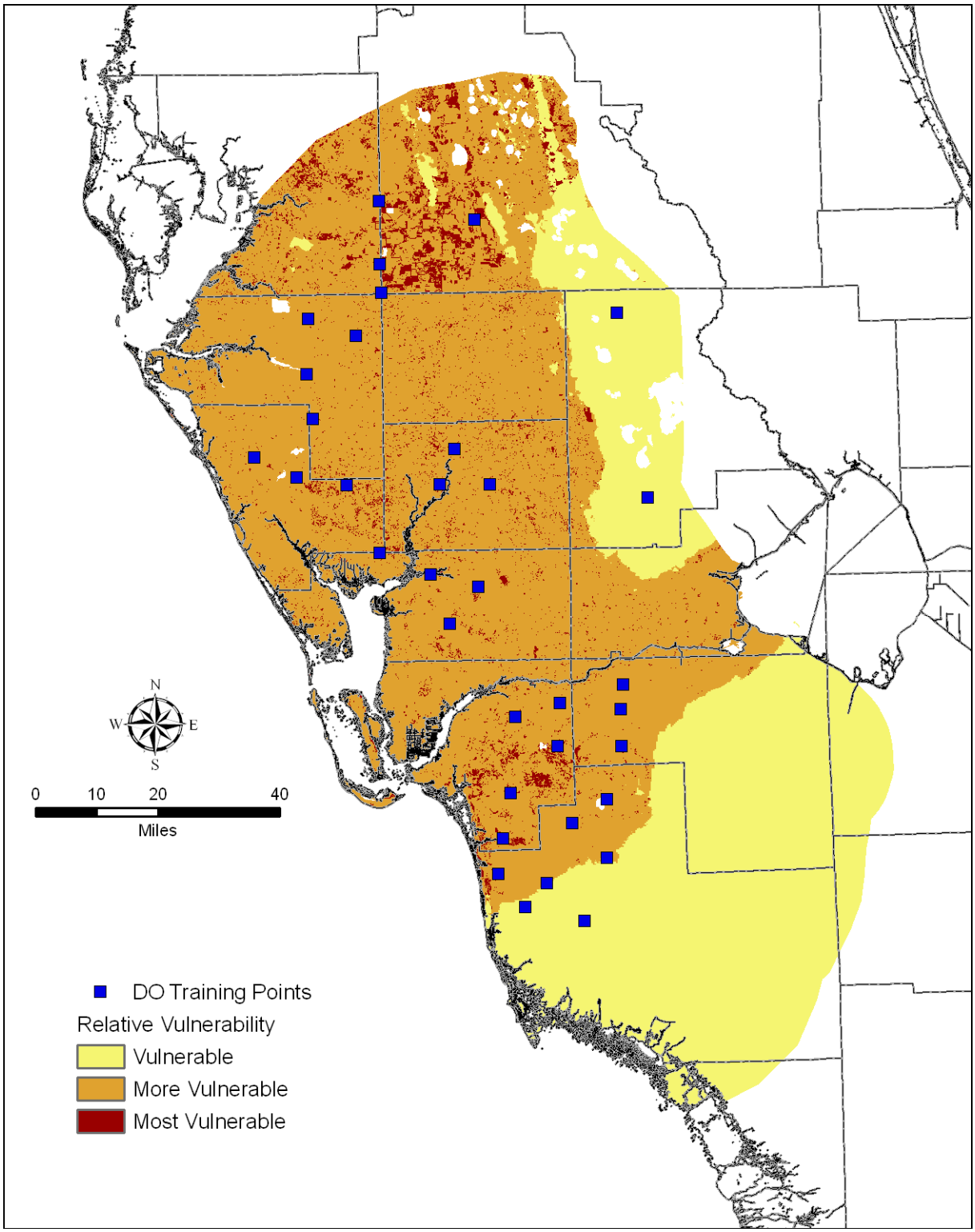

Figure 58. Dissolved oxygen validation training points plotted in the dissolved nitrogen response theme. Comparison reveals 32 of 35 wells (91.4%) of the independent water quality dataset are located in areas with predicted probability values higher than the prior probability.

FLORIDAN AQUIFER SYSTEM

Study Area

The study area is the same as the original FAVA model extent (Figure 59). Because of the sizes of some polygons representing soil data, a grid cell size of approximately 30 meter squares (or 900 m^2) was selected for evidential theme development. This grid cell size, while necessary to capture resolution available in some input data layers, does not reflect appropriate resolution of final model output. Appropriate scale of use of model results is discussed in *Model Implementation and Limitations*.

Water bodies were omitted from the model extent for two main reasons: first, the main goal of this project is to estimate vulnerability of the Florida aquifer system (FAS) and not vulnerability of surface water features, and second, data for water bodies is typically not available – i.e., wells are not drilled in water bodies, nor do soil surveys normally contain information regarding lake and stream bottoms.

Training Point Theme

In the model analysis, training points are groundwater wells tapping the Floridan aquifer system (FAS) with water quality data indicative of high recharge. Dissolved nitrogen analytical values served as training point data for the FAS model. Naturally occurring oxygen and nitrogen are generally considered ubiquitous at land surface as primary components of the atmosphere; moreover, relatively low concentrations of these analytes occur in well protected – or less vulnerable – aquifer systems. Accordingly, where these analytes occur in elevated concentrations in groundwater, yet are not attributable to human activity, they are good indicators of aquifer vulnerability (Arthur et al., 2007).

Water quality data sources explored include the FDEP background water quality network and FDEP STATUS network. From these data sources, 1,068 wells measured for dissolved nitrogen were identified as being potential candidates for training points. Statistical analyses revealed 252 samples were considered statistical outliers. The upper 25th percentile of this set – or all wells with median dissolved nitrogen values greater than or equal to 0.42 milligrams per liter (mg/L) – served as the training point theme and consists of 192 wells. Figure 60 displays the distribution of water wells used to derive training points and the resulting training point theme across the study area.

Training points are used to calculate prior probability, weights for each evidential theme, and posterior probability of the response theme (see *Glossary*). Prior probability (training point unit area divided by total study area) is the probability that a training point will occupy a defined unit area within the study area, independent of any evidential theme data. The prior probability value, a unitless parameter, for the FAS model is 0.0017 ([1 km^2 model unit area * 192 training points] / 115,364.72 km^2 = 0.0017). Posterior probability values generated during response theme development are interpreted relative to the value of prior probability with higher values generally indicating areas with higher probability of containing a training point.

Figure 59. Floridan Aquifer System Vulnerability Assessment project study area extent.

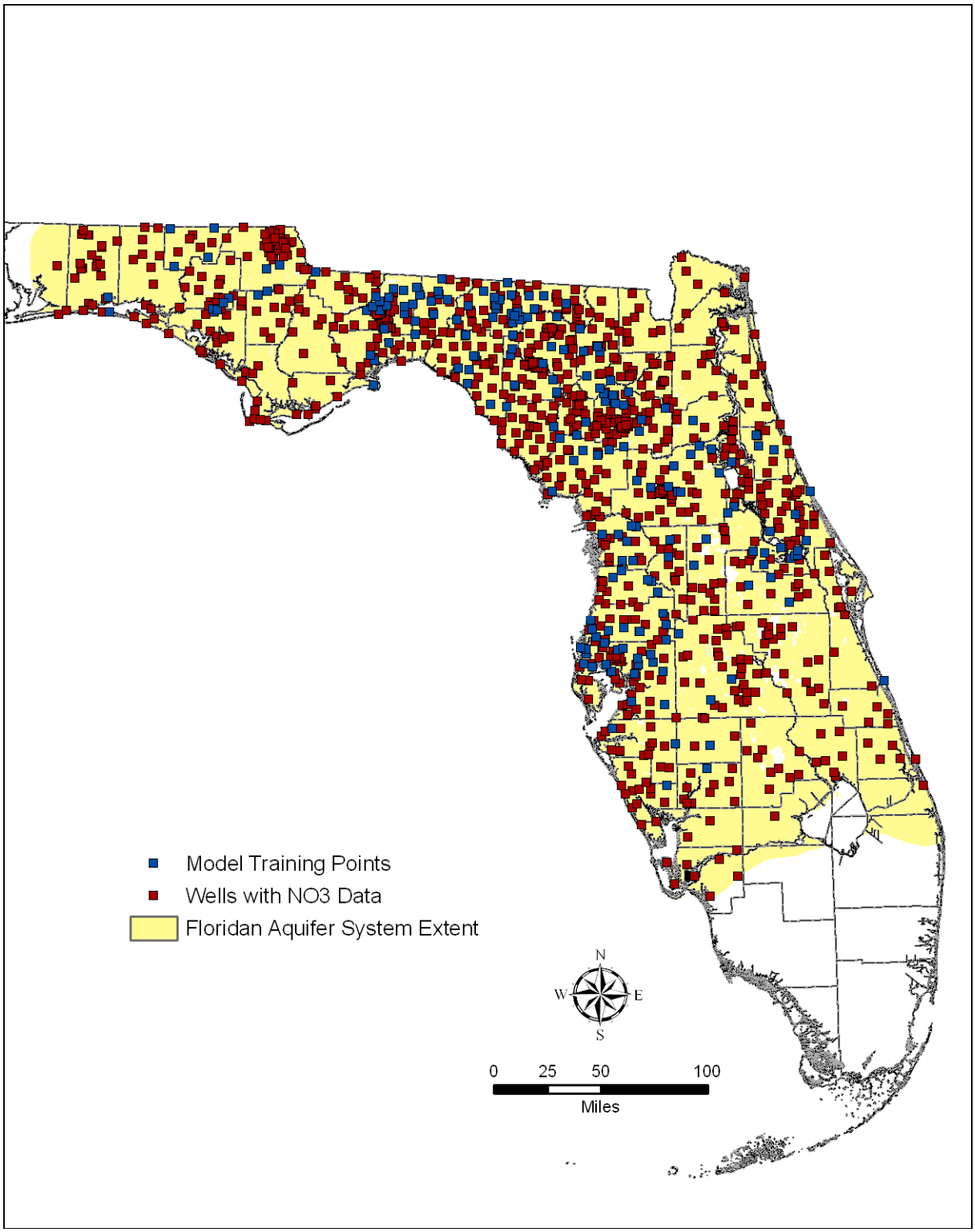

Figure 60. Location of all wells measured for dissolved nitrogen (dark red boxes), and locations of training point wells with median dissolved nitrogen values greater than 0.42 mg/L (blue boxes).

Evidential Themes – Model Input Layers

Input data layers, or evidential themes, representing hydrogeologic factors controlling the location of training points, and thereby vulnerability, were developed for model input. The factors considered for the IAS project include closed topographic depressions, intermediate confining unit, IAS overburden, soil pedality, and soil hydraulic conductivity.

Soil Hydraulic Conductivity and Soil Pedality Themes

The rate that water moves through soil is a critical component of any aquifer vulnerability analysis, as soil is literally an aquifer system's first line of defense against potential contamination (Arthur et al., 2005). Two parameters of soils were evaluated for input into the FAS model: *soil hydraulic conductivity*, which is the "amount of water that would move vertically through a unit area of saturated soil in unit time under unit hydraulic gradient" (U.S. Department of Agriculture, 2005); and *soil pedality*, which is calculated based on soil type, soil grade, and soil pedon size, and is a unitless parameter. Soil pedality is a relatively new concept used to estimate the hydrologic parameter of soil and is generated for the FAS using the pedality point method developed by Lin et al. (1999).

Countywide datasets representing soil hydraulic conductivity and soil pedality were developed for use as input into the FAS model. Multiple empirical values are reported in soil surveys representing various zones in each soil column underlying a particular soil polygon. Representative values for each horizon in a column are combined using a sum of the weighted mean. This is completed for both hydraulic conductivity and soil pedality. Figure 61 displays values of soil hydraulic conductivity.

Intermediate Confining Unit and Overburden Thickness Themes

Aquifer confinement – either in the form of overburden overlying the FAS, or the ICU – is another critical layer in determining aquifer vulnerability. Where aquifer confinement is thick and the FAS is deeply buried, aquifer vulnerability is generally lower, whereas in areas of thin to absent confinement, the vulnerability of the FAS is generally higher.

GIS models were developed of the top of the FAS and top of the IAS. The intent of these models was to allow the calculation of aquifer confinement thickness in the study area. Surface models were developed using a dataset of borehole records from the Florida Geological Survey. These surfaces were used to calculate thickness of the ICU (Figure 62) and thickness of overburden overlying the FAS in the study area. These two layers were tested for input in the model as described in *Sensitivity Analysis*.

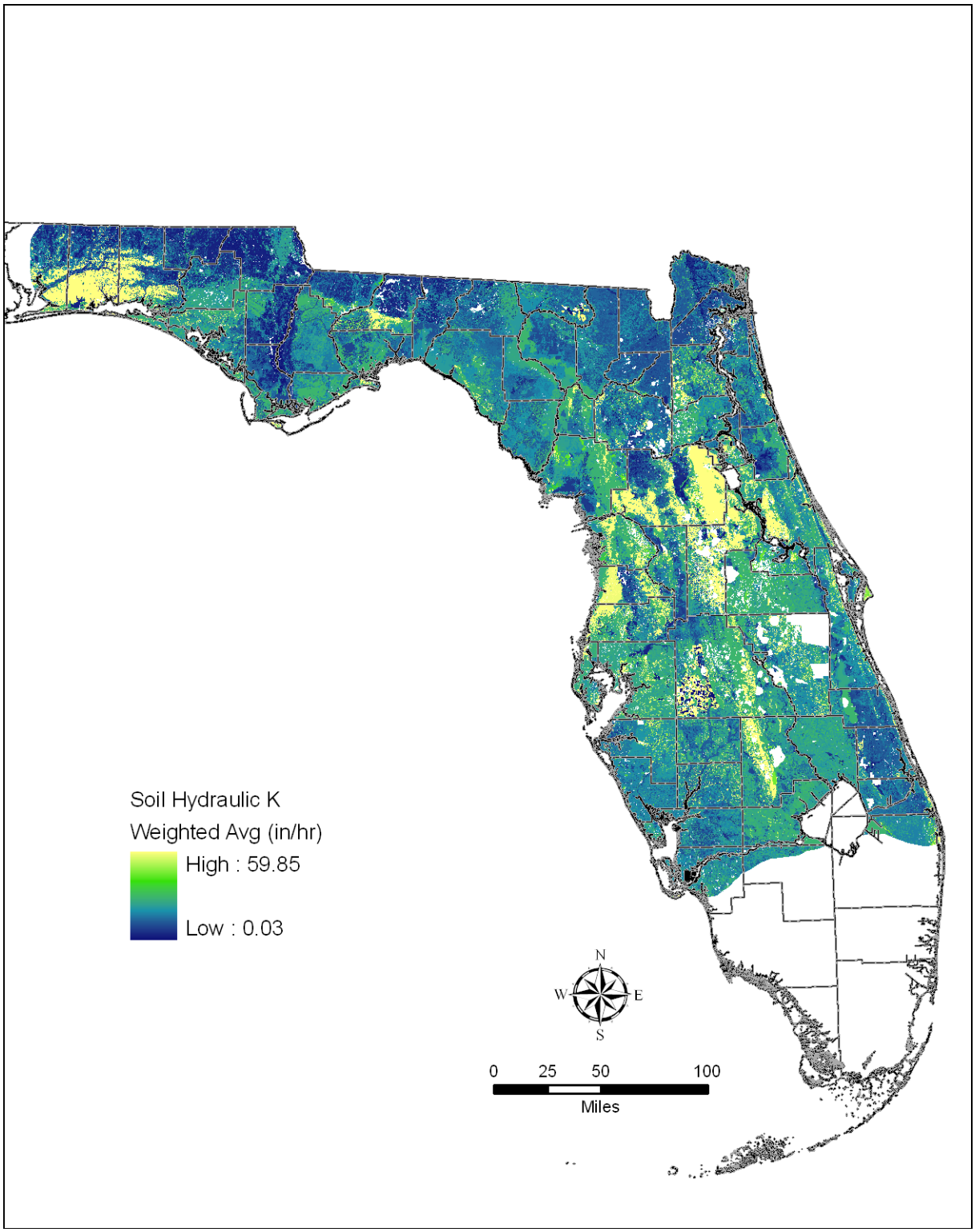

Figure 61. Distribution of soil hydraulic conductivity values across the Floridan Aquifer study area. White areas represent 'no data' areas in the soil survey data or locations of water bodies.

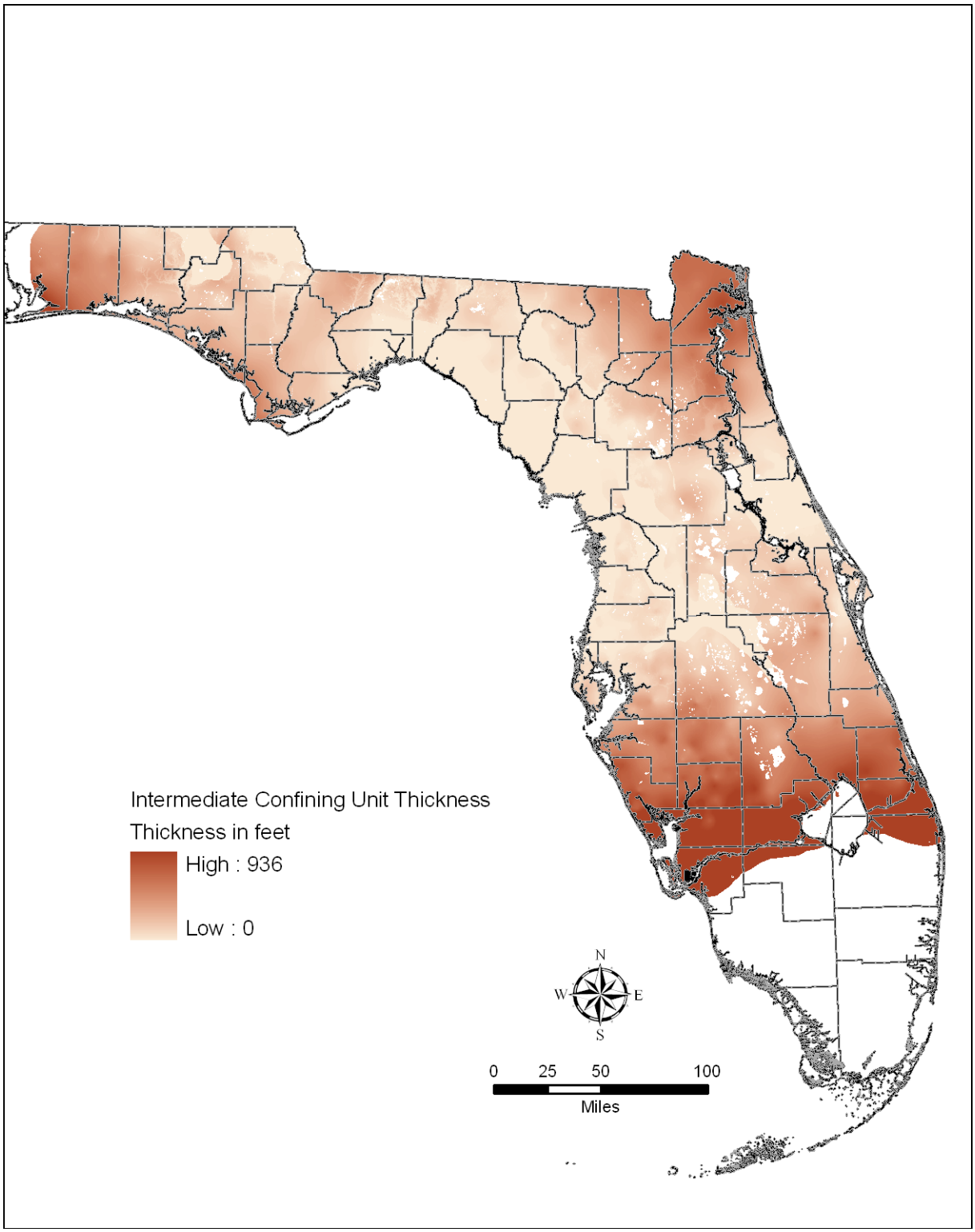

Figure 62. Thickness of intermediate confining unit calculated by subtracting predicted top of IAS surface (generated by FGS/FDEP) from predicted top of FAS surface.

Potential Karst Feature Theme

Karst features, or sinkholes and depressions, can provide preferential pathways for movement of surface water into the underlying aquifer system and enhance an area's aquifer vulnerability where present. The closer an area is to a karst feature, the more vulnerable it may be considered. Closed topographic depressions extracted from U.S. Geological Survey 7.5-minute quadrangle maps served as the initial dataset from which to estimate potential karst features in the study area.

It is recognized that using closed topographic depressions to develop a potential karst features theme may or may not represent all true karst features, however, application of analytical processes to digital elevation maps and models to estimate karst has been successfully completed in numerous projects (Baker et al., 2007; Arthur et al., 2005; Cichon et al., 2005; Baker et al., 2005; and Denizman, 2003). grid and only selecting those areas where that were less than or equal to 140 feet in thickness.

The most statistically significant and defensible method evaluated for this project is the circular index method described below. Once the circular index calculation is completed for all closed depressions a secondary filter was applied to remove those areas that are not karst. This was completed by taking the ICU thickness grid and only selecting those areas that were less than or equal to 140 feet in thickness.

Circular index method

Karst features, which form as the result of the dissolution of carbonate rocks and subsequent collapse of overlying material, are generally circular in nature. In contrast, non-karstic depressional features are common in near-shore modern terrains, relic dune terrains and other provinces, and tend to have a non-circular shape. To filter these features and other types of non-karst features in the study area, a circular index shape analysis (Denizman, 2003) was used to compare the roundness of depressional features to an ideal circle. The area of each closed depression was divided by the area of an ideal circle with the same perimeter as the depression. This resulted in a "roundness ratio", representing the degree of similarity between two such features. Several roundness ratio values were evaluated for use in the model; normally values of 0.75 to 0.80 are found to be most suitable for study areas of this size. Further filtering occurred by removing those potential karst features (Figure 63) that were in areas where the ICU thickness was greater than 140 feet.

Sensitivity Analysis/Evidential Theme Generalization

Sensitivity analysis allows decisions to be made about proposed evidential themes by evaluating each theme's association with training points – or aquifer vulnerability – and ultimately helps determine model input. For example, soil hydraulic conductivity and soil pedality were both developed to represent soil properties; sensitivity analysis allows, through statistical analysis, determination of which of these two layers served as the most appropriate input representing soil properties for the final FAS analysis. Results of this process indicate that soil hydraulic conductivity, intermediate confining unit thickness, and potential karst features depressions were the best suited evidential themes for use in final modeling.

Following sensitivity analysis and selection of evidential themes to be input into the FAS model, themes were generalized to assess which areas of the evidence share a greater association with locations of training points. During calculation of weights for each theme, a contrast value was calculated for each class of the theme by combining the positive and negative weights. Contrast is a measure of a theme's significance in predicting the location of training points and helps to determine the threshold or thresholds that maximize the spatial association between the evidential theme map pattern and the training point theme pattern (Bonham-Carter, 1994). Contrast and weights are described in more detail below in *Discussion*.

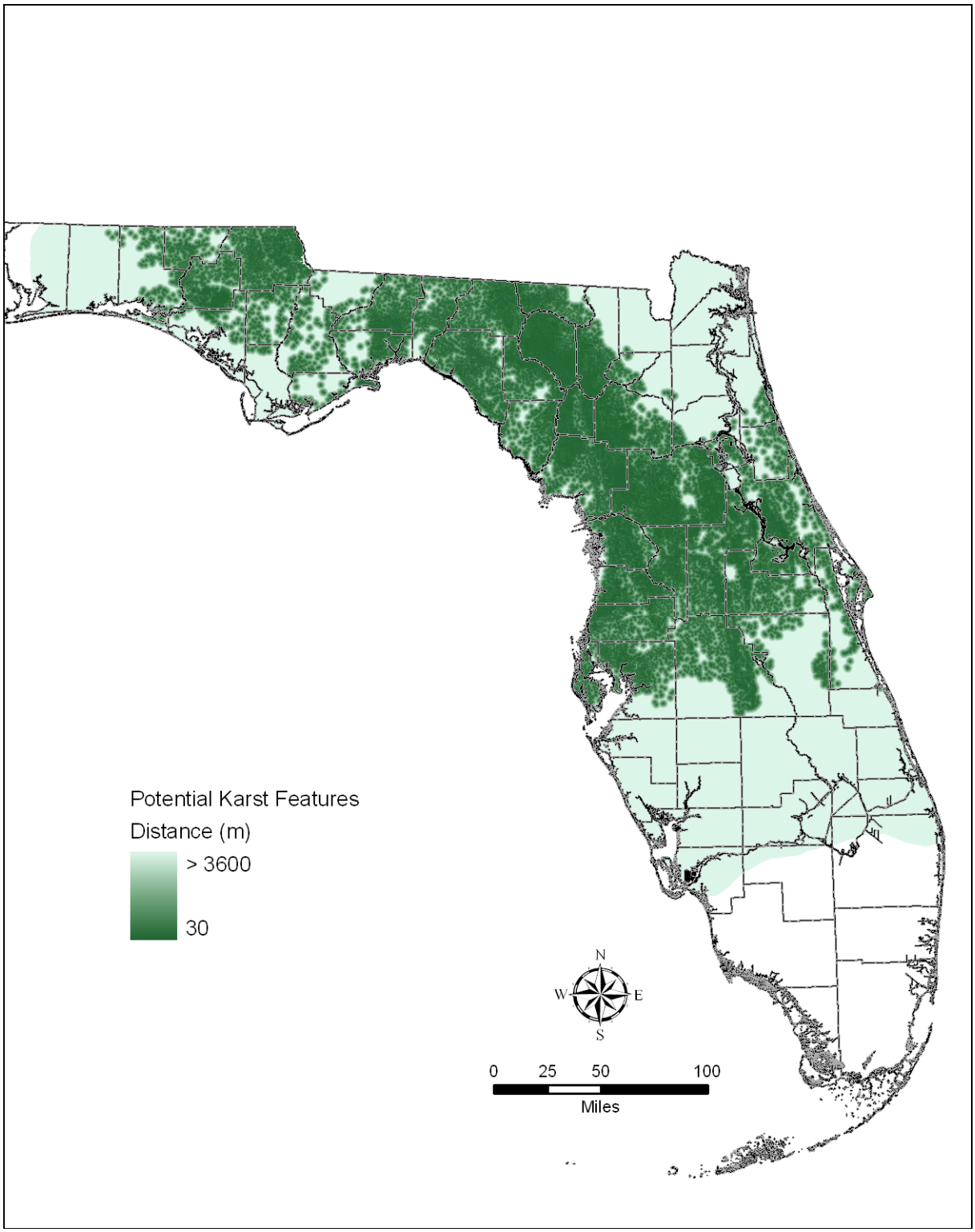

Figure 63. Potential karst features resulting from circular index method applied to U.S. Geological Survey 7.5 minute topographical contour lines and filtered by ICU thickness.

Contrast values were used to determine where to sub-divide evidential themes into generalized categories prior to final modeling. The simplest and most accepted method used to subdivide an evidential theme is to select the maximum contrast value as a threshold value to create binary generalized evidential themes. In other models, categorization of more than two classes may be justified (Arthur et al., 2005). For the FAS project, a binary break was typically defined by the weights of evidence analysis for each evidential theme creating two spatial categories: one with stronger association with the training point theme and one with weaker association.

Soil Hydraulic Conductivity/ Soil Pedality

Weights calculated during sensitivity analysis for soil hydraulic conductivity were stronger (i.e., had higher absolute value) than weights calculated for soil pedality. As a result, soil hydraulic conductivity was chosen as the better predictor of aquifer vulnerability because it shared the best association with training points.

Soil hydraulic conductivity, ranges from 0.03 to 59.85 in/hr across the study area. Based on calculated weights, this theme had justification for a multiple class generalization. Test modeling indicated that areas greater than or equal to 40.63 in/hr were most associated with the training points, areas that are greater than or equal to 14.80 in/hr and less than 40.63 in/hr were less associated with training points and areas less than 14.80 in/hr were least associated with the training points. Based on this analysis, the evidential theme was generalized into three classes as displayed in Figure 64.

Intermediate Confining Unit and Overburden Thickness Themes

Weights calculated during sensitivity analysis for the ICU thickness were stronger (i.e., had higher absolute value) than weights calculated using overburden thickness. As a result, the ICU thickness was chosen as the better predictor of aquifer vulnerability because it shared the best association with training points.

The ICU thickness ranges from absent to 1,209 feet thick across the study area. The analysis revealed that areas underlain by 364 feet or less of ICU thickness were more associated with the training points, and therefore associated with higher aquifer vulnerability. Areas underlain by greater than 364 feet of ICU thickness were less associated with the training points, and therefore lower aquifer vulnerability. Based on this analysis, the evidential theme was generalized into two classes as displayed in Figure 65.

Potential Karst Features

As mentioned above, areas closer to a karst feature are normally associated with higher aquifer vulnerability. Based on this, features were buffered into 30 meter zones to allow for a proximity analysis. The analysis indicated that areas within 3,480 meters of a closed topographic depression were more associated with the training points, and therefore with higher aquifer vulnerability. Conversely, areas greater than 3,480 meters from a karst feature were less associated with the training points, and therefore lower aquifer vulnerability. Based on this analysis, the evidential theme was generalized into two classes as displayed in Figure 66.

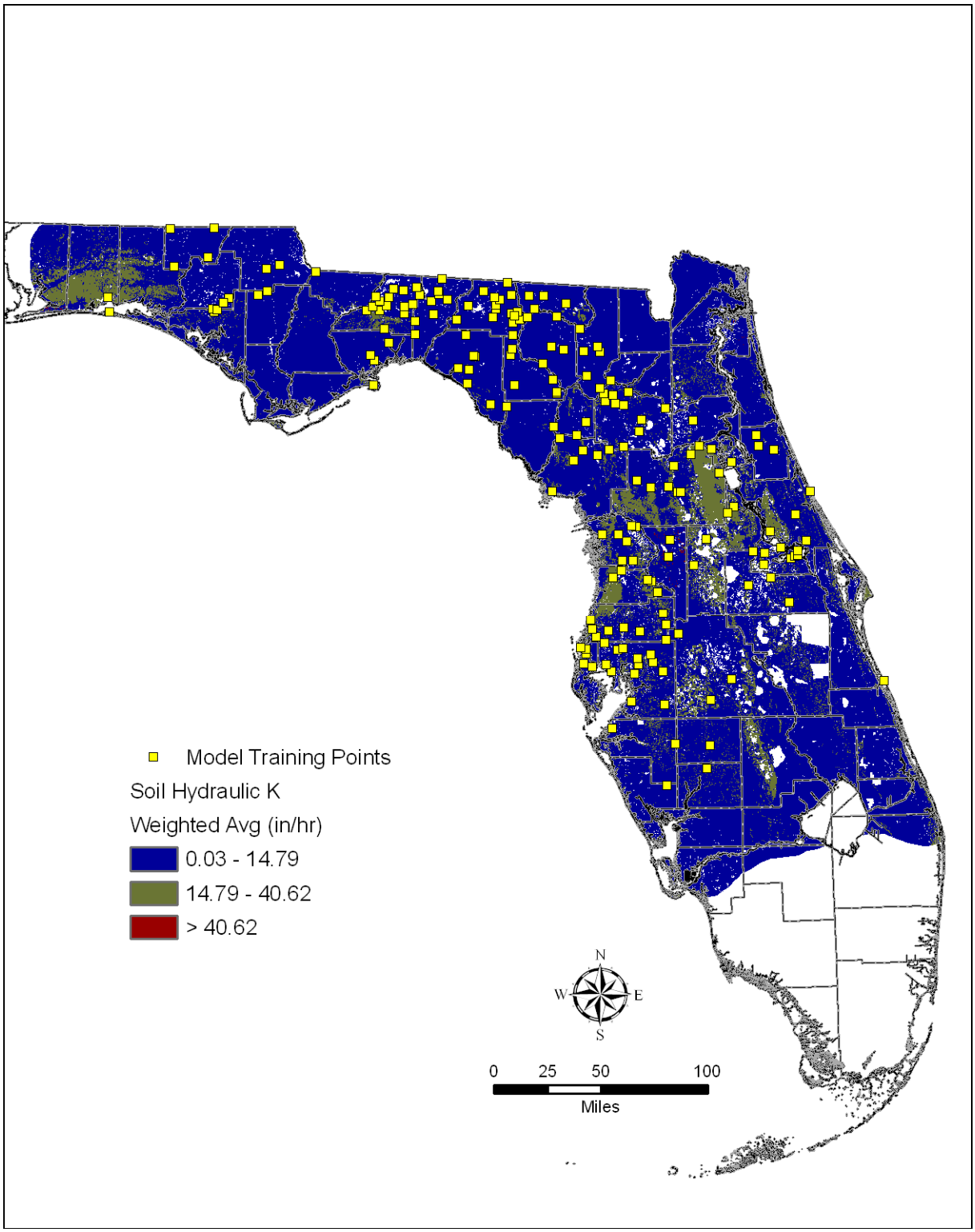

Figure 64. Generalized soil hydraulic conductivity evidential theme; based on calculated weights, a multi-class generalization with a break at a value of 14.79 and 40.62 in/hr was defined by the analysis. Based on the location of training points, blue areas share a weaker association with training points and thereby relatively lower aquifer vulnerability, whereas red areas share a stronger association with training points.

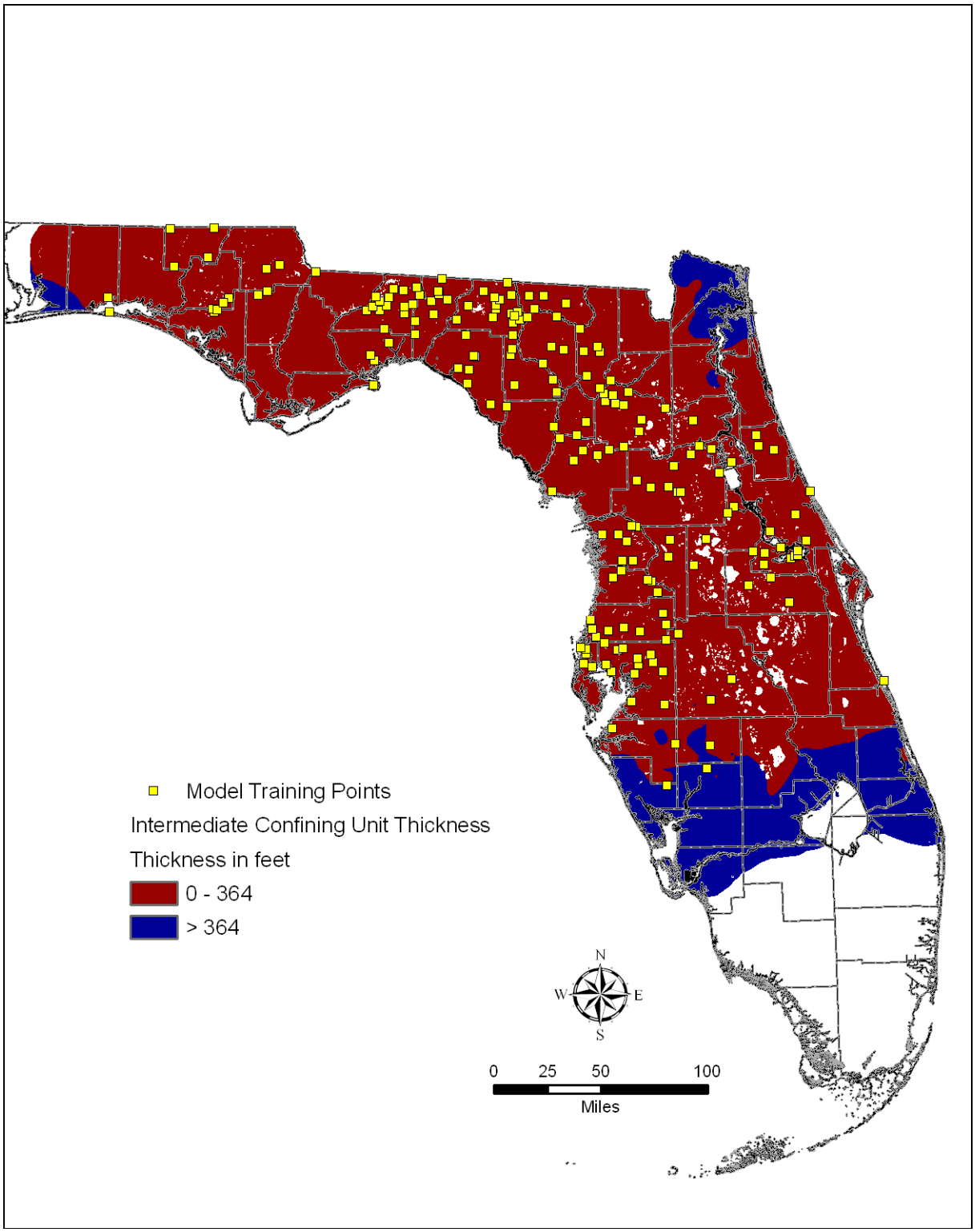

Figure 65. Generalized ICU evidential theme; based on calculated weights analysis blue areas share a weaker association with training points and thereby relatively lower aquifer vulnerability, whereas red areas share a stronger association with training points.

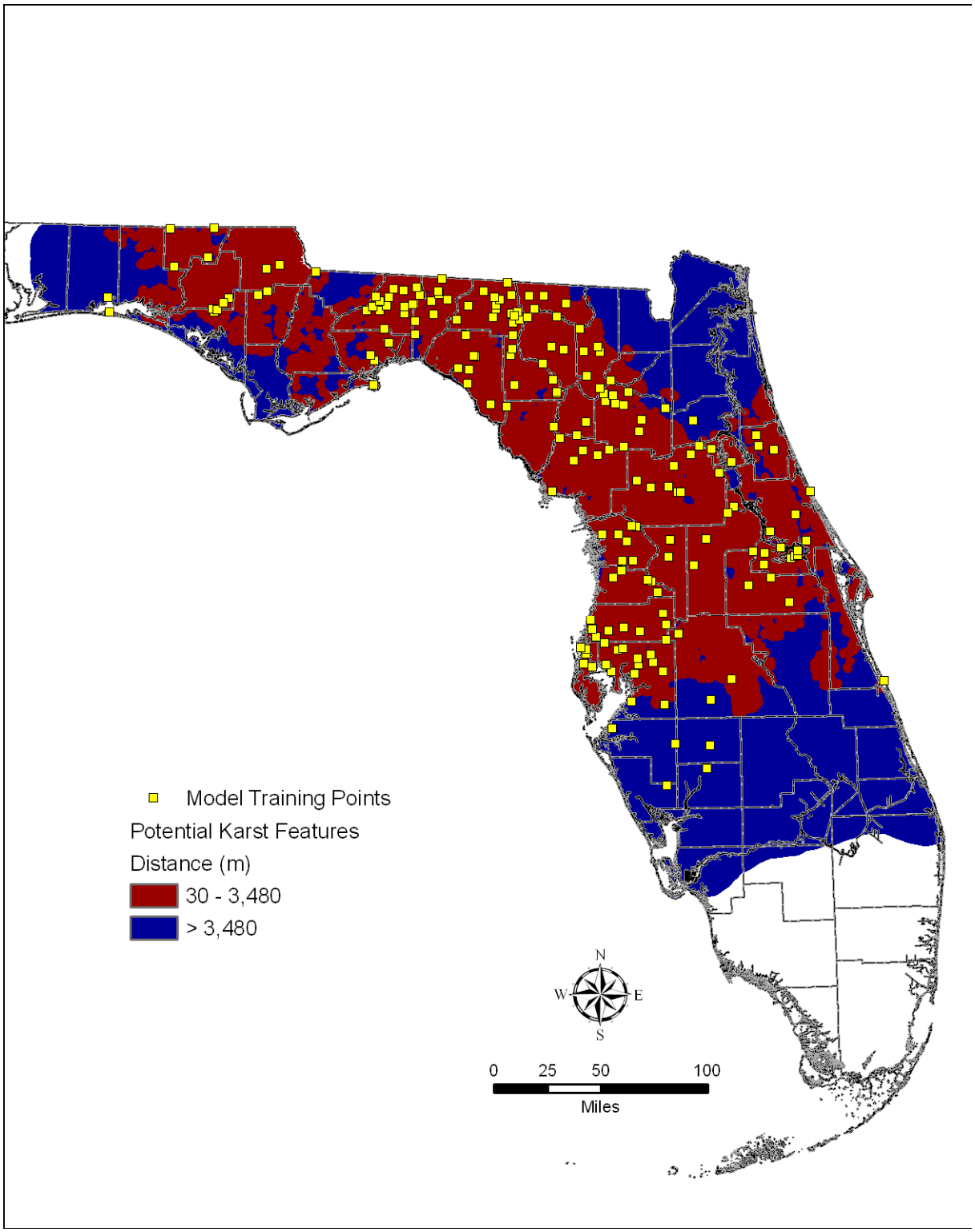

Figure 66. Generalized potential karst features evidential theme; based on calculated weights analysis blue areas share a weaker association with training points and thereby relatively lower aquifer vulnerability, whereas red areas share a stronger association with training points.

Response Theme

Using evidential themes representing soil hydraulic conductivity, ICU thickness, and potential karst, weights of evidence was applied to generate a response theme, which is a GIS raster consisting of *posterior probability* values ranging from 0.00000739 to 0.02732 across the study area. These probability values describe the relative probability that a unit area of the model will contain a training point – i.e., a point of aquifer vulnerability as defined above in *Training Points* – with respect to the prior probability value of 0.0017 ([1 km^2 model unit area * 192 training points] / 115,364.72 km^2 = 0.0017). Prior probability is the probability that a training point will occupy a defined unit area within the study area, independent of evidential theme data. Probability values at the locations of 179 of the 192 training points are above the prior probability, indicating that this model is a strong predictor of training point locations.

The response theme was broken into classes of relative vulnerability based on the prior probability value and on inflections in a chart in which cumulative study area was plotted against posterior probability (Figure 67). Higher posterior probability values correspond with more vulnerable areas, as they essentially have a higher chance of containing vulnerability based on the definition of a training point. Conversely, lower posterior probability values correspond to less vulnerable areas as they essentially have a lower chance of containing vulnerability based on the definition of a training point.

As expected, the FAS response theme indicates that areas of highest vulnerability are associated with areas where the ICU is thinnest, in areas of dense karst features, and areas of higher soil hydraulic conductivity. Conversely, areas of lowest vulnerability are determined by thick ICU values, sparse karst feature distribution, and lower soil hydraulic conductivity values. Relative vulnerability classes are displayed in Figure 68.

Discussion

Prior to discussion of weights calculations during model execution, two components of a weights of evidence analysis are described to assist in interpretation of FAS model results: *Conditional Independence* and *Model Confidence*.

Conditional Independence

Conditional independence is a measure of the degree that evidential themes are affecting each other due to similarities between themes. Evidential themes are considered independent of each other if the conditional independence value is around 1.00, and conditional independence values within the range of 1.00 ± 0.15 generally indicate limited to no dependence among evidential themes (Bonham-Carter, 1994). Values significantly outside this range can inflate posterior probabilities resulting in unreliable response themes. Conditional independence was calculated at 0.85 for the FAS project indicating that evidential themes had little conditional dependence.

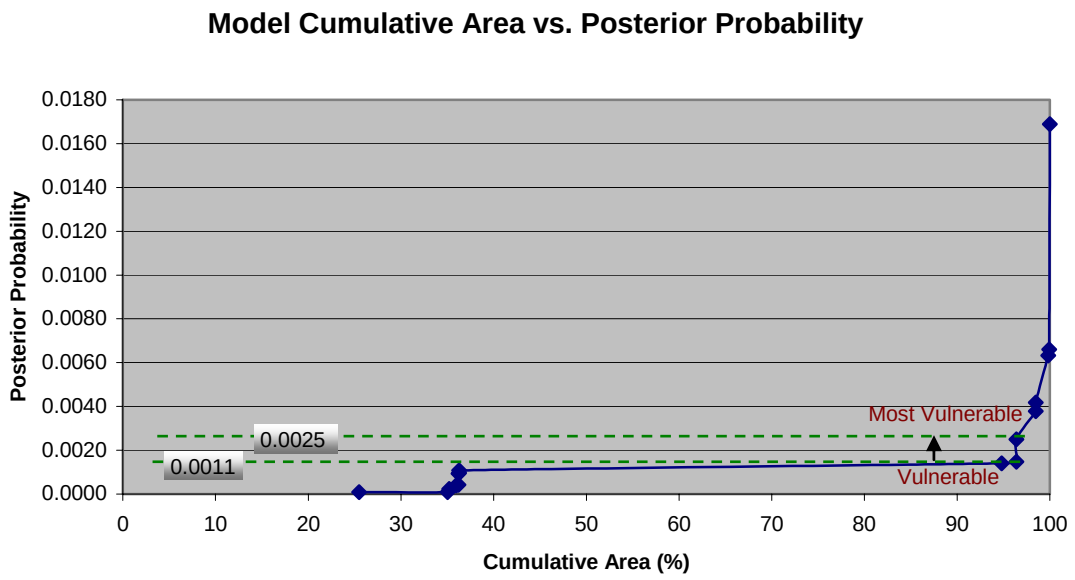

Figure 67. Vulnerability class breaks are defined by selecting where a significant increase in probability and area are observed.

Model Confidence

During model execution, confidence values are calculated both for each generalized evidential theme and for the final response theme. Confidence values approximately correspond to the statistical levels of significance listed in Table 3.

Confidence of the evidential theme equals the contrast divided by the standard deviation (a student T-test) for a given evidential theme and provides a useful measure of significance of the contrast due to the uncertainties of the weights and areas of possible missing data (Raines, 1999). A test value of 2.2259 corresponds to approximately 97.5% confidence – or level of significance – and was the minimum calculated confidence level for the FAS project evidential themes (see Table 10 below for evidential theme confidence values).

A confidence map is also calculated for a response theme by normalizing the theme's posterior probability by its total uncertainty (standard deviation). A confidence map can be generated based on these calculations. The confidence map for the FAS response theme is displayed in Figure 69. Areas with high posterior probability values typically correspond to higher confidence values and as a result have a higher level of certainty with respect to predicting aquifer vulnerability.

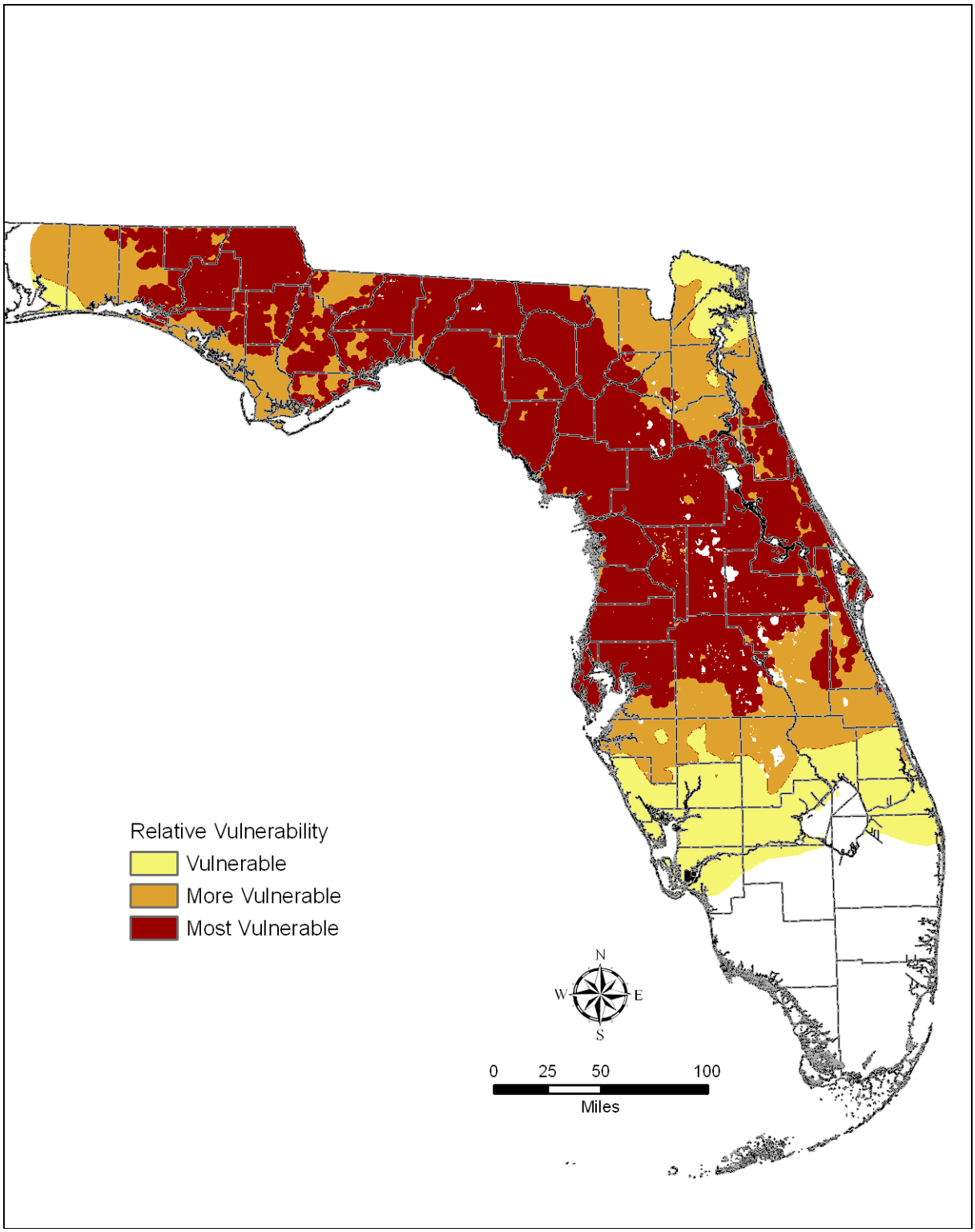

Figure 68. Relative vulnerability map for the Floridan Aquifer Vulnerability Assessment project. Classes of vulnerability are based on calculated probabilities of a unit area containing a training point, or a monitor well with water quality sample results indicative of vulnerability.

Weights Calculations

Table 10 displays evidential themes used in the FAS model, weights calculated for each theme, along with contrast and confidence values. Positive weights indicate areas where training points are likely to occur, while negative weights indicate areas where training points are not likely to occur. The contrast column is a combination of the highest and lowest weights (positive weight – negative weight) and is a measure of how well the generalized evidential themes predict training points. Confidence of the evidential theme is also calculated and is equal to the contrast divided by its standard deviation (a student T test). Confidence is a measure of significance due to uncertainties of the weights and missing data (Raines, 1999). A positive contrast that is significant, based on its confidence, suggests that a generalized evidential theme is a useful predictor.

Table 10. Weights of evidence final output table listing weights calculated for each evidential theme and their associated contrast and confidence values of the evidential themes.

Evidential Theme	W1	W2	W3	Contrast	Confidence
Soil Hydraulic Conductivity	2.1478	0.5368	-0.1016	2.2193	2.2259
ICU Thickness	0.1753	-3.4569		3.6323	3.6227
Potential Karst Features	0.5012	-1.8606		2.3618	8.2205

Because positive weights (W1) values for soil hydraulic conductivity are stronger (have greater absolute values) than the negative weights (W3), it is a better predictor of where training points are likely to occur, whereas the ICU thickness and potential karst feature themes are better indicators of where training points are less likely to occur. Based on contrast values, the ICU thickness theme has the strongest (highest absolute value) weight and is the primary determinant in predicting areas of vulnerability in the FAS model.

Validation

The weights of evidence approach, because it relies on a set of training points, which by definition are known sites of vulnerability, is essentially self-validated. One hundred seventy nine of 192 points were predicted in zones of posterior probability greater than the prior probability (in other words, classified accurately). Further strengthening the results were the evaluation of a minimum confidence threshold for evidential themes, and generation of a confidence map of the response theme. In addition to these exercises, and in the style of previous aquifer vulnerability assessments (Cichon et al., 2005; Baker et al., 2005; Arthur et al., 2005), additional validation techniques were applied to the FAS model to further strengthen its defensibility, and, ultimately, its utility: (1) comparison of dissolved nitrogen values to posterior probability and evaluation of an associated trend; and (2) generation of a test response theme based on a subset of training points and comparison of points not used in subset to model results and (3) comparison of dissolved oxygen values with vulnerable zones of the response theme.

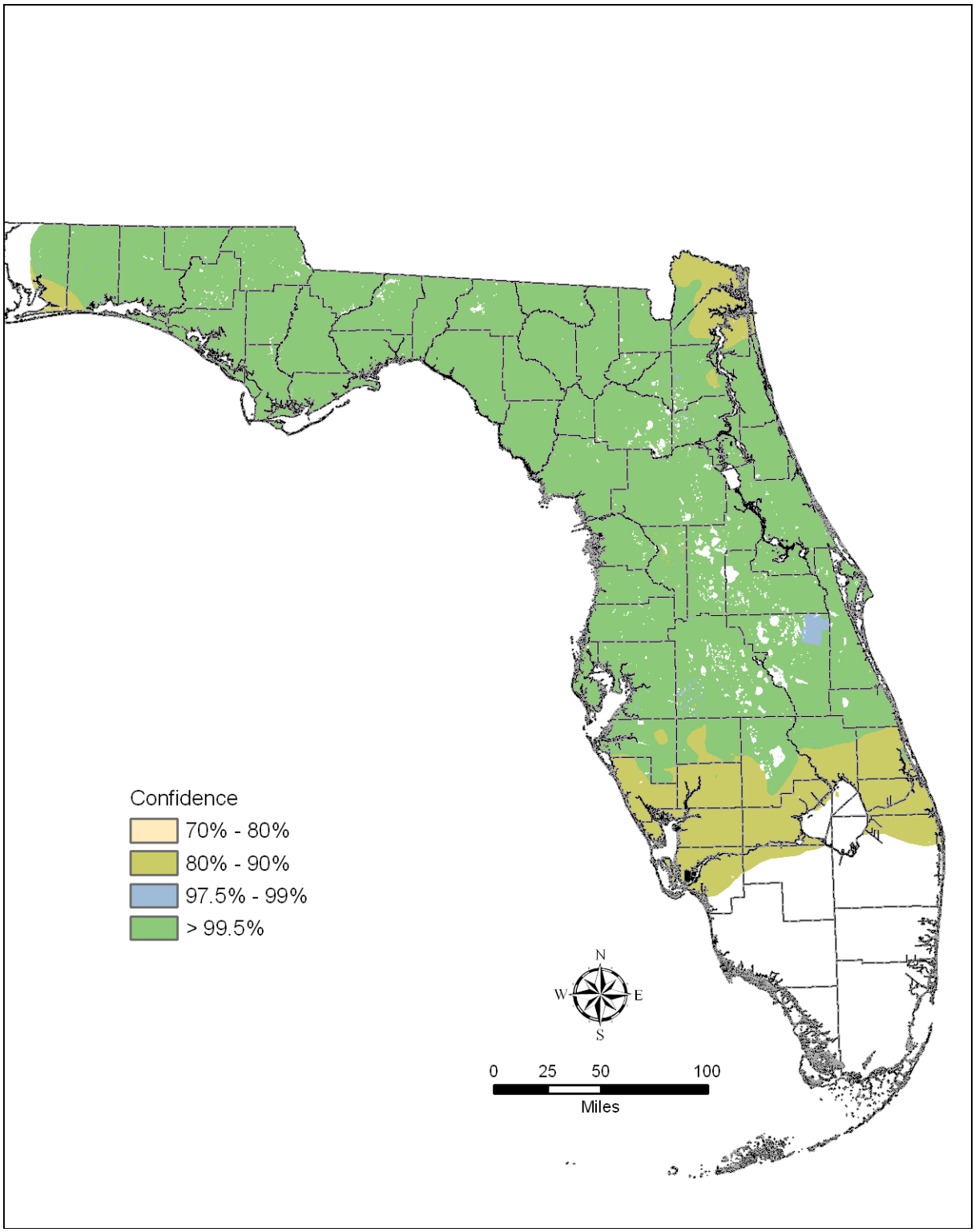

Figure 69. Confidence map for the Floridan Aquifer model calculated by dividing the posterior probability values by the total uncertainty for each class to give an estimate of how well specific areas of the model are predicted.

Dissolved Nitrogen Data vs. Posterior Probability

It was expected that comparison of posterior probability values to the dissolved nitrogen dataset from which the training point theme was extracted would reveal a proportional trend, in other words, as dissolved nitrogen values increase, so should posterior probability values. Dissolved nitrogen median concentrations were binned and averaged for each posterior probability value calculated in model output. The average values were plotted in a chart against posterior probability values (Figure 70) and a positive trend was observed.

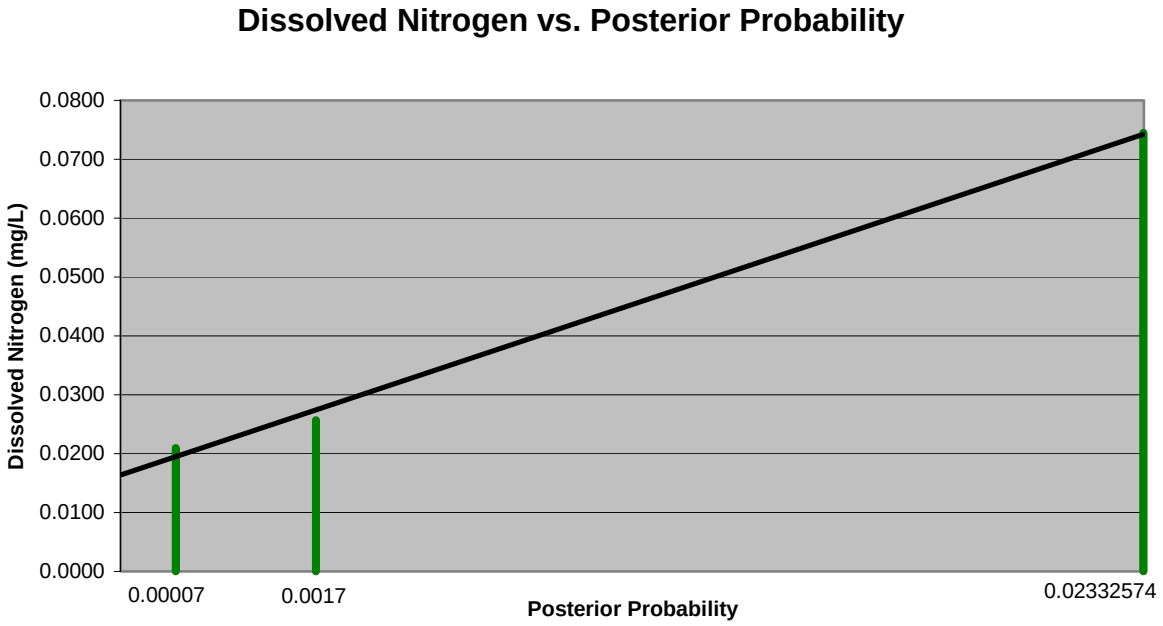

Figure 70. Dissolved nitrogen values (averaged per posterior probability class) versus probability values to reveal trend between increasing dissolved nitrogen concentrations and posterior probability.

An additional test involved applying a Pearson's correlation coefficient (r) test to all dissolved nitrogen values versus posterior probability values. This test revealed a value of 0.22 indicating more than a 95% degree of statistical significance between the response theme values and the dissolved nitrogen data.

Subset Response Theme

Another meaningful validation exercise similar to the exercise above is to use the existing training point dataset to develop two subsets: one to generate a test response theme, and one to validate output from this test response theme. Results from this exercise helped to further assess whether the dissolved nitrogen training points are reasonable predictors of aquifer vulnerability.

From the FAS training point theme, a subset of 75% (144 wells) were randomly selected and used to develop a test response theme; the remaining 25% (48 wells) of the training points were used as the validation dataset for the test response theme (Figure 71). This comparison revealed that 44 of the 48 test wells in the validation subset, or 92%, occur in areas of the test response theme with predicted probability values higher than the prior probability value. This further supports the conclusion that the FAS model response theme is a reasonable estimator of vulnerability.

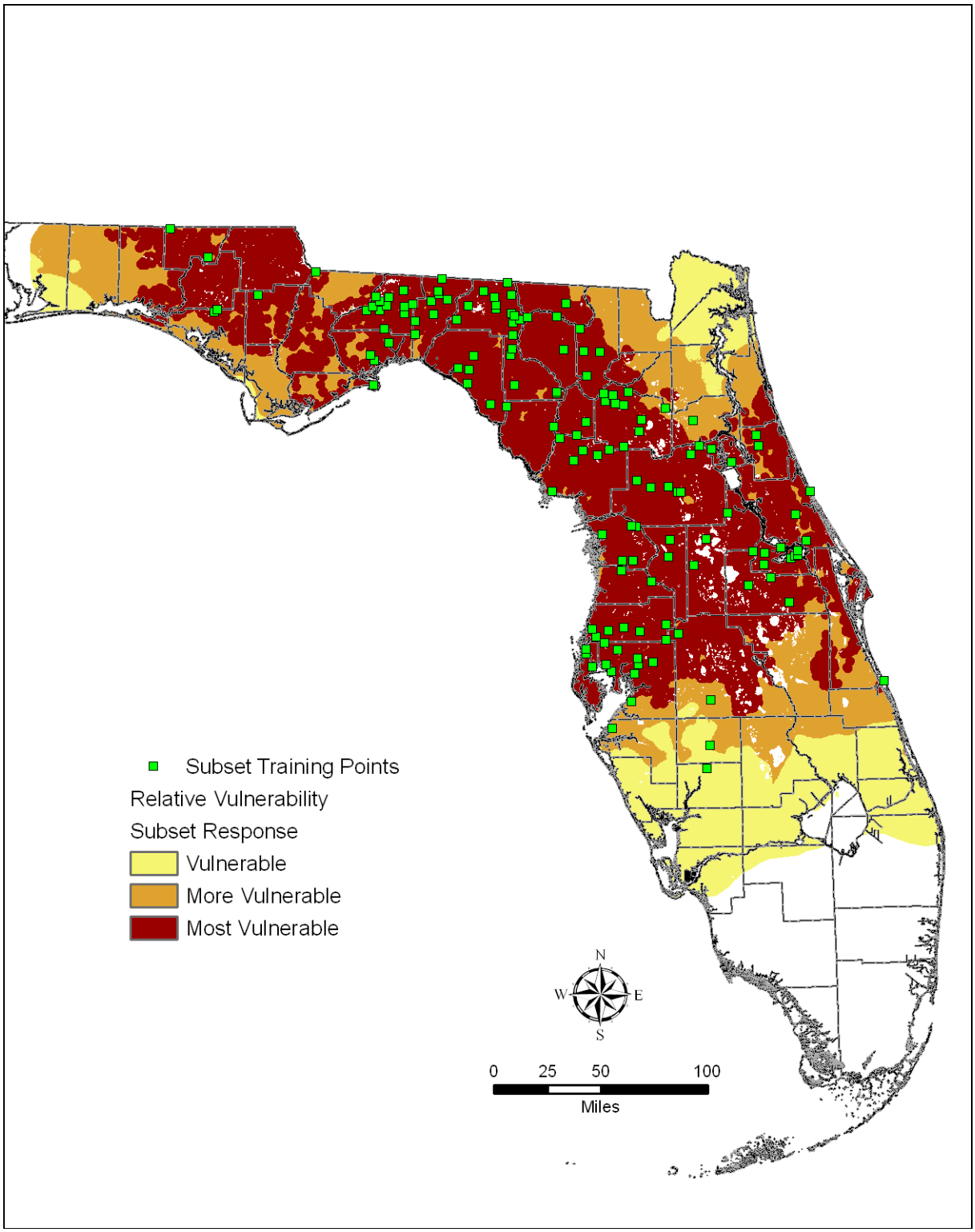

Figure 71. Subset response training points plotted in the dissolved nitrogen response theme.

Dissolved Oxygen Data

Perhaps the most rigorous validation exercise used to evaluate quality of model-generated output is to compare predicted model values with independent test values not used in the model. For the FAS model, this was accomplished by comparison of a separate well dataset based on dissolved oxygen. As mentioned above in *Training Point Theme*, dissolved oxygen is indicative of aquifer vulnerability, but is independent of dissolved nitrogen. Applying the methodology described in *Training Point Theme* to dissolved oxygen data (obtained from the same data sources as dissolved nitrogen data) resulted in a dissolved oxygen dataset of 245 wells each indicative of aquifer vulnerability.

These 245 points were evaluated against posterior probability values of the FAS model output. Extracting the value of posterior probability from the dissolved nitrogen response theme for the location of each of the 245 dissolved oxygen training points revealed that 214 of the 245 dissolved oxygen training points occur in areas of the dissolved nitrogen model with predicted probability values higher than the prior probability value. In other words, 87.3% of the dissolved oxygen wells were located in areas predicted to have a greater than chance probability of containing a training point. Based on this test, the dissolved nitrogen model is not only a good predictor of vulnerability as defined by the training point theme, it is also a good predictor of the location of an independent parameter also representing aquifer vulnerability. Figure 72 displays dissolved oxygen data points plotted on the dissolved nitrogen response theme.

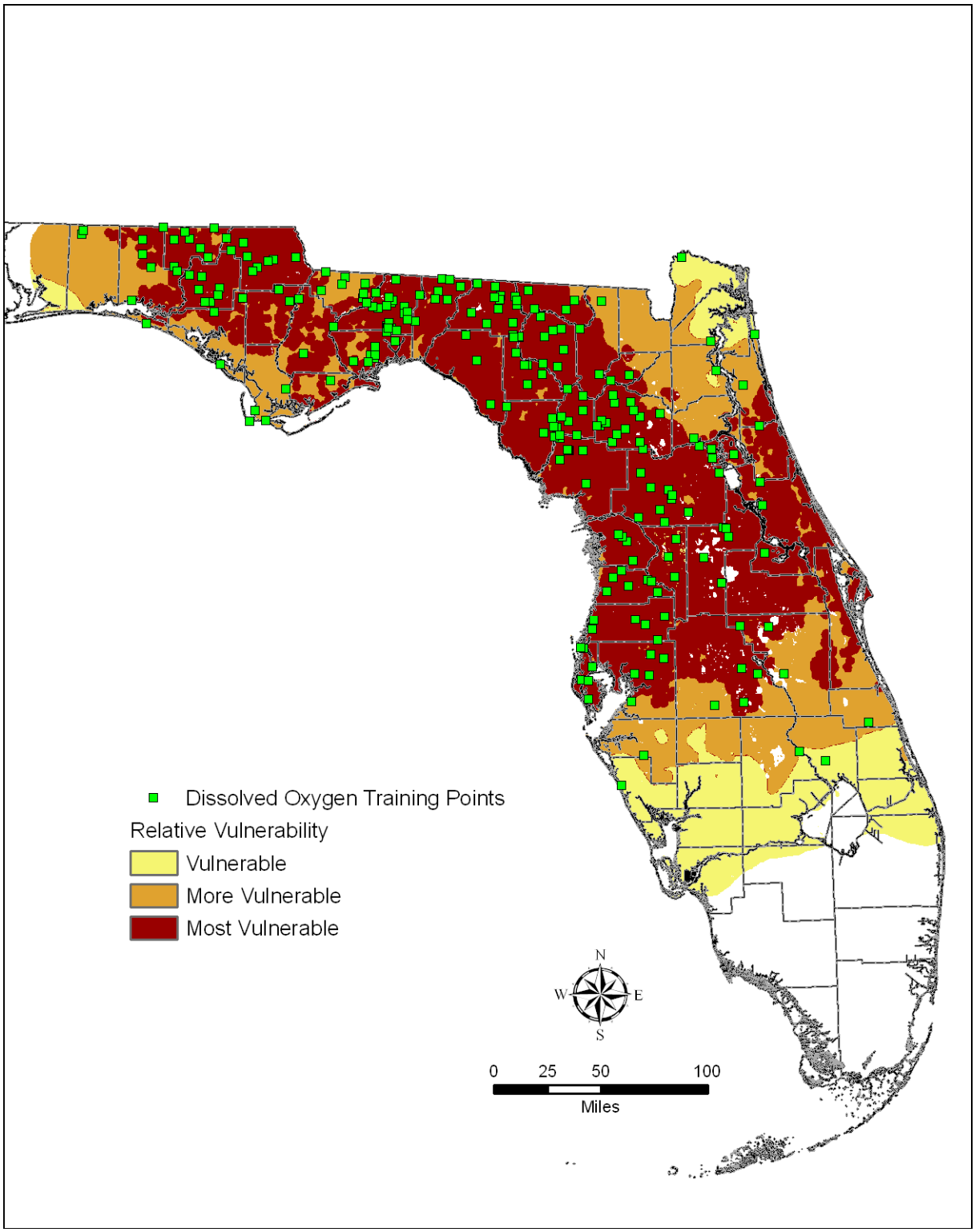

Figure 72. Dissolved oxygen validation training points plotted in the dissolved nitrogen response theme. Comparison reveals 214 of 245 wells (87.3%) of the independent water quality dataset are located in areas with predicted probability values higher than the prior probability.

Model Implementation and Limitations

When implementing the project results, it is essential to remember that all aquifer systems in Florida, to some degree, are vulnerable to contamination; an invulnerable aquifer does not exist. Further, model results are based solely on features of the natural system that have significant association with the location of training points and thereby aquifer vulnerability. The project results provide a probability map that identifies zones of relative vulnerability in the study area based on these input data; as a result the model output is an estimation of intrinsic or natural aquifer vulnerability. Additionally, model results do not account for human activities at land surface, take into consideration contaminant types, or estimate groundwater flow paths or fate/transport of chemical constituents.

Confidence Map

As mentioned above, a confidence map of the model's posterior probability values can be calculated by dividing the posterior probability by its total uncertainty. This essentially applies an informal student T-test (as in Table 3) to the posterior probability values. The higher the confidence values, the greater the certainty is with regard to the posterior probability. This map essentially indicates the degree of confidence to which the posterior probabilities are meaningful and should be referenced when interpreting and implementing the model results. In other words, the confidence map should be used to help guide implementation of the vulnerability map as it reveals the confidence level associated with each vulnerability class (Mihasky and Moyer, 2004).

Recommendations on Scale of Use

Use of highly detailed evidential theme data as model input results in highly resolute model output as can be seen in the model response theme. These resolute features are reflections of real data used as input; however, the final maps should not be applied to very large scales such as to compare adjacent small parcels.

Model output is, in a sense, as accurate as the most detailed input layer, and as inaccurate as the least detailed layer. Every raster cell of the model output coverage has significance per the model input as discussed above. However, it is important to note that aquifer vulnerability assessments are predictive models and no assumptions are made that all input layers are accurate, precise or complete at a single-raster cell scale. As mentioned above, the confidence map, because it is an indicator of the meaningfulness of the vulnerability classes, should be used to help guide implementation of the vulnerability map. For example, in the FAS confidence map (Figure 69), land-use decisions might be more defensible with the higher vulnerability class since these areas are usually associated with the highest confidence values.

Ultimately, accuracy of the maps does not allow for evaluation of aquifer vulnerability at a specific parcel or site location. It is the responsibility of the end users of the model output to determine specific and appropriate applications of these maps. In no instance should use of aquifer vulnerability assessment results substitute for a detailed, site-specific hydrogeological analysis (see FAVA version 1.0 for additional recommendations).

CONCLUSION

As demands for fresh groundwater increase resulting from continued population growth, identification of zones of relative vulnerability becomes an increasingly important tool for implementation of a successful groundwater protection and management program. The results of the project provide a science-based, water-resource management tool allowing for a pro-active approach to protection of the aquifer system, and, as a result, have the potential to increase the value of protection efforts. Model results will enable improved decisions to be made about aquifer vulnerability based on the input selected, including focused protection of sensitive areas such as springsheds and groundwater recharge areas.

The results of the vulnerability model are useful for development and implementation of groundwater protection measures; however, the vulnerability output map included in this report should not be viewed as a static evaluation of the vulnerability of the aquifer system. Because the assessments are based on snapshots of best-available data, the results are static representations; however, a benefit of this methodology is the flexibility to easily update the response themes as more refined or new data becomes available. In other words, as the scientific body of knowledge grows regarding hydrogeologic systems, this methodology allows the ongoing incorporation and update of datasets to modernize vulnerability assessments thereby enabling end users to better meet their objectives of protecting these sensitive resources. The weights of evidence modeling approach to aquifer vulnerability is a highly adaptable and useful tool for implementing ongoing protection of Florida's vulnerable groundwater resources.

QUALIFICATIONS

Disclaimer

Maps generated as part of this project were developed by Advanced GeoSpatial Inc. (AGI) to provide FDEP with a ground-water resource management and protection tool to carry out responsibilities related to natural resource management and protection regarding Florida's aquifer systems. Although efforts were made to ensure information in these maps is accurate and useful, neither, the Florida Department of Environmental Protection nor AGI assumes responsibility for errors in the information and does not guarantee that the data is free from errors or inaccuracies. Similarly the Florida Department of Environmental Protection and AGI assume no responsibility for consequences of inappropriate uses or interpretations of the data on these maps. Accordingly, these maps are distributed on an "as is" basis and the user assumes all risk as to their quality, results obtained from their use, and performance of the data. the Florida Department of Environmental Protection and AGI further make no warranties, either expressed or implied as to any other matter whatsoever, including, without limitation, the condition of the product, or its suitability for any particular purpose. The burden for determining suitability for use lies entirely with the end user. In no event shall the Florida Department of Environmental Protection and AGI, or their respective employees have any liability whatsoever for payment of any consequential, incidental, indirect, special, or tort damages of any kind, including, but not limited to, any loss of profits arising out of use of or reliance on the project results. The Florida Department of Environmental Protection and AGI bear no responsibility to inform users of any changes made to this data. Anyone using this data is advised that resolution implied by the data may far exceed actual accuracy and precision.

Because this data was developed and collected with FDEP funding, no proprietary rights may be attached to it in whole or in part, nor may it be sold to FDEP or any other government agency as part of any procurement of products or services.

Ownership of Documents and Other Materials

This project represents significant effort and resources on both the part of FDEP and AGI to establish peer-reviewed, credible and defensible aquifer vulnerability model results. Unauthorized changes to results can have far reaching implications including confusing end users with multiple model results, and discrediting validity and defensibility of original results.

A main goal of the project is to maintain the integrity and defensibility of the final model output by preserving its data-driven characteristics. Modification or alteration of the model or its output can only be executed by trained professionals experienced with the project and with weights of evidence.

To protect both FDEP and AGI from potential misuse or unauthorized modification of the project results, all input and output results of aquifer vulnerability assessments, and the aquifer vulnerability

assessment models, along with project documents, reports, drawings, estimates, programs, manuals, specifications, and all goods or products, including intellectual property and rights thereto, created under this project or developed in connection with this project will be and will jointly remain the property of FDEP and AGI.

For additional information regarding this project, please refer to the associated 24” x 36” interpretive poster of the same title as this report, and/or the GIS project data and associated metadata. At the time of this report, these GIS files may be accessed using ArcMap™, version 9.x.

WEIGHTS OF EVIDENCE GLOSSARY

Conditional Independence – Occurs when an evidential theme does not affect the probability of another evidential theme. Evidential themes are considered independent of each other if the conditional independence value calculated is within the range 1.00 ± 0.15 (Raines, personal communication, 2003). Values that significantly deviate from this range can inflate the posterior probabilities resulting in unreliable response themes.

Confidence of Evidential Theme – Contrast divided by its estimated standard deviation; provides a useful measure of significance of the contrast.

Confidence of Posterior Probability – A measure based on the ratio of posterior probability to its estimated standard deviation.

Contrast – W+ minus W- (see weights), which is an overall measure of the spatial association (correlation) of an evidential theme with the training points.

Data Driven – Refers to a modeling process in which decisions made in regard to modeling input are driven by empirical data. Examples include the weights of evidence approach or logistic regression approach as in the FDEP's FAVA project (Arthur et al., 2005).

Evidential Theme – A set of continuous spatial data that is associated with the location and distribution of known occurrences (i.e., training points); a map data layer used as a predictor of vulnerability.

Expert Driven – A scientific approach which relies on the expertise and knowledge of one or more specialists to drive decisions in a modeling project. An example is the EPA's index ranking method known as "DRASTIC".

Posterior Probability – The probability that a unit cell contains a training point after consideration of the evidential themes. This measurement changes from location to location depending on the values of the evidence.

Prior Probability – The probability that a unit cell contains a training point before considering the evidential themes. It is a constant value over the study area equal to the training point density (total number of training points divided by total study area in unit cells).

Response Theme – An output map that displays the probability that a unit area would contain a training point, estimated by the combined weights of the evidential themes. The output is displayed in classes of relative aquifer vulnerability or probability to contamination (i.e., this area is more vulnerable than that area). The response theme is the relative vulnerability map.

Spatial Data – Information about the location and shape of, and relationships among, geographic features, usually stored as coordinates and topology.

Training Points – A set of locations (points) reflecting a parameter used to calculate weights for each evidential theme, one weight per class, using the overlap relationships between points and the various classes. In an aquifer vulnerability assessment, training points are wells with one or more water quality parameters indicative of relatively higher recharge which is an estimate of relative vulnerability.

Weights – A measure of an evidential-theme class. A weight is calculated for each theme class. For binary themes, these are often labeled as W+ and W-. For multiclass themes, each class can also be described by a W+ and W- pair, assuming presence/absence of this class versus all other classes. Positive weights indicate that more points occur on the class than due to chance, and the inverse for negative weights. The weight for missing data is zero. Weights are approximately equal to the proportion of training points on a theme class divided by the proportion of the study area occupied by theme class, approaching this value for an infinitely small unit cell.

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Assessment of the Extent and Effectiveness of the Wellfield Protection Area and Ordinance:

The professional assessment of the geographic extent of the well field protection area and Ordinance A GIS based spatial analysis of GIS layers and development in conjunction with the County's East Milton Well Field Protection Project.

June 28, 2011

Submitted by Alan Baker, President,
Advanced GeoSpatial Inc.

Professional Geologist's Statement

he hydrogeologic analyses and interpretations assembled, discussed, and reported on in this document were prepared by a licensed Florida professional geologist as required by Chapter 492, Florida Statutes.

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Certified Mapping Scientist's Statement

The mapping, GIS analyses, and professional interpretations conducted in support of this report were conducted pursuant to the Code of Ethics of the American Society for Photogrammetry and Remote Sensing (ASPRS).

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Introduction

In late 2010, Santa Rosa County (the County) developed an initial Wellfield Protection Zoning Overlay Area map (Figure 1), in conjunction with a Wellfield Protection Ordinance, for the purpose of source water protection in the East Milton area. The current wellfield protection area boundary was developed by the County based on the locations of the wells (and wellhead protection zones), the existence of a topographic divide which roughly parallels Highway 90, and based on land-uses in the vicinity of the wellfield. To ensure that the delineated area is sufficient to protect groundwater quality and vital recharge areas within the wellfield and the associated groundwater capture zones, the County has decided to undertake a hydrogeologic analysis of the wellfield and surrounding areas.

Figure1 – Location of the WPA in Santa Rosa County

This report provides an evaluation of the adequacy of the current Wellfield Protection Zoning Overlay Area Map and of the land-use limitations included in the initial Wellfield Protection Ordinance. Geospatial analyses were conducted using hydrogeologic data developed for use in Phase II of the Floridan Aquifer Vulnerability Assessment (FAVA) model, in addition to other relevant datasets and reports, to determine whether alterations to the extent of the currently protected area are warranted. FAVA Phase II included a detailed groundwater vulnerability assessment of the sand-and-gravel aquifer, which identified several areas within and adjacent to the current protected area which were deemed susceptible to contamination based on the FAVA modeling methodology. Furthermore, the report provides a series of recommendations on potential updates to both the Wellfield Protection Zoning Overlay Area Map and the initial Wellfield Ordinance. A metadata report, an informational poster, and a large-format informational poster with recommended updates to the existing Wellfield Protection Area (WPA) are provided as attachments to the report.

Project Background

The WPA encompasses two water systems, the Fairpoint Regional Utility System and East Milton Water System, which collectively supply drinking water to approximately 51% of the residences and businesses within the County. The two water systems collectively include 11 public supply wells with ten completed in the sand-and-gravel aquifer system. One Floridan aquifer system well is also located in the WPA and is operated by East Milton Water System. Additionally, there are two more proposed wells to be located within the WPA (Figure 2; Table 1). Both the East Milton Water System and the Fairpoint Regional Utility System (FRUS) operate wells in this area

The current WPA encompasses approximately 27,000 acres, and is bounded to the east by the Santa Rosa-Okaloosa County boundary and to the west by Highway 87. Highway 90, which generally follows a natural topographic divide between the Blackwater and Yellow Rivers, forms the northern boundary of the WPA. The WPA is bounded to the south by the Yellow River. Approximately 7% of the County's population lives within the WPA and a variety of commercial, agricultural, conservation, and institutional land-uses are currently present

within the area (Table 2). The top three land-uses (by total acreage) within the WPA are publicly owned lands, recreation/open space, and silviculture, which collectively comprise approximately 64% of the total acreage of the WPA.

According to the 2009 Draft Santa Rosa County Water Supply Facilities Plan, the County population is projected to increase by approximately 26% between the years 2007 and 2025 (Miller, 2009). As a result of this growth, additional development is expected within and adjacent to the current WPA. This trend reinforces the need for effective groundwater protection measures within and adjacent to the WPA.

Table 1. Sand-and-Gravel aquifer system public supply wells in and adjacent to the current WPA

Map ID	Well Name	Water System	Well Dia. (in.)	Cased Depth (ft.)	Total Well Depth (ft.)	Well Use
1	EMW S#1	East Milton	16	200	246	Public Supply
2	EMW S#2	East Milton	16	143	183	Public Supply
3	EMW S#4	East Milton	24	200	260	Public Supply
4	EMW S#5	East Milton	24	170	270	Public Supply
5	FRUS #1	FRUS	24	185	275	Public Supply
6	FRUS #3A	FRUS	24	135	215	Public Supply
7	FRUS #3B	FRUS	24	135	215	Public Supply
8	FRUS #4	FRUS	24	170	260	Public Supply
9	FRUS #5	FRUS	24	140	220	Public Supply
10	FRUS #6	FRUS	24	170	260	Public Supply
11	FRUS #7B Test	FRUS	24	170	260	Test
12	EMW S#6 Test	East Milton	24	160	210	Test

Table 2. Land-Uses by Acreage and as a Percent of the Total WPA

Land use Designation	Acreage	Percentage of Total WPA
Agricultural	331.72	1.2
Agricultural Homestead	1149.48	4.3
Commercial	33.27	0.1
Industrial	138.80	0.5
Institutional	14.89	0.1
Military	787.75	2.9
Mixed Residential/Commercial	46.29	0.2
Office	29.75	0.1
Publicly-Owned Lands	3329.92	12.3
Recreation/Commercial	160.81	0.6
Recreation/Open Space	10676.39	39.5
Right-of-Way	907.75	3.4
Single Family Residential	3114.85	11.5
Silviculture	3276.84	12.1
Unclassified	184.16	0.7
Utilities	97.08	0.4
Vacant Lands	2691.26	10.0
Water	25.92	0.1
	Total Acreage = 26996.95	

The initial Wellfield Protection Ordinance outlines zoning and land-use restrictions for the WPA and provides several important updates to the County's individual wellhead protection zone regulations. Article 6.05.25 specifically prohibits certain activities and land-uses within the WPA, including the following:

1) Landfills
2) Resource Extraction activities
3) Underground fuel storage activities
4) The bulk storage, handling, or processing of materials listed as Hazardous or Extremely Hazardous on Table 302.4 of 40 CFR and Appendix A to 40 CFR, part 355, respectively, and
5) Mines or mining activities.

Article 12.13.02 mandates additional land-use limitations within the County's wellhead protection zones, which are defined as 500-foot buffer zones around each public supply well

completed in the sand-and-gravel aquifer system.

Figure 2 – FRUS and EMWS public supply wells in and around the WPA

The following land-uses are prohibited within the wellhead protection zones:

1) *Landfills, resource extraction areas, and the like;*
2) *Underground fuel storage facilities;*
3) *Projects with impervious cover of 50% or more;*
4) *The bulk storage, handling, or processing of materials listed as Hazardous or Extremely Hazardous on Table 302.4 of 40 CFR and Appendix A to 40 CFR, part 355, respectively;*
5) *Projects that require the storage, use, handling, production, or transportation of restricted substances such as toxic chemicals, petroleum products, hazardous/toxic wastes, industrial chemicals, medical wastes, and the like;*
6) *Wastewater treatment plants, percolation ponds, and similar facilities;*
7) *Mines or mining activities; and*
8) *Excavation of waterways or drainage facilities which intersect the water table.*

The Sand-and-Gravel Aquifer System

The sand-and-gravel aquifer system exists in portions of Santa Rosa, Walton, Okaloosa, and Escambia Counties in the western panhandle of north Florida and throughout southwestern Alabama (refer to Figure 3 for the extent of the sand-and-gravel aquifer in northwest Florida). The aquifer plays an important role in meeting regional water supply needs within Northwest Florida by supplying more than 114 million gallons per day (mgd) to meet demands associated with public supply utilities, agricultural operations, and other significant groundwater users in Santa Rosa, Escambia, and Okaloosa counties (USGS, 2005). The sand-and-gravel aquifer (Table 3) is an unconfined surficial aquifer which consists of a complex sequence of sands, gravel, clays, and silts (Miller, 1990).

Across Santa Rosa, Escambia, and Okaloosa counties, the aquifer is up to 450 feet thick and includes three distinct zones: the surficial zone, the low permeability zone, and the main producing zone (Pratt et al., 1999). The main producing zone of the sand-and-gravel aquifer ranges from confined to semi-confined across the study area. In some portions of the aquifer, laterally discontinuous clay beds within the surficial zone create localized perched water-table aquifer conditions.

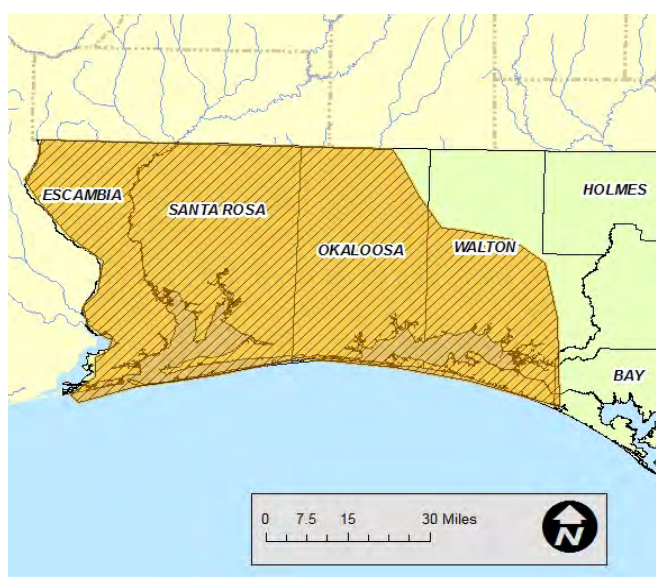

Figure 3 – Extent of the sand-and-gravel aquifer system in Northwest Florida

Due to the generally unconfined nature of the upper portion of the aquifer system, the groundwater in the system is considered highly vulnerable to contamination associated with activities occurring at the land surface (Miller, 1990). Within the study area, the sand-and-gravel aquifer system overlies the Floridan aquifer system, which consists of a thick sequence of marine-origin limestone, dolostone, and anhydrites. Although the sand-and-gravel aquifer contains three distinct zones across much of its extent, for the purposes of this assessment, the vulnerability of the aquifer system is addressed as a whole.

Source Water Protection & Groundwater Vulnerability

A variety of methods can be used to determine where source water protection efforts should be focused, depending on the type of aquifer and the land-uses present in and around a public supply wellfield. Typically, groundwater flow modeling is conducted to determine the extent of the cumulative (or individual) capture zones or cones of depression associated with the wells in the wellfield. Groundwater protection regulations are often focused on these zones, as the groundwater in these zones is eventually withdrawn through the supply wells in the wellfield. Theoretically, contamination from activities occurring at land surface which occurs within mapped wellhead capture zones has a higher likelihood of migrating to the supply wells, thereby endangering source water quality.

A key component of our approach to determine the sufficiency of the current WPA and the Wellfield Ordinance was an analysis of the aquifer vulnerability and land uses within the existing wellhead capture zones. Existing and future land use GIS data provided by the County, in addition to relative aquifer vulnerability data from FAVA Phase II, source water protection areas/wellhead capture zones from the Florida Department of Environmental Protection (FDEP), and topographic and potentiometric data from FDEP and the Northwest Florida Water Management District (NWFWMD) were used to perform the analysis.

The following sections describe the data used to conduct our assessment and the analyses conducted with each data set.

<u>FAVA Phase II – Sand-and-Gravel Aquifer Vulnerability Assessment</u>

The vulnerability assessment of the sand-and-gravel aquifer, conducted during FAVA Phase II, is an important tool in understanding aquifer susceptibility to contamination. The FAVA Phase II methodology involves a scientific approach in which multiple, detailed hydrogeologic data sets which are pertinent to aquifer vulnerability were synthesized and modeled to derive a single, raster-based visualization of aquifer vulnerability across the sand-and gravel aquifer system. The sand-and-gravel aquifer vulnerability analysis used the following data sets:

Table 3. Hydrogeologic Framework of the Sand-and-Gravel aquifer system (Adapted from Miller, 1990)

Series	***Stratigraphic & Hydrologic Units***			***Lithology***
Holocene & Pliocene	Alluvium & Terrace Deposits	SAND AND GRAVEL AQUIFER	Surficial Zone	Poorly sorted silt, sand, clays, and gravel.
Pleistocene	Citronelle Fm.	SAND AND GRAVEL AQUIFER	Confining Zone	Poorly sorted sands with some hardpan layers.
Miocene	Choctawhatchee Formation	SAND AND GRAVEL AQUIFER	Main Producing Zone	Sand, shell, and marl
Miocene	Alum Bluff Grp., Shoal River Fm., & Chipola Fm.	SAND AND GRAVEL AQUIFER	Main Producing Zone	Sand with lenses of silt, clay, and gravel
Miocene	Pensacola Clay	CONFINING UNIT		Grey sandy clay; acts as a basal confining unit
Miocene	St. Marks Fm.	FLORIDAN AQUIFER SYSTEM		Limestone and Dolomite

Soil Hydraulic Conductivity Theme - The infiltration rate of water through soils is a key element in the analysis of aquifer vulnerability,

as soils are an aquifer system's initial line of defense against the downward leakage of potential contaminants (Baker, 2009).

The hydraulic conductivity of soils is especially important in areas where effective aquifer confinement does not exist. Soil hydraulic conductivity is defined as "the amount of water that would move vertically through a unit area of saturated soil in unit time under unit hydraulic gradient" (United States (U.S.) Department of Agriculture, 2005). The detailed hydraulic conductivity data set used in the FAVA study (Figure 4) was developed in 2006 by the Natural Resources Conservation Service (NRCS). The initial data was obtained in an ESRI shapefile format from NRCS and was transformed into a raster-based format for use in the FAVA study.

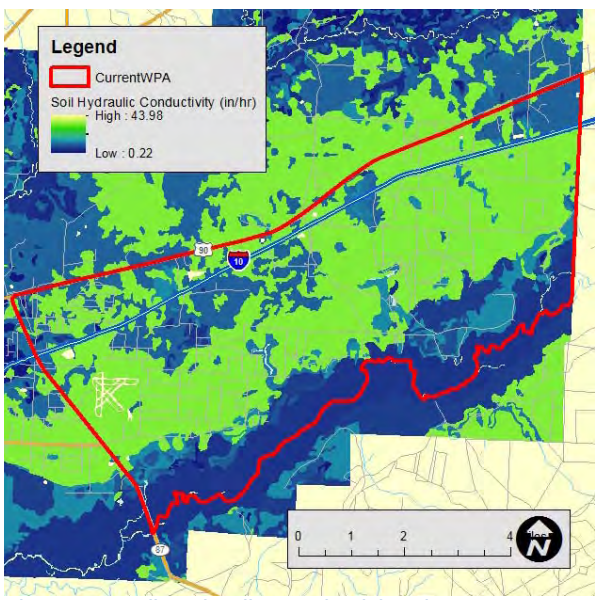

Figure 4 – Soil Hydraulic Conductivity Theme

Closed Topographic Depression Theme - Karst features, which include sinkholes, swallets, and other closed topographic depressions, can provide preferential pathways for the migration and concentration of groundwater into underlying hydrostratigraphic units and may increase an aquifer systems susceptibility to contamination where they are present (Baker, 2009).

Closed depressions are generally shown as hatchured lines on topographic maps, and their shapes are typically circular or elongated polygons. The closer a site is to a closed depression or a series of depressions, the greater the overall vulnerability of the underlying aquifer(s).

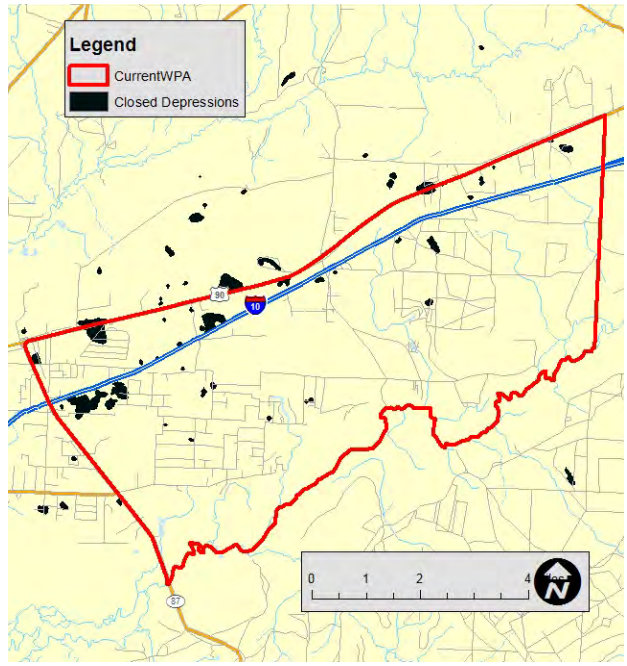

Figure 5 – Closed Topographic Depression Theme

The closed topographic depressional-features layer used in the FAVA study (Figure 5) was developed by digitizing said features from U.S. Geological Survey (USGS) topographic 24K quadrangle maps on a statewide basis. The depressional-features theme was further developed by buffering the features into 30-meter zones out to a distance of 3,000 meters to allow for proximity analysis (Baker, 2009).

Depth to Water Theme – Depth to water is the vertical distance from land surface to the underlying water table (Figure 6). This theme was developed by subtracting a water table surface elevation raster layer from a high-resolution Digital Elevation Model (DEM). The water table surface elevation raster was created using depth to water measurements obtained from the NWFWMD and using a linear regression methodology developed by Nic Sepulveda of the USGS (2002) to create a surface (Baker, 2009).

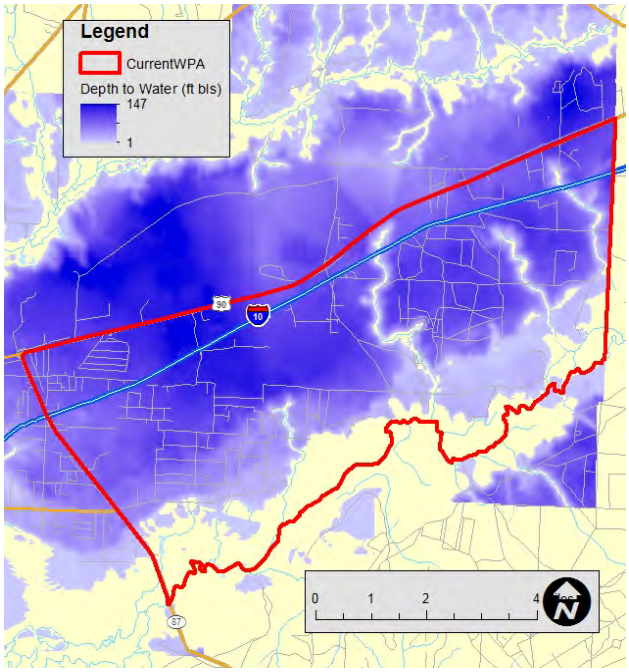

Figure 6 – Depth to Water Theme

The input data sets for the sand-and-gravel vulnerability assessment were generalized to assess which portions of each layer have the greatest relationship with the locations of training points, which are actual monitoring well locations used in the calibration of the FAVA model. Aquifer vulnerability criteria, assessed at each of the training point locations, are used to refine the sensitivity of the model by determining the threshold(s) that maximize the spatial association between the patterns observed in the input data layers (Baker, 2009).

Table 4. Input Themes to the FAVA Model		
Theme	***Range of Values***	***Range Associated with the Highest Aquifer Vulnerability***
Soil Hydraulic Conductivity	0.03 to 43.98 in./hr.	9.20 to 43.98 in./hr.
Proximity to Closed Topographic Depressions	30 to 3,000+ m.	< 1,470 m.
Depth to Water	1.0 to 116.0 ft.	< 33 ft.

The FAVA sand-and-gravel modeling process defined binary breaks for each of the three data sets. The binary breaks essentially create two separate spatial classifications, one with a stronger relationship to the training points, and one with a weaker association to the training points. The ranges for each model input theme and the range associated with the greatest aquifer vulnerability for each input theme are shown in Table 4.

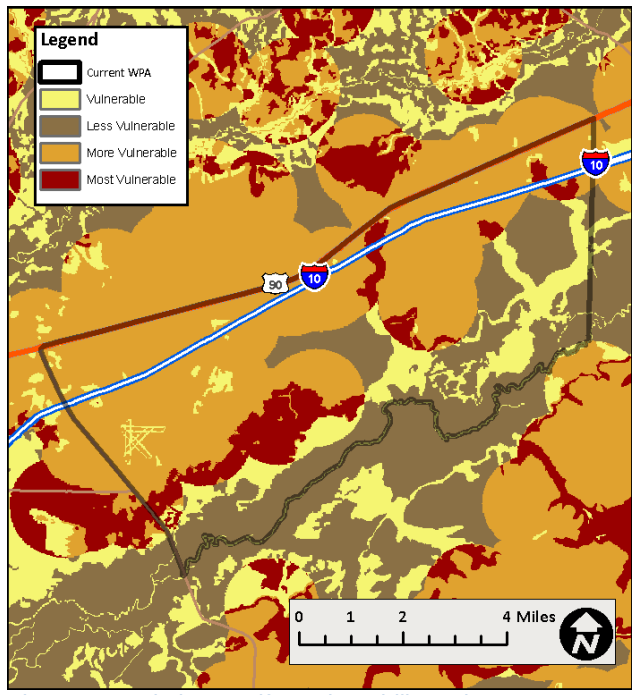

Figure 7 – Relative Aquifer Vulnerability Index

The FAVA model then concurrently processed the generalized input layers to derive a single output raster layer, which was classified into four relative aquifer vulnerability rankings (Figure 7). The output of the modeling effort indicates that the areas ranked most vulnerable generally have a shallow depth to water, high soil conductivity values, and are in close proximity to closed topographic depressional-features (Baker, 2009). A full description of the modeling process conducted to derive the model output can be found in the FAVA Phase II Report (Arthur et.al, 2007).

It is important to note that the FAVA GIS modeling methodology and model outputs underwent an extensive quality assurance/quality control process, as well as several years of sensitivity testing and peer review prior to publication.

Wellhead Capture Zones

Source water protection area delineations were obtained from FDEP's Source Water Assessment and Protection Program in an ESRI shapefile format (Figure 8). For wells which serve a population of more than 1,000 people, FDEP requires a delineation of the five-year wellhead capture zone, which corresponds to the areal extent of groundwater which is predicted to provide recharge to the wellhead over a five-year period. Where groundwater modeling has not yet been conducted by the FDEP, 1,000-foot buffer zones are used in place of the five-year capture zones. Wells 10 and 11 (shown in Figure 8) do not have buffer zones delineated by FDEP. However, for the purposes of this study, 1,000-foot buffer zones have been delineated and added to the figure.

According to Charles Gallion, head of the FDEP Source Water Assessment and Protection Program (SWAPP), groundwater capture zone modeling has only been conducted for three of the 11 East Milton/FRUS public supply wells (Table 5; C. Gallion personal commun, June 15, 2011). The FDEP has no current plans or funding to perform capture zone modeling for the additional eight wells.

Mapped source water protection/capture zone areas for six of the 10 current East Milton/FRUS public supply plus one proposed well (Map ID 11) wells are fully within the current WPA, while the capture zones for the remaining five existing wells plus one proposed well (Map ID 12) are either partially within the WPA or are completely outside of the boundary. A comparison of the FAVA output (Aquifer Vulnerability Theme) with the extents of the individual source water protection/capture zones indicates that the majority of the acreage within each capture zone is classified as "Most Vulnerable" per the FAVA model (Table 5).

For the capture zones outside of the current WPA, it appears that the protections afforded by Article 12.13.02 of the Wellfield Protection Ordinance are not sufficient to protect source water quality within the five-year wellhead capture zones (or 1,000-foot wellhead protection zones).

Table 5. Source Water Assessment and Protection Areas

Well Name	***Water System***	***SWAPP Method***	***Within WPA?***	***Total Acres***	***Percent of Acreage Classified as Most Vulnerable per the FAVA Model***
EMWS #1	East Milton	5-year capture zone	Partial	99	87.4%
EMWS #2	East Milton	5-year capture zone	Yes	93	81.9%
EMWS #4	East Milton	5-year capture zone	No	99	71.1%
EMWS #5	East Milton	1,000-ft. wellhead buffer	No	72	91.3%
FRUS #1	FRUS	1,000-ft. wellhead buffer	Partial	72	100%
FRUS #3A	FRUS	1,000-ft. wellhead buffer	Yes	72	100%
FRUS #3B	FRUS	1,000-ft. wellhead buffer	Yes	72	100%
FRUS # 4	FRUS	1,000-ft. wellhead buffer	Yes	72	98.6%
FRUS #5	FRUS	1,000-ft. wellhead buffer	Yes	72	93.5%
FRUS #6	FRUS	1,000-ft. wellhead buffer	Yes	72	90.8%
FRUS #7B Test	FRUS	1,000-ft. wellhead buffer	Yes	72	100%
EMWS# 6 Test	East Milton	1,000-ft. wellhead buffer	Yes	72	98.2%

Figure 8 – SWAPP Zones in and adjacent to the WPA

Article 12.13.02 specifies land-use limitations within 500 feet of public supply wells within the County boundary. Based on the sizes of the source water protection/capture zone areas, additional land-use protections are warranted for the region surrounding each wellhead.

Minimally, the current WPA boundary and associated land-use restrictions should be extended to encompass each of the individual source water protection/capture zones.

Furthermore, groundwater modeling should be conducted to determine the five-year capture zones for each of the wells in the WPA. If the modeling has been completed then the identified zones should be incorporated.

Existing Contaminated Sites

Spatial data reflecting current and historic contaminated sites was acquired from FDEP for use in the analysis of the WPA (Figure 9). Based on the FDEP data, no active contaminated sites appear within the wellhead capture zones/source water protection areas; however several active and inactive solid waste sites are located within the WPA boundary. Additionally, seven petroleum contamination sites (leaky underground storage tanks) exist on the northern and western periphery of the WPA. Most of these sites, with the exception of several solid waste facilities, are participating (or participated) in one of several FDEP-administered cleanup programs, and there are essentially no local regulations or programs that could be effectively implemented to hasten their remediation. It is advisable that the County maintain a current inventory of contaminated sites within and immediately adjacent to the WPA. Knowing the location and status of each of these sites will be important during the siting of new public supply wells in the area.

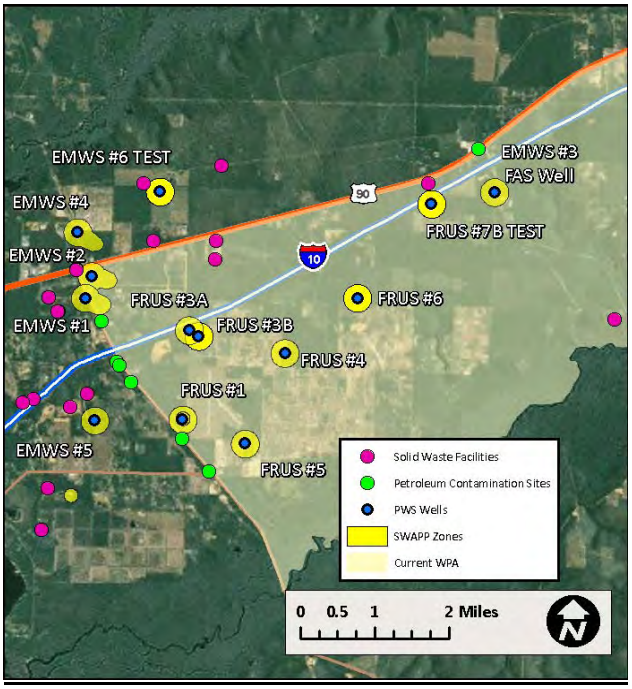

Figure 9 – Contaminated Sites in and adjacent to the WPA

Topographic and Potentiometric Data

Topographic and potentiometric datasets were also examined in support of determining where potential recharge areas in and around the wellfield may exist. Although detailed recharge maps of the sand-and-gravel aquifer are not available, general recharge areas can be inferred based on water level and elevation characteristics. Recharge to the sand-and-gravel aquifer is typically greatest in topographically elevated areas (with the

greatest depths to groundwater), such as hilltops or ridges, and is generally less at lower elevations, especially near surface water bodies, which may receive discharge (baseflow) from the aquifer (UF IFAS, 2011). Because the northern boundary of the WPA (along Highway 90) roughly follows the local topographic divide (ridge) between the Blackwater and Yellow Rivers, substantial recharge areas up-gradient of the supply wells are already protected within the WPA. To ensure the future functionality of the recharge areas within the WPA, impervious area limitations, such as those outlined in Article 12.13.02, should be incorporated into Article 6.05.25.

Updates to the WPA Boundary & the Wellfield Protection Ordinance

While the WPA protects vital wellfield recharge areas and effectively protects substantial undeveloped acreage, which could be used to expand the wellfield in the future, alterations to the WPA boundary (provided in the enclosed large-format WPA map in Appendix A) are warranted. The overall WPA boundary should be expanded to the west and southwest of the current boundary to encompass the capture zones/source water protection areas for the four public supply wells which are fully or partially outside of the current WPA.

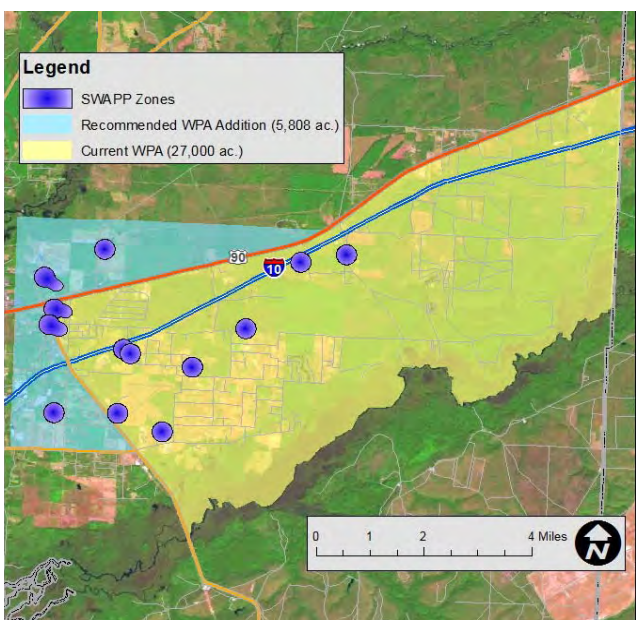

Figure 10 - Recommended Addition to the Current WPA

The recommended new WPA boundary (Figure 10) will protect approximately 32,808 acres, an increase of 5,808 acres over the current WPA. From the western extent of the current WPA boundary at Highway 87, the new WPA should extend westward along Hickory Hammock Road until a point slightly west of B. Lowery Road. From Hickory Hammock Road, the new boundary should extend due north under I-10 and follow Persimmon Hollow Road until the intersection at Highway 90. From Highway 90, the boundary should continue due north to the Blackwater River. From the river, the boundary should head roughly east to meet the current WPA boundary at Highway 90, slightly northeast of the intersection of Highway 90 and Pond Road. The updated boundary was digitized using the County's current land-use layer (elum.shp) as a guide for the boundary line. Therefore, the recommended boundary lines are concordant with the mapped divisions between various land-uses in the vicinity of the wellfield. A summary of land-uses present in the recommended WPA is provided in Table 6.

We recommend updating the Wellfield Ordinance by adopting selected provisions of the Article 12.13.02 for the entire WPA. Additionally, the County should investigate the feasibility of implementing limitations on septic systems in large planned residential developments within the WPA. Large developments which are not connected to a sanitary sewer system could constitute appreciable nutrient and bacteriological loading to the groundwater system. This will be especially important as the residential population residing within the WPA grows.

Suggested updated land-use limitations for inclusion in the Wellfield Protection Ordinance (Article 6.05.25) are as follows:

1) *Landfills, resource extraction areas, and the like;*
2) *Underground fuel storage facilities;*
3) *Projects with impervious cover of 50% or more;*
4) *The bulk storage, handling, or processing of materials listed as Hazardous or Extremely Hazardous on Table 302.4 of 40 CFR and Appendix A to 40 CFR, part 355, respectively;*
5) *Projects that require the storage, use, handling, production, or transportation of restricted substances such as toxic chemicals, petroleum products, hazardous/toxic wastes, industrial chemicals, medical wastes, and the like;*
6) *Wastewater/reclaimed water sprayfields, land application sites, percolation ponds, and similar facilities;*
7) *Mines or mining activities;*
8) *Excavation of waterways or drainage facilities which intersect the water table; and*
9) *Onsite septic systems for residential developments with greater than 100 planned housing units*

Conclusions

In summary, an assessment of the current WPA boundary and the Wellfield Protection Ordinance was conducted using several GIS data sets. The analyses conducted in support of this assessment yielded the following conclusions:

Table 6. Land-Uses by Acreage and as a Percent of the Total WPA (with the Recommended Addition)

Land use Designation	***Acreage***	***Percentage of Total WPA***
Agricultural	639.95	2.0
Agricultural Homestead	1539.33	4.7
Commercial	63.86	0.2
Industrial	290.66	0.9
Institutional	268.97	0.8
Military	787.75	2.4
Mixed Residential/Commercial	84.20	0.3
Office	29.75	0.1
Publicly-Owned Lands	4236.70	12.9
Recreation/Commercial	160.81	0.5
Recreation/Open Space	11378.55	34.7
Right-of-Way	1237.20	3.8
Single Family Residential	3812.91	11.6
Silviculture	3997.58	12.2
Unclassified	259.14	0.8
Utilities	220.32	0.7
Vacant Lands	3771.53	11.5
Water	25.92	0.1
	Total Acreage = ~32,808	

- Large portions of the WPA were determined by the FAVA model to be “Highly Vulnerable” to groundwater contamination.

- The current WPA does not include all of the FDEP mapped source water protection/wellhead capture zones. Five of the individual source water protection//wellhead capture zones are within the WPA, two are partially within the WPA and two are fully outside of the WPA.

- The current WPA appears to encompass significant aquifer recharge areas up-gradient of most of the supply wells.

- Article 12.13.02 of the Wellfield Protection Ordinance outlines land-use restrictions for the 500-foot buffer zones surrounding each wellhead. The 500-foot buffer zones are not sufficient to protect source water quality given the local hydrogeologic conditions and does not cover the mapped FDEP source water protection/wellhead capture zones of 1,000 feet. For reference the 1,000-foot zones are approximately 72 acres whereas the current 500-foot buffer zone encompasses 18 acres.

Recommendations

Based on the analyses and research conducted in support of this report, we offer the following recommendations:

- Expand the WPA boundary to encompass the mapped source-water-protection//wellhead capture-zone areas that correspond with each of the ten East Milton/Fairpoint public supply wells. Refer to Appendix A, map of the recommended boundary. Also see the submitted WPA Addition submitted as part of the GIS deliverables for this project.

- Develop a groundwater monitoring plan for the WPA and vicinity. Water quality trends could be identified through periodic monitoring or examination of data currently collected by the utility system and could be used to further evaluate the effectiveness of the Wellfield Protection Ordinance. Alternatively, coordinate with agencies such as NWFWMD and USGS, who may already perform groundwater monitoring in the vicinity of the WPA to keep up to date on local groundwater quality trends.

- Perform groundwater modeling to determine the five-year capture zones for each of the East Milton/FRUS wells. Make additional adjustments to the WPA boundary based on the results, if warranted. Additionally, prior to installing new public supply wells in the WPA, five-year capture zone modeling should be conducted for the proposed well locations and pumpage. The capture zones should be overlain with a current inventory of contaminated sites and land uses to ensure that the new wells will not have a significant risk of groundwater contamination.

- Consider adopting language to the Wellfield Protection Ordinance prohibiting septic tanks for residential developments with greater than 100 planned housing units and limiting impervious acreage within new developments. Adopt the groundwater protection measures outlined in Article 12.13.02 into Article 6.05.25, which would better protect the entire WPA.

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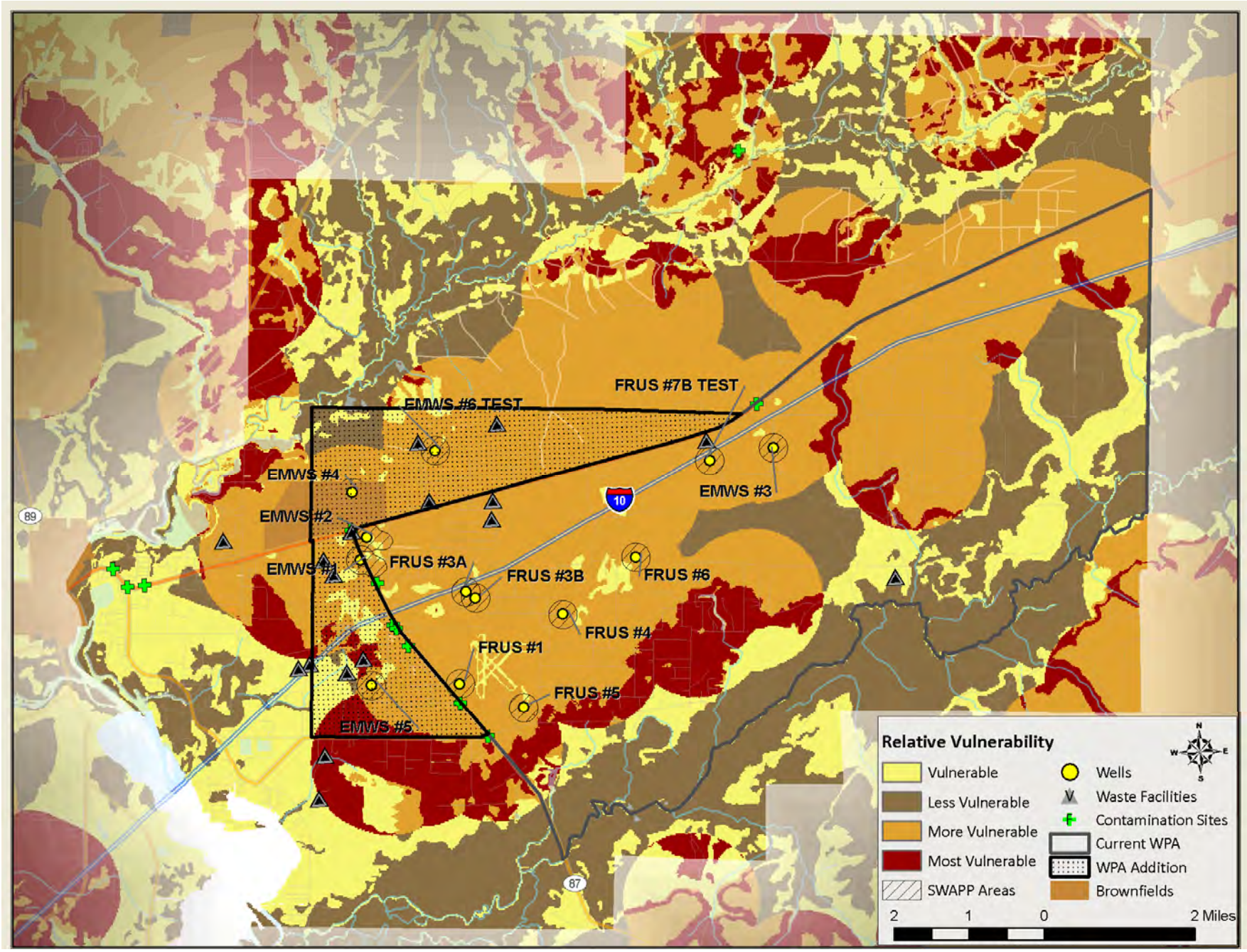
Assessment of the Extent & Effectiveness of the WPA & Wellfield Protection Ordinance

Appendix "A"



SUSCEPTIBILITY OF PUBLIC SUPPLY WELLS TO GROUND WATER CONTAMINATION IN SOUTHERN ESCAMBIA COUNTY, FLORIDA

Water Resources Special Report 99-1

Prepared for:

Escambia County Utilities Authority
City of Pensacola
Escambia County
Florida Department of Environmental Protection
U.S. Environmental Protection Agency

Prepared by:

Northwest Florida Water Management District

Tainshing Ma, Thomas R. Pratt, Jim Dukes
Roger A. Countryman and Gary Miller

December 1999

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INTRODUCTION

Purpose and Scope

This report is being submitted to provide the Escambia County Utilities Authority (ECUA), the City of Pensacola, Escambia County, the Florida Department of Environmental Protection and other interested parties with a means of assessing the risk posed to public supply wells (existing and proposed) by ground water contamination. It is the intent of this work to further local management of the Sand-and-Gravel Aquifer as a source of potable water. The work was performed under Florida Department of Environmental Protection (FDEP) Contract Number WM637. Specifically, the scope of this work includes the following activities:

- Review pertinent literature. Obtain existing geographic information systems (GIS) and/or compatible data layers from various governmental agencies. As required, develop new data layers. Collate data layers into ArcView shape files.

- Develop database of sites where drycleaning solvents may historically have been used. Obtain FDEP underground storage tanks database. Based on street addresses for these two classes of sites, geocode cleaning business locations and USTs. Check accuracy of geocoded locations with differentially corrected GPS. Prepare statistical description of locational inaccuracies.

- Identify parameters of relevance to describing risk to ground water in southern Escambia County. Develop multi-variate statistical model to evaluate that risk.

- Develop ArcView extension to implement RISK analysis system. Develop associated data layers.

- Prepare final report describing data analysis, methodologies, results and pertinent GIS application documentation.

This project and the preparation of this report were funded in part by a Section 319 Nonpoint Source Management Program grant from the USEPA. The grant was awarded through a contract with the Stormwater/Nonpoint Source Management Section of the FDEP. The total cost of the project was approximately $252,000, of which $151,200 (approximately 60 percent) was provided by the USEPA. The ECUA, the Florida Department of Environmental Protection and the Northwest Florida Water Management District provided the remainder of the project funds.

Study Area Location

The area described in the report consists of the southern portion of Escambia County (Figure 1). The northern limit of the study area corresponds to the general vicinity of Molino. The study area consists of all of Escambia County south of Molino and includes the principal urban center of the county; specifically the City of Pensacola and the associated urbanized unincorporated portions of Escambia County. The vast majority of Escambia County residents live within the

study area. The public supply wells (and associated treatment and distribution systems) which supply water to this population are also located within the study area.

Previous Investigations

This work builds upon a number of previously conducted investigations of the Sand-and-Gravel Aquifer in southern Escambia County. Those of greatest direct technical relevance were conducted by the NWFWMD on behalf of the ECUA. Beginning in September 1990 and concluding in June 1993, the NWFWMD developed a three-dimensional, finite-element flow and solute transport model of the Sand-and-Gravel Aquifer in Escambia County. The conceptual model upon which the numerical model was based is described in Roaza et al. (1991). The completed numerical model is documented in Roaza et al. (1993).

Subsequent to 1993, the ECUA model was used for several site-specific investigations. In February 1994, the NWFWMD completed an assessment of the feasibility of installing a new production well at a site on Fairfield Drive. In April 1996, the NWFWMD assessed the feasibility of installing additional production capacity near the Pensacola Regional Airport (Roaza et al., 1996). The primary emphasis of the latter work was to examine the potential for saltwater intrusion, which could result from additional pumpage near the airport.

In 1997 work was completed on application of the model for delineation of wellhead protection areas (WHPAs). Delineations were performed for 56 of the principal public supply wells in the southern half of the county. WHPAs were delineated for wells owned by the following entities: ECUA, U.S. Navy, Peoples Water Service, Farm Hill Utilities, Gonzalez Utilities, Cottage Hill Utilities and Molino Utilities. Delineations were not performed for wells with water use classifications other than public supply. This includes the large number of self-supplied industrial use wells located in the area (i.e. wells owned by Champion International, Monsanto Corporation, Gulf Power and others). Results of this effort are documented in Richards et al. (1997).

Ground Water Use in Escambia County

Effectively, all of the water used for public supply, domestic, agriculture and recreation/landscape uses comes from the Sand-and-Gravel Aquifer. Over half of the water used for commercial and industrial uses comes from the aquifer. Only in the case of power generation does a substantial portion of the water use come from surface water. Table 1 summarizes the most recent water use figures for Escambia County by use classification and by source. Table 2 details public water supply use by system. The systems for which WHPAs were delineated constitute about 97 percent of the public water supply of the county.

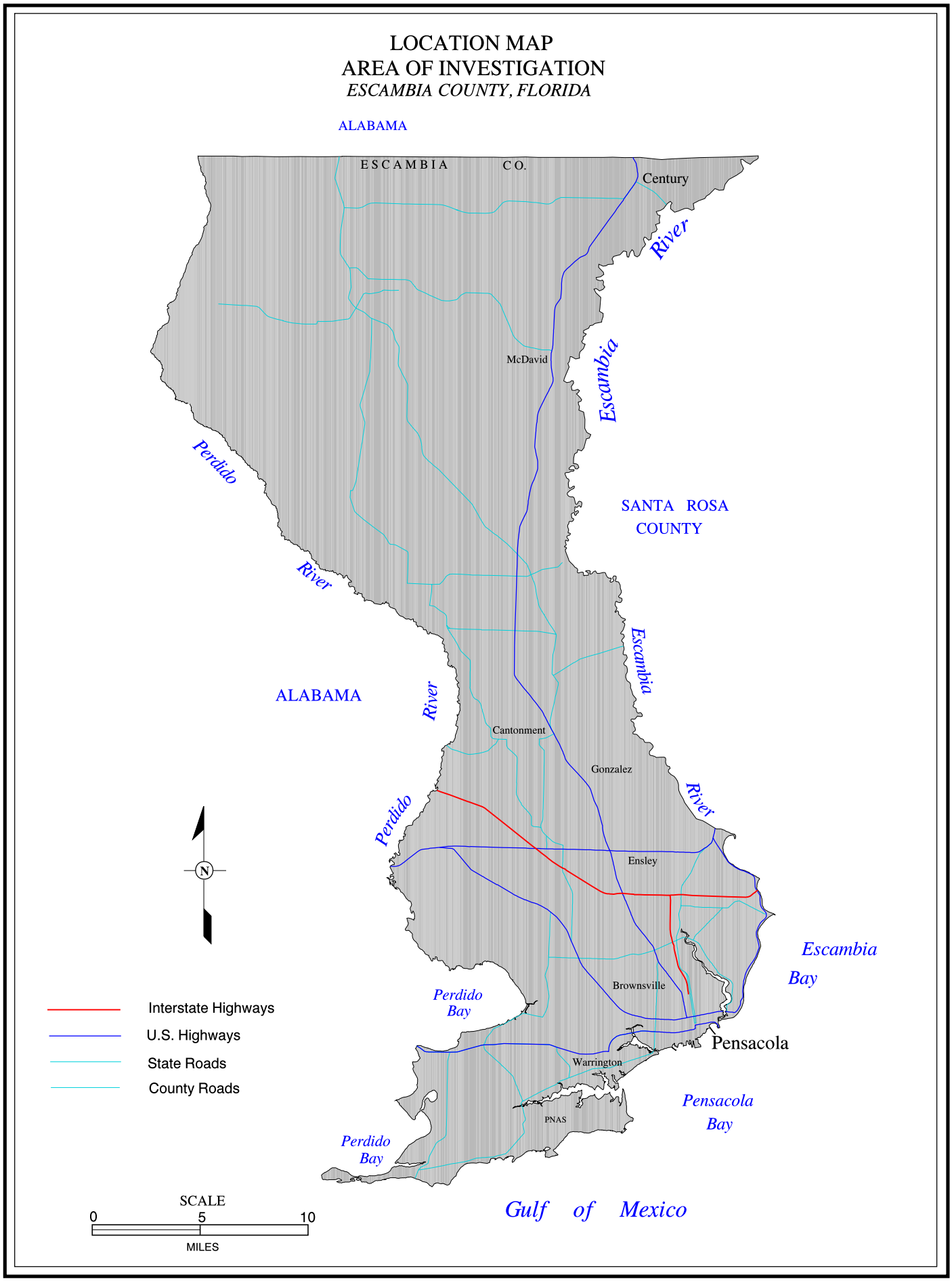

Figure 1. Area of Investigation.

Table 1. Estimated Average Water Use in Escambia County, 1995.

Use Classification	Ground Water (Mgal/d)	Surface Water (Mgal/d)	Total (Mgal/d)
Public Supply	37.7	0.0	37.7
Self-supplied Domestic	3.39	0.0	3.39
Agriculture	1.66	0.31	1.97
Recreation/Landscape	4.74	0.62	5.36
Commercial/Industrial*	37.2	22.2	59.4
Power Generation	2.11	160	162
Total	86.8	183	270

Source: Marella, R.L., M.F. Mokray and M.J. Hallock-Solomon, 1998. Water Use Trends and Projections in the Northwest Florida Water Management District. U.S. Geological Survey. Open File Report 98-269. 35 pages.

* denotes that the commercial/industrial use class includes ground water production from Corry Station that is actually used for public supply at Corry Station and at NAS Pensacola.

Table 2. Estimated Average Public Water Supply by System, 1995.

Public Supply System	Ground Water Use (Mgal/d)	Percent of County Public Supply Total
ECUA	32.9	87
Peoples Water Service	2.08	5.5
Molino Utilities	0.58	1.5
Century Utilities	0.51	1.4
Gonzalez Utilities	0.39	1.0
Cottage Hill Utilities	0.33	0.9
Farm Hill Utilities	0.29	0.8
Century Water Works	0.26	0.7
Bratt-Davisville Water System	0.20	0.5
Walnut Hill Water Works	0.19	0.5
Total	37.7	100

Source: Marella, R.L., M.F. Mokray and M.J. Hallock-Solomon, 1998. Water Use Trends and Projections in the Northwest Florida Water Management District. U.S. Geological Survey. Open File Report 98-269. 35 pages.

HYDROGEOLOGY OF THE SAND-AND-GRAVEL AQUIFER IN SOUTHERN ESCAMBIA COUNTY

Regional Setting of the Sand-and-Gravel Aquifer

The Sand-and-Gravel Aquifer is a surficial aquifer system unique to the western portion of the Florida panhandle. It constitutes a major aquifer system in Florida and consists of a complex sequence of sand, gravel, silt and clay. Separating this surficial aquifer from the underlying Floridan Aquifer is a thick, effective confining unit known as the Intermediate System. The Floridan Aquifer is deeply buried in this region. Although it is an important source of ground water in much of northwest Florida, in Escambia and much of Santa Rosa counties, the Floridan Aquifer is highly mineralized and is not suitable as a potable supply source. For this reason, the Sand-and-Gravel Aquifer is the sole source for fresh ground water in all of Escambia County.

The base of the Sand-and-Gravel Aquifer is marked by the thick Intermediate System. The Intermediate System is a competent confining unit that effectively separates the Sand-and-Gravel Aquifer from the underlying Floridan Aquifer System. The Intermediate System is composed of thick beds of clays and other low-permeability sediments. It includes the Miocene age Pensacola Clay and the lower portion of the Miocene Coarse Clastics. In Escambia County its thickness ranges between 300 and 1,200 ft. It is thinnest in the northern part of the county and thickest in the south. Beneath urbanized Pensacola, its thickness exceeds 1,000 ft. No significant water bearing zones exist within this system in Escambia County. Because of its thickness and low permeability, the top of the Intermediate System forms the base of the Sand-and-Gravel Aquifer flow system.

The Sand-and-Gravel Aquifer is essentially a vast but thin veneer of sand underlying all of Escambia County. The thickness of the Sand-and-Gravel Aquifer ranges between 150 ft near Bayou Texar to 450 ft around Cantonment.

Hydrostratigraphic Zonation of the Sand-and-Gravel Aquifer

The Sand-and-Gravel Aquifer includes the Pleistocene terrace deposits, the Pliocene Citronelle Formation and the upper portion of the Pliocene/Miocene Coarse Clastics. Locally, where clay, silt and fine sand dominate the sediments, low-permeability zones exist which may partially confine the underlying sands. These semi-confining zones, however, are discontinuous and lithologically variable and function as leaky confining layers. Intervals dominated by sand and gravel form the highly permeable, productive portions of the aquifer.

At any given site in Escambia County, a vertical profile of the Sand-and-Gravel Aquifer consists of layers of sand and gravel interbedded with layers of lower permeability silt, clay and fine sand sediments. This interbedded nature of the aquifer allows the Sand-and-Gravel Aquifer to be subdivided into three major zones. The designation of these zones is based on permeability contrasts. These major zones are the surficial zone, the low-permeability zone and the main-producing zone.

The surficial zone consists of the uppermost layers of saturated sand and gravel. The surficial zone is composed primarily of sand and gravel, but layers of silt and clay also occur. Beneath the surficial zone is the low-permeability zone. The low-permeability zone is composed of various mixtures of clay, silt and sand. Due to the highly discontinuous nature of individual beds

within this zone and their variable lithology, the zone does not constitute an areally continuous confining bed. Thus, the low-permeability zone is very leaky and hydraulically interconnected throughout. Beneath this semi-confining layer lies the main-producing zone. This zone consists of moderate to well-sorted sand and gravel layers, typically interbedded with fine sand and clayey beds. The majority of the ground water withdrawn from the Sand-and-Gravel Aquifer is withdrawn from the main-producing zone.

These three zones vary greatly throughout the county. In addition, individual layers of sand or clay within these zones are highly discontinuous, resulting in considerable heterogeneity within the zones. This sometimes makes it difficult to map the extent of a zone from one area of the county to another. However, despite local variations in lithology, these zones can be generalized and mapped at the county scale.

The zonation of the Sand-and-Gravel Aquifer is best delineated by analysis of lithologic and geophysical logs of deeply penetrating or fully penetrating boreholes. The presence of variable lithology and heterogeneity within the zones make it difficult to delineate the three major zones from well logs that only penetrate a limited portion of the aquifer. The zonation described here and used in the ECUA numerical model application is based on analysis of approximately 180 geophysical logs (Roaza et al., 1991).

Surficial Zone

The surficial zone consists of the uppermost layer of saturated sediments. It includes the interval of sediments between the water table and the first substantial, regionally continuous, low-permeability layer which marks the top of the low-permeability zone. Within the surficial zone, ground water exists under unconfined conditions. The surficial zone is a hydrogeologic unit and is not associated with any single stratigraphic unit. Locally, higher topographic areas generally exhibit a thicker surficial zone than adjacent areas of lower elevations. In some areas adjacent to the Perdido and Escambia rivers and some other major streams, the surficial zone has been completely eroded away, leaving the low-permeability zone exposed at the surface. Hydraulic property data for the surficial zone is virtually non-existent.

The surficial zone consists primarily of quartz grains, with grain size ranging from sand to gravel. Thin streaks of limonite-cemented sandstone also occur. The amount of gravel generally increases in the northern portion of the county. In addition to sand and gravel, the surficial zone also contains relatively thin and extremely discontinuous layers of clay and silt. These low-permeability layers occur within both the surficial zone and in the overlying unsaturated materials. Where present, these layers can create a perched water table considerably higher than that of the true water table of the surficial zone. The presence of perched water levels is most common in the middle portion of the county. For example, in the vicinity of the intersection of Interstate 10 and Highway 29, there is a continuous drainage of perched ground water into the interstate drainage system. The land surface elevation at this site is approximately 120 ft above sea level. The underlying surficial zone potentiometric surface lies at an elevation of about 65 ft above sea level.

The surficial zone is dissected by the Perdido and Escambia rivers as well as by many smaller streams. Where the streams and rivers have eroded into the water table, discharge takes place. This has resulted in the development of numerous independent flow systems within the surficial zone. These local flow systems each consist of an upland recharge area and adjacent lowland (perennial stream) discharge area. This localized flow system development is

particularly prevalent in the northern half of the county. In the southern half of the county, much of the surface discharge from the surficial zone occurs as discharge to the bays and bayous.

Low-Permeability Zone

The low-permeability zone is the first substantial, regionally continuous low-permeability layer encountered within the Sand-and-Gravel Aquifer. It forms a semi-confining layer, which acts to restrict the vertical flow of ground water between the overlying surficial zone and the underlying main-producing zone. The low-permeability zone is present throughout Escambia County and generally consists of a poorly sorted mixture of sand, silt and clay. The actual lithology of this unit is variable, ranging from poorly sorted sand and silt to sandy clay to clay. Locally, well-sorted, productive sands can also occur within this zone. The distinction between the low-permeability zone and the overlying and underlying materials can be quite subtle and difficult to detect.

In the southern portion of the county, the low-permeability zone consists of poorly sorted sand with some clay and gravel. Poor sorting with grain sizes ranging from fine sand to gravel, along with relatively minor amounts of clay and silt, distinguish this zone from the better-sorted surficial and main-producing zones. In the central and northern portions of the county, clay and silt content increase considerably. In these areas, this zone predominately consists of sandy clay and clay. This results in a more competent semi-confining layer in the central and northern portions of Escambia County. Throughout the county, the thickness of the low-permeability zone ranges between 20 ft and 100 ft.

The key significance of the low-permeability zone lies in its ability to restrict the flow of water between the surficial zone and the main-producing zone. This arises from the contrasts in vertical hydraulic conductivity among the three zones. Typically, the vertical hydraulic conductivity of the low-permeability zone is lower than that of the overlying and underlying zones. For example, at an aquifer test site in the central portion of the southern half of the county (ECUA OLF4A site), the vertical hydraulic conductivity of the low-permeability zone was determined to be 0.24 ft/d. For the underlying main-producing zone, the vertical hydraulic conductivity was determined to be 5.8 ft/d, or about 24 times that of the low-permeability zone.

This contrast in hydraulic conductivity is sufficient to generate a head difference between the surficial and main-producing zones, with the higher heads occurring in the surficial zone over much of the study area. Over most of this area, head differences range from a few feet up to about 10 ft. The maximum head difference between the surficial zone and the main-producing zone in the southern half of the county is on the order of 20 ft.

Typically, heads in the surficial zone are higher than in the main-producing zone. Only in the low areas in the immediate proximity of major discharge boundaries are heads in the main-producing zone higher. For example, along the Pensacola Bay shoreline in downtown Pensacola, heads in the main-producing zone are about five feet above sea level while heads in the surficial zone are only slightly above sea level.

Main-Producing Zone

The main-producing zone is the most productive portion of the Sand-and-Gravel Aquifer and is the zone tapped by most of the major wells in the county. It includes the interval of the Sand-

and-Gravel Aquifer situated below the low-permeability zone. The ground water within this zone exists under semi-confined conditions. The top of the Intermediate System marks the base of the main-producing zone. The thickness of the main-producing zone ranges between 90 ft and 290 ft in southern Escambia County.

The main-producing zone consists of moderate to well-sorted sand and gravel along with interbedded layers of sandy clay and clay. Thin streaks of limonite cemented sandstone, frequently referred to as hardpan, also occur. The clay content within the main-producing zone is, for the most part, limited to the clayey layers. The sand and gravel intervals of the main-producing zone typically contain very little clay. It is these clay-free intervals of sand and gravel which form the productive portion of the main-producing zone.

In southern Escambia County, the productive intervals consist primarily of medium to coarse sand. Local changes in lithology include areal variations as well as variations with depth at any given location. Changes in lithology are frequently subtle and include varying grain size distribution and significant changes in the degree of sorting. Changes in the lithology of the clayey layers involve the sand content, and can range from clayey sand to clay. In general, it appears as though these clayey layers tend to be sandier in the southern portion of the county.

The main-producing zone is primarily composed of productive intervals of sand and gravel. The clayey layers interbedded within the sand and gravel generally constitute from 10 percent to 40 percent of the thickness of the main-producing zone. In some areas, the productive intervals and the clayey layers can be correlated and appear to be continuous over distances of miles. In the Pensacola vicinity, numerous well logs show the productive sand intervals and a clayey layer (located within the bottom third of the main-producing zone) to be continuous throughout most of the area. Elsewhere in the county, a sufficient density of well log data is not available to determine if individual layers within the main-producing zone are indeed continuous over larger areas or if they exist as discontinuous lithologic units within the main-producing zone.

Recharge, Discharge and Movement of Ground Water

Southern Escambia County receives, on average, about 60 inches of rainfall per year. Most of this rainfall either returns to the atmosphere via evapotranspiration or runs off overland to rivers or bays. However, some of it recharges the Sand-and-Gravel Aquifer. Recharge takes place over most of the study area. Infiltrated rainfall that escapes being recycled to the atmosphere via evapotranspiration moves downward through the unsaturated soils under the influence of gravity and encounters the water table. When this occurs, the infiltrated rainfall becomes part of the saturated ground water flow system.

Over most of the study area, heads in the surficial zone are higher than the heads in the underlying main-producing zone. The difference ranges from a few feet to a maximum of about 40 ft. This results in a downward hydraulic gradient, a downward flow component and attendant recharge to the main-producing zone. Once water enters the main-producing zone, it moves horizontally to points of discharge. Natural discharge occurs in the low-lying areas where the head in the main-producing zone is greater than the head in the surficial zone, producing an upward flow component. Accordingly, in these areas, ground water moves from the main-producing zone through the low-permeability zone to discharge into the surficial zone and the bays, bayous and rivers. Discharge also occurs via pumping wells.

Both the Escambia River and the Perdido River form significant discharge boundaries for the Sand-and-Gravel Aquifer. Because these discharge boundaries are relatively close together near Cantonment, essentially no ground water flows from the northern portion of the county to the southern portion of the county. Ground water in northern Escambia County naturally discharges to either the Escambia River or the Perdido River, or is discharged through wells, many of which are located in the Cantonment area. The area south of Cantonment is effectively hydraulically isolated from the northern portion of the county. All ground water in the southern half of the county is derived from local recharge.

Recharge within the study area is substantial. In spite of pumpage in excess of 80 Mgal/d, there is still about 50 ft of hydraulic head (referenced to sea level) in the main-producing zone in the center of the southern half of the county. Ground water flows radially away from the potentiometric high and discharges to adjacent bays and bayous. Additional discharge occurs via pumping wells.

Results of the regional model of the Sand-and-Gravel Aquifer (Roaza et al., 1993) provided an estimate of the recharge to the main-producing zone in the southern half of the county. Over this area, the steady-state recharge to the main-producing zone was estimated to be 124 Mgal/d (12.5 inches per year over the 209-mi^2 recharge area generally south of Molino). Of this quantity, pumpage accounted for 75 Mgal/d and discharge to natural boundaries accounted for the balance.

PROJECT SHAPE FILES

The following ArcView shape files were developed for the project, either as input to the Risk Analysis ArcView extension or for the purpose of illustrating various relevant aspects of the hydrogeology of southern Escambia County. Each shape file is described in greater detail in the following pages. Each is found on the accompanying CD.

- *Observed 1991 potentiometric surfaces of the Sand-and-Gravel Aquifer main-producing zone and lower portion of the main-producing zone.*
- *Observed 1991 surficial zone potentiometric surface.*
- *Regional potentiometric surface of the main-producing zone, as simulated using the ECUA WHPA delineation model.*
- *Wells used to simulate pumpage in the ECUA WHPA delineation model.*
- *Wellhead protection areas for 7-year horizontal plus vertical time of travel (TOT), 7-year horizontal only TOT, 20-year horizontal plus vertical TOT and 20-year horizontal only TOT.*
- *Calibrated vertical hydraulic conductivity distribution of the low-permeability zone (model layer 6), as developed during calibration of the ECUA WHPA delineation model.*
- *Calibrated horizontal hydraulic conductivity distribution of the main-producing zone (model layer 2), as developed during calibration of the ECUA WHPA delineation model.*
- *Palafox Corridor Brownfield.*
- *National Priorities List (NPL) sites.*
- *State-Funded Action sites and one miscellaneous site.*
- *Ground water contamination distributions.*
- *Businesses historically engaged in the cleaning of clothes in southern Escambia County.*
- *FDEP Drycleaning Solvent Cleanup Program eligible and not eligible facilities in Escambia County.*
- *FDEP Storage Tank/Contamination Monitoring (STCM) database sites in southern Escambia County.*
- *FDEP Generalized Water Information System (GWIS) water quality data.*

OBSERVED 1991 MAIN-PRODUCING ZONE POTENTIOMETRIC SURFACES

DESCRIPTION OF DATA LAYER

Data layer name..............*various*
Description......................*Observed 1991 potentiometric surfaces of the Sand-and-Gravel Aquifer main-producing zone and lower portion of the main-producing zone.*
Type................................*line*
Datum ....*NAD 83*
Projection........................*UTM Zone 16*
Map Units........................*Meters*

Conversion from source to data layer: *lines were exported from ARC/Info coverage.*

DESCRIPTION OF SOURCE MATERIALS

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1991 Observed Main-Producing Zone Potentiometric Surface

Source reference materials: *"Numerical Modeling of Ground Water Flow and Contaminant Transport in the Sand-and-Gravel Aquifer, Escambia County, Florida", prepared by the Northwest Florida Water Management District, June 1993, Water Resources Special Report 93-4.*

Data layer name... ***1991_mpz_pot.shp***
Delineation represents conditions in.............................. *August 1991*
Delineation represents conditions in.............................. *main-producing zone*

Source material location............. *NWFWMD headquarters, Ground Water Bureau*
Media of source.......................... *ARC/Info coverage*
Media of secondary source .... *paper map, Plate 2*
Scale of source *1:100,000*

••

1991 Observed Lower Main-Producing Zone Potentiometric Surface

Source reference materials: *"Numerical Modeling of Ground Water Flow and Contaminant Transport in the Sand-and-Gravel Aquifer, Escambia County, Florida", prepared by the Northwest Florida Water Management District, June 1993, Water Resources Special Report 93-4.*

Around Cantonment, the main-producing zone can be divided into an upper and a lower unit by the presence of a fairly extensive, low permeability unit. Many of the Champion and Monsanto wells have screened intervals completed in this lower interval. Given that a number of these wells were measured in 1991, it was possible to contour the potentiometric surface of the lower unit over a limited area. Those data are given in ***1991_deep_mpz_pot.shp***. South of

Cantonment head differences between the upper and lower portions of the main-producing zone are minimal. This is due to the lack of a persistent, lower permeability unit within main-producing zone in the south.

Data layer name.. ***1991_deep_mpz_pot.shp***
Delineation represents conditions in.............................. *August 1991*
Delineation represents conditions in.............................. *lower, basal portion of the main-producing zone*

Source material location............. *NWFWMD headquarters, Ground Water Bureau*
Media of source.......................... *ARC/Info coverage*
Media of secondary source .... *paper map, Plate 3*
Scale of source *1:100,000*

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DATA ATTRIBUTES

Column	Item name	Description
9	Contour	Contour values, in feet. Contour interval is 10 feet.

••

DATA LAYER PROVIDING ORGANIZATION

Providing agency.............*Northwest Florida Water Management District*
Contact person................*Chief—Bureau of Ground Water*
Phone number.................*850-539-5999*
Agency address ....*81 Water Management Drive, Havana, FL 32333*

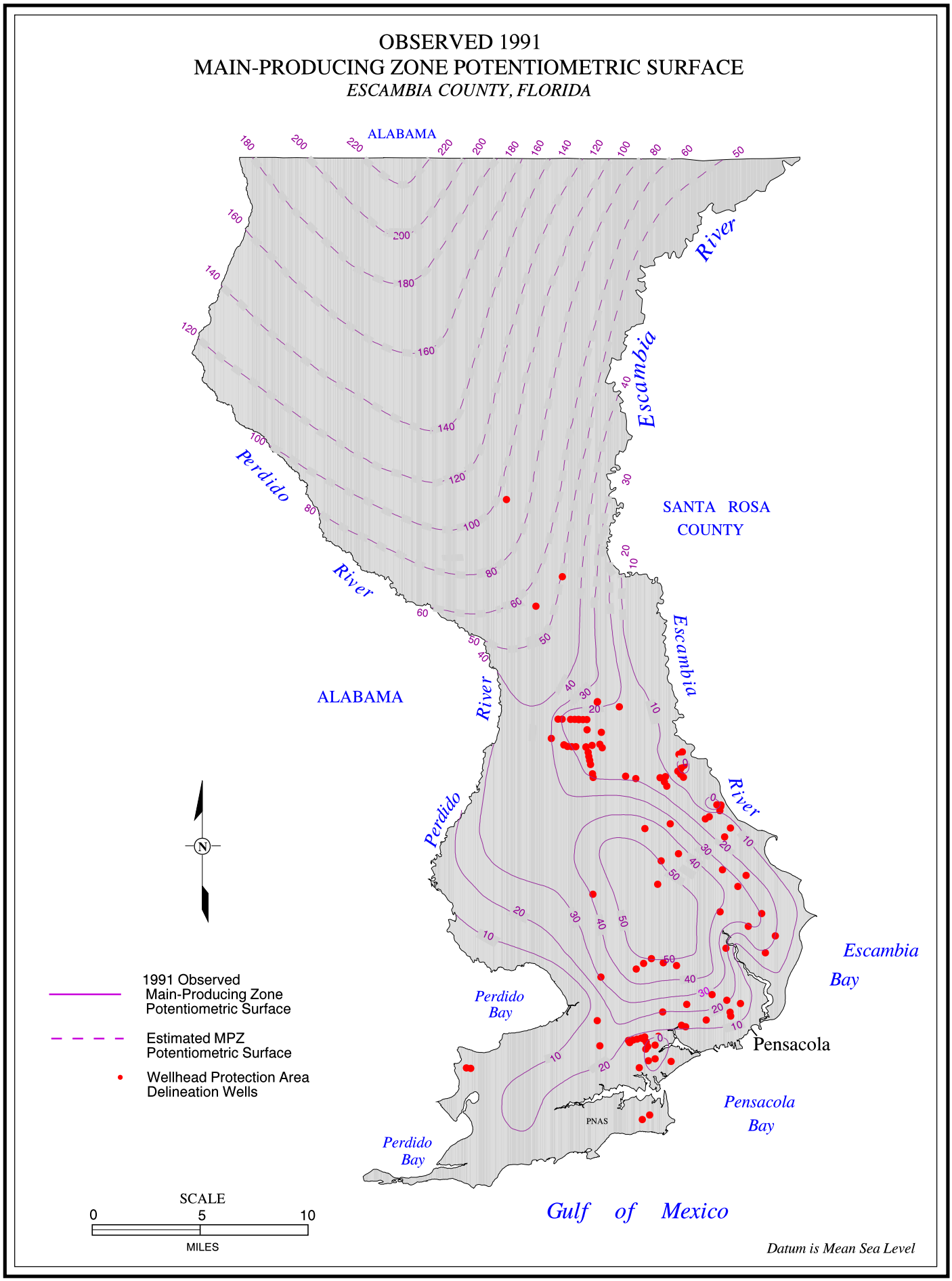

Figure 2. Observed 1991 Main-Producing Zone Potentiometric Surface.

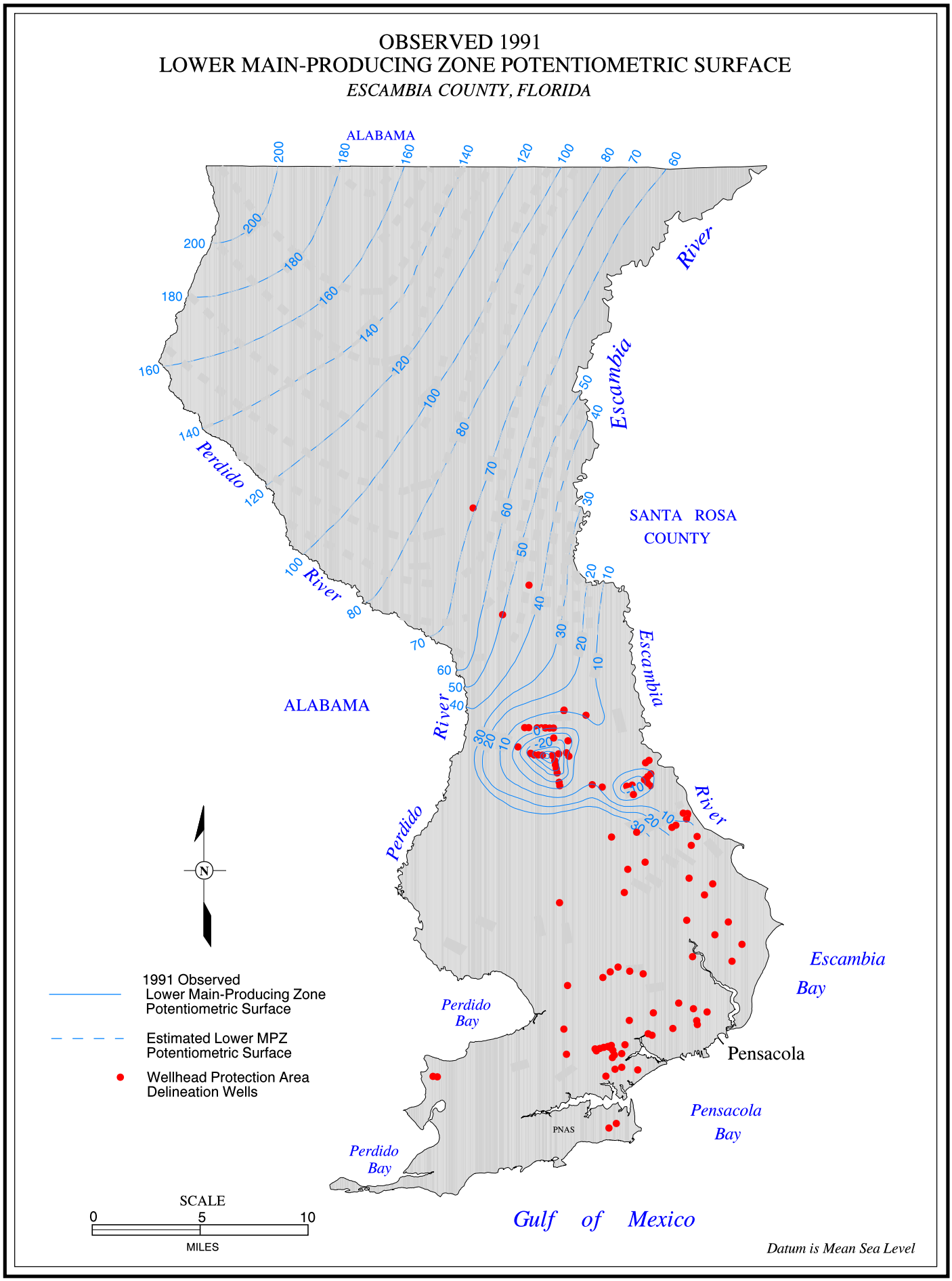

Figure 3. Observed 1991 Lower Main-Producing Zone Potentiometric Surface.

1991_SURFICIAL_POT.SHP

DESCRIPTION OF DATA LAYER

Data layer name..............***1991_surficial_pot.shp***
Description......................*Observed 1991 surficial zone potentiometric surface.*
Type................................*line*
Datum ....*NAD 83*
Projection........................*UTM Zone 16*
Map Units........................*Meters*

Conversion from source to data layer: *lines were exported from ARC/Info coverage.*

DESCRIPTION OF SOURCE MATERIALS

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Source reference materials: *"Numerical Modeling of Ground Water Flow and Contaminant Transport in the Sand-and-Gravel Aquifer, Escambia County, Florida", prepared by the Northwest Florida Water Management District, June 1993, Water Resources Special Report 93-4.*

Source material location............. *NWFWMD headquarters, Ground Water Bureau*
Media of source.......................... *ARC/Info coverage*
Media of secondary source .... *paper map, Plate 1*
Scale of source *1:100,000*

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DATA ATTRIBUTES

Column	Item name	Description
9	Contour	Contour values, in feet. Contour interval is 20 feet, with a supplemental 10-ft contour interval.

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DATA LAYER PROVIDING ORGANIZATION

Providing agency.............*Northwest Florida Water Management District*
Contact person................*Chief—Bureau of Ground Water*
Phone number.................*850-539-5999*
Agency address ....*81 Water Management Drive, Havana, FL 32333*

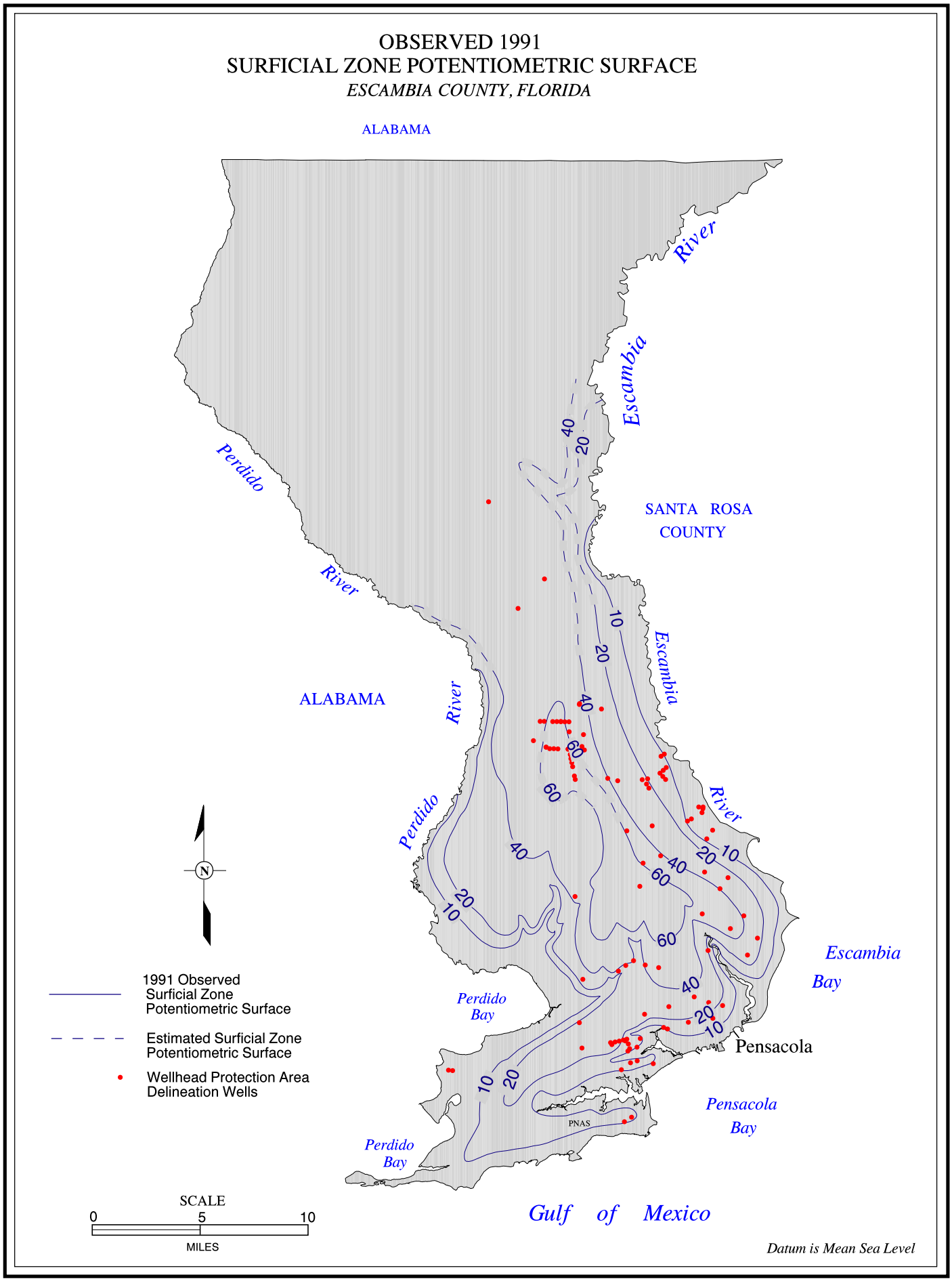

Figure 4. Observed 1991 Surficial Zone Potentiometric Surface.

DELINEATION-SIMULATED
MAIN-PRODUCING ZONE POTENTIOMETRIC SURFACES

DESCRIPTION OF DATA LAYER

Data layer name..............***slice_3_simulated_mpz.shp; slice_4_simulated_mpz.shp***
Description......................*Regional potentiometric surface of the main- producing zone, as simulated using the ECUA WHPA delineation model.*
Type................................*line*
Datum ....*NAD 83*
Projection........................*UTM Zone 16*
Map Units........................*Meters*

Conversion from source to data layer: *lines were exported from ARC/Info coverage.*

DESCRIPTION OF SOURCE MATERIALS

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Source reference materials: *"Numerical Modeling of Ground Water Flow and Contaminant Transport in the Sand-and-Gravel Aquifer, Escambia County, Florida", prepared by the Northwest Florida Water Management District, June 1993, Water Resources Special Report 93-4; and*
"Wellhead Protection Area Delineation in Southern Escambia County, Florida", prepared by the Northwest Florida Water Management District, December 1997, Water Resources Special Report 97-4.

The finite-element numerical flow and solute transport model developed for the above referenced reports consists of six model layers bounded by seven slices of nodes. Node slices are numbered from the bottom of the model domain to the top. Slices 1 through 6 bound the main-producing zone. Slices 6 and 7 bound the overlying low-permeability zone. Slices 3 and 4 represent the middle portion of the main-producing zone. In the Cantonment area slices 3 and 4 bound the lower and upper surfaces, respectively, of the lower permeability unit found within the main-producing zone.

Source material location............. *NWFWMD headquarters, Ground Water Bureau*
Media of source.......................... *ARC/Info coverage*
Scale of source .... *NA*

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DATA ATTRIBUTES

Column	Item name	Description
9	Contour	Contour values, in feet. Contour interval is five feet.

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DATA LAYER PROVIDING ORGANIZATION

Providing agency.....*Northwest Florida Water Management District*
Contact person.....*Chief—Bureau of Ground Water*
Phone number.....*850-539-5999*
Agency address .....*81 Water Management Drive, Havana, FL 32333*

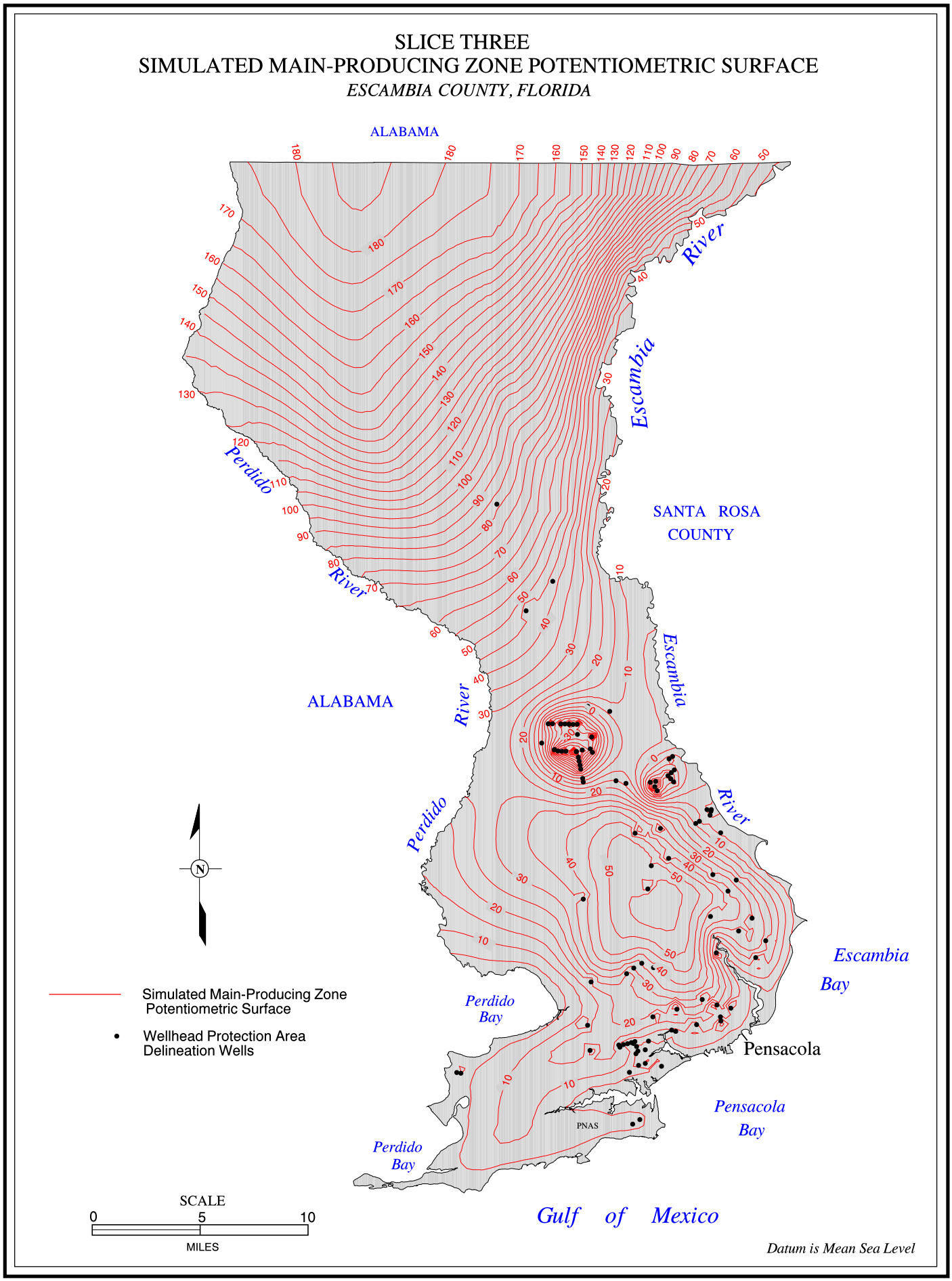

Figure 5. Slice Three Simulated Main-Producing Zone Potentiometric Surface.

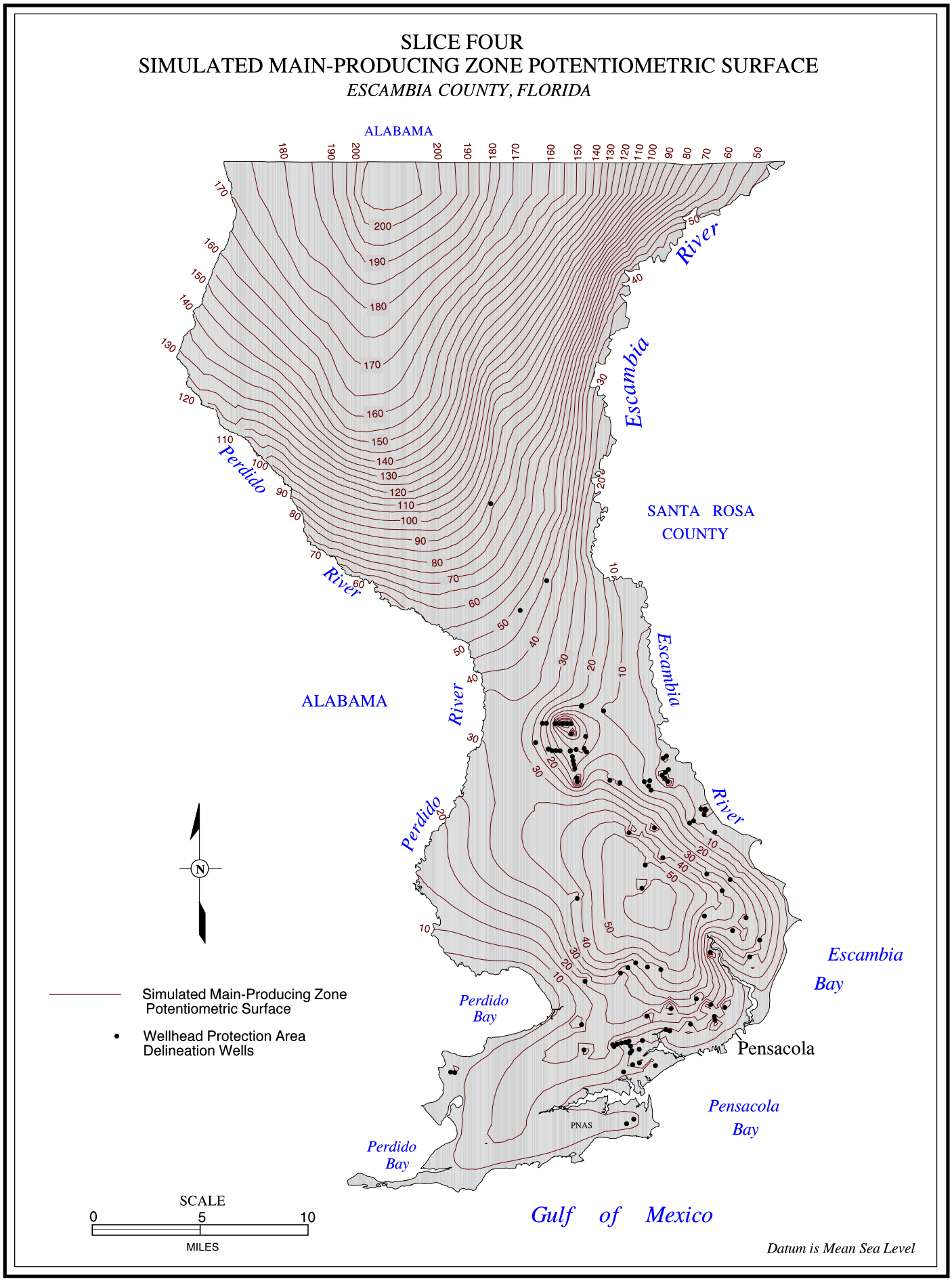

Figure 6. Slice Four Simulated Main-Producing Zone Potentiometric Surface.

WHPA_WELLS.SHP

DESCRIPTION OF DATA LAYER

Data layer name..............***whpa_wells.shp***
Description......................*Wells used to simulate pumpage in the ECUA WHPA delineation model.*
Type................................*Point*
Datum ....*NAD 83*
Projection........................*UTM Zone 16*
Map Units........................*Meters*

Conversion from source to data layer: *data were imported from Oracle database.*

DESCRIPTION OF SOURCE MATERIALS

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Source reference materials: *"Wellhead Protection Area Delineation in Southern Escambia County, Florida", prepared by the Northwest Florida Water Management District, December 1997, Water Resources Special Report 97-4.*

Source material location............. *NWFWMD headquarters, Ground Water Bureau*
Media of source.......................... *Oracle database containing GPSed well locations*
Scale of source .... *NA*

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DATA ATTRIBUTES

Column	Item name	Description
2	Index#	Table sequence number.
3	Well_name	NWFWMD well name.
4	Gal/day	delineation pumpage rate, see WRSR 97-4.
5	Whpa	denotes whether or not wellhead protection area was determined for well, yes denotes that whpa was defined, see WRSR 97-4.
6	Altitude	land surface elevation at wellhead, in feet above mean sea level.
7	Well_depth	well depth below land surface, in feet.
8	Csg_depth	casing depth below land surface, in feet.
9	Site_id	USGS/NWFWMD/FDEP site identification number.
10	X-coord	UTM zone16/NAD 83 well coordinate, in meters.
11	Y-coord	UTM zone16/NAD 83 well coordinate, in meters.
12	Code1	code to denote if pumpage was assigned to ECUA wellhead protection area delineation model finite-element layer 1, 1 denotes yes, 0 denotes no, see WRSR 97-4.

13	Code2	code to denote if pumpage was assigned to ECUA wellhead protection area delineation model finite-element layer 2, 1 denotes yes, 0 denotes no, see WRSR 97-4.
14	Code3	code to denote if pumpage was assigned to ECUA wellhead protection area delineation model finite-element layer 3, 1 denotes yes, 0 denotes no, see WRSR 97-4.
15	Code4	code to denote if pumpage was assigned to ECUA wellhead protection area delineation model finite-element layer 4, 1 denotes yes, 0 denotes no, see WRSR 97-4.
16	Code5	code to denote if pumpage was assigned to ECUA wellhead protection area delineation model finite-element layer 5, 1 denotes yes, 0 denotes no, see WRSR 97-4.
17	Code6	code to denote if pumpage was assigned to ECUA wellhead protection area delineation model finite-element layer 6, 1 denotes yes, 0 denotes no, see WRSR 97-4.
18	GAC	code to denote if well either is or previously was treated with a granular activated carbon (GAC) unit, 1 denotes that the well is (or was previously) treated, 0 denotes that the well neither is being nor has been treated with a GAC.

DATA LAYER PROVIDING ORGANIZATION

Providing agency.............*Northwest Florida Water Management District*
Contact person................*Chief—Bureau of Ground Water*
Phone number.................*850-539-5999*
Agency address ....*81 Water Management Drive, Havana, FL 32333*

Table 3. WHPA Delineation Wells.

INDEX#	WELL NAME	GAC UNIT INSTALLED (as of 1999)	WHPA	ALTITUDE (ft above sea level)	WELL DEPTH (ft below land surface)	CASING DEPTH (ft below land surface)
1	ECUA #40-CANTONMENT	no	**yes**	145	450	345
2	ECUA #42-MCCRORY	no	**yes**	111	335	220
3	ECUA #22-SWEENEY	no	**yes**	133	301	231
4	ECUA #28-OLF 4A	no	**yes**	127	338	220
5	ECUA #23-ENSLEY	**yes**	**yes**	134	280	185
6	ECUA #27-UNIVERSITY	no	**yes**	113	335	145
7	ECUA #39-ELLYSON	no	**yes**	93	370	145
8	ECUA #24-BROAD ST	no	**yes**	128	271	179
9	ECUA #20-OLIVE RD	no	**yes**	109	206	110
10	ECUA #25-DUNAWAY	no	**yes**	76	375	155
11	ECUA #21-DAVIS HWY	no	**yes**	108	255	105
12	ECUA #18-MCALLISTER	**yes**	**yes**	108	242	130
13	ECUA #17-9TH AVENUE	**yes**	**yes**	92	270	137
14	ECUA #19-AIRPORT NORTH	no	**yes**	116	267	162
15	ECUA #38-ROYCE ST	**yes**	**yes**	82.61	230	136
16	ECUA #6-HAGLER	no	**yes**	92	260	180
17	ECUA #15-MONTCLAIR #3	no	**yes**	70	198	117
18	ECUA #29-CARRIAGE HILLS	no	**yes**	68	201	151
19	ECUA #14-MONTCLAIR #2	**yes**	**yes**	79	192	117
20	ECUA #13-MONTCLAIR #1	**yes***	**yes**	90	201	125
21	ECUA #41-TENNANT	no	**yes**	75	225	150
22	ECUA #30-AVONDALE	no	**yes**	60	204	145
23	ECUA #9-F & SCOTT ST	**yes**	**yes**	65	244	130
24	ECUA #3-(#9)	**yes***	**yes**	52	252	152
25	ECUA #4-EAST PLANT	**yes**	**yes**	79	270	151
26	ECUA #8-W & AVERY ST	no	**yes**	86	251	156
27	ECUA #2-(#8)	**yes***	no	38	240	140
28	ECUA #7-WEST P'COLA	no	**yes**	70	266	164
29	ECUA #1-(#6)	**yes**	**yes**	33	240	110
30	ECUA #10-LILLIAN	**yes**	**yes**	23	195	100
31	ECUA #5-WEST PLANT	**yes**	**yes**	42	228	113
32	ECUA #37-VILLA DR	no	**yes**	29	232	105
33	ECUA #12-BRONSON #2	no	no	31	248	120
34	ECUA #11-BRONSON #1	no	**yes**	27	245	127
35	PEOPLES #8	no	**yes**	17.47	240	185
36	PEOPLES #5	**yes**	**yes**	29.60	231	150
37	PEOPLES #9A	no	**yes**	22	295	214
38	PEOPLES #3A	**yes**	**yes**	21	258	193
39	PEOPLES #4A	no	**yes**	23	304	180
40	PEOPLES #7	no	no	22	234	unknown
41	FARM HILL #2	no	**yes**	168	202	162
42	FARM HILL #1	no	**yes**	157	243	212
43	FARM HILL #3	no	**yes**	157	465	390
44	COTTAGE HILL #1	no	**yes**	127	207	175

Table 3. WHPA Delineation Wells (continued).

INDEX#	WELL NAME	GAC UNIT INSTALLED (as of 1999)	WHPA	ALTITUDE (ft above sea level)	WELL DEPTH (ft below land surface)	CASING DEPTH (ft below land surface)
45	COTTAGE HILL #2	no	**yes**	60	230	199
46	MOLINO #2	no	**yes**	221	246	210
47	MOLINO #1	no	**yes**	190	300	240
48	MOLINO #3	no	**yes**	192	415	335
49	CHAMPION #8	no	no	99	372	304
50	CHAMPION #9	no	no	99	292	109
51	CHAMPION #10	no	no	101	268	153
52	CHAMPION #6	no	no	122	391	321
53	CHAMPION #7	no	no	94	287	120
54	CHAMPION #11	no	no	102	398	328
55	CHAMPION #12R	no	no	104	369	295
56	CHAMPION #5	no	no	143	329	105
57	CHAMPION #2	no	no	142	410	112
58	CHAMPION #17	no	no	145	445	369
59	CHAMPION #34	no	no	144	452	363
60	CHAMPION #31	no	no	145	465	394
61	CHAMPION #30	no	no	138	436	370
62	CHAMPION #32	no	no	151	463	386
63	CHAMPION #35	no	no	140	480	370
64	CHAMPION #1	no	no	37	440	300
65	CHAMPION #20	no	no	142	450	293
66	CHAMPION #22	no	no	143	415	287
67	CHAMPION #25R	no	no	139	448	282
68	CHAMPION #23	no	no	138	485	296
69	CHAMPION #33	no	no	122	306	242
70	CHAMPION #29	no	no	125	324	212
71	CHAMPION #13R	no	no	100	385	300
72	CORRY #8	**yes**	**yes**	33.68	238	143
73	CORRY #10	**yes**	**yes**	24.36	209	109
74	CORRY #7	**yes**	**yes**	28.85	226	140
75	CORRY #14	**yes**	**yes**	26.64	230	130
76	CORRY #13	**yes**	**yes**	27.28	232	132
77	CORRY #15	**yes**	**yes**	29.97	230	144
78	CORRY #11	**yes**	**yes**	31.42	251	157
79	CORRY #9	**yes**	**yes**	29.50	251	157
80	CORRY #12	**yes**	**yes**	30.41	238	143
81	CORRY #16	**yes**	**yes**	29.21	242	174
82	NAS PENSACOLA #2	no	no	33	178	110
83	NAS PENSACOLA #1	no	no	36	175	105
84	MONSANTO #2	no	no	39	340	190
85	MONSANTO #8	no	no	50	332	187
86	MONSANTO #5	no	no	35	393	175
87	MONSANTO #6	no	no	50	364	185
88	MONSANTO #7A	no	no	65	378	207

Table 3. WHPA Delineation Wells (continued).

INDEX#	WELL NAME	GAC UNIT INSTALLED (as of 1999)	WHPA	ALTITUDE (ft above sea level)	WELL DEPTH (ft below land surface)	CASING DEPTH (ft below land surface)
89	MONSANTO #9	no	no	59	368	205
90	MONSANTO #C (#13)	no	no	105	497	352
91	MONSANTO #10	no	no	68	312	178
92	MONSANTO #D (#14)	no	no	81	485	323
93	MONSANTO #A (#11)	no	no	58	417	307
94	MONSANTO #B	no	no	68	440	330
95	CRIST PLANT #1	no	no	35	171	123
96	CRIST PLANT #2	no	no	26.18	197	137
97	CRIST PLANT #4	no	no	27	178	118
98	CRIST PLANT #3	no	no	55	220	160
99	CRIST PLANT #5	no	no	122	255	200
100	CRIST PLANT #6	no	no	85	220	165
101	REICHOLD #11	no	no	28	210	105
102	REICHOLD #14	no	no	24	220	145
103	UWF #2	no	no	87	270	155
104	UWF #1	no	no	88.50	273	220
105	GONZALEZ #1	no	**yes**	141	185	143
106	GONZALEZ #2	no	**yes**	152	183	160
107	COTTAGE HILL #3	no	**yes**	125	400	300

Note: * denotes that well previously had GAC installed to remove organics, as of late 1999 GAC has been removed.

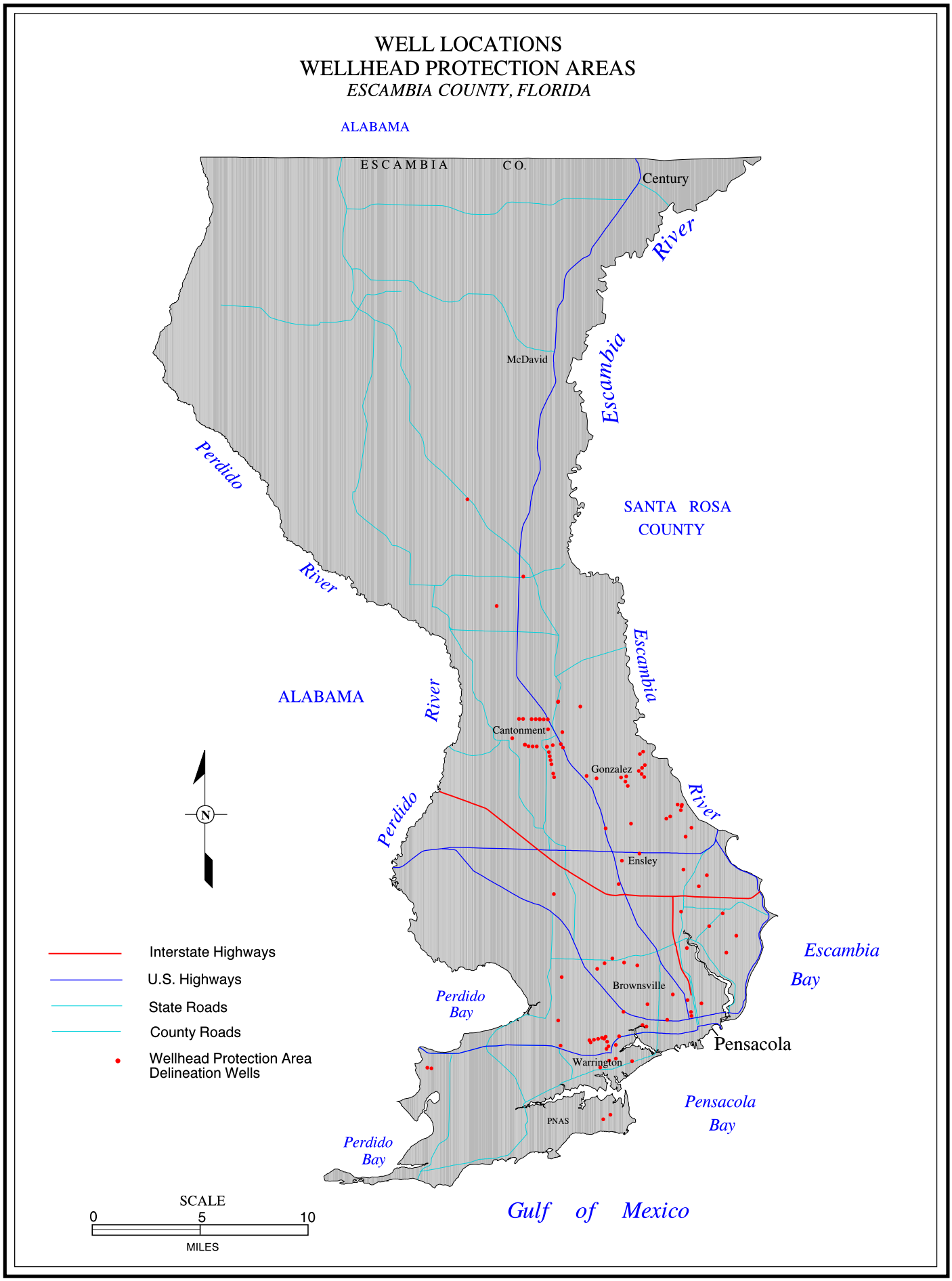

Figure 7. WHPA Well Locations.

TIME-OF-TRAVEL WELLHEAD PROTECTION AREA DELINEATIONS

DESCRIPTION OF DATA LAYER

Data layer names .... ***7yr_hor_vert.shp***
7yr_hor_only.shp
20yr_hor_vert.shp
20yr_hor_only.shp

Description .... *wellhead protection zones for:*
7-year horizontal plus vertical time of travel (TOT)
7-year horizontal only TOT
20-year horizontal plus vertical TOT
20-year horizontal only TOT, respectively.
Type .... *Polygon*
Datum .... *NAD 83*
Projection .... *UTM Zone 16*
Map Units .... *Meters*

Conversion from source to data layer: *polygons were exported from ARC/Info coverage.*

DESCRIPTION OF SOURCE MATERIALS

••

Source reference materials: *"Wellhead Protection Area Delineation in Southern Escambia County, Florida", prepared by the Northwest Florida Water Management District, December 1997, Water Resources Special Report 97-4.*

As a part of the above referenced effort, delineations based on two sets of assumptions were performed. In the first instance, delineations were developed by combining the vertical travel time through the low-permeability zone with the horizontal travel time through the main-producing zone. This resulted in the composite vertical/horizontal delineations ***7yr_hor_vert.shp*** and ***20yr_hor_vert.shp*.** In the second instance, delineations were based solely on horizontal travel times within the main-producing zone. For both methods, delineations were performed for seven and 20-year times-of-travel. The seven-year, vertical/horizontal combination was adopted (1999) by ordinance as the wellhead protection area for Escambia County.

Source material location .... *NWFWMD headquarters, Ground Water Bureau*
Media of source.......................... *ARC/Info coverages*
Scale of source .... *NA*

••

DATA ATTRIBUTES

Column	Item name	Description
2	Index#	Table sequence number.
3	Area	Polygon area, in square meters.

4	Perimeter	Polygon perimeter, in meters.
5	Area-acres	Polygon area, in acres.
6	Area-mi2	Polygon area, in square miles.
7	Yrs	Time of travel associated with wellhead protection areas.

••

DATA LAYER PROVIDING ORGANIZATION

Providing agency.............*Northwest Florida Water Management District*
Contact person................*Chief—Bureau of Ground Water*
Phone number.................*850-539-5999*
Agency address ....*81 Water Management Drive, Havana, FL 32333*

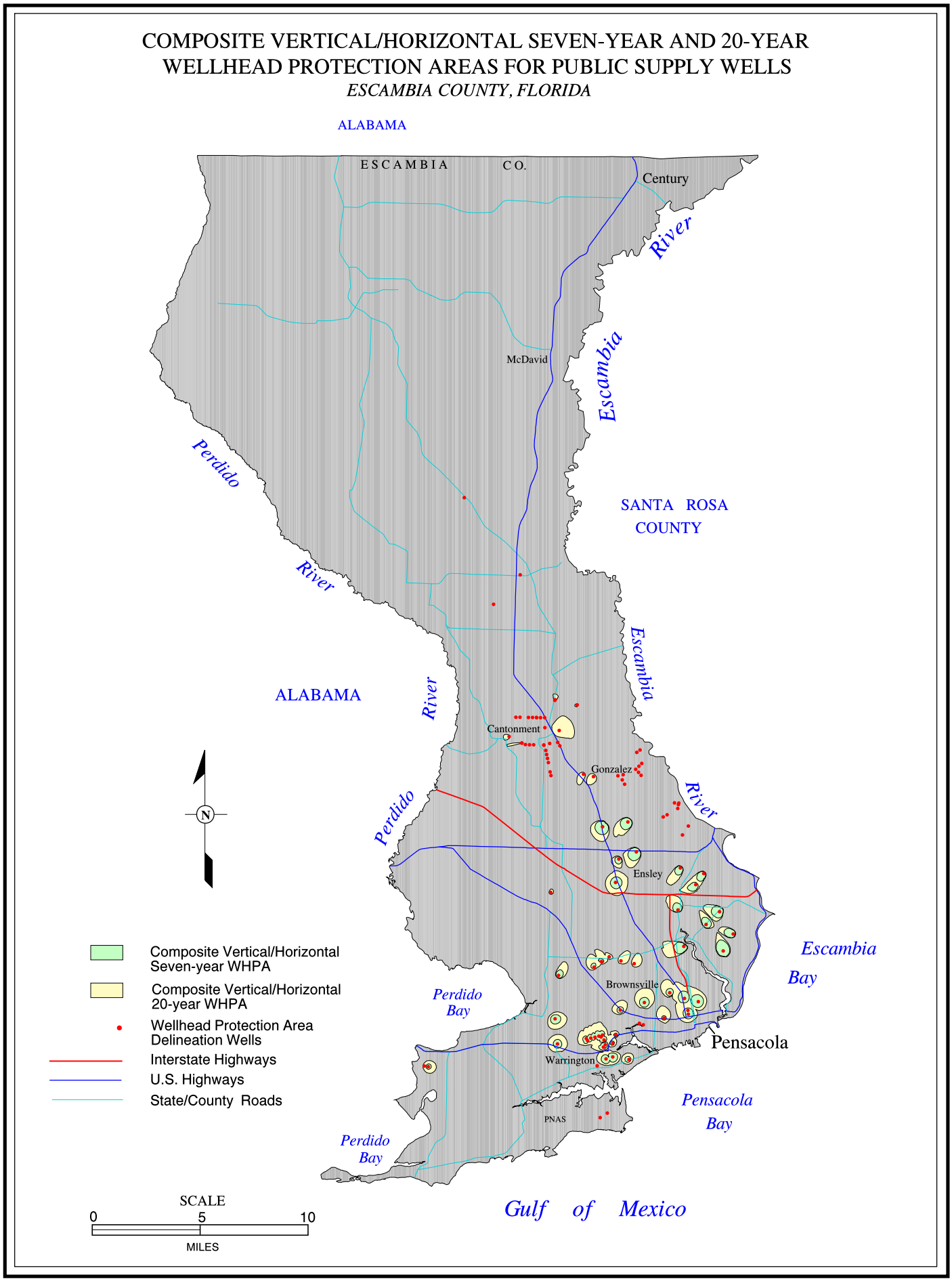

Figure 8. Composite Vertical/Horizontal Seven-year and 20-year Wellhead Protection Areas for Public Supply Wells, View One.

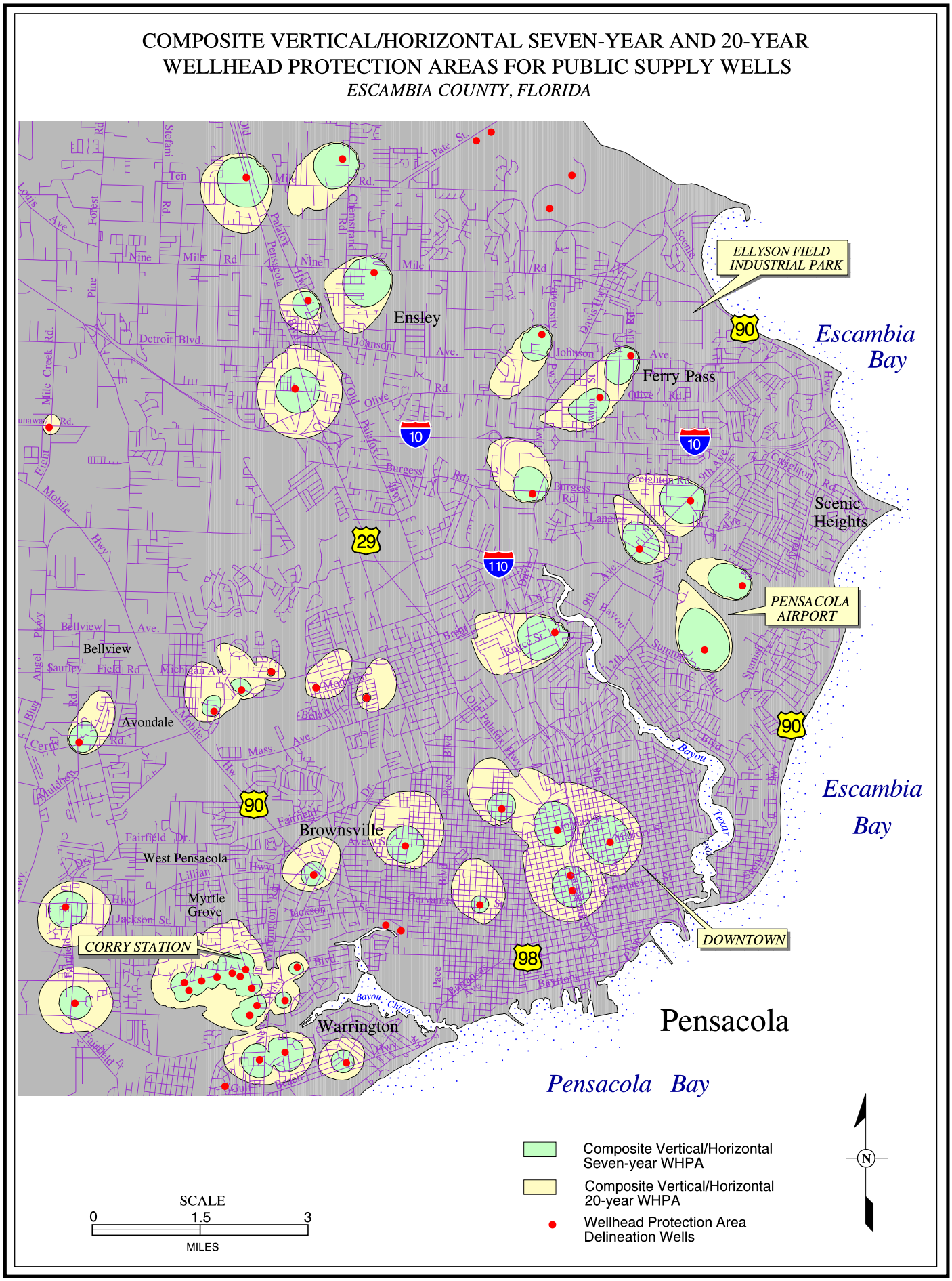

Figure 9. Composite Vertical/Horizontal Seven-year and 20-year Wellhead Protection Areas for Public Supply Wells, View Two.

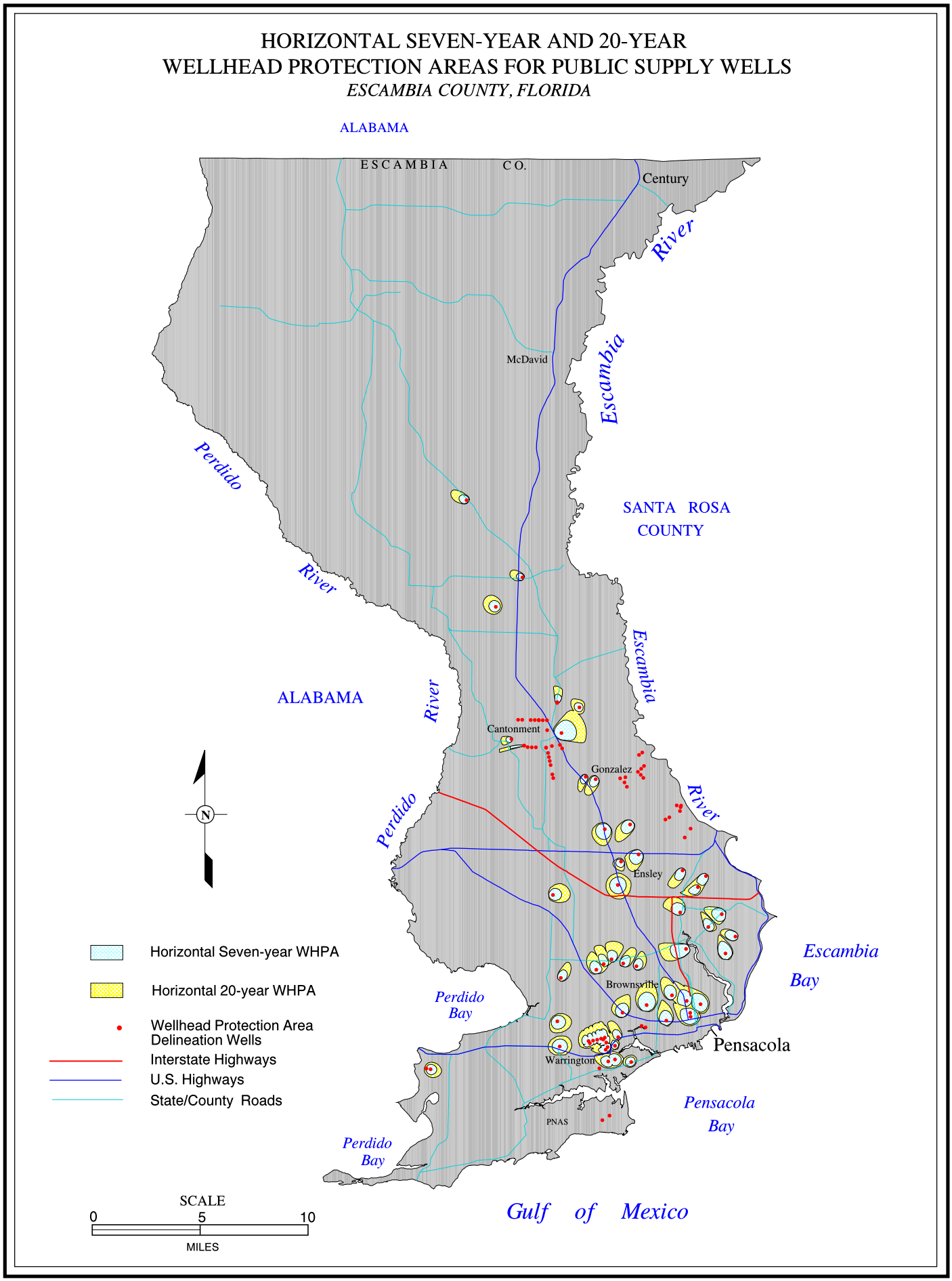

Figure 10. Horizontal Seven-year and 20-year Wellhead Protection Areas for Public Supply Wells, View One.

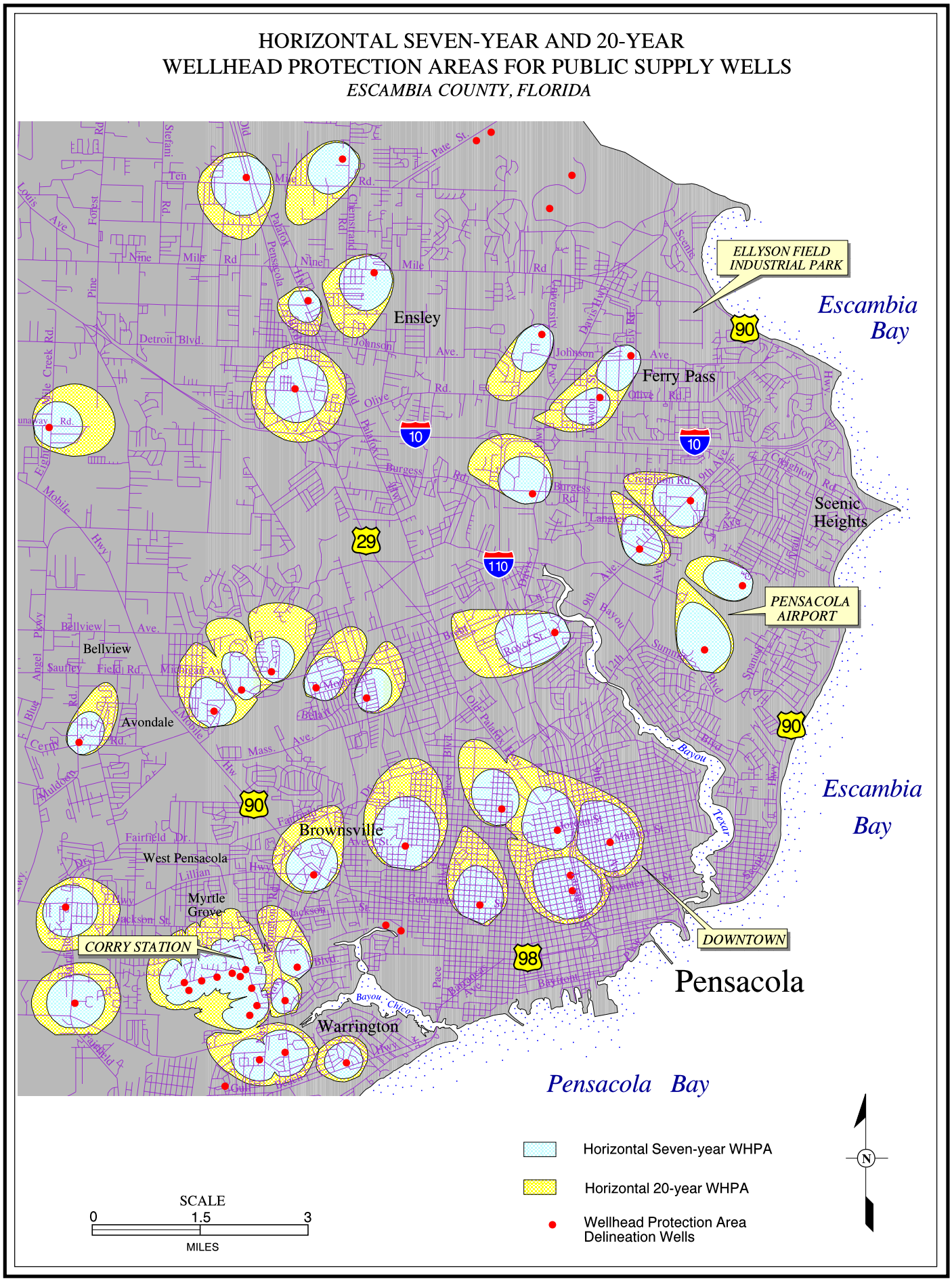

Figure 11. Horizontal Seven-year and 20-year Wellhead Protection Areas for Public Supply Wells, View Two.

MODEL-CALIBRATED LOW-PERMEABILITY ZONE VERTICAL HYDRAULIC CONDUCTIVITY

DESCRIPTION OF DATA LAYER

Data layer name..............***vertical_k_lpz.shp***
Description......................*Calibrated vertical hydraulic conductivity distribution of the low-permeability zone (model layer 6), as developed during calibration of the ECUA WHPA delineation model.*
Type................................*polygon*
Datum ....*NAD 83*
Projection........................*UTM Zone 16*
Map Units........................*Meters*

Conversion from source to data layer: *polygons were exported from ARC/Info coverage.*

DESCRIPTION OF SOURCE MATERIALS

••

Source reference materials: *"Wellhead Protection Area Delineation in Southern Escambia County, Florida", prepared by the Northwest Florida Water Management District, December 1997, Water Resources Special Report 97-4.*

Source material location............. *NWFWMD headquarters, Ground Water Bureau*
Media of source.......................... *ARC/Info coverage*
Scale of source .... *NA*

••

DATA ATTRIBUTES

Column	Item name	Description
2	Index#	Table sequence number.
3	Area	Polygon area, in square meters.
4	Perimeter	Polygon perimeter, in meters.
5	Kz	Low-permeability zone (model layer 6) vertical hydraulic conductivity, in ft/d.
6	Kx	Low-permeability zone horizontal hydraulic conductivity, in ft/d.
7	Ky	Low-permeability zone horizontal hydraulic conductivity, in ft/d.
8	Porosity	Numerical model value, dimensionless.

••

DATA LAYER PROVIDING ORGANIZATION

Providing agency.............*Northwest Florida Water Management District*
Contact person................*Chief—Bureau of Ground Water*
Phone number.................*850-539-5999*
Agency address ....*81 Water Management Drive, Havana, FL*

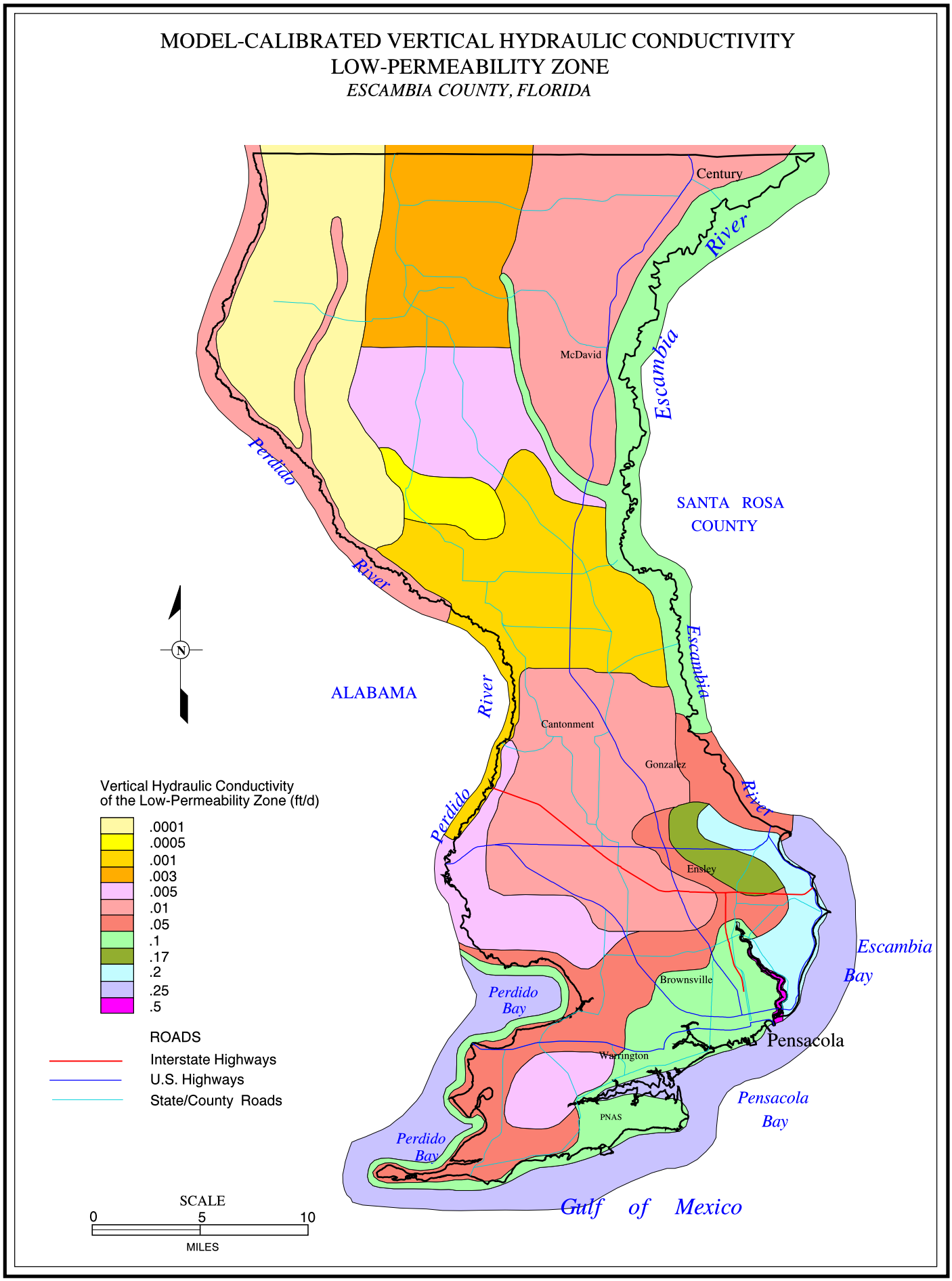

Figure 12. Model-Calibrated Low-Permeability Zone Vertical Hydraulic Conductivity.

MODEL-CALIBRATED MAIN-PRODUCING ZONE HORIZONTAL HYDRAULIC CONDUCTIVITY

DESCRIPTION OF DATA LAYER

Data layer name..............***horizontal_k_mpz.shp***
Description......................*Calibrated horizontal hydraulic conductivity distribution of the main-producing zone (model layer 2), as developed during calibration of the ECUA WHPA delineation model.*
Type................................*polygon*
Datum ....*NAD 83*
Projection........................*UTM Zone 16*
Map Units........................*Meters*

Conversion from source to data layer: *polygons were exported from ARC/Info coverage.*

DESCRIPTION OF SOURCE MATERIALS

••

Source reference materials: *"Wellhead Protection Area Delineation in Southern Escambia County, Florida", prepared by the Northwest Florida Water Management District, December 1997, Water Resources Special Report 97-4.*

Source material location............. *NWFWMD headquarters, Ground Water Bureau*
Media of source.......................... *ARC/Info coverage*
Scale of source .... *NA*

••

DATA ATTRIBUTES

Column	Item name	Description
2	Index#	Table sequence number.
3	Area	Polygon area, in square meters.
4	Perimeter	Polygon perimeter, in meters.
5	Kz	Main-producing zone (model layer 2) horizontal hydraulic conductivity, in ft/d.
6	Kx	Main-producing zone horizontal hydraulic conductivity, in ft/d.
7	Ky	Main-producing zone horizontal hydraulic conductivity, in ft/d.
8	Porosity	Numerical model value, dimensionless.

••

DATA LAYER PROVIDING ORGANIZATION

Providing agency.............*Northwest Florida Water Management District*
Contact person................*Chief—Bureau of Ground Water*
Phone number.................*850-539-5999*
Agency address ....*81 Water Management Drive, Havana, FL*

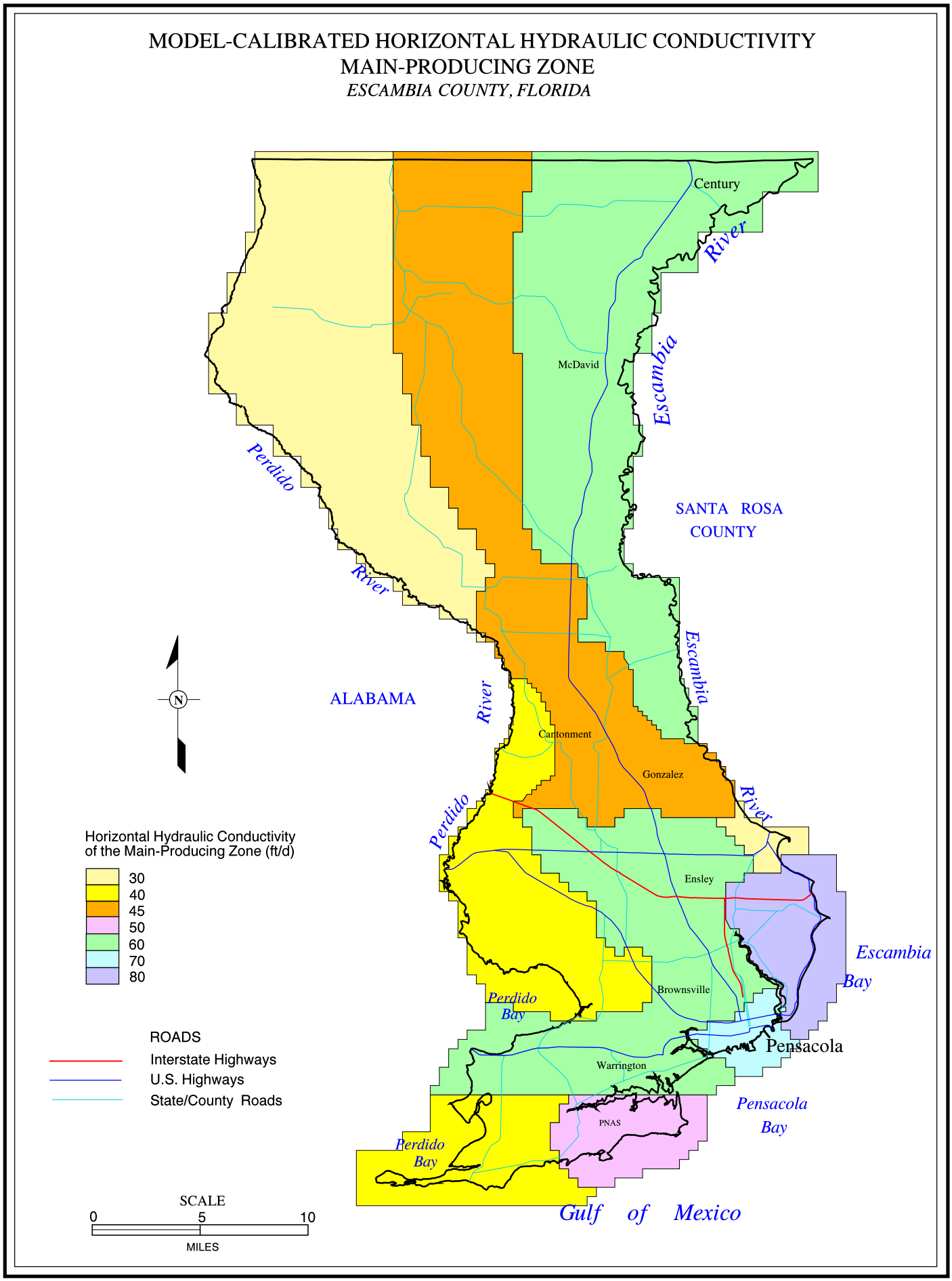

Figure 13. Model-Calibrated Main-Producing Zone Horizontal Hydraulic Conductivity.

PALAFOX_BROWNFIELD.SHP

DESCRIPTION OF DATA LAYER

Data layer name..............***palafox_brownfield.shp***
Description......................*Palafox Corridor Brownfield.*
Type................................*Polygon*
Datum ....*NAD 83*
Projection........................*UTM Zone 16*
Map Units........................*Meters*

Conversion from source to data layer: *polygon was interactively digitized from onscreen using a City of Pensacola city limits coverage and Streets.shp coverage as backdrops.*

DESCRIPTION OF SOURCE MATERIALS

••

Source reference materials: *paper map.*

Responsible agency........*Escambia County Community Redevelopment Agency*
Contact person................*Keith Wilkins*
Title.................................*Chief—Community Redevelopment Agency*
Phone number.................*850-595-3216*
Media of source..............*paper*
Scale of source ....*1 inch ≈ 1,580 ft*

••

DATA ATTRIBUTES

None

••

DATA LAYER PROVIDING ORGANIZATION

Providing agency.............*Northwest Florida Water Management District*
Contact person................*Chief—Bureau of Ground Water*
Phone number.................*850-539-5999*
Agency address ....*81 Water Management Drive, Havana, FL 32333*

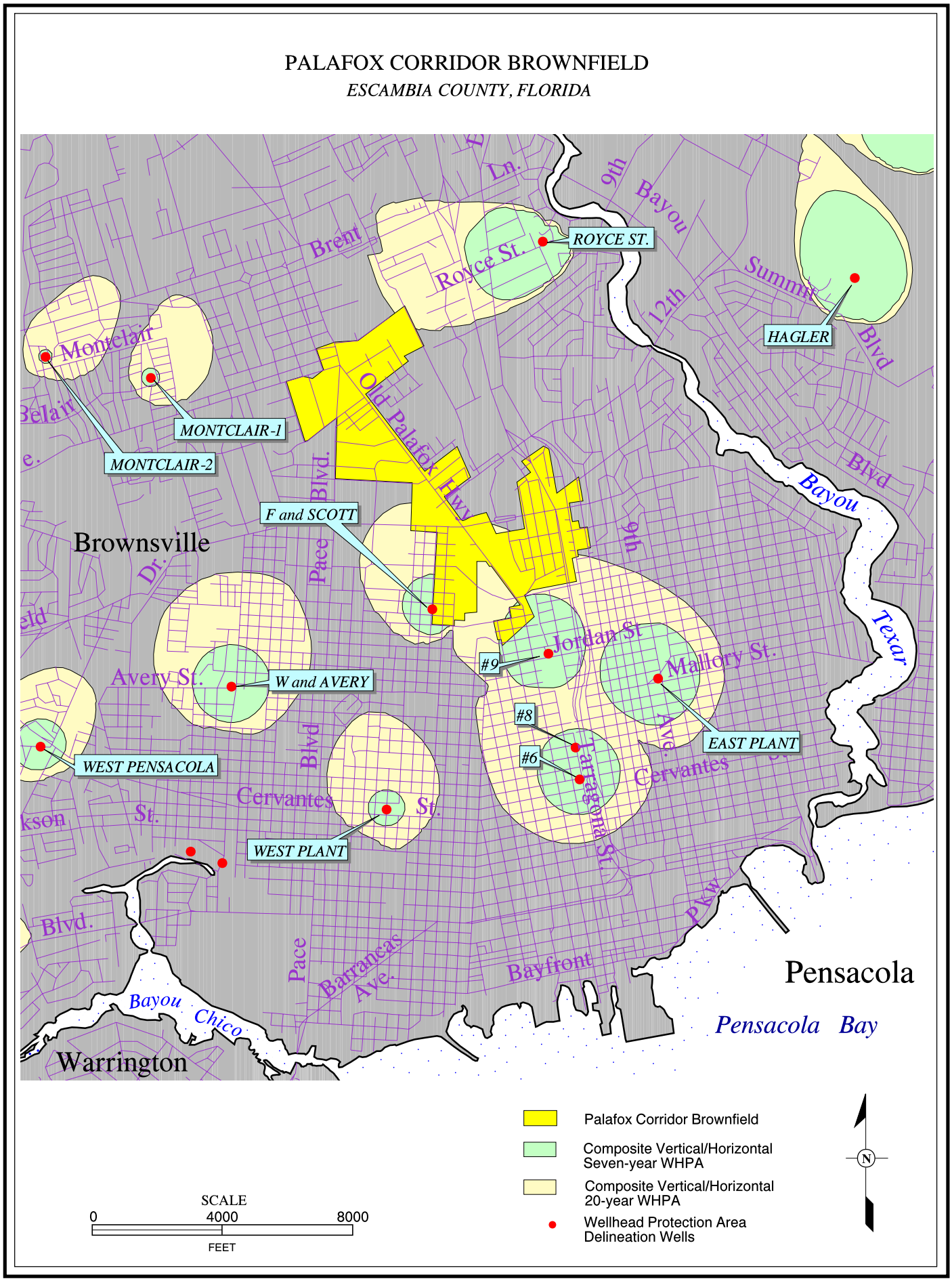

Figure 14. Palafox Corridor Brownfield.

NPL.SHP

DESCRIPTION OF DATA LAYER

Data layer name..............***npl.shp***
Description......................*National Priorities List (NPL) sites.*
Type................................*Polygon*
Datum ....*NAD 83*
Projection........................*UTM Zone 16*
Map Units........................*Meters*

Conversion from source to data layer: *polygons were interactively digitized from onscreen using DOQ.shp and/or Streets.shp as backdrops.*

DESCRIPTION OF SOURCE MATERIALS

••

Agrico Chemical

Source reference materials: *"Draft Feasibility Study, Agrico Chemical Site, Pensacola, Florida", prepared by Geraghty and Miller, Inc., April 1992, prepared for Conoco, Inc. and Freeport-McMoRan, Inc., Geraghty and Miller Project No. JF02919.*

Site status ....*National Priorities List site (active)*
Source material location.....*NWFWMD headquarters, Ground Water Bureau*
Media of source.................*paper map, Figure 1-2*
Scale of source ....1 *inch ≈ 200 ft*

••

American Creosote

Source reference materials: *"Phenolic Contamination in the Sand-and-Gravel Aquifer from a Surface Impoundment of Wood Treatment Wastes, Pensacola, Florida", prepared by the USGS, USGS WRI Report 84-4230, 1984.*

Site status ....*National Priorities List site (active)*
Source material location.....*NWFWMD headquarters, Ground Water Bureau*
Media of source.................*paper map, Figure 2*
Scale of source ....*1 inch ≈ 435 ft*

••

Beulah Landfill

Source reference materials: *"Five-Year Review Report , Beulah Landfill Site, Escambia County, Florida", prepared by Escambia County Department of Public Works, September 1998, prepared for USEPA.*

Site status ....*National Priorities List site (delisted)*
Source material location.....*NWFWMD headquarters, Ground Water Bureau*
Media of source..................*paper map, Figure 2*
Scale of source ....*1 inch ≈ 333 ft*

••

Dubose Oil Products

Source reference materials: *"Report of Site Data from the Remedial Investigation, Volume I", prepared by Engineering—Science, November 1988, prepared for the Dubose Oil Products Steering Committee.*

Site status ....*National Priorities List site (active)*
Source material location.....*NWFWMD headquarters, Ground Water Bureau*
Media of source..................*paper map, Figure 1.1*
Scale of source ....*1 inch ≈ 2,000 ft*

••

Escambia Treating Company

Source reference materials: *"Remedial Investigation – Phase I Site Characterization Summary Report for the Escambia Treating Company Site, Pensacola, Florida", prepared by CDM Federal Programs Corp., October 1996, prepared for the USEPA, under USEPA Contract No. 68-W9-0056, Work Assignment No. 062-4LGS.*

Site status ....*National Priorities List site (active)*
Source material location.....*NWFWMD headquarters, Ground Water Bureau*
Media of source..................*paper map, Figure 2-4*
Scale of source ....*1 inch ≈ 200 ft*

••

Pensacola Naval Air Station

Site status ....*National Priorities List site (active/federal)*
Source material location.....*NWFWMD headquarters, Ground Water Bureau*
Media of source..................*ARC/Info coverage*
Scale of source ....*NA*

••

Pioneer Sand Company

Source reference materials: *"Site Investigation, Pioneer Sand, Pensacola, Florida", prepared by Woodward-Clyde Consultants, December 1985, prepared for the FDER, WCC File No. W4C6080.*

Site status ....*National Priorities List site (delisted)*
Source material location.....*NWFWMD headquarters, Ground Water Bureau*
Media of source..................*paper map, Figure 2*
Scale of source ....*1 inch ≈ 160 ft*

••

DATA ATTRIBUTES

Column	Item name	Description
3	Index#	Table sequence number.
4	Area	Polygon area (square meters).
5	Perimeter	Polygon perimeter (meters).
6	Hectares	Polygon area (hectares).
7	Status	Present status (proposed, denied, deferred, active or delisted) of each NPL site.
8	Site_name	Site name assigned by FDEP/EPA to each NPL site.
9	Site_addre	Site address of each NPL site.
10	City	City of each NPL site.
11	Process	Process used at each NPL site.
12	Cat_1	Category of contamination found at each NPL site. Note: N/A refers to Department of Defense sites, some denied sites and some proposed sites.
13	Cat_2	Category of contamination found at each NPL site. Note: N/A refers to Department of Defense sites, some denied sites and some proposed sites.
14	Cat_3	Category of contamination found at each NPL site. Note: N/A refers to Department of Defense sites, some denied sites and some proposed sites.

Tabular data for these sites taken from the Florida Department of Environmental Protection statewide coverage of National Priorities List hazardous waste sites.

••

DATA LAYER PROVIDING ORGANIZATION

Providing agency.............*Northwest Florida Water Management District*
Contact person................*Chief—Bureau of Ground Water*
Phone number.................*850-539-5999*
Agency address ....*81 Water Management Drive, Havana, FL 32333*

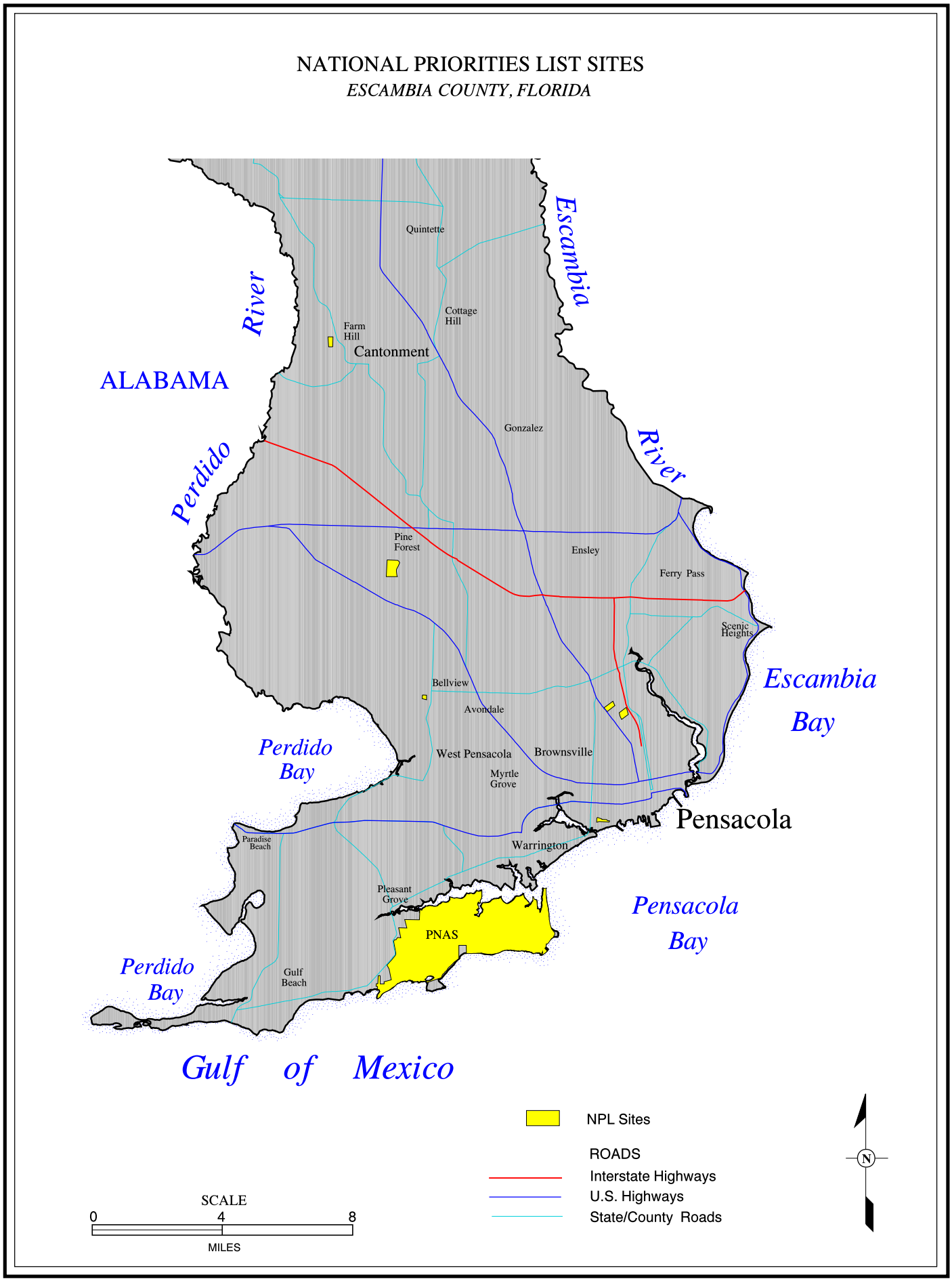

Figure 15. National Priorities List Sites.

MISC_SITES.SHP

DESCRIPTION OF DATA LAYER

Data layer name..............***misc_sites.shp***
Description......................*State-Funded Action sites and one miscellaneous site.*
Type................................*Polygon*
Datum ....*NAD 83*
Projection........................*UTM Zone 16*
Map Units........................*Meters*

Conversion from source to data layer: *polygons were interactively digitized from onscreen using DOQ.shp and/or Streets.shp as backdrops.*

DESCRIPTION OF SOURCE MATERIALS

••

Fashion Dry Cleaners

Source reference materials: *"Work Plan for the 30 Percent Remedial Design at the Fashion Dry Cleaners Contamination Site, Pensacola, Florida", prepared by Camp, Dresser and McKee, Inc., December 1992, prepared for the FDER.*

Site status ....*State-Funded Action site (active)*
Source material location.....*NWFWMD headquarters, Ground Water Bureau*
Media of source..................*paper map, Figure 1-2*
Scale of source ....*1 inch ≈ 600 ft*

••

Klondike Landfill

Source reference materials: *"Contamination Assessment Report for Klondike Landfill, Escambia County, Florida", prepared by CH2MHill Southeast, Inc. and Baskerville-Donovan Engineers, Inc., January 1991, prepared for Escambia County Board of County Commissioners.*

Site status ....*miscellaneous site*
Source material location.....*NWFWMD headquarters, Ground Water Bureau*
Media of source..................*paper map, Figure 2-1*
Scale of source ....*1 inch ≈ 500 ft*

••

Omni-Vest Landfill

Source reference materials: *"Omni-Vest Landfill, Pensacola, Florida, Phase 3 Contamination Assessment", prepared by Environmental Science and Engineering, Inc., October 1987, prepared for the FDER.*

Site status ....*State-Funded Action site (active)*
Source material location.....*NWFWMD headquarters, Ground Water Bureau*
Media of source..................*paper map, Figure 1-2*
Scale of source ....*1 inch ≈ 150 ft*

••

DATA ATTRIBUTES

Column	Item name	Description
3	Index#	Table sequence number.
4	Site_name	Site name assigned by FDEP.

••

DATA LAYER PROVIDING ORGANIZATION

Providing agency.............*Northwest Florida Water Management District*
Contact person................*Chief—Bureau of Ground Water*
Phone number.................*850-539-5999*
Agency address ....*81 Water Management Drive, Havana, FL 32333*

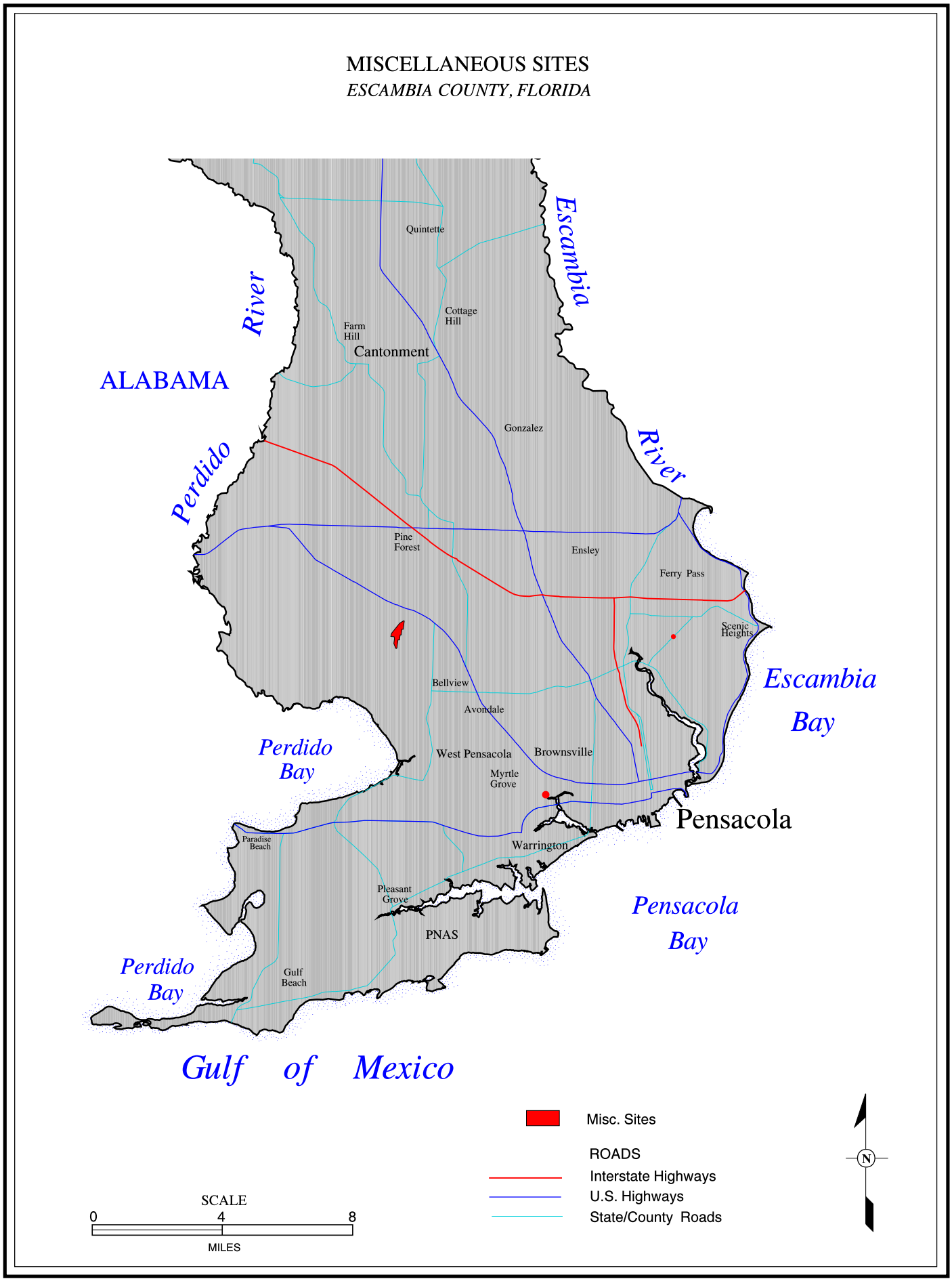

Figure 16. Miscellaneous Sites.

PLUME DELINEATIONS

DESCRIPTION OF DATA LAYER

Data layer name..............*Various*
Description......................*Ground water contamination distributions.*
Type................................*Polygon*
Datum ....*NAD 83*
Projection........................*UTM Zone 16*
Map Units........................*Meters*

Conversion from source to data layer: *polygons were interactively digitized from onscreen using DOQ.shp and/or Streets.shp as backdrops.*

DESCRIPTION OF SOURCE MATERIALS

••

Agrico Chemical Surficial Zone Fluoride Contaminant Delineation

Source reference materials: *"Draft Feasibility Study Agrico Chemical Site, Pensacola, Florida, Volume 1", prepared by Geraghty and Miller, Inc., April 1992, prepared for Conoco, Inc. and Freeport-McMoRan, Inc., Geraghty and Miller Project No. JF02919.*

Data layer name... ***agrico_sz_fluor.shp***
Delineation represents conditions in.............................. *February 1992*
Delineation represents conditions in.............................. *surficial zone*
Delineation represents fluoride concentrations ≥ than .... *1 mg/L.*

Source material location.....*NWFWMD headquarters, Ground Water Bureau*
Media of source.................*paper map, Figure 1-39*
Scale of source ....*1 inch ≈ 2,000 ft*

••

Agrico Chemical Main-Producing Zone Fluoride Contaminant Delineation

Source reference materials: *"Draft Feasibility Study Agrico Chemical Site, Pensacola, Florida, Volume 1", prepared by Geraghty and Miller, Inc., April 1992, prepared for Conoco, Inc. and Freeport-McMoRan, Inc., Geraghty and Miller Project No. JF02919.*

Data layer name... ***agrico_mpz_fluor.shp***
Delineation represents conditions in.............................. *February 1992*
Delineation represents conditions in.............................. *main-producing zone*
Delineation represents fluoride concentrations ≥ than .... *1 mg/L.*

Source material location.....*NWFWMD headquarters, Ground Water Bureau*
Media of source.................*paper map, Figure 1-40*
Scale of source ....1 *inch ≈ 2,000 ft*

Agrico Chemical Main-Producing Zone Nitrate Contaminant Delineation

Source reference materials: *"Draft Feasibility Study Agrico Chemical Site, Pensacola, Florida, Volume 1", prepared by Geraghty and Miller, Inc., April 1992, prepared for Conoco, Inc. and Freeport-McMoRan, Inc., Geraghty and Miller Project No. JF02919.*

Data layer name.. ***agrico_mpz_no3.shp***
Delineation represents conditions in.............................. *February 1992*
Delineation represents conditions in.............................. *main-producing zone*
Delineation represents nitrate concentrations ≥ than...... *10 mg/L.*

Source material location.....*NWFWMD headquarters, Ground Water Bureau*
Media of source..................*paper map, Figure 1-46*
Scale of source ....*1 inch ≈ 2,000 ft*

••

Agrico Chemical Main-Producing Zone Sulfate Contaminant Delineation

Source reference materials: *"Draft Feasibility Study Agrico Chemical Site, Pensacola, Florida, Volume 1", prepared by Geraghty and Miller, Inc., April 1992, prepared for Conoco, Inc. and Freeport-McMoRan, Inc., Geraghty and Miller Project No. JF02919.*

Data layer name.. ***agrico_mpz_so4.shp***
Delineation represents conditions in.............................. *February 1992*
Delineation represents conditions in.............................. *main-producing zone*
Delineation represents sulfate concentrations ≥ than ..... *25 mg/L.*

Source material location.....*NWFWMD headquarters, Ground Water Bureau*
Media of source..................*paper map, Figure 1-43*
Scale of source ....*1 inch ≈ 2,000 ft*

••

American Creosote Surficial Zone Total Phenol Contaminant Delineation

Source reference materials: *"Phenolic Contamination in the Sand-and-Gravel Aquifer from a Surface Impoundment of Wood Treatment Wastes, Pensacola, Florida", prepared by the USGS, USGS WRI Report 84-4230, 1984.*

Data layer name... ***ac_sz_phenol.shp***
Delineation represents conditions in..................................... *July 1981*
Delineation represents conditions in..................................... *surficial zone*
Delineation represents total phenol concentrations ≥ than..... *1 μg/L.*

Source material location.....*NWFWMD headquarters, Ground Water Bureau*
Media of source..................*paper map, Figure 7*
Scale of source ....*1 inch ≈ 455 ft*

••

E.M. Chadbourne Surficial Zone 1,1 Dichloroethene Contaminant Delineation

Source reference materials: *"Remedial Action Plan, E.M. Chadbourne Construction Facility, Pensacola, Escambia County, Florida", prepared by Westinghouse Remediation Services, Inc., April 1994, prepared for Florida Department of Transportation, WRS Project No. 2330-93-3386.*

Data layer name.................................***chadbourne_sz_dichloroethene.shp***
Delineation represents conditions in..................................... *January 1994*
Delineation represents conditions in..................................... *surficial zone*
Delineation represents total phenol concentrations ≥ than..... *7 μg/L.*

Source material location.....*NWFWMD headquarters, Ground Water Bureau*
Media of source..................*paper map, Figure 10*
Scale of source ....*1 inch ≈ 150 ft*

••

E.M. Chadbourne Surficial Zone 1,1,1 Trichloroethane Contaminant Delineation

Source reference materials: *"Remedial Action Plan, E.M. Chadbourne Construction Facility, Pensacola, Escambia County, Florida", prepared by Westinghouse Remediation Services, Inc., April 1994, prepared for Florida Department of Transportation, WRS Project No. 2330-93-3386.*

Data layer name.................................***chadbourne_sz_trichloroethane.shp***
Delineation represents conditions in..................................... *January 1994*
Delineation represents conditions in..................................... *surficial zone*
Delineation represents total phenol concentrations ≥ than..... *150 μg/L.*

Source material location.....*NWFWMD headquarters, Ground Water Bureau*
Media of source..................*paper map, Figure 12*
Scale of source ....*1 inch ≈ 150 ft*

••

E.M. Chadbourne Surficial Zone Trichloroethene Contaminant Delineation

Source reference materials: *"Remedial Action Plan, E.M. Chadbourne Construction Facility, Pensacola, Escambia County, Florida", prepared by Westinghouse Remediation Services, Inc., April 1994, prepared for Florida Department of Transportation, WRS Project No. 2330-93-3386.*

Data layer name.................................***chadbourne_sz_trichloroethene.shp***
Delineation represents conditions in..................................... *January 1994*
Delineation represents conditions in..................................... *surficial zone*
Delineation represents total phenol concentrations ≥ than..... *3 μg/L.*

Source material location.....*NWFWMD headquarters, Ground Water Bureau*
Media of source..................*paper map, Figure 14*
Scale of source ....*1 inch ≈ 150 ft*

••

Escambia Treating Main-Producing Zone "Total Organics" Contaminant Delineation

Source reference materials: *"Draft Feasibility Study Agrico Chemical Site, Pensacola, Florida, Volume 1", prepared by Geraghty and Miller, Inc., April 1992, prepared for Conoco, Inc. and Freeport-McMoRan, Inc., Geraghty and Miller Project No. JF02919.*

Data layer name.. ***et_mpz_organic.shp***
Delineation represents conditions in.. *February 1992*
Delineation represents conditions in.. *main-producing zone*
Delineation represents "total organics" concentrations ≥ than .... *10 mg/L.*

Source material location.....*NWFWMD headquarters, Ground Water Bureau*
Media of source..................*paper map, Figure 1-49*
Scale of source ....*1 inch ≈ 2,000 ft*

••

Fashion Dry Cleaners Tetrachloroethylene Contaminant Delineation

Source reference materials: *"30 Percent Design Report for the Fashion Dry Cleaners Contamination Site, Pensacola, Florida", prepared by Camp, Dresser and McKee, Inc., December 1992, prepared for the FDER.*

Data layer name.. ***fashion_pce.shp***
Delineation represents conditions in............................... *1992*
Delineation represents conditions in............................... *Sand-and-Gravel Aquifer*
Delineation represents PCE concentrations ≥ than......... *1 µg/L.*

Source material location.....*NWFWMD headquarters, Ground Water Bureau*
Media of source..................*paper map, Figure 1-10*
Scale of source ....*1 inch ≈ 600 ft*

••

Mariner Mall Tetrachloroethylene Contaminant Delineation

Source reference materials: *"Contamination Assessment Report Former Dry Cleaners Site, Mariner Mall, Pensacola, Florida", prepared by Woodward-Clyde Consultants, March 1996, prepared for Hibernia National Bank.*

Data layer name.. ***mariner_sz_pce.shp***
Delineation represents conditions in............................... *1995*
Delineation represents conditions in............................... *surficial zone*
Delineation represents PCE concentrations ≥ than......... *1 µg/L.*

Source material location.....*NWFWMD headquarters, Ground Water Bureau*
Media of source..................*paper map, Figure 13-1*
Scale of source ....*1 inch ≈ 120 ft*

••

DATA ATTRIBUTES

Column	Item name	Description
3	delin_zone	Sand-and-Gravel Aquifer zone which contains the mapped plume.
4	const	constituent mapped by each plume delineation.
5	const_conc	constituent concentrations within the plume delineation are greater than or equal to the value given.
6	site_name	name of each site as designated by FDEP/USEPA.
7	delin_date	date of sampling used to develop delineation contour.

••

DATA LAYER PROVIDING ORGANIZATION

Providing agency.............*Northwest Florida Water Management District*
Contact person................*Chief—Bureau of Ground Water*
Phone number.................*850-539-5999*
Agency address ....81 Water Management Drive, Havana, FL 32333

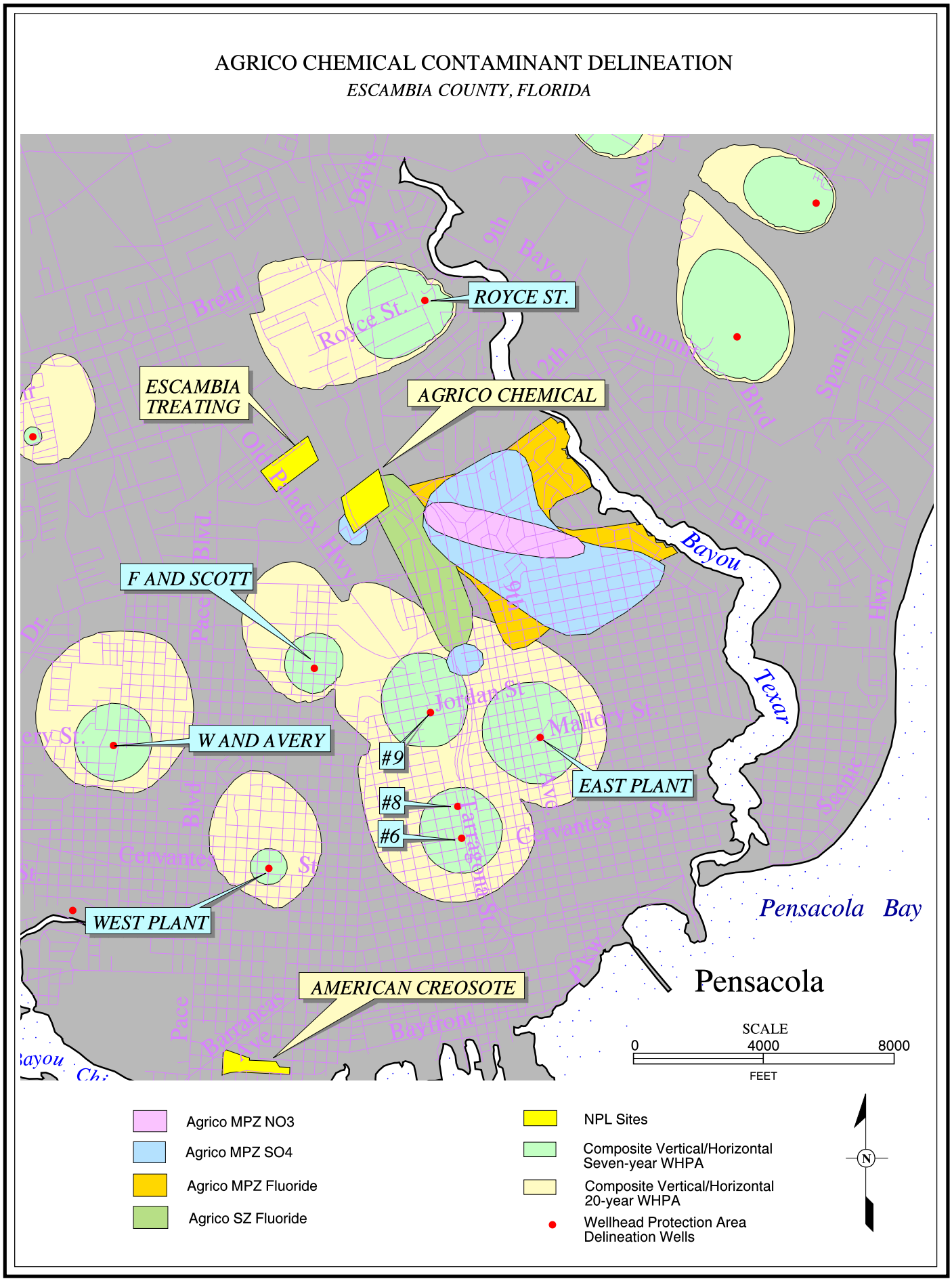

Figure 17. Agrico Chemical Contaminant Delineation.

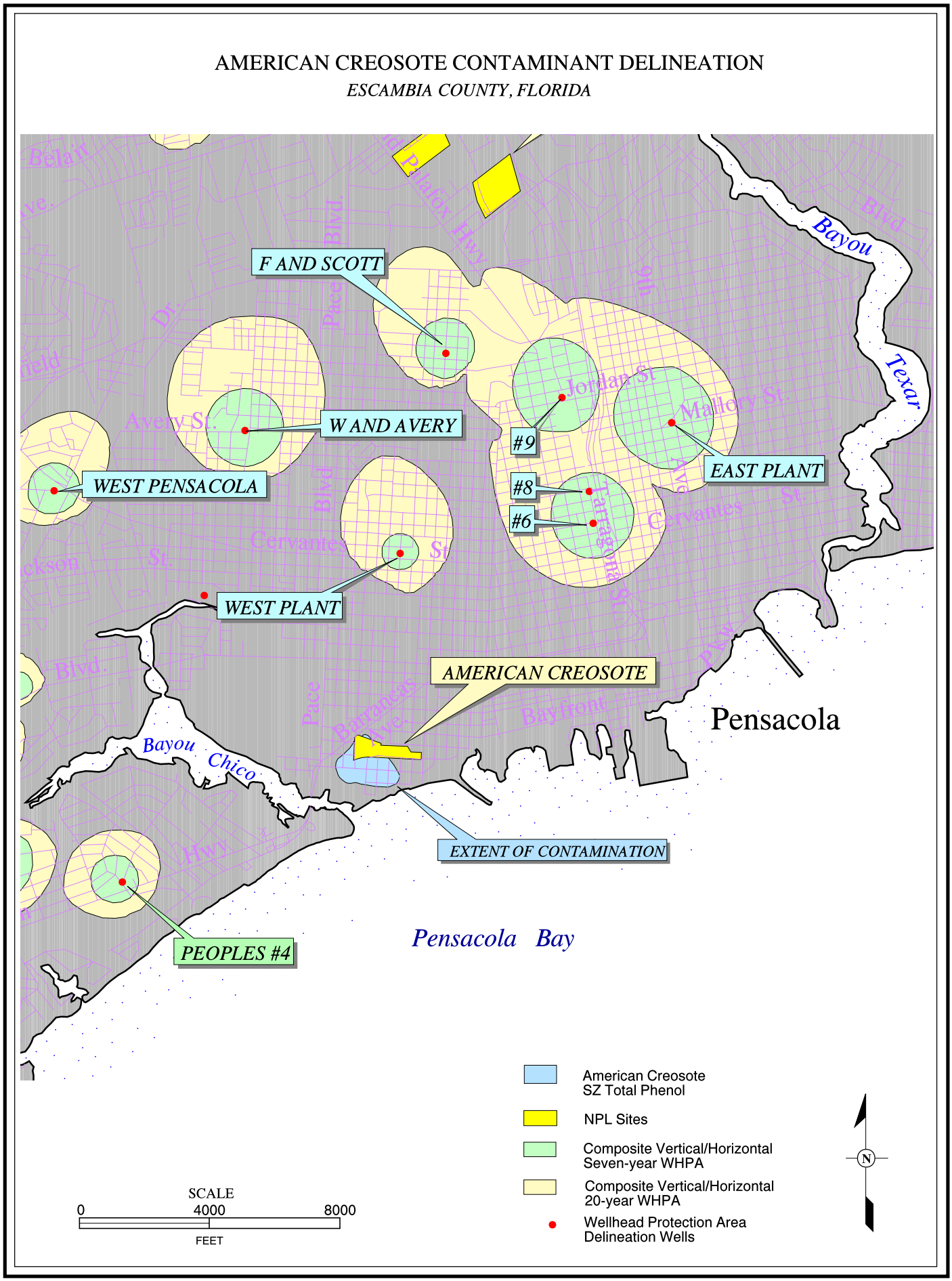

Figure 18. American Creosote Contaminant Delineation.

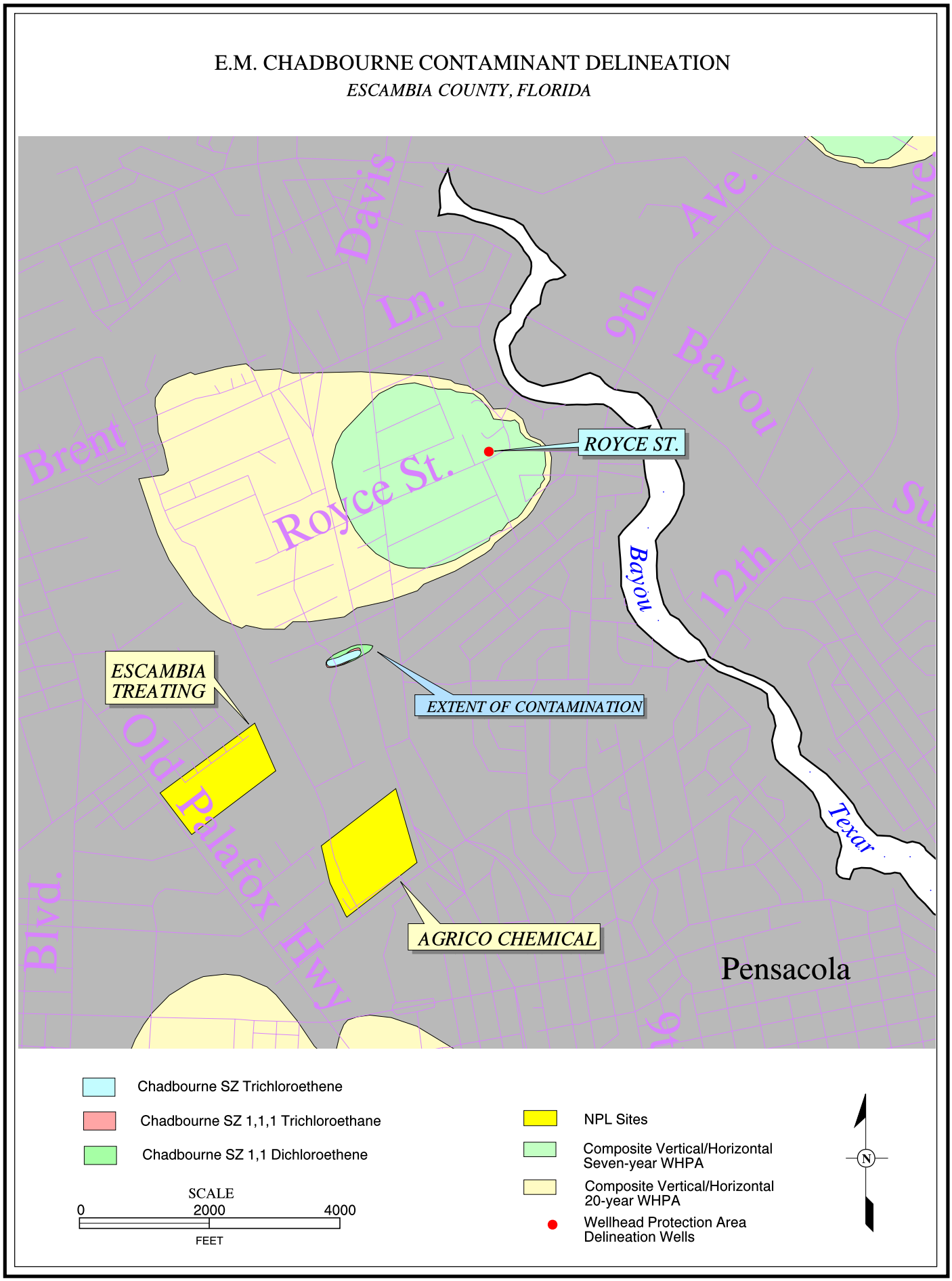

Figure 19. E.M. Chadbourne Contaminant Delineation.

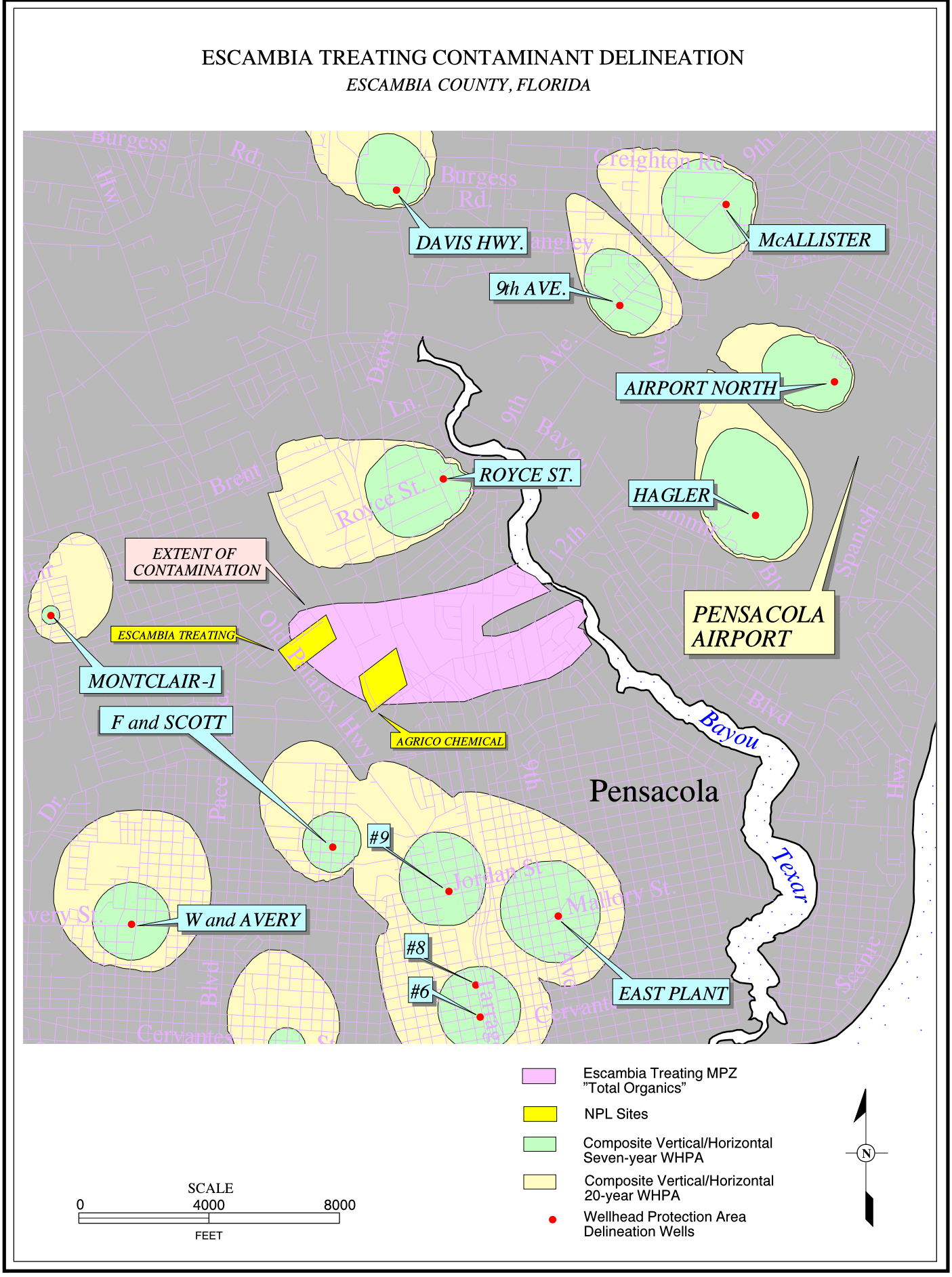

Figure 20. Escambia Treating Contaminant Delineation.

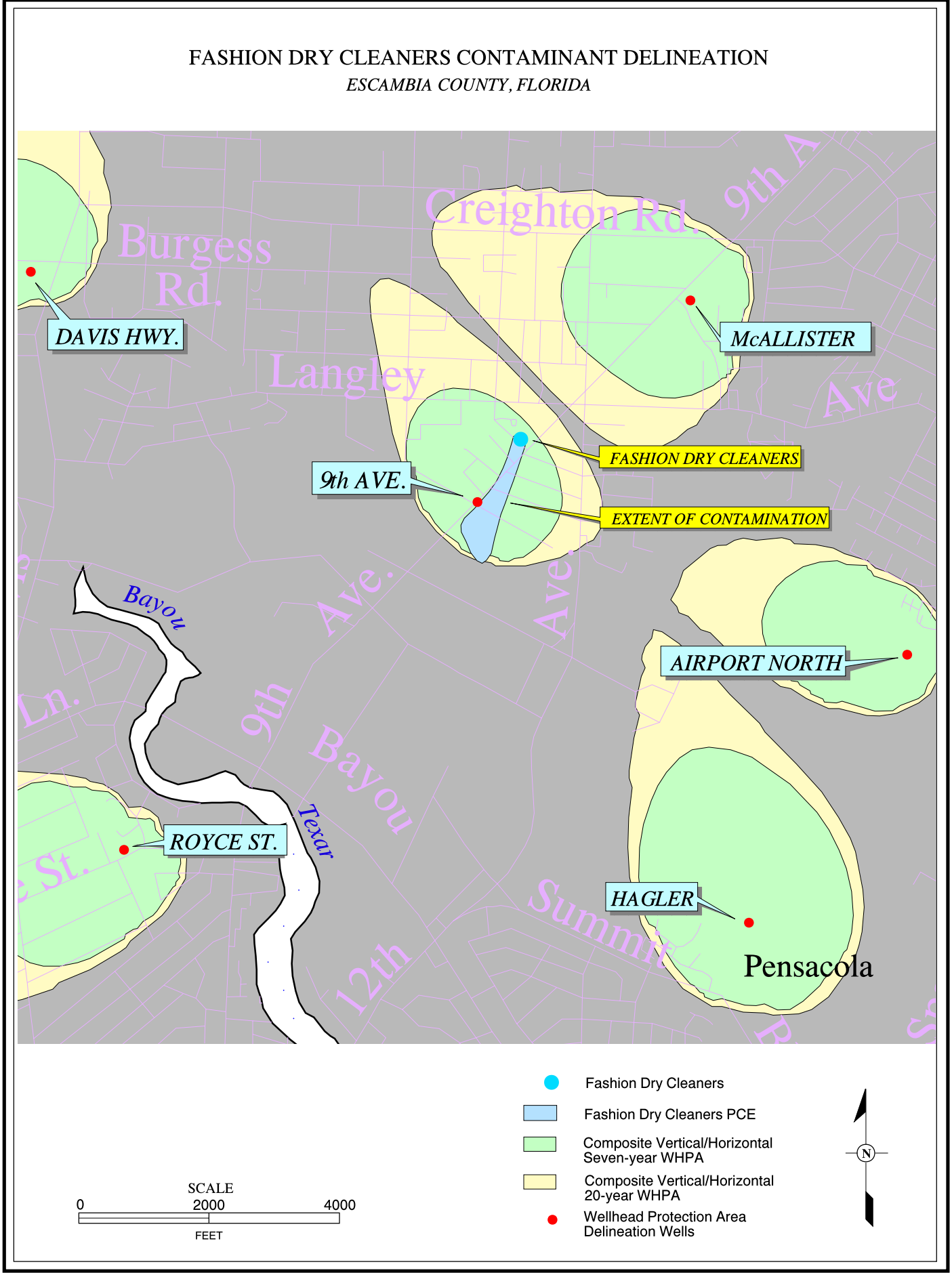

Figure 21. Fashion Dry Cleaners Contaminant Delineation.

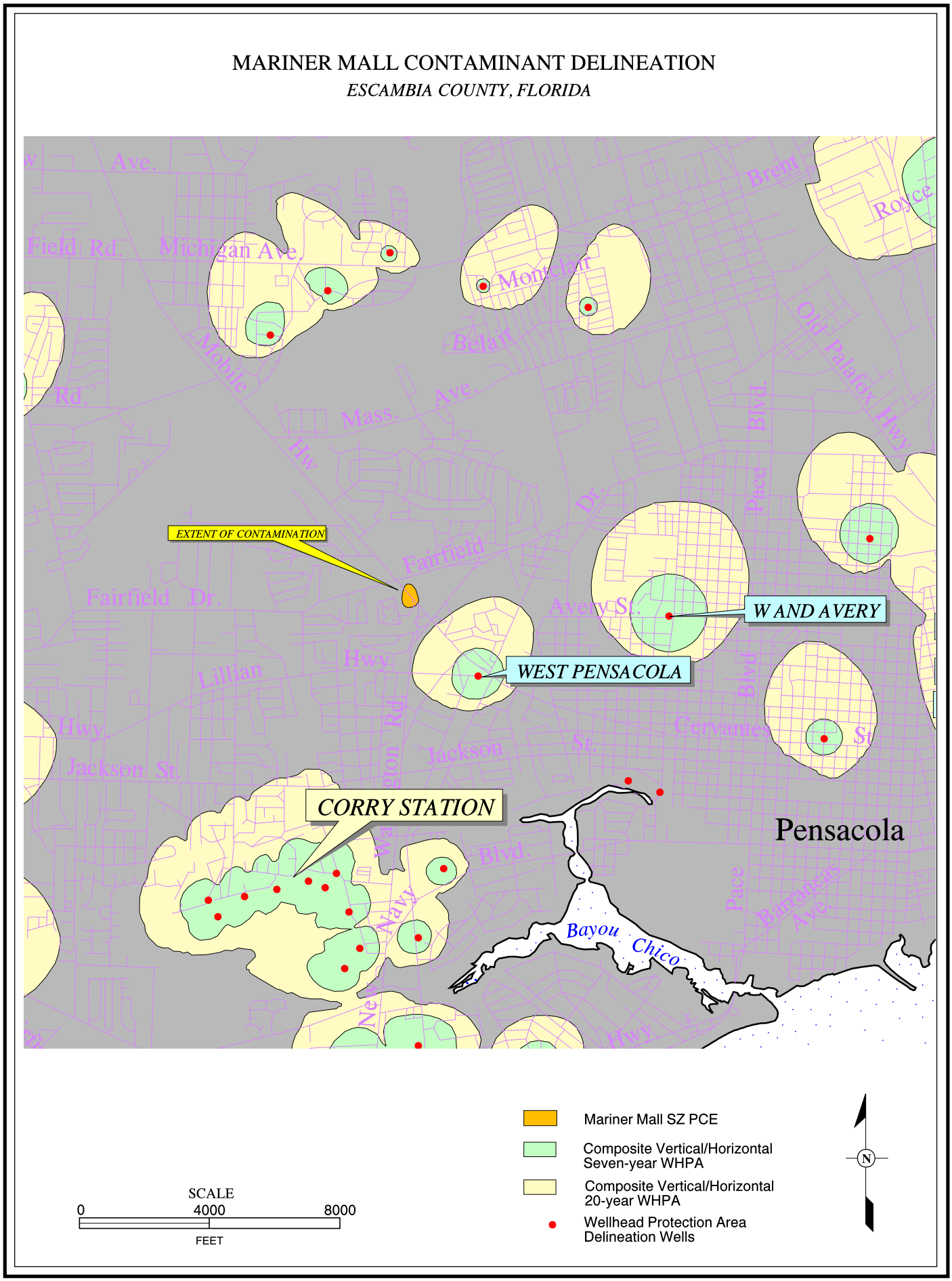

Figure 22. Mariner Mall Contaminant Delineation.

NWFWMD_CLEANERS.SHP

DESCRIPTION OF DATA LAYER

Data layer name.....***NWFWMD_cleaners.shp***
Description .....*Businesses historically engaged in the cleaning of clothes in southern Escambia County.*
Type .....*Point*
Datum *NAD83*
Projection .....*UTM Zone 16*
Map Units.....*Meters*

DESCRIPTION OF SOURCE MATERIALS

This shape file was developed to identify locations were dry-cleaning solvents may potentially have been used at one time or another. The inclusion of any particular business or business location in this shape file (and/or in the associated attribute table) does not imply that either solvents were used at the site or that solvents were released to the environment as a result of activities conducted at the site. Inference regarding whether or not solvents may have been used at these sites is based solely on the inclusion of businesses under business directory or telephone book classifications or listings that may reasonably be inferred to include businesses that use solvents.

The file was developed from information contained in publicly available business directories and telephone books (yellow pages) for the Pensacola area. To develop attribute and locational data, business directories and telephone books were queried for the names and addresses of businesses listed as “cleaners”, “cleaners and dyers”, “cleaners and pressers”, “dry cleaners” and/or “laundries.” The business directories and telephone books used as reference materials are currently available in the West Florida Regional Library. A copy of the relevant portions of the reference documents is available from the District.

Business directories were examined for the years: 1944, 1948, 1950, 1952, 1954, 1956, 1958, 1960, 1962, 1964, 1966, 1968, 1970, 1972, 1974, 1976, 1978, 1980, 1984, 1986, 1988 and 1992. Telephone books were examined for the years: 1956, 1960, 1962, 1964, 1966, 1970, 1972, 1974, 1976, 1978, 1980, 1982, 1984, 1986, 1988, 1994 and 1996. Based on the entries in these documents, business name and address were abstracted. Businesses were assigned to one of three general classifications, “cleaner”, “drycleaner”, or “laundry”, generally based on how the business was listed in the directory or telephone book.

From the review of the source documents, a total of 382 individual businesses meeting the criteria for inclusion were identified. Using the given street addresses, business locations were geo-coded. A total of 343 sites were geocoded. The remaining 39 sites could not be assigned a location. Sixty-six sites were cross-referenced with the FDEP Storage Tank/Contamination Monitoring (STCM) database. Thirty-four of thirty-six FDEP DSCP contaminated sites were also cross-referenced.

Source material location.....*NWFWMD headquarters, Ground Water Bureau*
Media of source.................*paper copies*
Scale of source ....*NA*

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DATA ATTRIBUTES

Column	Item name	Description
2	Index#	table sequence number.
3	Begin_year	Year business first appeared in a business directory or phone book.
4	End_year	Year business last appeared in a business directory or phone book.
5	FDEP_facility_id	FDEP STCM facility identification number, “0” denotes that business does not have a FDEP facility identification number.
6	Address	Business address as obtained from business directory or phone book.
7	Name	Business name as obtained from business directory or phone book.
8	Business_1	Business directory or phone book classification business was listed under, “C” denotes cleaners, “D” denotes drycleaners, and “L” denotes laundry.
9	Business_2	Business directory or phone book classification business was listed under, “C” denotes cleaners, “D” denotes drycleaners, and “L” denotes laundry.
10	Business_3	Business directory or phone book classification business was listed under, “C” denotes cleaners, “D” denotes drycleaners, and “L” denotes laundry.
11	Comments	

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DATA LAYER PROVIDING ORGANIZATION

Providing agency.............*Northwest Florida Water Management District*
Contact person................*Chief—Bureau of Ground Water*
Phone number.................*850-539-5999*
Agency address ....*81 Water Management Drive, Havana, FL 32333*

Table 4. NWFWMD Cleaning Business Inventory.

INDEX#	BEGIN YEAR	END YEAR	DEP STCM FACILITY ID	ADDRESS	NAME
1	1956	1982	0	100 GULF BEACH HWY	A & B CLEANERS
2	1968	1968	0	105 E JACKSON ST	AARON PRESSING AND ALTERATIONS
3	1984	1996	9500134	4170 BARRANCAS AVE	AMBASSADOR CLEANERS
4	1978	1984	0	100 S NAVY BLVD	AMBASSADOR CLEANERS
5	1996	1996	0	102 E NINE MILE RD	AMBASSADOR CLEANERS
6	1988	1988	0	13390 PERDIDO KEY DR	AMBASSADOR CLEANERS
7	1988	1988	0	416 OLD PALAFOX HWY	AMBASSADOR CLEANERS
8	1992	1996	0	4350 BAYOU BLVD	AMBASSADOR CLEANERS
9	1980	1980	0	5120 N PALAFOX HWY	AMBASSADOR CLEANERS
10	1986	1986	0	6707 PLANTATION RD	AMBASSADOR CLEANERS
11	1994	1994	0	8660 NAVARRE PKWY	AMBASSADOR CLEANERS
12	1970	1978	0	1001 CHIPLEY AVE	AMBASSADOR CLEANERS AND LAUNDRY
13	1966	1972	0	4129 BARRANCAS AVE	AMBASSADOR CLEANERS AND LAUNDRY
14	1972	1976	0	50 S NAVY BLVD	AMBASSADOR CLEANERS AND LAUNDRY
15	1962	1962	0	1500 N PALAFOX ST	AMERICAN UNIFORM & LINEN RENTAL SERVICE CO.
16	1960	1964	0	821 W JACKSON ST	ANN'S LAUNDERETTE
17	1980	1980	0	2901 N DAVIS HWY	ASTEC PAPER CO.
18	1950	1960	0	1 W JACKSON ST	AUTOMATIC LAUNDRY
19	1948	1948	0	OLD CORRY FIELD RD	B AND B LAUNDRY
20	1994	1996	9600452	5026 N DAVIS HWY	BAY COIN LAUNDRY
21	1960	1974	0	1322 N 14TH AVE	BAYVIEW LAUNDERETTE
22	1984	1992	9800052	180 E BURGESS RD	BEAUCLERC COIN LAUNDRY
23	1982	1982	0	182 E BURGESS RD	BEGNAL COIN LAUNDRY
24	1972	1972	0	MOBILE HWY	BELLVIEW CLEANERS
25	1984	1986	9600455	4375 W FAIRFIELD DR	BIG B CLEANERS
26	1986	1986	0	3960 W NAVY BLVD	BIG B CLEANERS
27	1966	1976	9801143	1805 W FAIRFIELD DR	BIG B ONE HOUR CLEANERS INC.
28	1962	1976	9801095	3100 N PACE BLVD	BIG B ONE HOUR CLEANERS INC.
29	1988	1988	9800964	8084 N DAVIS HWY	BIG B ONE HOUR CLEANERS INC.
30	1974	1988	9800021	5100 N 9TH AVE	BIG B ONE HOUR CLEANERS INC.
31	1984	1988	9600459	5142 N PALAFOX HWY	BIG B ONE HOUR CLEANERS INC.
32	1962	1988	9503060	118 E GARDEN ST	BIG B ONE HOUR CLEANERS INC.
33	1984	1988	0	3911 CREIGHTON RD	BIG B ONE HOUR CLEANERS INC.
34	1988	1988	0	4081 E OLIVE RD	BIG B ONE HOUR CLEANERS INC.
35	1994	1996	9600453	2905 E CERVANTES ST	BIG M LAUNDRY AND CLEANERS
36	1976	1996	9501911	5201 N DAVIS HWY	BILL DOYLE CLEANERS
37	1994	1994	0	8711 PENSACOLA BLVD	BILL DOYLE CLEANERS
38	1978	1980	0	3002 N 9TH AVE	BLAKE'S HIGHLANDER CENTER
39	1962	1964	0	53 GULF BEACH HWY	BUSY B CLEANERS
40	1960	1972	0	514 W BELMONT	C T's CLEANERS AND TAILORS
41	1960	1960	0	MUSCOGEE RD	CANTONMENT CLEANERS AND LAUNDRY
42	1956	1956	0	PALAFOX HWY	CANTONMENT CLEANERS AND LAUNDRY
43	1956	1956	0	12 E BLOUNT ST	CAREYS DRY WASH AND CLEANERS
44	1966	1974	0	1200 N ALCANIZ ST	CARMICHAEL'S WASHETERIA
45	1974	1996	9500660	7010 LILLIAN HWY	CHATEAU LAUNDROMAT COIN-O-MAGIC
46	1980	1980	0	8069 N DAVIS HWY	CHRISTIAN'S CORNER STORE
47	1978	1984	0	929 NEW WARRINGTON RD	CIRCLE CLEANERS

Table 4. NWFWMD Cleaning Business Inventory (continued).

INDEX#	BEGIN YEAR	END YEAR	DEP STCM FACILITY ID	ADDRESS	NAME
48	1962	1964	0	4304 LILLIAN HWY	CIRCLE LAUNDRY
49	1966	1970	0	4113 W FAIRFIELD DR	CIRCLE LAUNDRY AND CLEANERS
50	1972	1972	0	4114 W FAIRFIELD DR	CIRCLE LAUNDRY AND CLEANERS
51	1956	1960	0	3707 MOBILE HWY	CITY CLEANERS AND LAUNDRY
52	1962	1976	0	720 N GREEN ST	CITY CLEANERS AND LAUNDRY
53	1986	1996	9501364	1305 N 9TH AVE	CLEAN SCENE LAUNDRY AND DRY CLEANING
54	1976	1980	0	1502 N 9TH AVE	C-METHOD CLEANERS
55	1980	1984	0	440 E HEINBERG ST	COIN LAUNDRY EQUIPMENT CO.
56	1970	1974	0	303 S OLD CORRY FIELD RD	COIN O MATIC LAUNDRAMAT AND DRY CLEANERS
57	1976	1978	0	1011 S OLD CORRY FIELD RD	COIN O'MAGIC LAUNDROMAT AND DRY CLEANERS
58	1964	1972	0	37 N NAVY BLVD	COLONIAL CLEANERS
59	1992	1994	9800533	2013 N PALAFOX ST	CONCORD CUSTOM CLEANERS
60	1994	1996	9600461	1690 N AIRPORT BLVD	CONCORD CUSTOM CLEANERS
61	1992	1992	9600460	6625 N DAVIS HWY	CONCORD CUSTOM CLEANERS
62	1992	1996	9600458	1001 N NAVY BLVD	CONCORD CUSTOM CLEANERS
63	1994	1996	9600457	104 E GREGORY ST	CONCORD CUSTOM CLEANERS
64	1992	1996	9600456	801 W FAIRFIELD DR	CONCORD CUSTOM CLEANERS
65	1992	1996	9600454	3900 CREIGHTON RD	CONCORD CUSTOM CLEANERS
66	1992	1994	9502176	1703 W FAIRFIELD DR	CONCORD CUSTOM CLEANERS
67	1992	1996	9502140	8181 N DAVIS HWY	CONCORD CUSTOM CLEANERS
68	1992	1996	9502138	4081 E OLIVE RD	CONCORD CUSTOM CLEANERS
69	1992	1996	0	15 BRENT LN	CONCORD CUSTOM CLEANERS
70	1992	1996	0	4335 W FAIRFIELD DR	CONCORD CUSTOM CLEANERS
71	1984	1996	9500469	100 ENTRANCE RD	CORRY FIELD MART LAUNDRY
72	1956	1956	0	1409 GULF BEACH HWY	CROWN LAUNDRY AND CLEANERS
73	1956	1958	0	201 E MAIN ST	CROWN LAUNDRY AND CLEANERS
74	1958	1964	0	1118 NORTH T ST	CROWN LAUNDRY AND DRY CLEANERS
75	1956	1966	0	1415 W CERVANTES ST	CROWN LAUNDRY AND DRY CLEANERS
76	1958	1968	0	1500 N ALCANIZ ST	CROWN LAUNDRY AND DRY CLEANERS
77	1960	1962	0	1522 BARRANCAS AVE	CROWN LAUNDRY AND DRY CLEANERS
78	1958	1958	0	2313 N BORDER	CROWN LAUNDRY AND DRY CLEANERS
79	1960	1968	0	2900 N ALCANIZ ST	CROWN LAUNDRY AND DRY CLEANERS
80	1982	1984	0	2906 N DAVIS HWY	CROWN LAUNDRY AND DRY CLEANERS
81	1958	1958	0	303 E GREGORY ST	CROWN LAUNDRY AND DRY CLEANERS
82	1960	1966	0	3437 N 12TH	CROWN LAUNDRY AND DRY CLEANERS
83	1960	1966	0	3622 POTTERY RD	CROWN LAUNDRY AND DRY CLEANERS
84	1960	1964	0	3628 POTTERY RD	CROWN LAUNDRY AND DRY CLEANERS
85	1960	1962	0	3668 PENSACOLA BLVD	CROWN LAUNDRY AND DRY CLEANERS
86	1960	1966	0	408 E BLOUNT ST	CROWN LAUNDRY AND DRY CLEANERS

Table 4. NWFWMD Cleaning Business Inventory (continued).

INDEX#	BEGIN YEAR	END YEAR	DEP STCM FACILITY ID	ADDRESS	NAME
87	1962	1962	0	4822 W JACKSON ST	CROWN LAUNDRY AND DRY CLEANERS
88	1958	1960	0	727 NEW WARRINGTON RD	CROWN LAUNDRY AND DRY CLEANERS
89	1962	1966	0	7715 PENSACOLA BLVD	CROWN LAUNDRY AND DRY CLEANERS
90	1962	1966	0	8112 N PALAFOX HWY	CROWN LAUNDRY AND DRY CLEANERS
91	1958	1960	0	813 N ALCANIZ ST	CROWN LAUNDRY AND DRY CLEANERS
92	1960	1960	0	955 W MASSACHUSETTS AVE	CROWN LAUNDRY AND DRY CLEANERS
93	1988	1988	9500735	1501 N GUILLEMARD ST	CROWN MANAGEMENT SERVICES
94	1966	1966	0	2613 W AVERY ST	D & R CLEANERS
95	1994	1996	9502668	4124 MOBILE HWY	DAVE'S LAUNDROMAT
96	1994	1996	9800878	5007 N DAVIS HWY	DEBONAIR CLEANERS
97	1968	1968	0	4479 MOBILE HWY	DELMAR CLEANERS
98	1956	1964	0	110 S BARRANCAS AVE	DELUXE CLEANERS INC
99	1950	1950	0	418 E CROSS ST	DEXTER JEWEL
100	1968	1996	9500224	2301 N PALAFOX ST	DIXIE CLEANERS
101	1966	1996	0	1121 N 9TH AVE	DIXIE CLEANERS
102	1952	1966	0	1209 W CERVANTES ST	DIXIE CLEANERS
103	1964	1964	0	1211 N 9TH AVE	DIXIE CLEANERS
104	1950	1958	0	1222 E GADSDEN ST	DIXIE CLEANERS
105	1950	1966	0	2403 N PALAFOX ST	DIXIE CLEANERS
106	1962	1962	0	4029 POTTERY RD	DIXIE CLEANERS
107	1950	1962	0	701 E CERVANTES ST	DIXIE CLEANERS
108	1962	1964	0	213 FAIRPOINT DR	DONNA'S DRY CLEANING AND LAUNDRY
109	1958	1958	0	1204 GULF BEACH HWY	DOYLE BILL CLEANERS AND LAUNDERERS
110	1956	1956	0	17 E GARDEN ST	DOYLE BILL CLEANERS AND LAUNDERERS
111	1964	1964	0	312 N DE VILLIERS ST	DRY CLEANING AND LAUNDRY
112	1964	1970	0	234 E INTENDENCIA ST	DUBUISSON'S COIN OPERATED LAUNDRY
113	1952	1952	0	24 E CROSS ST	DUNCAN AL
114	1974	1988	0	1122 N 9TH AVE	EAST HILL AUTOMATIC LAUNDRY
115	1948	1948	0	917 W CERVANTES ST	EASY
116	1960	1960	0	1021 N 9TH AVE	EMPIRE LAUNDERERS & CLEANERS
117	1944	1968	0	12 N PALAFOX ST	EMPIRE LAUNDERERS & CLEANERS
118	1956	1966	0	1202 E GONZALEZ ST	EMPIRE LAUNDERERS & CLEANERS
119	1960	1960	0	300 N 4TH AVE	EMPIRE LAUNDERERS & CLEANERS
120	1962	1962	0	32 S BARRANCAS AVE	EMPIRE LAUNDERERS & CLEANERS
121	1960	1960	0	4728 N DAVIS HWY	EMPIRE LAUNDERERS & CLEANERS
122	1950	1950	0	100 S BARRANCAS AVE	EMPIRE LAUNDRY CO
123	1956	1956	0	1023 N 9TH AVE	EMPIRE LAUNDRY CO
124	1950	1952	0	107 ENTRANCE RD	EMPIRE LAUNDRY CO
125	1950	1950	0	719 HAYNE	EMPIRE LAUNDRY CO
126	1956	1956	0	900 S BARRANCAS AVE	EMPIRE LAUNDRY CO
127	1962	1964	0	7408 ARGO DR	ENSLEY CLEANERS
128	1956	1956	0	ENSLEY	ENSLEY CLEANERS
129	1960	1960	0	1214 GULF BEACH HWY	ESQUIRE TAILORS AND CLEANERS
130	1992	1996	0	4771 BAYOU BLVD	EXCLUSIVE CLEANERS

Table 4. NWFWMD Cleaning Business Inventory (continued).

INDEX#	BEGIN YEAR	END YEAR	DEP STCM FACILITY ID	ADDRESS	NAME
131	1986	1996	9500346	3900 N 9TH AVE	EXCLUSIVE CLEANERS AND LAUNDRY
132	1988	1988	0	1901 NORTH U ST	FAMILY LAUNDROMAT
133	1950	1956	0	2023 N ALCANIZ ST	FASHION CLEANERS
134	1994	1996	0	2121 W NINE MILE RD	FASHION CLEANERS
135	1966	1972	0	2931 W FAIRFIELD DR	FASHION CLEANERS
136	1950	1960	0	3127 E JORDAN ST	FASHION CLEANERS
137	1952	1962	0	315 E JORDAN ST	FASHION CLEANERS
138	1964	1974	0	128 E CHASE ST	FERRISS FUR SERVICE
139	1984	1984	0	3850 CREIGHTON BLVD	FIVE FLAG COMMERCIAL CLEANERS
140	1950	1954	0	17 N PALAFOX ST	FLORIDA LAUNDRIES AND CLEANERS INC
141	1952	1956	0	19 15TH AVE	FLORIDA LAUNDRIES AND CLEANERS INC
142	1954	1962	0	2201 W NAVY BLVD	FLORIDA LAUNDRIES AND CLEANERS INC
143	1956	1956	0	19 S OLD CORRY FIELD RD	FLORIDA LAUNDRY AND CLEANERS INC
144	1950	1950	0	22 S OLD CORRY FIELD RD	FLORIDA LAUNDRY AND CLEANERS INC
145	1966	1966	0	805 E MAXWELL ST	FRAN'S LAUNDERETTE
146	1982	1996	0	4824 W JACKSON ST	FRAN'S SELF-SERVICE LAUNDERETTE
147	1958	1958	0	706 NORTH A ST	GAMLIN LAUNDRY AND DRY CLEANERS
148	1984	1996	9502376	8187 W FAIRFIELD DR	GARDEN COIN LAUNDRY
149	1976	1996	0	1328 W GARDEN ST	GARDEN ST. COIN LAUNDRY AND DRY CLEANING
150	1970	1970	0	7711 PENSACOLA BLVD	GRIFFIN LAUNDRY AND CLEANERS
151	1960	1972	0	3015 N PACE BLVD	GRIFFIN'S CLEANERS AND LAUNDRY
152	1968	1988	0	804 W MICHIGAN AVE	G's SIXTY MINUTE CLEANERS
153	1950	1972	0	1021 N DAVIS HWY	GULF CLEANERS
154	1948	1954	0	1309 W CERVANTES ST	GULF CLEANERS
155	1944	1980	0	306 DE VILLIERS ST	GULF CLEANERS
156	1980	1986	0	929 NEW WARRINGTON RD	GULF COAST LEATHER CLEANERS
157	1994	1996	0	2915 W NAVY BLVD	GULF COAST LINEN & RENTAL SERVICE
158	1956	1956	0	505 NEW WARRINGTON RD	HALL'S SPIC 'N SPAN LAUNDRY
159	1962	1964	0	3631 POTTERY RD	HANSON'S BRANCH LAUNDRY
160	1976	1976	0	1102 N 9TH AVE	HELEN'S LAUNDERETTE
161	1978	1982	0	2121 N 8TH AVE	HELEN'S LAUNDERETTE
162	1970	1974	0	805 E MAXWELL ST	HELEN'S LAUNDERETTE
163	1966	1966	0	3084C N 9TH AVE	HELEN'S LAUNDERETTE AND DRY CLEANERS
164	1974	1984	0	1800 PATRICIA DR	HIGHLANDER CENTER
165	1962	1978	0	612 NORTH T ST	HIGHTOWER'S LAUNDERETTE
166	1948	1950	0	105 N 4TH AVE	HOLLAND LAUNDRY AND DRY CLEANING CO
167	1944	1944	0	108 E INTENDENCIA ST	HOLLAND LAUNDRY AND DRY CLEANING CO
168	1948	1950	0	116 E INTENDENCIA ST	HOLLAND LAUNDRY AND DRY CLEANING CO
169	1948	1948	0	26 S BARRANCAS AVE	HOLLAND LAUNDRY AND DRY CLEANING CO
170	1956	1970	0	201 SOUTH C ST	IMPERIAL DRY CLEANERS
171	1950	1950	0	830 N DE VILLIER ST	J & K CLEANERS
172	1970	1970	0	1810 W MICHIGAN AVE	JET SET COIN LAUNDERETTE

Table 4. NWFWMD Cleaning Business Inventory (continued).

INDEX#	BEGIN YEAR	END YEAR	DEP STCM FACILITY ID	ADDRESS	NAME
173	1972	1988	0	947 W MASSACHUSETTS AVE	JET SET COIN LAUNDRY AND DRY CLEANING
174	1956	1956	0	103 N 4TH AVE	JIM'S SPEEDY LAUNDRY AND CLEANING
175	1966	1986	0	1147 W LLOYD ST	JOHNSON'S CLEANERS
176	1964	1964	0	103 NEW WARRINGTON RD	JRI INC
177	1978	1986	9700278	501 N NAVY BLVD	KING'S WASH BOWL
178	1964	1964	0	695 OLD CORRY FIELD RD	LARSON'S COIN OPERATED DRY CLEANERS
179	1950	1980	0	9 W BLOUNT ST	LAUNDER-DRY
180	1964	1964	0	3633 POTTERY RD	LAUNDER-MATIC LAUNDRY AND DRY CLEANERS
181	1960	1964	0	707 N PACE BLVD	LAUNDER-MATIC LAUNDRY AND DRY CLEANERS
182	1976	1976	0	503 NEW WARRINGTON RD	LAUNDRY AND DRY CLEANING
183	1962	1962	0	303 W BARRANCAS AVE	LEE'S LAUNDERETTE
184	1954	1954	0	252 SOUTH H ST	LEO'S DRIVE-IN LAUNDRY AND CLEANERS
185	1984	1996	0	4907 LILLIAN HWY	LILLIAN HIGHWAY COIN LAUNDRY
186	1958	1958	0	23 S MERRITT ST	LILLIAN'S CLEANERS
187	1996	1996	0	3960 W NAVY BLVD	LINDA'S AFFORDABLE LAUNDRY SERVICE INC.
188	1950	1950	0	500 N ALCANIZ ST	LITTLE STAR CLEANERS
189	1960	1962	0	101 N 4TH AVE	LIZ'S LAUNDERETTE
190	1964	1972	0	2801 E CERVANTES ST	LIZ'S LAUNDERETTE
191	1984	1996	9600494	8102 N DAVIS HWY	MAGIC TOUCH CLEANERS
192	1986	1996	9501051	3110 E CERVANTES ST	MAGIC TOUCH CLEANERS
193	1986	1986	0	5710 N DAVIS HWY	MAGIC TOUCH CLEANERS
194	1984	1988	0	9TH AVE	MAGIC TOUCH CLEANERS
195	1984	1996	0	7145 N 9TH AVE	MAGIC TOUCH DRY CLEANERS
196	1992	1996	9600496	1612 N PACE BLVD	MATTHEWS CLEANERS
197	1960	1960	0	29 PARK PL	MAYTAG COIN-A -MATIC
198	1996	1996	9500753	43 S NAVY BLVD	MAYTAG STORE LAUNDRY & DRY CLEANERS
199	1978	1984	0	1803 W FAIRFIELD DR	MCDONALD'S COIN LAUNDRY AND DRY CLEANING
200	1956	1976	0	428 N PALAFOX ST	MELODY CLEANERS
201	1952	1958	0	3115 MOBILE HWY	MERIT CLEANERS
202	1950	1950	0	3119 MOBILE HWY	MERRITT CLEANERS
203	1950	1950	0	331 W INTENDENCIA ST	MERRITT CLEANERS
204	1956	1960	0	135 W GOVERNMENT ST	MIKES SPEEDY WEE WASH IT
205	1944	1948	0	1113 N DAVIS HWY	MILLER A J CLEANER AND DYER
206	1944	1948	0	2617 W CERVANTES ST	MILLER A J CLEANER AND DYER
207	1948	1950	0	29 E WRIGHT ST	MILLER A J CLEANER AND DYER
208	1944	1944	0	33 E WRIGHT ST	MILLER A J CLEANER AND DYER
209	1944	1944	0	505 N DE VILLIERS ST	MILLER A J CLEANER AND DYER
210	1986	1992	0	3109 W MICHIGAN AVE	MODERN DAY LAUNDRY AND DRY CLEANING
211	1950	1996	9500479	2502 W CERVANTES ST	MODERN DRY CLEANERS
212	1962	1966	0	4312 W JACKSON ST	MODERN DRY CLEANERS
213	1964	1966	0	2002 N PALAFOX ST	MORRIS DRY CLEANING AND LAUNDRY
214	1950	1950	0	321 N ALCANIZ ST	MURRAY WM J
215	1944	1968	0	57 E GREGORY ST	NATIONAL LAUNDRY AND CLEANING CO

Table 4. NWFWMD Cleaning Business Inventory (continued).

INDEX#	BEGIN YEAR	END YEAR	DEP STCM FACILITY ID	ADDRESS	NAME
216	1956	1972	0	35 PARK PL	NAVY POINT LAUNDER-EASY
217	1948	1948	0	39 PARK PL	NAVY POINT STORES
218	1968	1968	0	426 W GREGORY ST	NEIGHBORHOOD SHOP CLEANERS AND LAUNDRY
219	1950	1950	0	702 NORTH A ST	NEW DEAL CLEANERS
220	1956	1960	0	1124 N 9TH AVE	NEW-WAY CLEANERS
221	1948	1970	0	2503 N PALAFOX ST	NEW-WAY CLEANERS
222	1988	1996	9502423	312 E NINE MILE RD	NINE MILE CLEANERS & LAUNDRY
223	1978	1996	9801152	6220 N 9TH AVE	NINTH AVE COIN-O-MAGIC LAUNDROMAT
224	1982	1982	0	4220 N 9TH AVE	NINTH AVE COIN-O-MAGIC LAUNDROMAT
225	1984	1986	0	6200 N 9TH AVE	NINTH AVE COIN-O-MAGIC LAUNDROMAT
226	1978	1980	0	116 ENTRANCE RD	NORGE VILLAGE COIN LAUNDRY
227	1964	1974	0	116 ENTRANCE RD	NORGE VILLAGE LAUNDRY AND CLEANING
228	1964	1966	0	30 SOUTH 3RD AVE	NORGE VILLAGE LAUNDRY AND CLEANING
229	1980	1980	0	9 W BLOUNT ST	NORTH HILL LAUNDRY
230	1950	1952	0	217 E JACKSON ST	ODESSA'S HAND LAUNDRY
231	1976	1986	9600756	6157 N 9TH AVE	ONE HOUR FASHION CLEANERS
232	1970	1974	0	5757 N 9TH AVE	ONE HOUR MARTINIZING
233	1968	1974	0	901 NEW WARRINGTON RD	ONE HOUR MARTINIZING
234	1962	1966	0	905 NEW WARRINGTON RD	ONE HOUR VALETONE
235	1964	1976	0	929 NEW WARRINGTON RD	ONE HOUR VALETONE
236	1966	1970	0	707 N PACE BLVD	OWENS CLEANERS AND LAUNDRY
237	1964	1966	0	711 N PACE BLVD	OWENS CLEANERS AND LAUNDRY
238	1966	1966	0	955 W MASSACHUSETTS AVE	OWENS CLEANERS AND LAUNDRY
239	1950	1950	0	37 W GARDEN ST	PADGETT'S JIMMIE CLEANERS AND SHOE SHOP
240	1954	1954	0	3801 NAVY BLVD	PADGETT'S JIMMIE DRY CLEANERS
241	1950	1950	0	406 E CHASE ST	PALMER EDW R
242	1978	1978	0	FAIRFIELD PLAZA	PAT'S WASH BOWL
243	1994	1996	9501833	6879 N 9TH AVE	PEACHES LAUNDRY & DRY CLEANING
244	1948	1948	0	3998 MOBILE HWY	PENSACOLA DYE WORKS
245	1986	1986	0	5303 N DAVIS HWY	PENSACOLA SOAP OPERA
246	1994	1996	9500854	6901 PENSACOLA BLVD	PETER PAN CAR CITY CLEANERS
247	1956	1956	0	300 E JORDAN ST	PHIL'S CLEANERS
248	1976	1978	0	3300 N PACE BLVD	PLAZA CLEANERS
249	1974	1992	0	6879 N 9TH AVE	PLAZA HIGHLANDER CENTER
250	1996	1996	9501157	1595 N PACE BLVD	PROFESSIONAL ONE HOUR CLEANERS
251	1992	1994	0	1421 N PACE BLVD	PROFESSIONAL ONE HOUR CLEANERS
252	1956	1956	0	1415 GULF BEACH HWY	QUALITY LAUNDRY AND CLEANERS
253	1950	1950	0	MURRAY BLVD	QUALITY LAUNDRY AND CLEANERS
254	1952	1966	0	507 NEW WARRINGTON RD	QUALITY LAUNDRY AND DRY CLEANERS
255	1962	1964	0	129 KILBEE AVE	QUICK CLEAN LAUNDRY
256	1960	1980	0	406 GULF BEACH HWY	RAY'S CLEANERS AND LAUNDRY
257	1972	1974	0	415 W GOVERNMENT ST	RAY'S CLEANERS AND LAUNDRY
258	1996	1996	9500546	13430 GULF BEACH HWY	REAL KLEAN CLEANERS
259	1976	1996	9500322	3121 MOBILE HWY	REAL KLEAN CLEANERS

Table 4. NWFWMD Cleaning Business Inventory (continued).

INDEX#	BEGIN YEAR	END YEAR	DEP STCM FACILITY ID	ADDRESS	NAME
260	1974	1976	0	2501 N PACE BLVD	REAL KLEAN CLEANERS
261	1966	1968	0	2617 W FAIRFIELD DR	REEL KLEAN CLEANERS AND LAUNDRY
262	1972	1982	0	2011 NORTH E ST	REESE CLEANERS AND DYERS
263	1944	1966	0	307 E WRIGHT ST	REESE CLEANING CO
264	1966	1970	0	919 N PACE BLVD	REESE CLEANING CO
265	1968	1970	0	1017 NORTH L ST	RELIABLE CLEANERS
266	1972	1972	0	2717 NORTH E ST	RE-NEW-IT CLEANERS
267	1970	1970	0	2725 NORTH E ST	RE-NEW-IT CLEANERS
268	1976	1984	9800747	4504 SAUFLEY FIELD RD	SAUFLEY SQUARE LAUNDRY & DRY CLEANING
269	1978	1984	0	4512 SAUFLEY FIELD RD	SAUFLEY SQUARE LAUNDRY & DRY CLEANING
270	1986	1996	9600497	555 SCENIC HWY	SCENIC HIGHWAY COIN LAUNDRY AND CLEANERS
271	1984	1984	0	408 GULF BEACH HWY	SEMINOLE INTERNATIONAL SERVICES
272	1978	1978	0	451 S OLD CORRY FIELD RD	SENTINEL CHEMICAL CO
273	1970	1972	0	3100 N PACE BLVD	SHIRTS WORLD INC
274	1958	1958	0	5030 N PALAFOX HWY	SMITHS LAUNDRY AND DRY CLEANING
275	1956	1956	0	4914 N PALAFOX HWY	SMITH'S LAUNDRY AND DRY CLEANING
276	1952	1966	0	408 E GADSDEN ST	SNO-WHITE AUTOMOTIVE DRIVE-IN LAUNDRY
277	1956	1960	0	402 E GADSDEN ST	SPARKLE DRIVE-IN CLEANERS
278	1954	1954	0	904 N NAVY BLVD	SPEEDY LAUNDRY AND CLEANERS
279	1956	1956	0	904 N NAVY BLVD	SPEEDY WEE WASH IT LAUNDRY & CLEANERS
280	1996	1996	9600232	3001 N 9TH AVE	SPIC AND SPAN CLEANERS AND LAUNDRY
281	1996	1996	0	2101 W GARDEN ST	SPIC AND SPAN CLEANERS AND LAUNDRY
282	1972	1972	0	2306 N DAVIS HWY	SPIC AND SPAN CLEANERS AND LAUNDRY
283	1950	1986	0	815 SOUTH E ST	SPIC AND SPAN CLEANERS AND LAUNDRY
284	1956	1970	0	4405 N DAVIS HWY	SPOTLESS CLEANERS & LAUNDRY
285	1960	1960	0	5028 N PALAFOX HWY	SPOTLESS LAUNDRY
286	1950	1960	0	105 E GARDEN ST	STAR LAUNDRY AND DRY CLEANING CO
287	1944	1948	0	5 S BRUE	STAR LAUNDRY AND DRY CLEANING CO
288	1950	1954	0	1019 NORTH L ST	STREAMLINE CLEANERS
289	1966	1970	0	6920 N 9TH AVE	STUCKEY'S LAUNDRIES
290	1988	1992	0	3 W NINE MILE RD	SUNSHINE CLEANERS
291	1994	1996	0	9321 OLD PALAFOX HWY	SUNSHINE COIN LAUNDRY & DRY CLEANERS
292	1966	1974	0	5024 N DAVIS HWY	SWAN DRY CLEANERS
293	1958	1958	0	820 W GREGORY ST	SYBLE'S LAUNDERETTE
294	1960	1960	0	319 N TARRAGONA ST	TAYLOR STARKS
295	1984	1986	0	3830 N 9TH AVE	TERRACE COIN LAUNDRY AND DRY CLEANING
296	1944	1944	0	22 E GOVERNMENT ST	THE PALACE CLEANERS
297	1978	1982	0	11938 LONGWOOD DR	THOMPSON J J

Table 4. NWFWMD Cleaning Business Inventory (continued).

INDEX#	BEGIN YEAR	END YEAR	DEP STCM FACILITY ID	ADDRESS	NAME
298	1968	1974	0	1119 E GONZALEZ ST	THREADGILL CLEANERS AND LAUNDERERS
299	1960	1988	0	1823 N PALAFOX ST	THREADGILL CLEANERS AND LAUNDERERS
300	1962	1976	0	511 N 9TH AVE	THREADGILL CLEANERS AND LAUNDERERS
301	1950	1964	0	10 S BARRANCAS AVE	TILLER'S CLEANERS AND LAUNDRY
302	1950	1950	0	1330 W GARDEN ST	TILLER'S CLEANERS AND LAUNDRY
303	1984	1988	0	500 N NAVY BLVD	TOUCH OF CLASS CLEANERS
304	1956	1956	0	2428 N 12TH AVE	TWELFTH AND SCOTT LAUNDROMAT
305	1950	1980	0	2617 W CERVANTES ST	VEASEY'S BROWNSVILLE CLEANERS
306	1956	1956	0	307 E GONZALES ST	VEASEY'S BROWNSVILLE CLEANERS
307	1964	1964	0	1701 N KIRK AVE	VEASEY'S CLEANERS & LAUNDRY
308	1964	1970	0	301 MASSACHUSETTS AVE	VEASEY'S CLEANERS & LAUNDRY
309	1964	1966	0	35 W GOVERNMENT ST	VEASEY'S HATTERS
310	1964	1968	0	417 N TARRAGONA ST	VEASLEY LAUNDRY AND CLEANERS
311	1986	1992	9601077	2 E NINE MILE RD	VICK'S CLEANERS
312	1944	1974	9600865	328 E GADSDEN ST	VICK'S CLEANERS
313	1974	1996	9600493	2500 N 12TH AVE	VICK'S CLEANERS
314	1986	1996	9600492	8645 PENSACOLA BLVD	VICK'S CLEANERS
315	1992	1996	9600491	6224 N 9TH AVE	VICK'S CLEANERS
316	1978	1996	9600490	30 E NINE MILE RD	VICK'S CLEANERS
317	1976	1996	9600468	600 E CERVANTES ST	VICK'S CLEANERS
318	1994	1996	9502749	470 HIGHWAY 29	VICK'S CLEANERS
319	1986	1996	9502748	5998 MOBILE HWY	VICK'S CLEANERS
320	1994	1996	9502747	7861 PINE FOREST RD	VICK'S CLEANERS
321	1994	1996	9502746	13019 SORRENTO RD	VICK'S CLEANERS
322	1984	1996	9500366	2915 W NAVY BLVD	VICK'S CLEANERS
323	1956	1960	0	1009 W GARDEN ST	VICK'S CLEANERS
324	1988	1988	0	17 S PALAFOX ST	VICK'S CLEANERS
325	1964	1974	0	2740 CREIGHTON BLVD	VICK'S CLEANERS
326	1968	1972	0	2900 N 12TH AVE	VICK'S CLEANERS
327	1958	1966	0	2902 N 12TH AVE	VICK'S CLEANERS
328	1960	1960	0	314 DE VILLIERS ST	VICK'S CLEANERS
329	1958	1962	0	4408 W JACKSON ST	VICK'S CLEANERS
330	1966	1966	0	5112 N PALAFOX HWY	VICK'S CLEANERS
331	1966	1966	0	5122 N PALAFOX HWY	VICK'S CLEANERS
332	1994	1994	0	59 E GREGORY ST	VICK'S CLEANERS
333	1954	1958	0	636 N PACE BLVD	VICK'S CLEANERS
334	1964	1970	0	6569 N DAVIS HWY	VICK'S CLEANERS
335	1986	1988	0	6750 N 9TH AVE	VICK'S CLEANERS
336	1986	1988	0	6886 N 9TH AVE	VICK'S CLEANERS
337	1962	1970	0	7914 N PENSACOLA BLVD	VICK'S CLEANERS
338	1972	1978	0	8069 N DAVIS HWY	VICK'S CLEANERS
339	1960	1962	0	8116 N PALAFOX HWY	VICK'S CLEANERS
340	1964	1970	0	8924 PENSACOLA BLVD	VICK'S CLEANERS
341	1972	1984	0	8924 PENSACOLA BLVD	VICK'S CLEANERS
342	1964	1966	0	MUSCOGEE RD	VICK'S CLEANERS
343	1964	1970	0	NAVY BLVD AND BARRANCAS ST	VICK'S CLEANERS
344	1974	1996	9502228	6425 N 9TH AVE	VOGUE CLEANERS
345	1988	1992	0	5039 BAYOU BLVD	VOGUE CLEANERS

Table 4. NWFWMD Cleaning Business Inventory (continued).

INDEX#	BEGIN YEAR	END YEAR	DEP STCM FACILITY ID	ADDRESS	NAME
346	1968	1974	0	5935 N 9TH AVE	VOGUE CLEANERS
347	1960	1962	0	904 N NAVY BLVD	VOGUE LAUNDERETTE
348	1950	1996	9501455	921 N ALCANIZ ST	WALLACE DRY CLEANING SERVICE
349	1956	1962	0	913 N ALCANIZ ST	WALLACE DRY CLEANING SERVICE
350	1964	1976	0	237 W GOVERNMENT ST	WALTON'S CLEANERS
351	1956	1956	0	3105 NORTH T ST	WARD'S WET WASH
352	1966	1972	0	4100 BARRANCAS AVE	WARRINGTON CLEANERS AND LAUNDRY
353	1962	1964	0	1616 BARRANCAS AVE	WARRINGTON DRY CLEANERS
354	1964	1966	0	1316 W GOVERNMENT ST	WARRINGTON DRY CLEANERS
355	1954	1960	0	1630 BARRANCAS AVE	WARRINGTON DRY CLEANERS
356	1966	1966	0	49 GULF BEACH HWY	WARRINGTON DRY CLEANERS
357	1986	1996	9502667	40 W NINE MILE RD	WASCO CLEAN COIN LAUNDRY
358	1982	1982	9501457	33 BRENT LN	WASCO-CLEAN
359	1982	1982	0	8187 W FAIRFIELD DR	WASCO-CLEAN
360	1972	1986	9700554	4335 W FAIRFIELD DR	WASHBOWL-WESTWOOD
361	1984	1992	0	2718 W CERVANTES ST	WASHER AND DRYER SERVICE CENTER
362	1988	1992	0	3802 BARRANCAS AVE	WASHING WELL COIN LAUNDRY
363	1986	1992	0	2401 W CERVANTES ST	WATER WORKS LAUNDRY AND DRY CLEANING
364	1964	1964	0	705 E GREGORY ST	WAY-SIDE LAUNDERETTE
365	1944	1944	0	1110 W CERVANTES ST	WEST CERVANTES STREET HAND LAUNDRY
366	1978	1978	0	7355 VELMA DR	WHITE CHAS A
367	1948	1948	0	10 W INTENDENCIA ST	WHITE TAILORING CO
368	1950	1950	0	25 E GREGORY ST	WHITEHEAD'S CLEANERS
369	1958	1958	0	4851 MOBILE HWY	WHITEHEAD'S CLEANERS & LAUNDRY
370	1944	1972	0	610 N ALCANIZ ST	WHITEHEAD'S CLEANERS & LAUNDRY
371	1988	1996	9501479	804 W MICHIGAN AVE	WOOD'S CLEANERS
372	1970	1970	0	110 ENTRANCE RD	WOOD'S CLEANERS
373	1956	1956	0	103 BARRANCAS AVE	WORKMAN'S CLEANERS
374	1956	1972	0	1325 W CERVANTES ST	WORKMAN'S CLEANERS
375	1950	1954	0	1425 W CERVANTES ST	WORKMAN'S CLEANERS
376	1950	1974	0	1429 N PALAFOX ST	WORKMAN'S CLEANERS
377	1950	1954	0	2407 W CERVANTES ST	WORKMAN'S CLEANERS
378	1950	1966	0	329 E GADSDEN ST	WORKMAN'S CLEANERS
379	1960	1964	0	4319 LILLIAN HWY	WORKMAN'S CLEANERS
380	1960	1968	0	4321 LILLIAN HWY	WORKMAN'S CLEANERS
381	1968	1968	0	803 E MAXWELL ST	WORKMAN'S CLEANERS
382	1988	1988	0	6702 W HWY 98	YOUR VALET CLEANERS

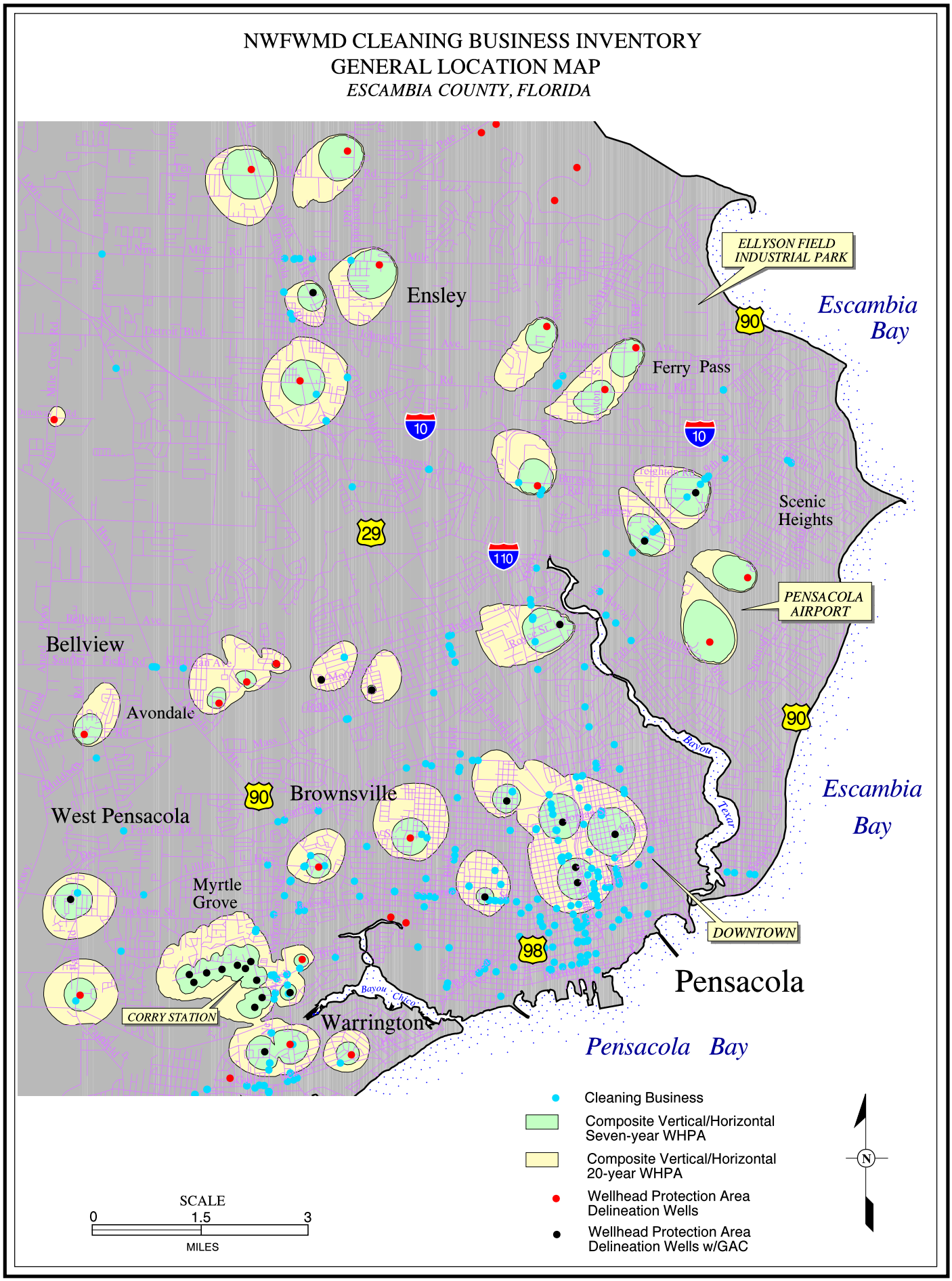

Figure 23. NWFWMD Cleaning Business Inventory, General Location Map.

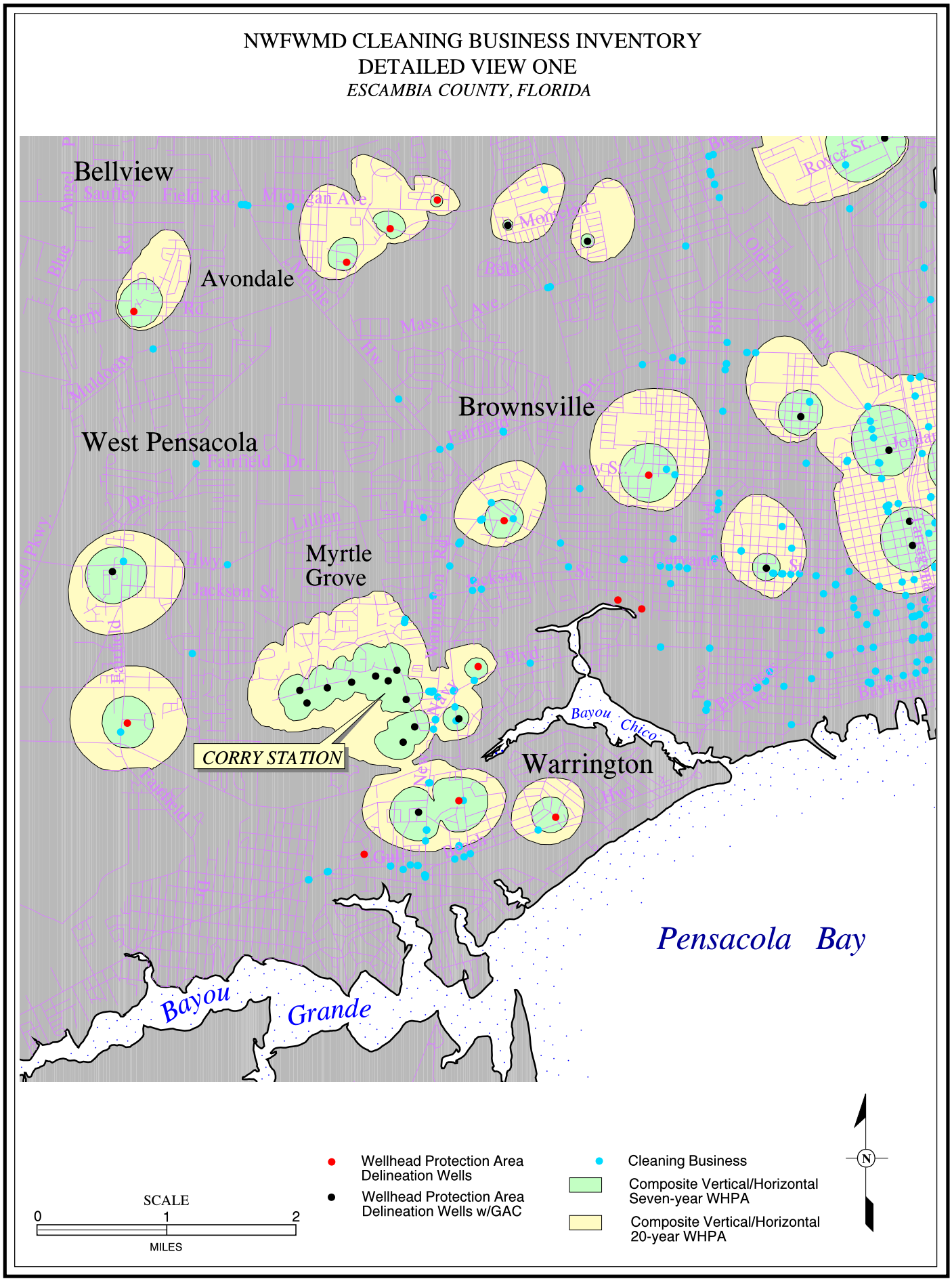

Figure 24. NWFWMD Cleaning Business Inventory, Detailed View One.

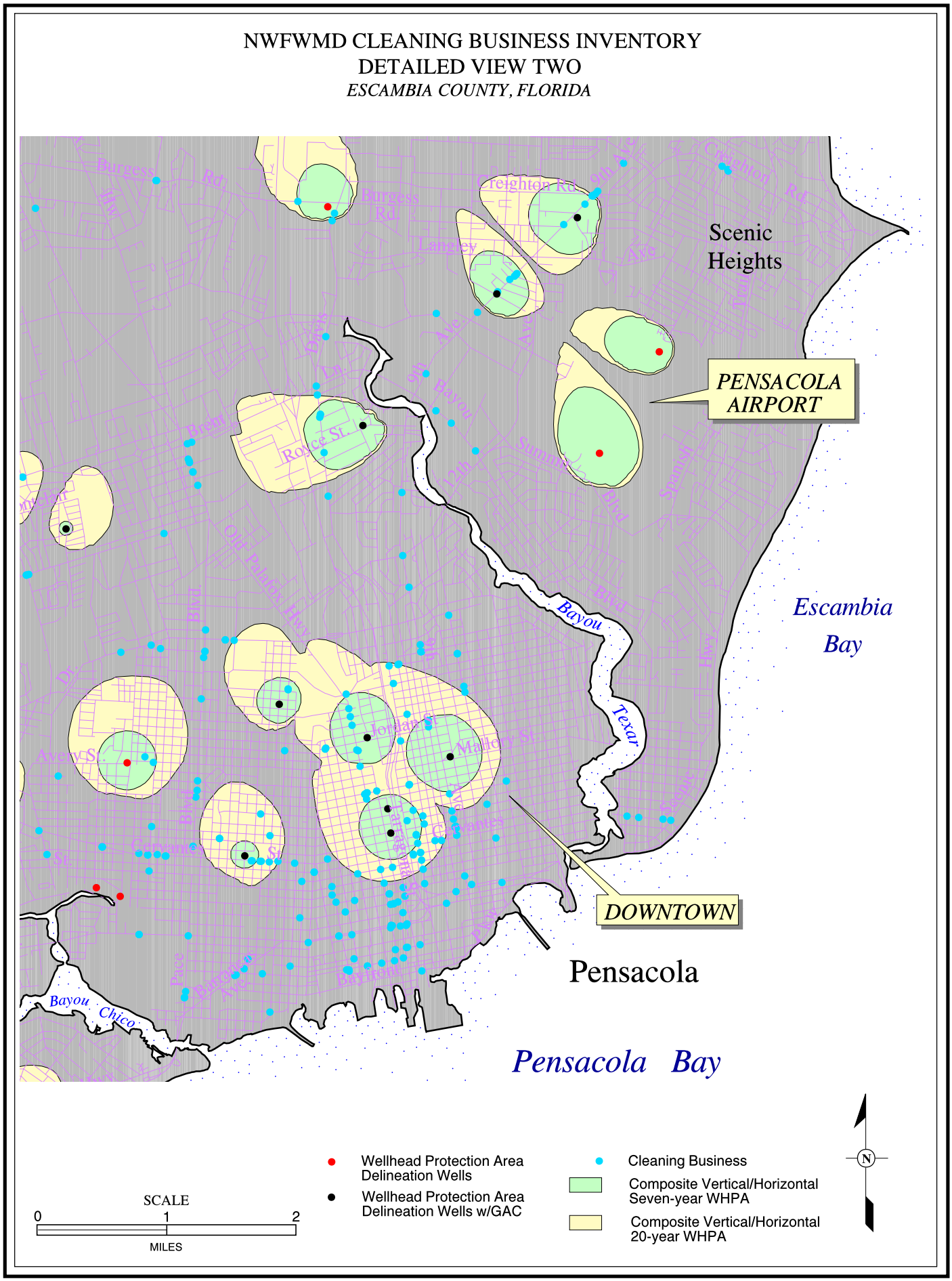

Figure 25. NWFWMD Cleaning Business Inventory, Detailed View Two.

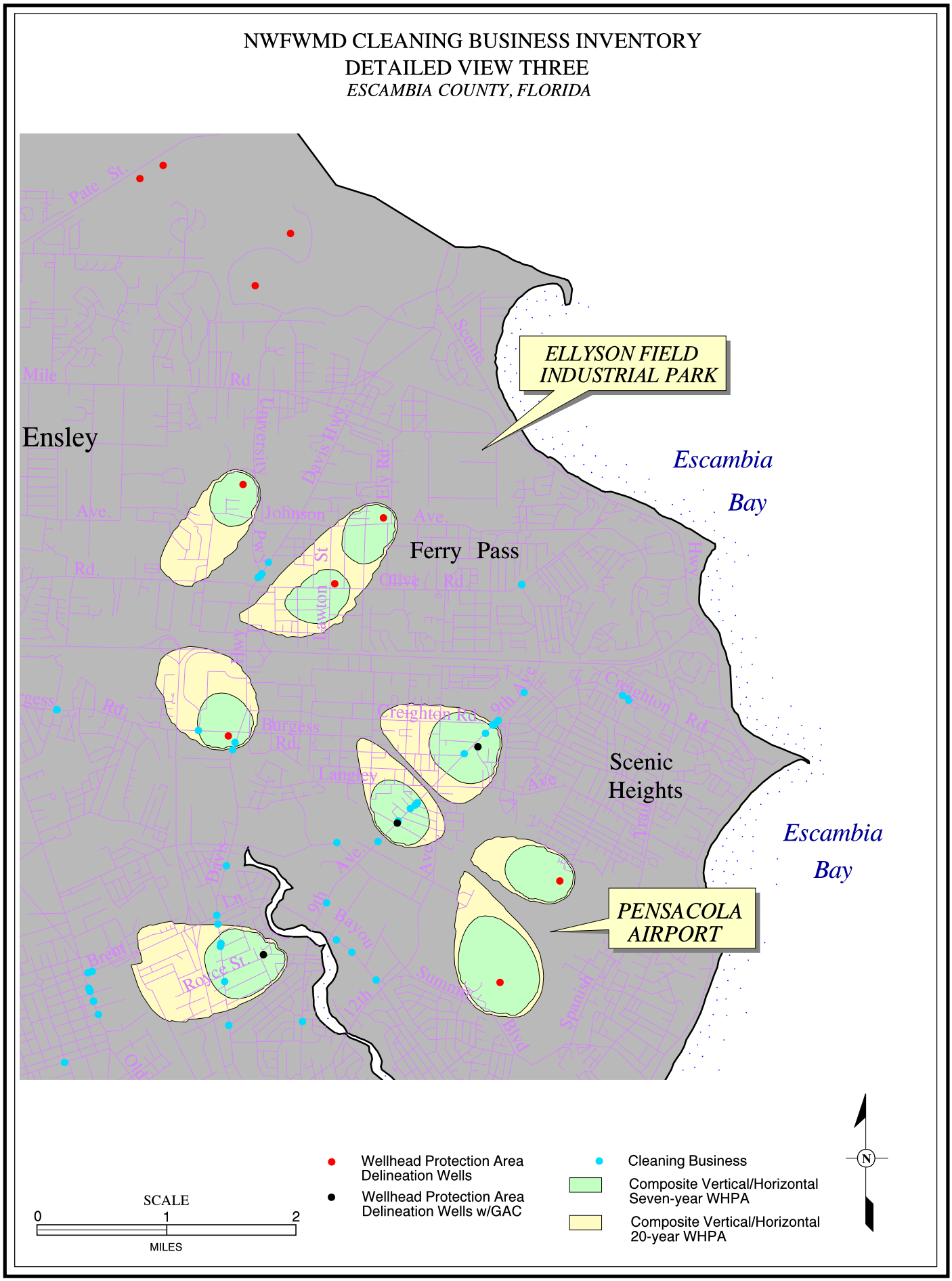

Figure 26. NWFWMD Cleaning Business Inventory, Detailed View Three.

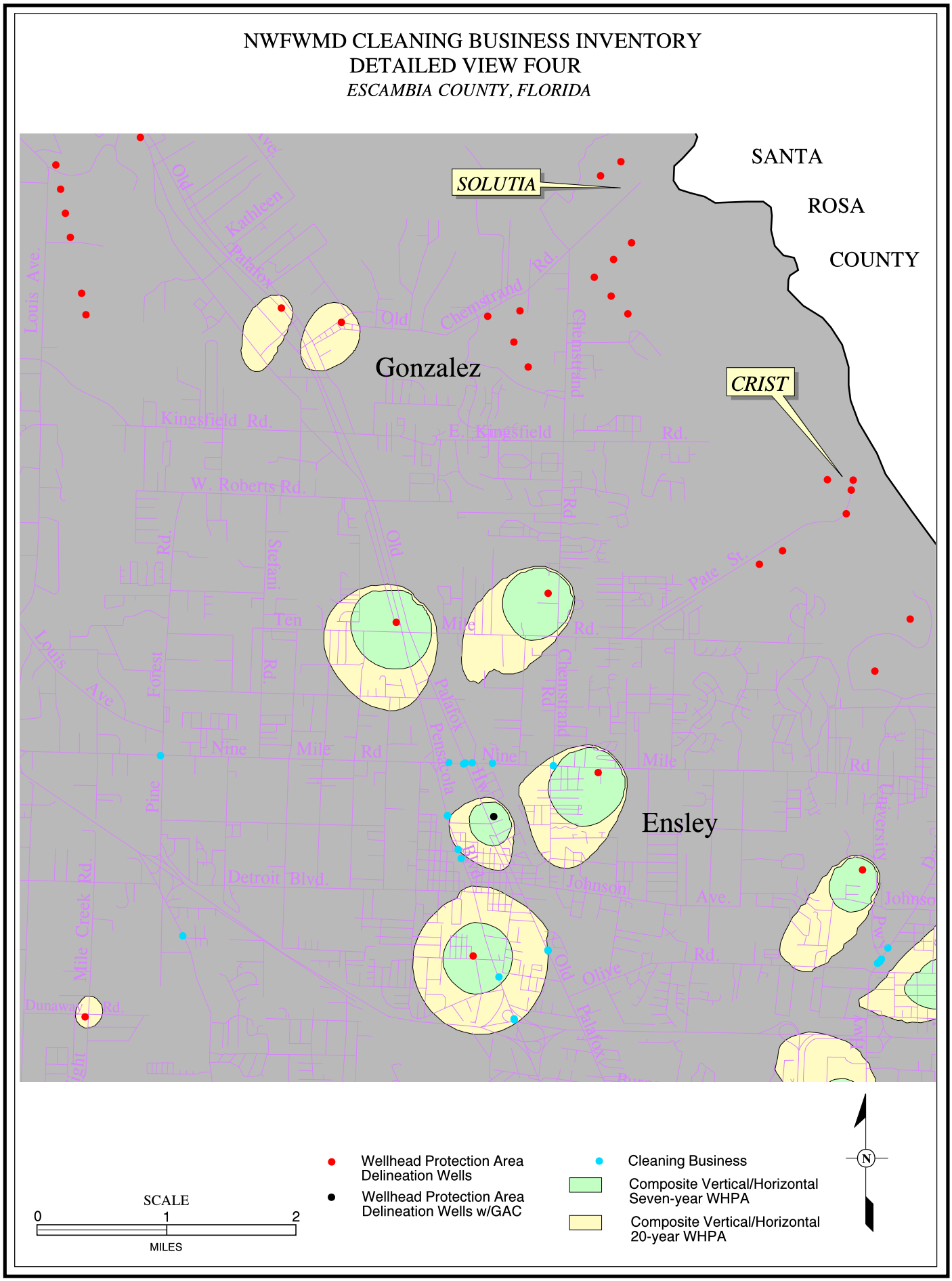

Figure 27. NWFWMD Cleaning Business Inventory, Detailed View Four.

DSCP_CONTAM.SHP

DESCRIPTION OF DATA LAYER

Data layer name..............***DSCP_contam.shp***
Description......................*FDEP Drycleaning Solvent Cleanup Program eligible and not eligible facilities in Escambia County.*
Type................................*Point*
Datum *NAD83*
Projection........................*UTM Zone 16*
Map Units........................*Meters*

Conversion from source to data layer: *data imported from spreadsheet.*

DESCRIPTION OF SOURCE MATERIALS

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FDEP DSCP Contaminated Sites

Source reference materials: *spreadsheet.*

This file contains sites determined either eligible or not eligible for cleanup assistance under the FDEP Drycleaning Solvent Cleanup Program (62-782, F.A.C.). Database is as of August 1999. Sites coded either eligible or not eligible have been determined by the Department to have had a release of drycleaning solvent to the environment. Thirty-two of 36 facility locations were determined by the NWFWMD using real-time, differentially corrected GPS. The remaining four sites were located by geocoding street addresses contained in the FDEP DSCP database.

As of September 1999 a statewide total of 1,390 drycleaning facilities have been determined to be eligible for cleanup assistance under 62-782 F.A.C. Statewide, 164 sites have been tasked to contractors and 1,226 have not. Of the 1,390 eligible facilities statewide, 32 (2.3 percent) are located in Escambia County. To date, of the sites in the county, seven have been tasked to contractors for cleanup. The remaining 25 await release to contractors. The order in which sites are assigned to contractors is based on the site “Rank.” Statewide, rankings range from 1 to 1,226. The rankings for un-tasked sites in Escambia County range from 120 to 1,220.

Responsible agency............. *Florida Department of Environmental Protection*
Contact person..................... *Doug Fitton*
Phone number...................... *850-488-0190 (Waste Management)*
Media of source.................... *spreadsheet*
Source material location....... *FDEP Drycleaning Solvent Cleanup (DSCP) database*

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DATA ATTRIBUTES

Column	Item name	Description
2	Index#	Table sequence number.
3	Fac_id	Site number specified by the FDEP’s Registration Section for

		each facility (drycleaner or wholesale supply company). This field was downloaded from Storage Tank/Contamination Monitoring (STCM) database.
4	Fac_stat	FDEP facility status: open denotes business is open; closed denotes business is closed; open-nsh denotes business is open and has no history of solvent use; open-sh denotes business is open and has a history of solvent use; duplicate denotes record is a duplicate of another record.
5	Name	Facility name, field downloaded from STCM.
6	Address	Facility address, field downloaded from STCM.
7	Elig_stat	Eligibility status, denotes whether or not facility is eligible for state-funded cleanup assistance under 62-782 (F.A.C.). "E" denotes facility has documented contamination and is eligible for cleanup assistance; "N" denotes facility has documented contamination and is not eligible for state-funded cleanup assistance.
8	Score	FDEP facility score.
9	Rank	Statewide site ranking used to determine sequence in which sites are released to contractors for cleanup. "T" denotes that site has been tasked to contractor for action. "NA" denotes that site was determined to be not eligible for participation in program.
10	GPS_Lat	NWFWMD obtained GPS latitude, 0.0000 denotes that site was not GPSed.
11	GPS_Long	NWFWMD obtained GPS longitude, 0.0000 denotes that site was not GPSed.

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DATA LAYER PROVIDING ORGANIZATION

Providing agency.............*Northwest Florida Water Management District*
Contact person................*Chief—Bureau of Ground Water*
Phone number.................*850-539-5999*
Agency address ....*81 Water Management Drive, Havana, FL 32333*

Table 5. FDEP DSCP Contaminated Sites.

INDEX#	FAC_ID	RANK	NAME	ADDRESS	ELIG_STAT	SCORE
1	9800052	1216	BEAUCLERC SHOPPING CENTER	180 E BURGESS RD	E	20
2	9700278	**T**	BIG B CLEANERS	501 N NAVY BLVD	E	148
3	9801143	602	BIG B CLEANERS #18	1805 W FAIRFIELD DR	E	49
4	9801142	**T**	BIG B CLEANERS #36	4011 BARRANCAS AVE	E	132
5	9800964	76	BIG B CLEANERS #71	8084 N DAVIS HWY	E	120
6	9501911	553	BILL DOYLE CLEANERS	5201 N DAVIS HWY	E	57
7	9801093	1205	CHASE STREET & DELEON	400-410 E CHASE ST	E	22
8	9800533	540	CONCORD CUSTOM CLEANERS	2013 N PALAFOX ST	E	59
9	9502140	75	CONCORD CUSTOM CLEANERS #065	8181 N DAVIS HWY	E	120
10	9502138	427	CONCORD CUSTOM CLEANERS #074	4081 E OLIVE RD	E	72
11	9502176	82	CONCORD CUSTOM CLEANERS #6018	1703 W FAIRFIELD DR	E	119
12	9800021	600	CORDOVA MALL	5100 N 9TH AVE	E	49
13	9500224	576	DIXIE CLEANERS INC	2301 N PALAFOX ST	E	54
14	9601077	**T**	ENSLEY SQUARE CLEANERS	2 E NINE MILE RD	E	119
15	9500346	575	EXCLUSIVE CLEANERS & LAUNDRY INC	3900 N 9TH AVE	E	54
16	9503060	**T**	FIRST UNION NATIONAL BANK PROPERTIES (BIG B)	118 E GARDEN ST	E	123
17	9502376	527	GARDEN COIN LAUNDRY & DRY CLEANING	8187 W FAIRFIELD DR	E	62
18	9502749	635	HERITAGE CLEANERS	470 N HIGHWAY 29	E	39
19	9700554	72	MARINER MALL (FORMERLY BIG B CLEANERS)	4335 FAIRFIELD DRIVE	E	120
20	9500479	1220	MODERN CLEANERS INC	2502 W CERVANTES ST	E	17
21	9502423	**T**	NINE MILE CLEANERS	312 E NINE MILE RD	E	129
22	9801152	**NA**	NINTH AVENUE COIN-O-MAGIC LAUNDRY	6220 N 9TH AVE	**N**	**NA**
23	9501157	**NA**	ONE HOUR MARTINIZING	1595 N PACE BLVD	**N**	**NA**
24	9500854	538	PETER PAN CAR CITY CLEANERS	6901 PENSACOLA BLVD	E	59
25	9800747	73	SAUFLEY SQUARE DRY CLEANERS	4504 SAUFLEY FIELD RD	E	120
26	9600232	590	SPIC N SPAN	3001 N 9TH AVE	E	51
27	9502748	282	VICKS CLEANERS	5998 MOBILE HWY	E	90
28	9600865	554	VICKS CLEANERS	328 E GADSDEN ST	E	57
29	9500366	**NA**	VICKS CLEANERS INC	2915 W NAVY BLVD	**N**	**NA**
30	9600468	**T**	VICKS CLEANERS INC	600 E CERVANTES ST	E	52
31	9600492	**T**	VICKS CLEANERS INC	8645 PENSACOLA BLVD	E	138
32	9600493	598	VICKS CLEANERS INC	2500 N 12TH AVE	E	49
33	9600494	287	VICKS CLEANERS INC	8102 N DAVIS HWY	E	89
34	9801095	603	VICKS CLEANERS INC	3100 N PACE BLVD	E	49
35	9502228	562	VOGUE CLEANERS	6425 N 9TH AVE	E	56
36	9501479	**NA**	WOODS CLEANERS	804 W MICHIGAN AVE	**N**	**NA**

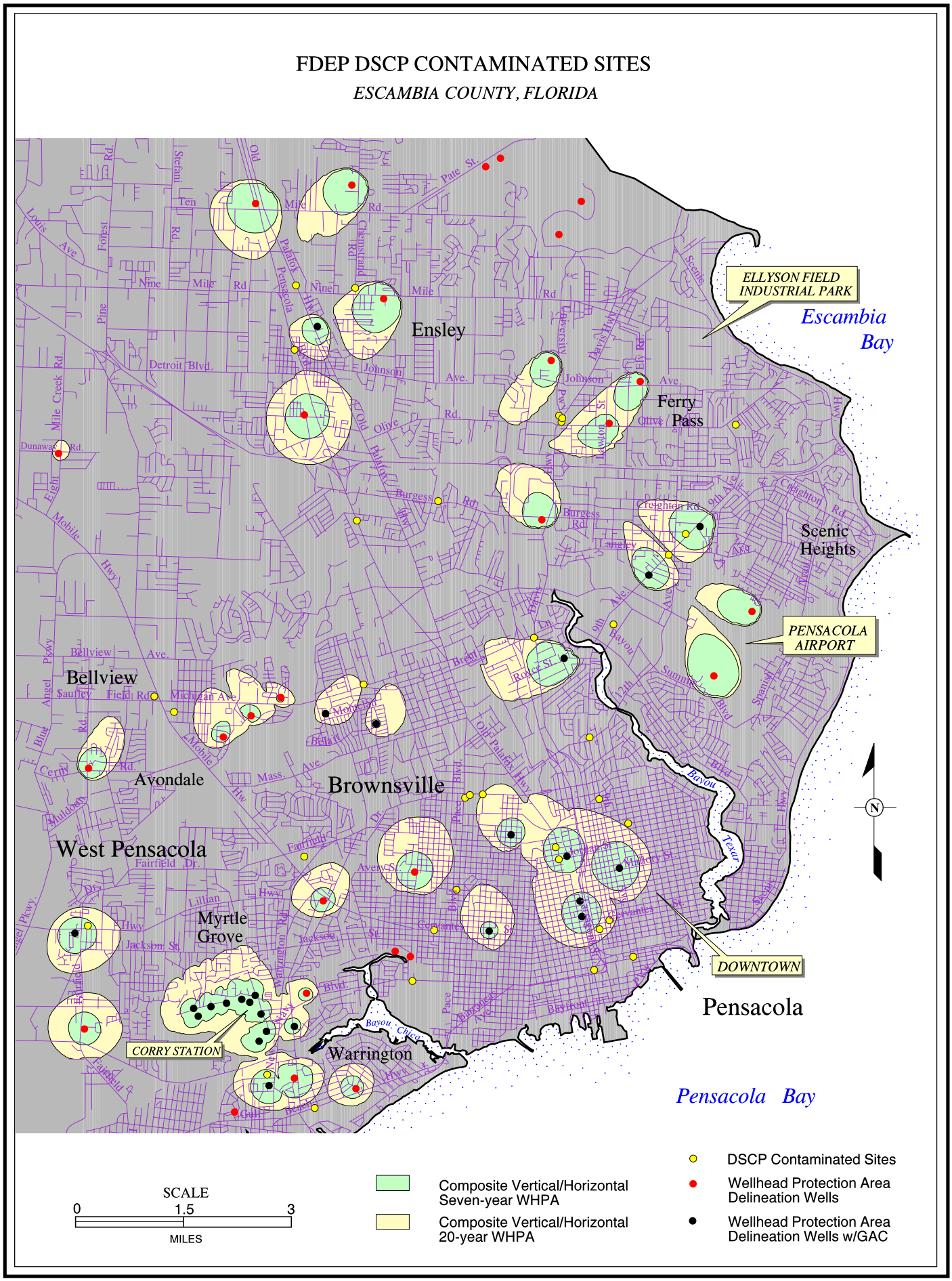

Figure 28. FDEP DSCP Contaminated Sites.

STCM_TANKS.SHP

DESCRIPTION OF DATA LAYER

Data layer name..............*STCM_tanks.shp*
Description......................*FDEP Storage Tank/Contamination Monitoring (STCM) database sites in southern Escambia County.*
Type................................*Point*
Datum *NAD83*
Projection........................*UTM Zone 16*
Map Units........................*Meters*

Conversion from source to data layer: *data imported from spreadsheet.*

DESCRIPTION OF SOURCE MATERIALS

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FDEP STCM Tanks Database Sites

Source reference materials: *spreadsheet*

Responsible agency............. *Florida Department of Environmental Protection/Bureau of Petroleum Storage Systems*
Contact person..................... *Brian Dougherty*
Phone number...................... *850-487-3299*
Media of source.................... *spreadsheet*
Source material location....... *FDEP*

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DATA ATTRIBUTES

Column	Item name	Description
2	Index#	Table sequence number.
3	Fac_no	FDEP site number
5	Fac_name	FDEP facility name.
6	Fac_address	FDEP facility address.
7	Fac_city	City where facility is located.
8	Fac_open	Denotes whether facility is open or closed.
9	X-coord	Facility UTM x coordinate.
10	Y-coord	Facility UTM y coordinate.

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DATA LAYER PROVIDING ORGANIZATION

Providing agency.............*Northwest Florida Water Management District*
Contact person................*Chief—Bureau of Ground Water*
Phone number.................*850-539-5999*
Agency address ....*81 Water Management Drive, Havana, FL 32333*

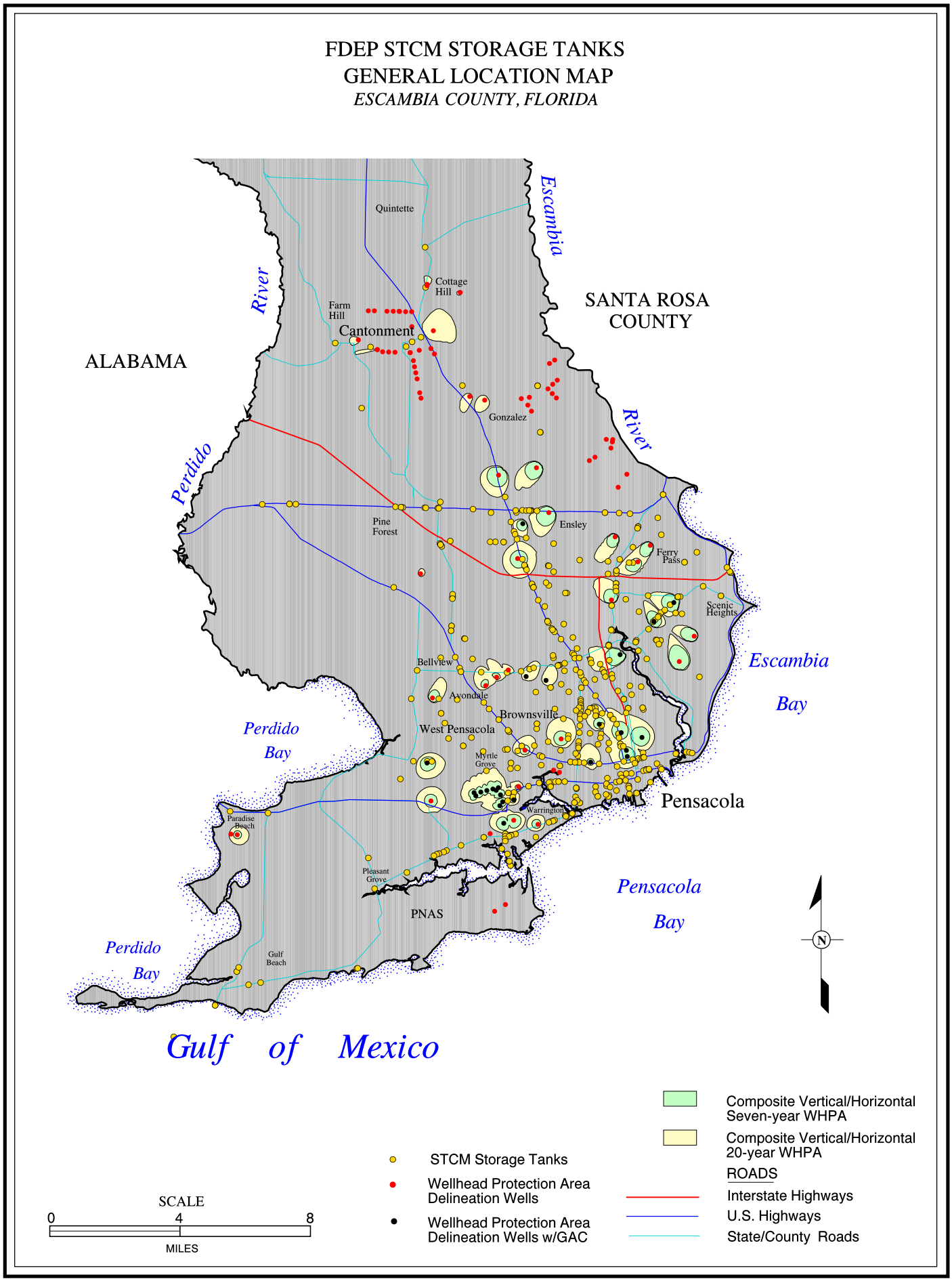


Figure 29. FDEP STCM Storage Tanks, General Location Map.

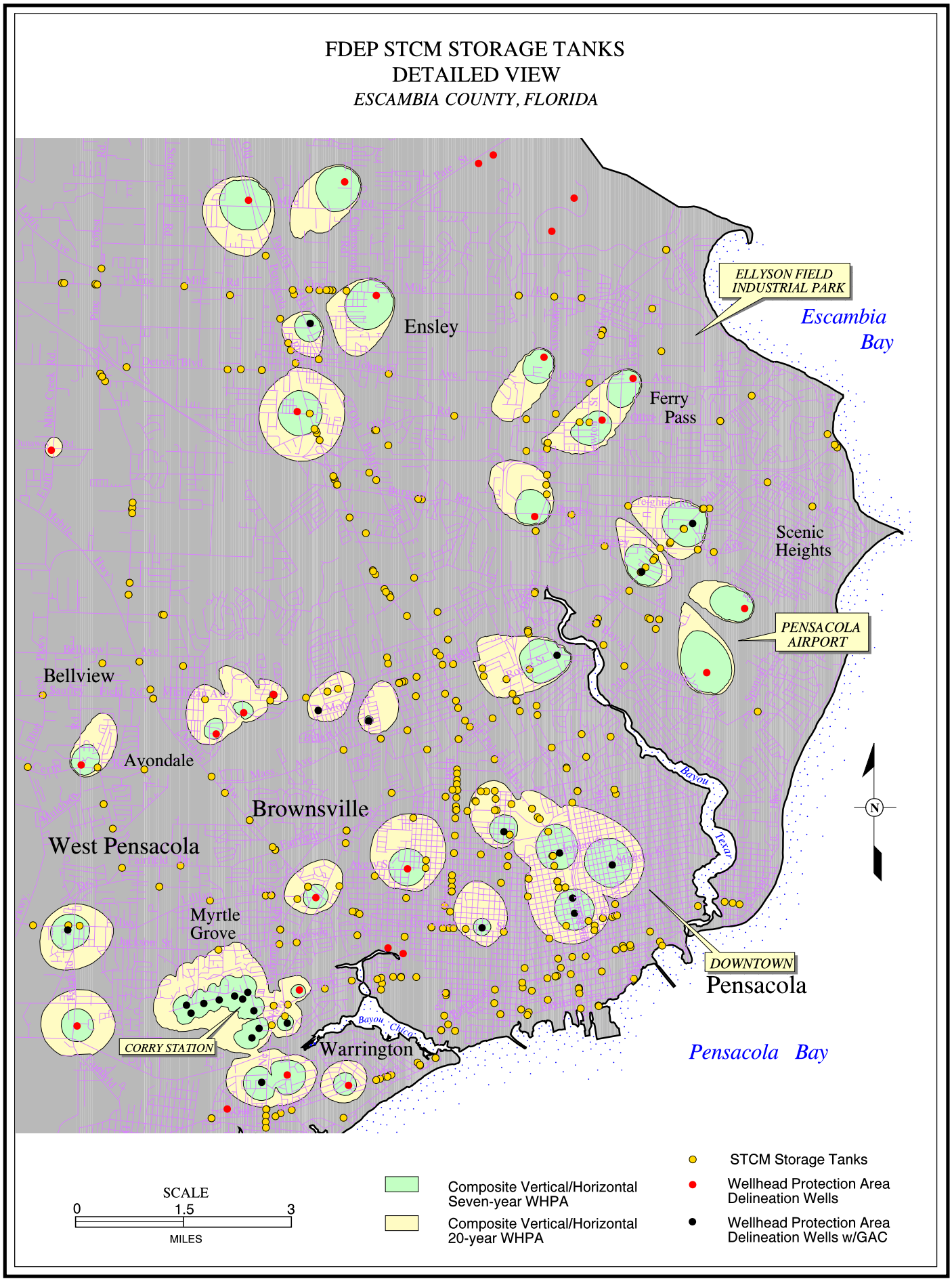


Figure 30. FDEP STCM Storage Tanks, Detailed View.

FDEP GWIS GROUND WATER QUALITY DATA

DESCRIPTION OF DATA LAYER

Data layer name

(Background Network)	*(VISA Network)*	*Parameter*
BTEX_bkn.shp	***BTEX_vn.shp***	***BTEX***
	34611vn.shp	***2,4-Dinitrotoluene***
	34696vn.shp	***Naphthalene***
34475bkn.shp	***34475vn.shp***	***Tetrachloroethene***
39180bkn.shp	***39180vn.shp***	***Trichloroethene***
82198bkn.shp	***82198vn.shp***	***Bromacil***
38815bkn.shp	***38815vn.shp***	***Hexazinone***
1105bkn.shp	***1105vn.shp***	***Aluminum***
1002bkn.shp	***1002vn.shp***	***Arsenic***
1034bkn.shp	***1034vn.shp***	***Chromium***
1042bkn.shp	***1042vn.shp***	***Copper***
950bkn.shp	***950vn.shp***	***Fluoride***
1051bkn.shp	***1051vn.shp***	***Lead***
631bkn.shp	***631vn.shp***	***Nitrate+nitrite***
1055bkn.shp	***1055vn.shp***	***Manganese***

Description .... *Selected parameter shape files depicting analytical values from the most recent FDEP Ambient Monitoring Network sampling event for which the parameter was analyzed. The shape files do not represent a single sampling event in time.*

Type .... *Point*

Datum *NAD83*

Projection .... *UTM Zone 16*

Map Units .... *Meters*

DESCRIPTION OF SOURCE MATERIALS

••

The FDEP Ambient Monitoring Section has maintained two sub-networks of wells in Escambia County to evaluate ground water quality. The Background sub-network was established to evaluate ground water quality in areas relatively unaffected by human activities and provide baseline data for comparison with the VISA sub-network data. The VISA sub-network was established to evaluate the affects of land use on ground water quality. Selected parameters were chosen based on whether an analyte had frequent or elevated detections, or was significant to commercial and industrial activities (i.e. gas stations, dry cleaners, etc.). Due to the difference in the spatial data densities between the sub-networks, each shape file represents data from only one network. The shape file names utilize the USEPA STORET parameter code as a prefix and a well sub-network abbreviation. The abbreviations “bkn” and “vn” represent the Background and VISA sub-networks, respectively. For example, the shape file depicting the most recent tetrachloroethene (STORET# 34475) values from the Escambia County Background network is named 34475bkn.shp. The one exception to this naming convention is the BTEX parameter. This parameter represents the sum of the following four

volatile organic compounds: benzene, toluene, ethylbenzene, and xylene. The water quality data were retrieved from the FDEP GWIS (Generalized Water Information System) Version 3.0, with a data release date of April 1999.

Source material location....... *NWFWMD headquarters, Ground Water Bureau*
Media of source.................... *FDEP-GWIS Application and Database CD-ROM*

••

DATA ATTRIBUTES

Column	Item name	Description
2	Well_depth	Total depth of well from land surface (feet).
3	Casing_depth	Total depth of well casing from land surface to the top of screen or open hole (feet).
6	Station_id	15-digit well identification number.
7	Station	FDEP well name.
8	Sample_date	Date water sample was collected from well.
9	Sample_time	Time water sample was collected from well.
10	Storet	USEPA Storet parameter code.
11	Parameter	Analyte name
12	Value	Analytical value of the most recent sampling event for which the parameter was sampled.
13	Val_qual	Analytical value lab qualifier (see definitions below).
14	Units	Parameter units.

The following value qualifier definitions are referenced from the FDEP Ambient Monitoring Section's "Data Management Standard Operating Procedures and Data Dictionaries, September 1997 Versions".

U **Indicates that the compound was analyzed for but not detected. The reported value shall be the method detection limit.**

A **Value reported is the average of two or more determinations.**

I **The reported value is between the laboratory method detection limit and the laboratory practical quantitation limit.**

T **Value reported is less than the laboratory method detection limit.**

K **The actual value is less than the value given.**

N **Presumptive evidence of presence of material, component tentatively identified based on mass spectral library searches.**

O **Sampled but analysis lost or not performed. Reported value shall be 0.**

Q **Sample held beyond the accepted holding time.**

J **The reported value failed to meet the established laboratory quality control criteria for either precision or accuracy; OR the sample matrix interfered with the ability to**

make an accurate lab determination; OR the value is questionable because of improper laboratory protocols.

F ***The reported value failed to meet the established field quality control criteria for either precision or accuracy; OR the sample matrix interfered with the ability to make an accurate field determination; OR the value is questionable because of improper field sampling protocols.***

V **Indicates that the analyte was detected in both the sample and any of the associated blanks, at similar concentrations.**

W ***Aspects of the well construction may significantly influence the representativeness of this value. See guidelines on assigning W qualifier below.***

! **Indicates that the reported value deviates from historically established concentration ranges.**

Notes:

Italicized descriptions deviate from EPA and/or DEP QAS descriptions.

The W qualifier is to be used in the following ways.

1) If turbidity is greater than 100 NTU, all analytes coming from that well will be qualified with a "W".

2) If the well currently has, or historically had, a water level recording device employing a lead weight, all lead values coming from that well will be qualified with a "W" and marked inactive.

3) All VOCs will be qualified for all glued PVC wells.

4) The following detections of analytes coming from galvanized steel wells will be qualified with a "W": iron, manganese, zinc, cadmium.

5) The following detections of analytes coming from stainless steel wells will be qualified with a "W": nickel, chromium.

6) All detections of trace metals coming from any type of iron well will be qualified with a "W".

Additional notes pertaining to attribute fields not listed in the shape files, but possibly required for data analysis, can be found in the above referenced FDEP document.

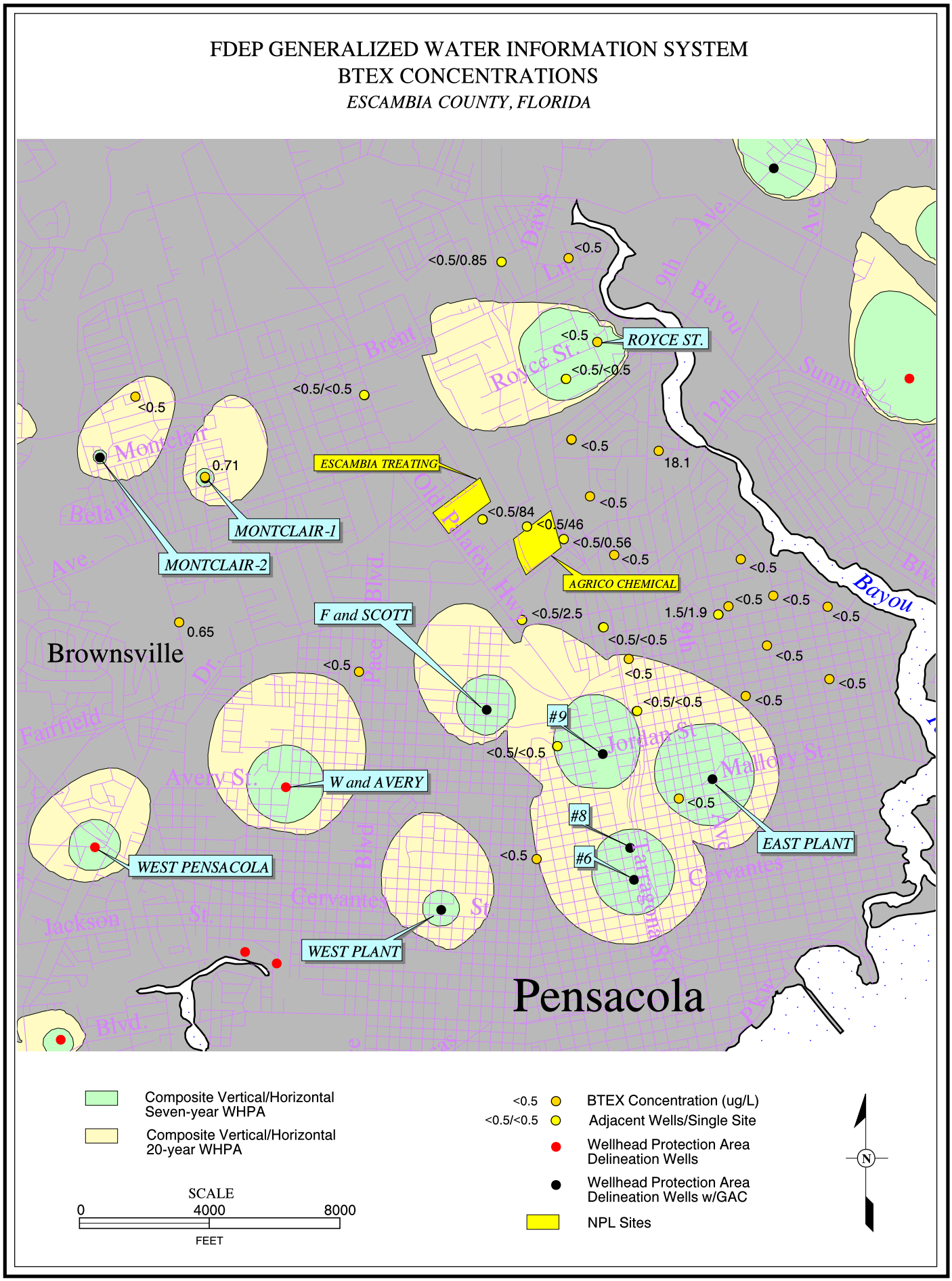


Figure 31. FDEP GWIS BTEX Concentrations.

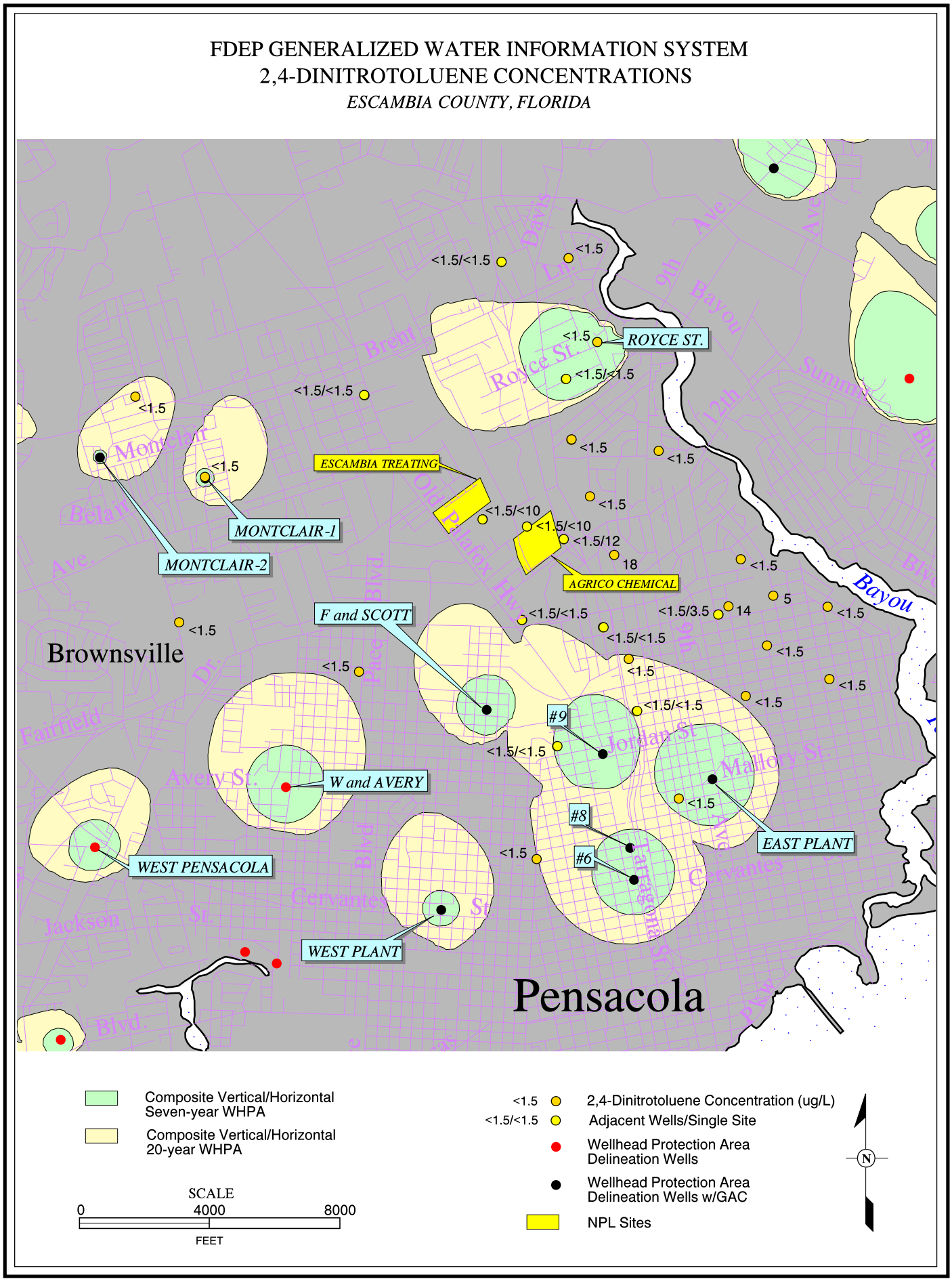


Figure 32. FDEP GWIS 2,4-Dinitrotoluene Concentrations.

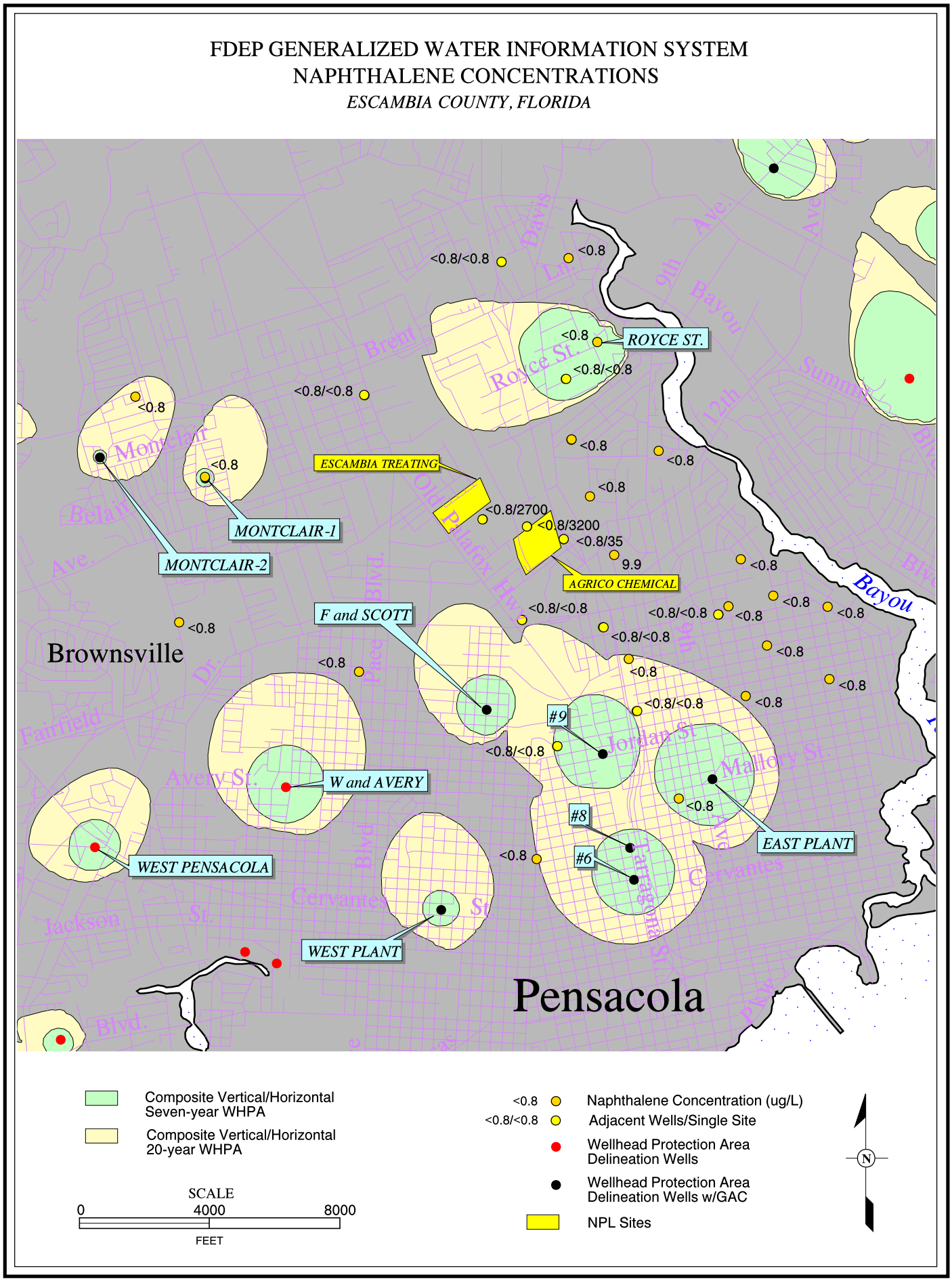


Figure 33. FDEP GWIS Naphthalene Concentrations.

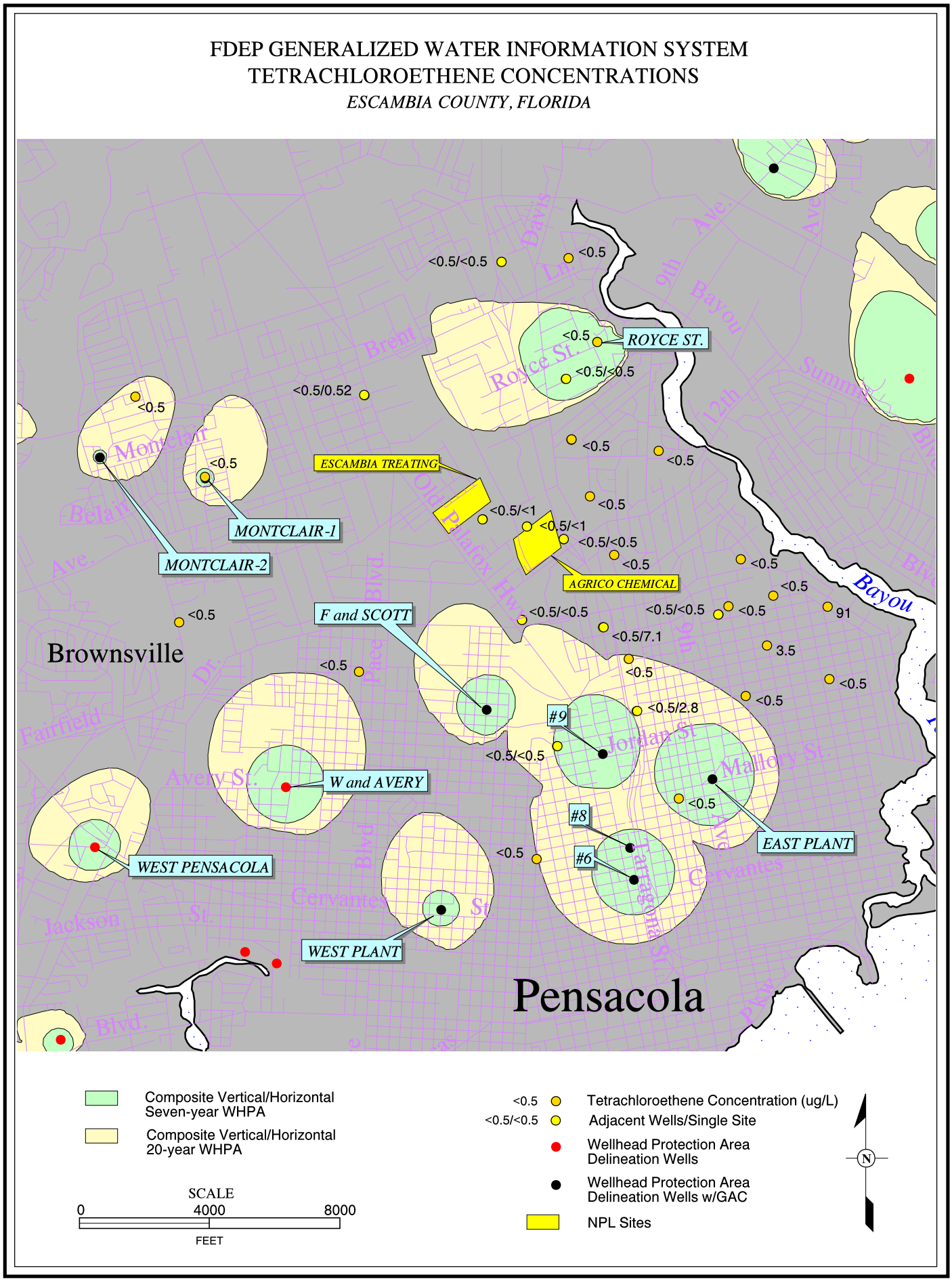


Figure 34. FDEP GWIS Tetrachloroethene Concentrations.

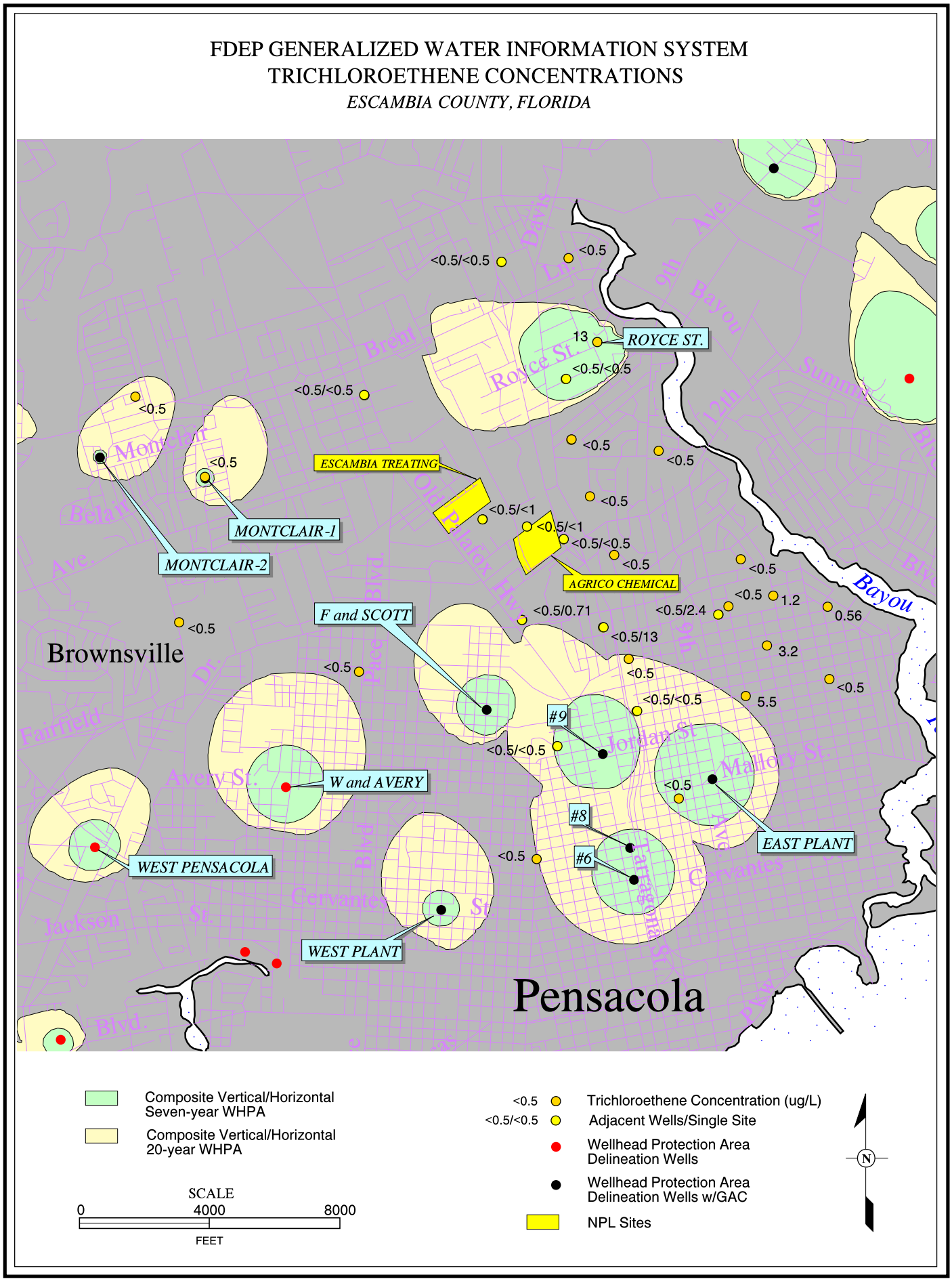


Figure 35. FDEP GWIS Trichloroethene Concentrations.

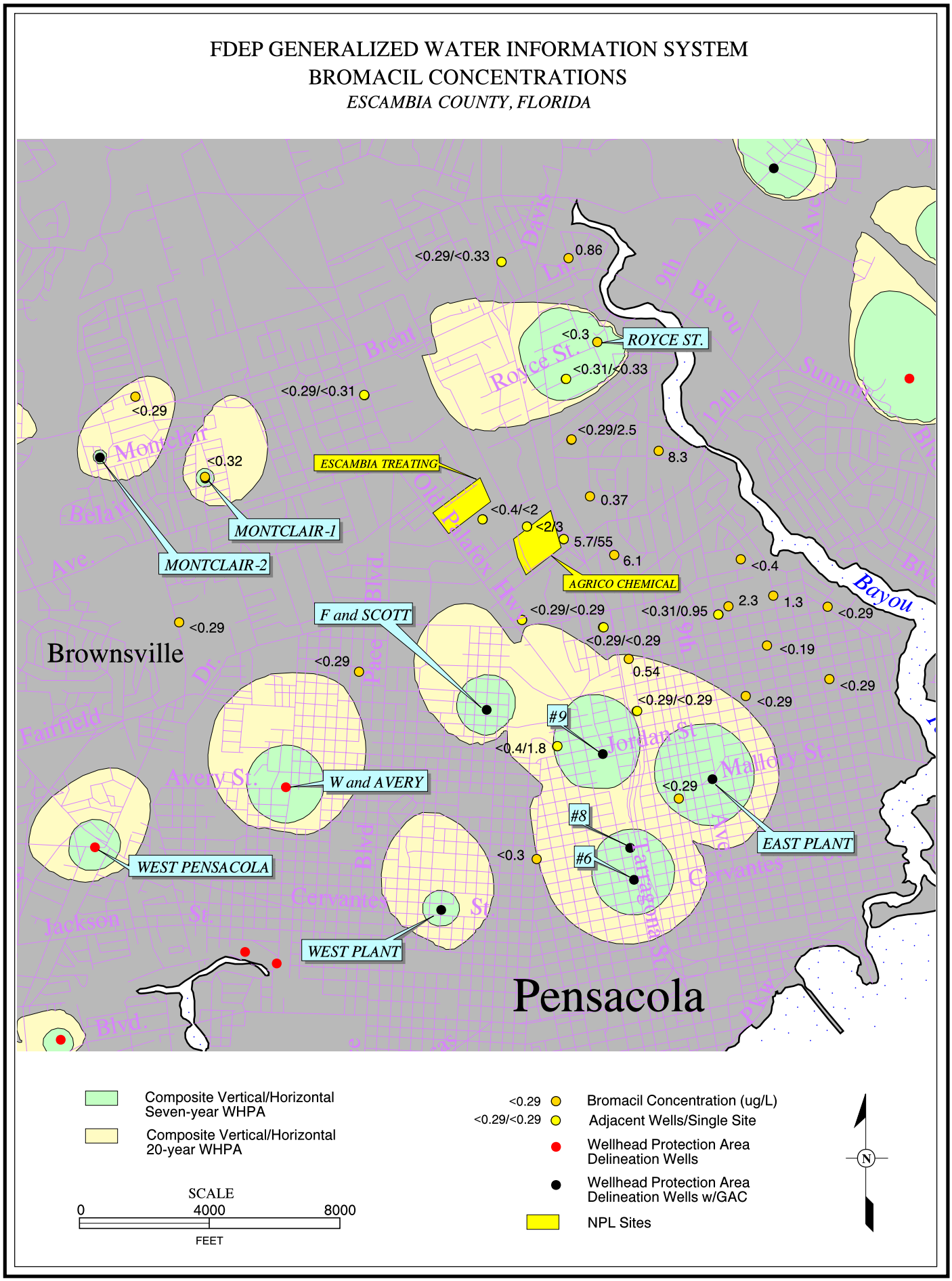


Figure 36. FDEP GWIS Bromacil Concentrations.

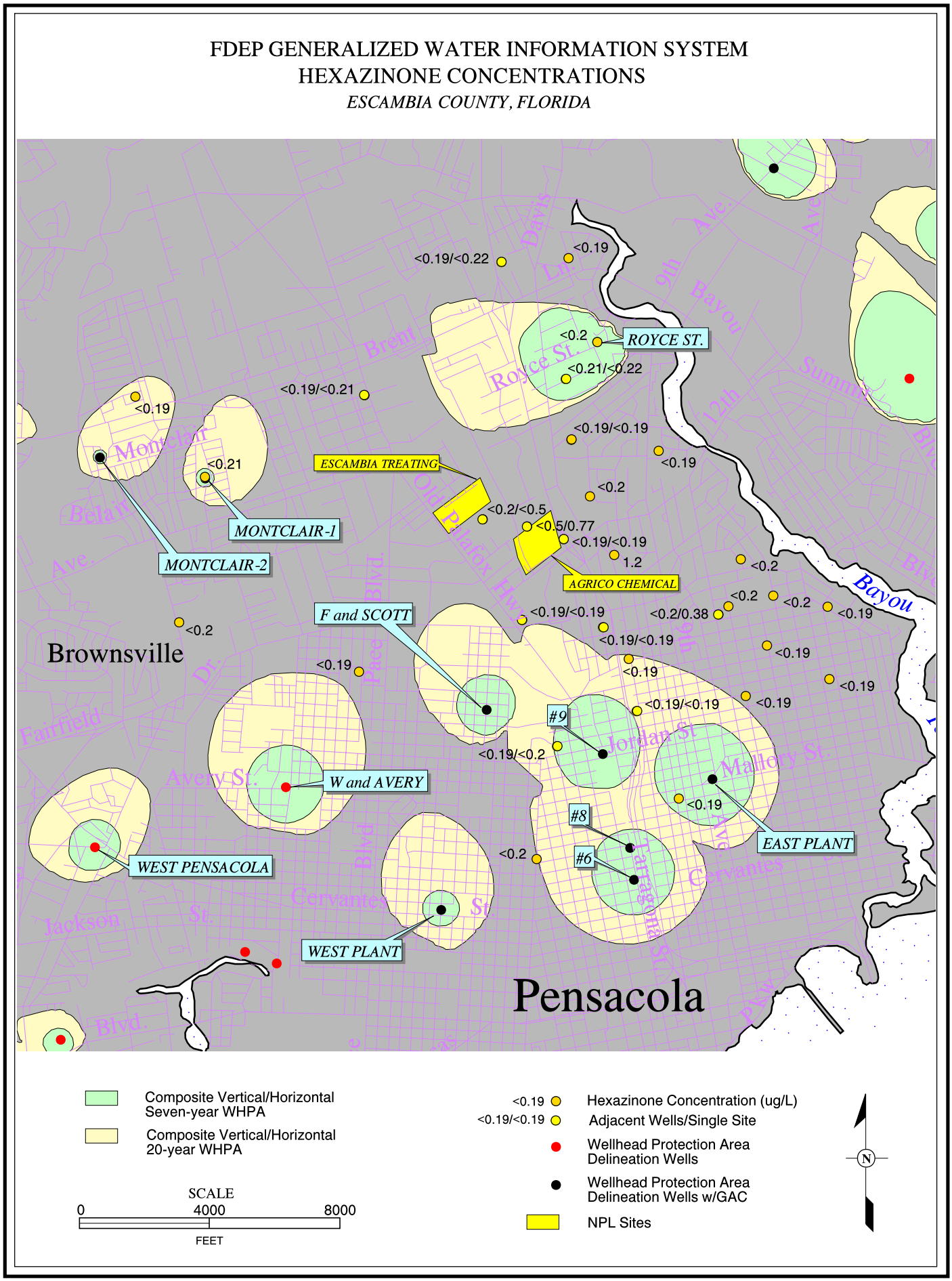


Figure 37. FDEP GWIS Hexazinone Concentrations.

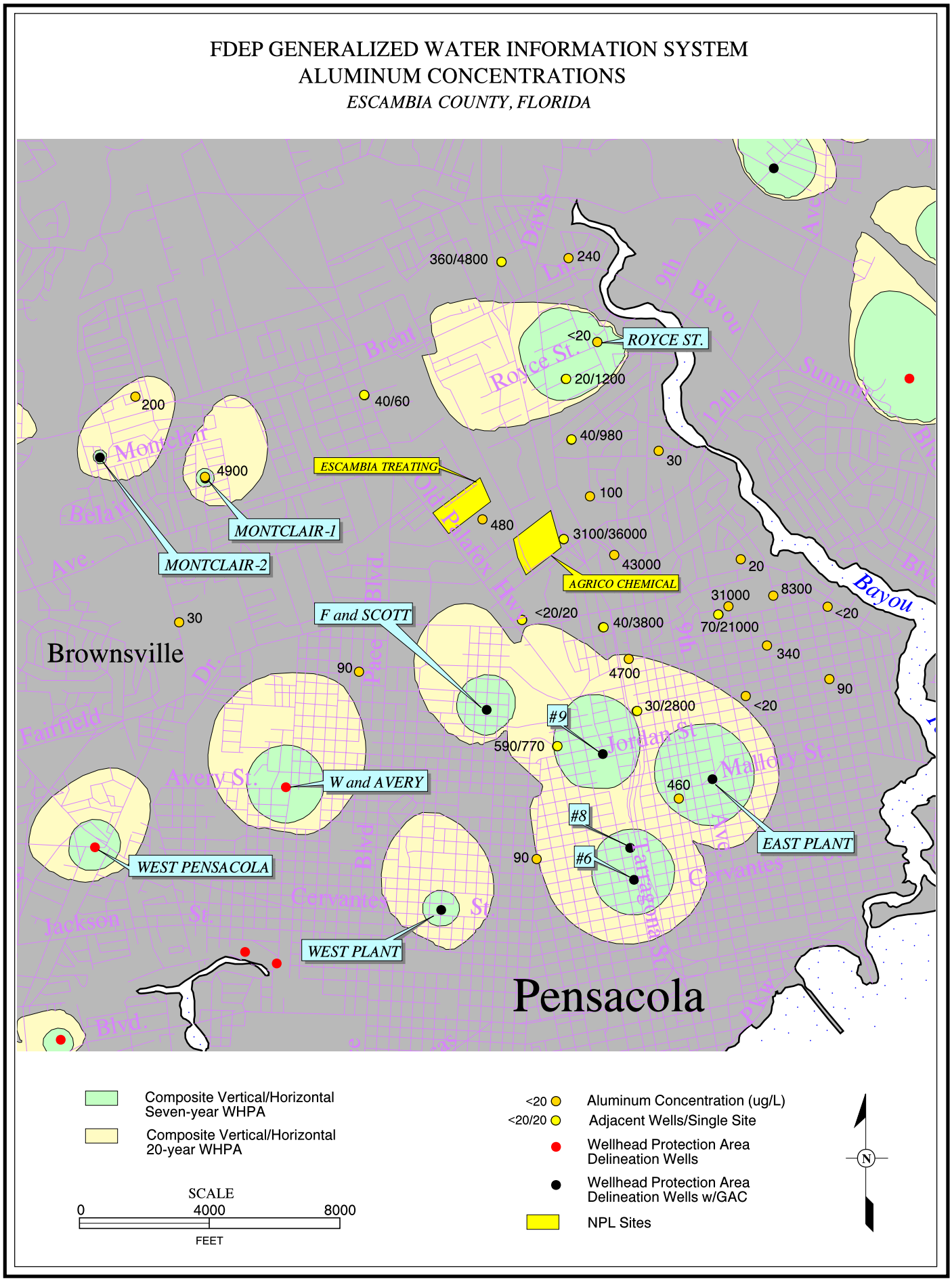


Figure 38. FDEP GWIS Aluminum Concentrations.

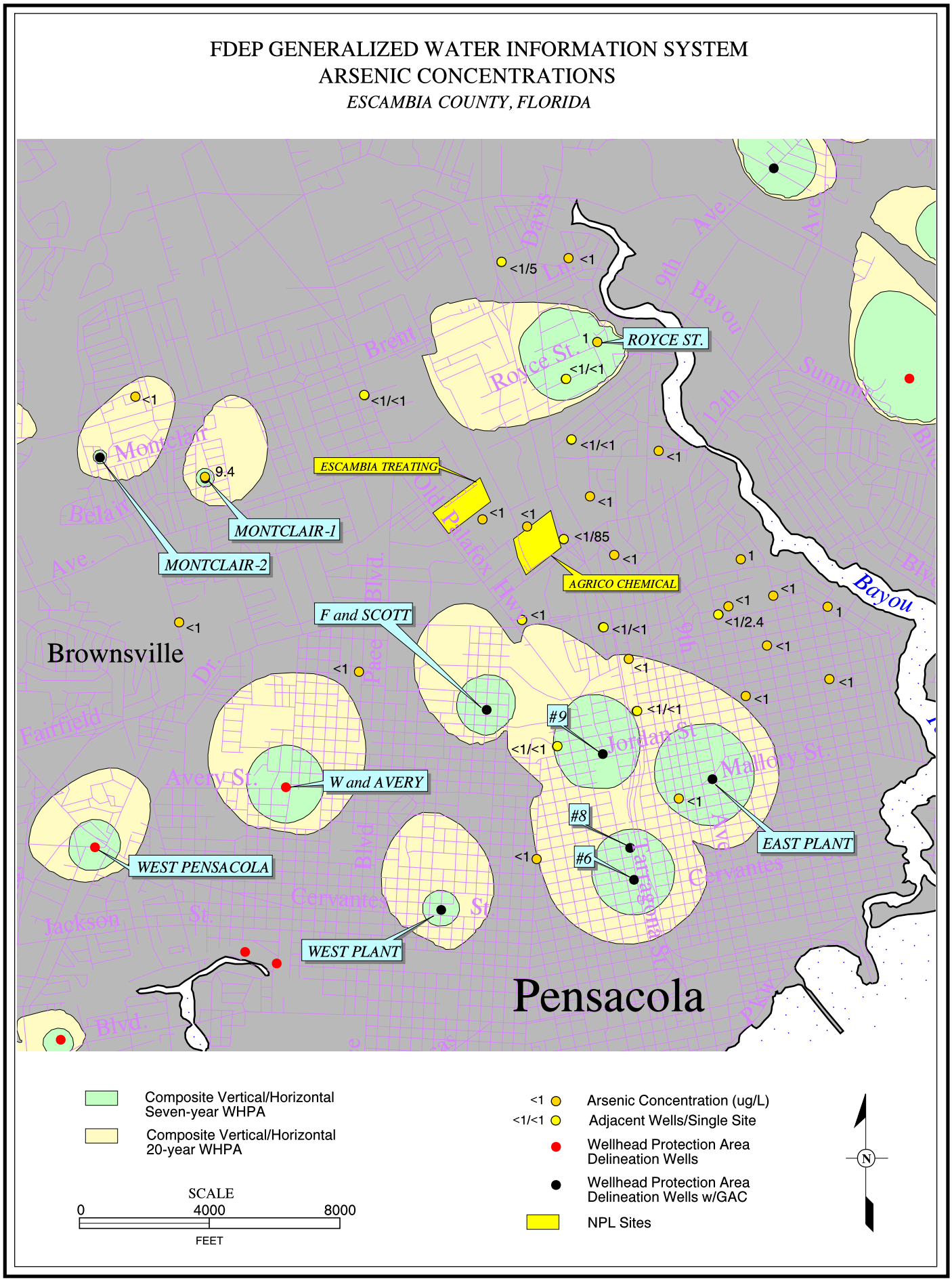


Figure 39. FDEP GWIS Arsenic Concentrations.

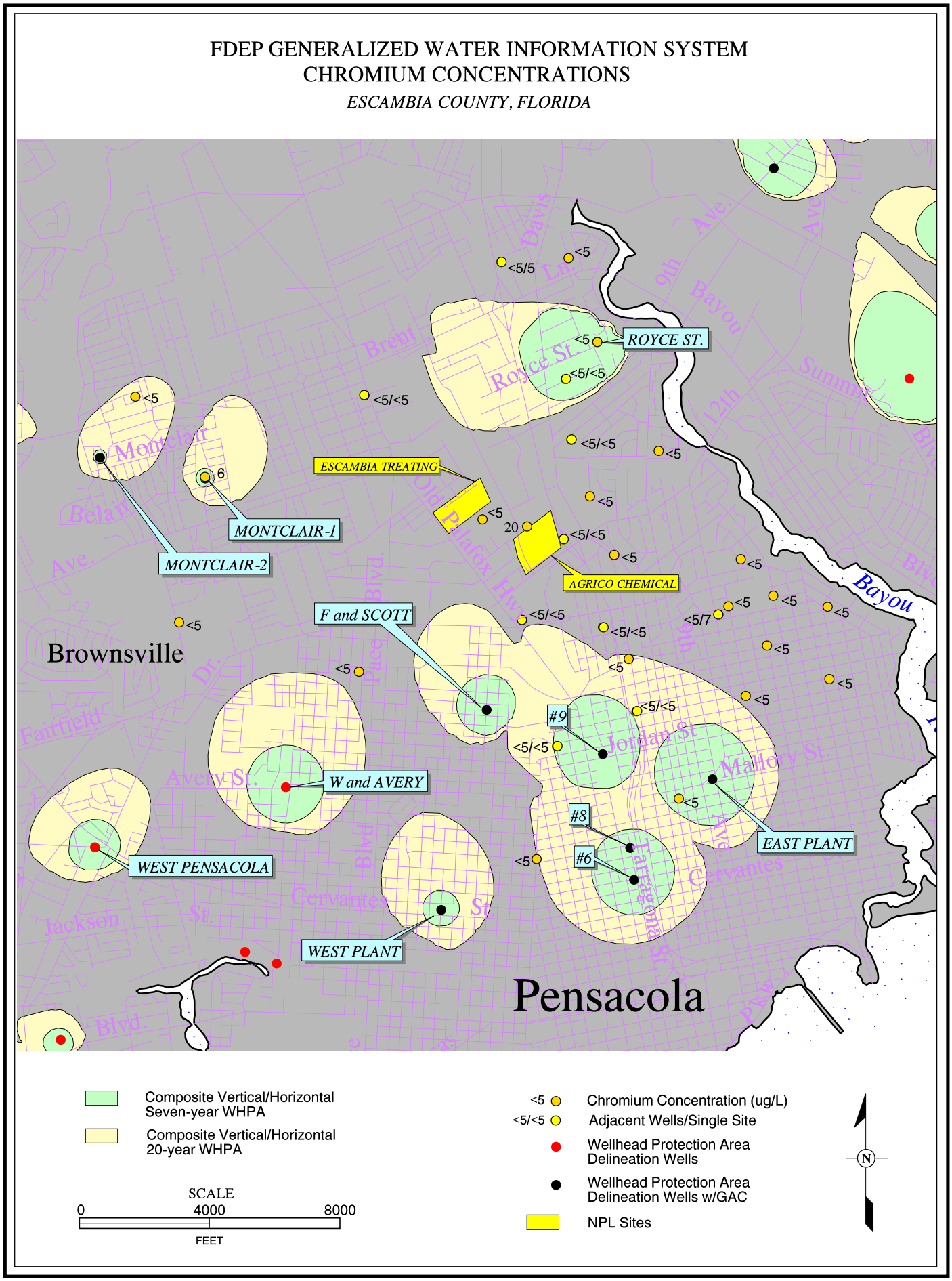


Figure 40. FDEP GWIS Chromium Concentrations.

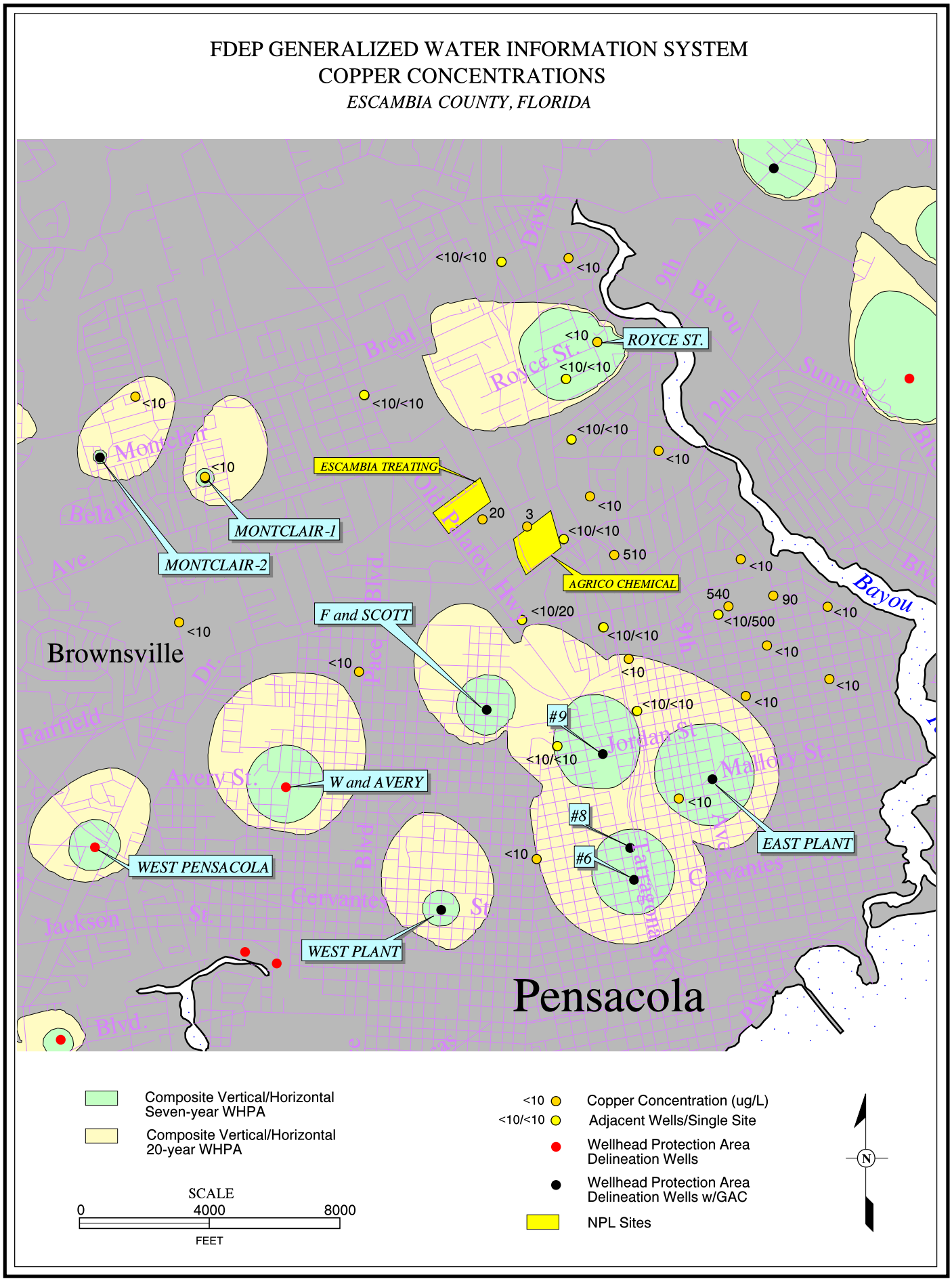


Figure 41. FDEP GWIS Copper Concentrations.

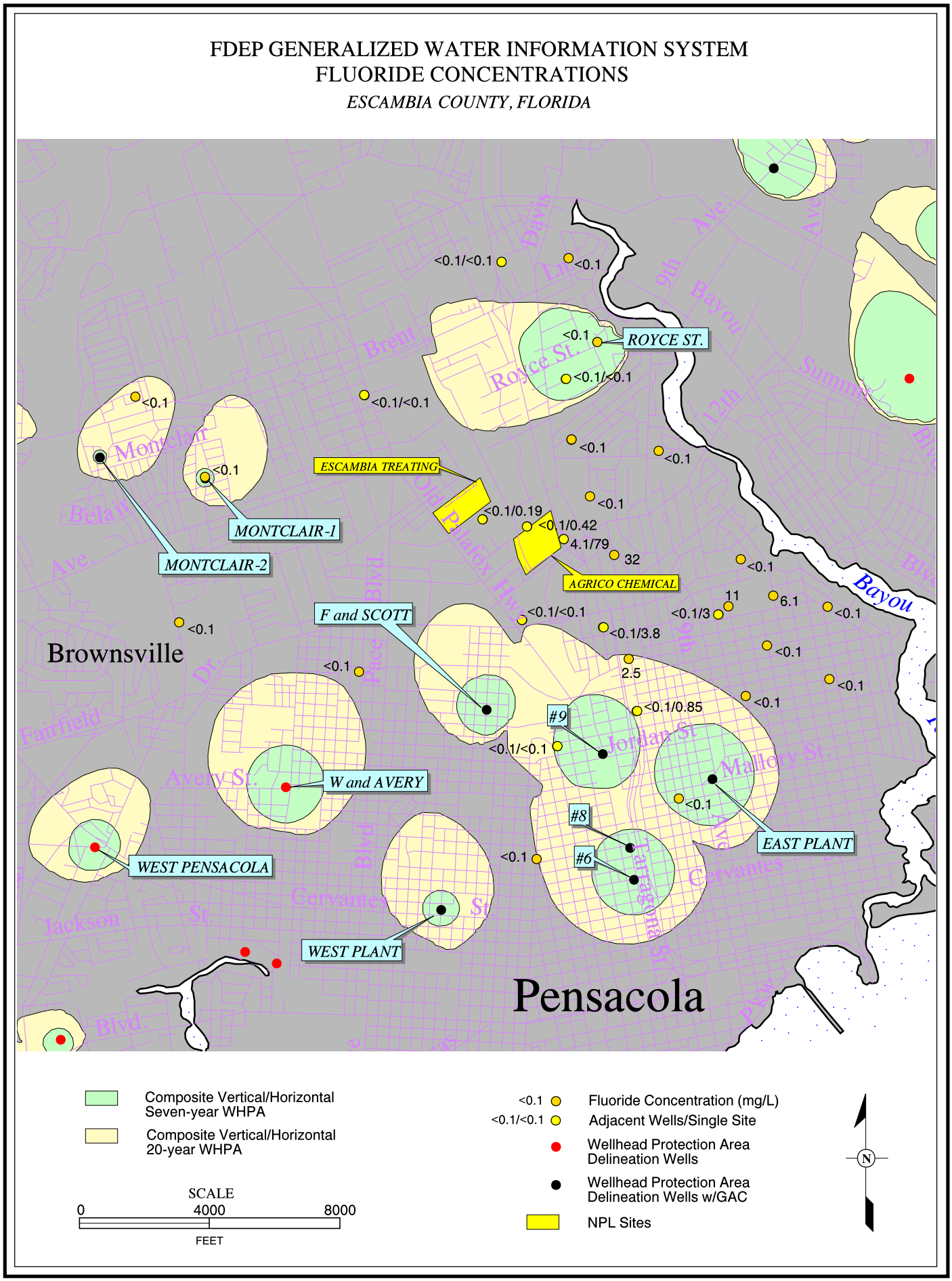


Figure 42. FDEP GWIS Fluoride Concentrations.

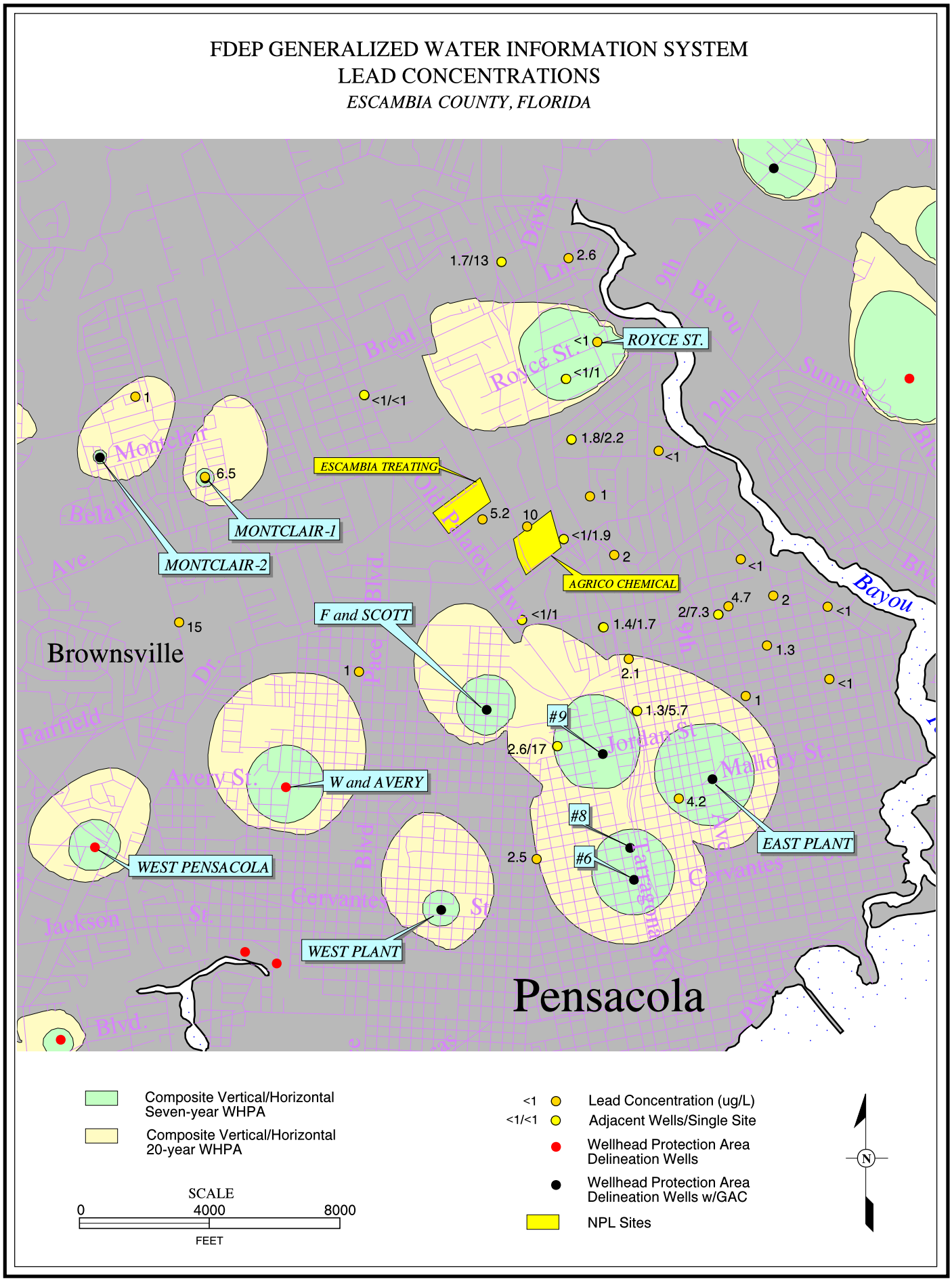


Figure 43. FDEP GWIS Lead Concentrations.

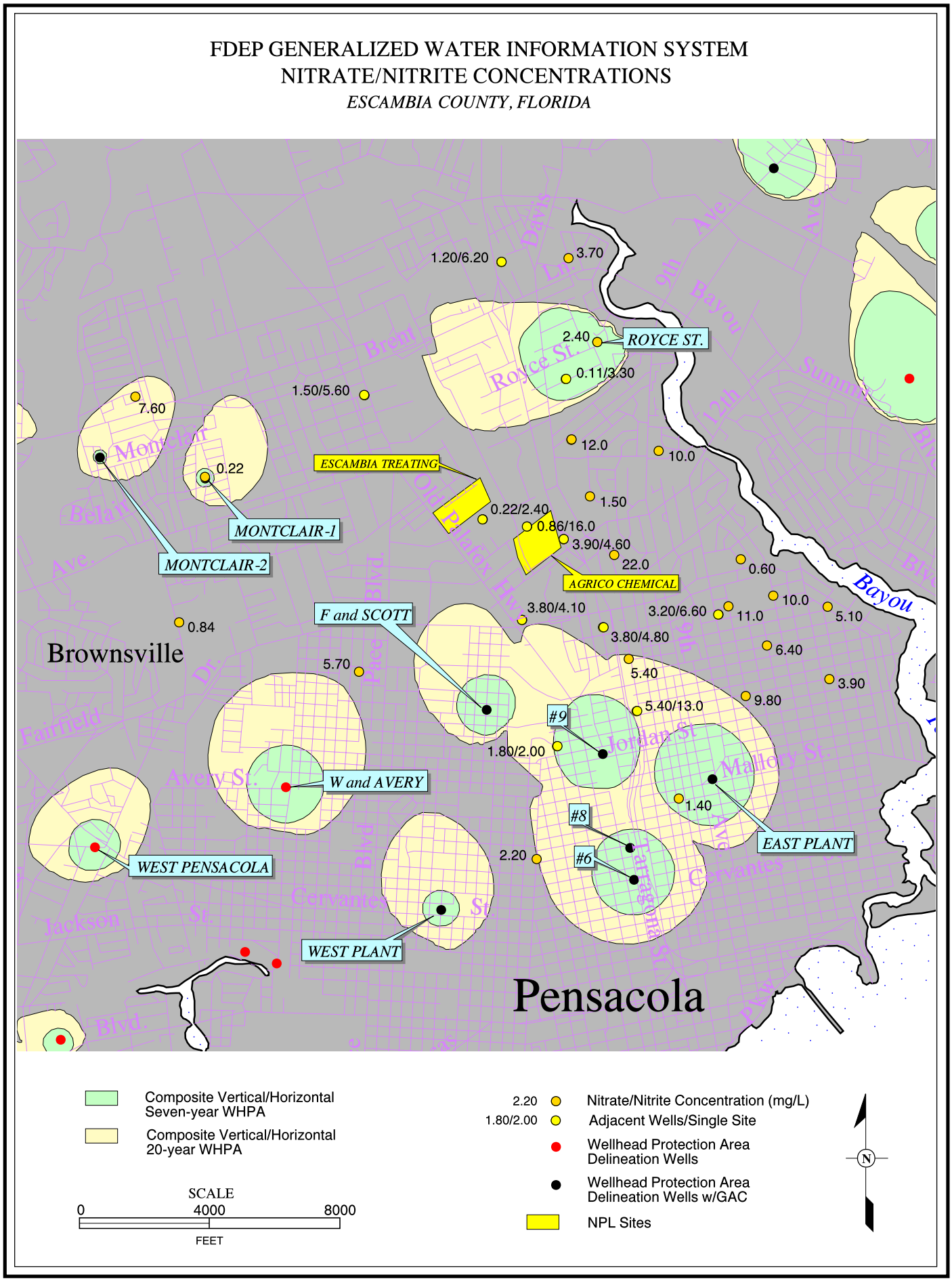


Figure 44. FDEP GWIS Nitrate/Nitrite Concentrations.

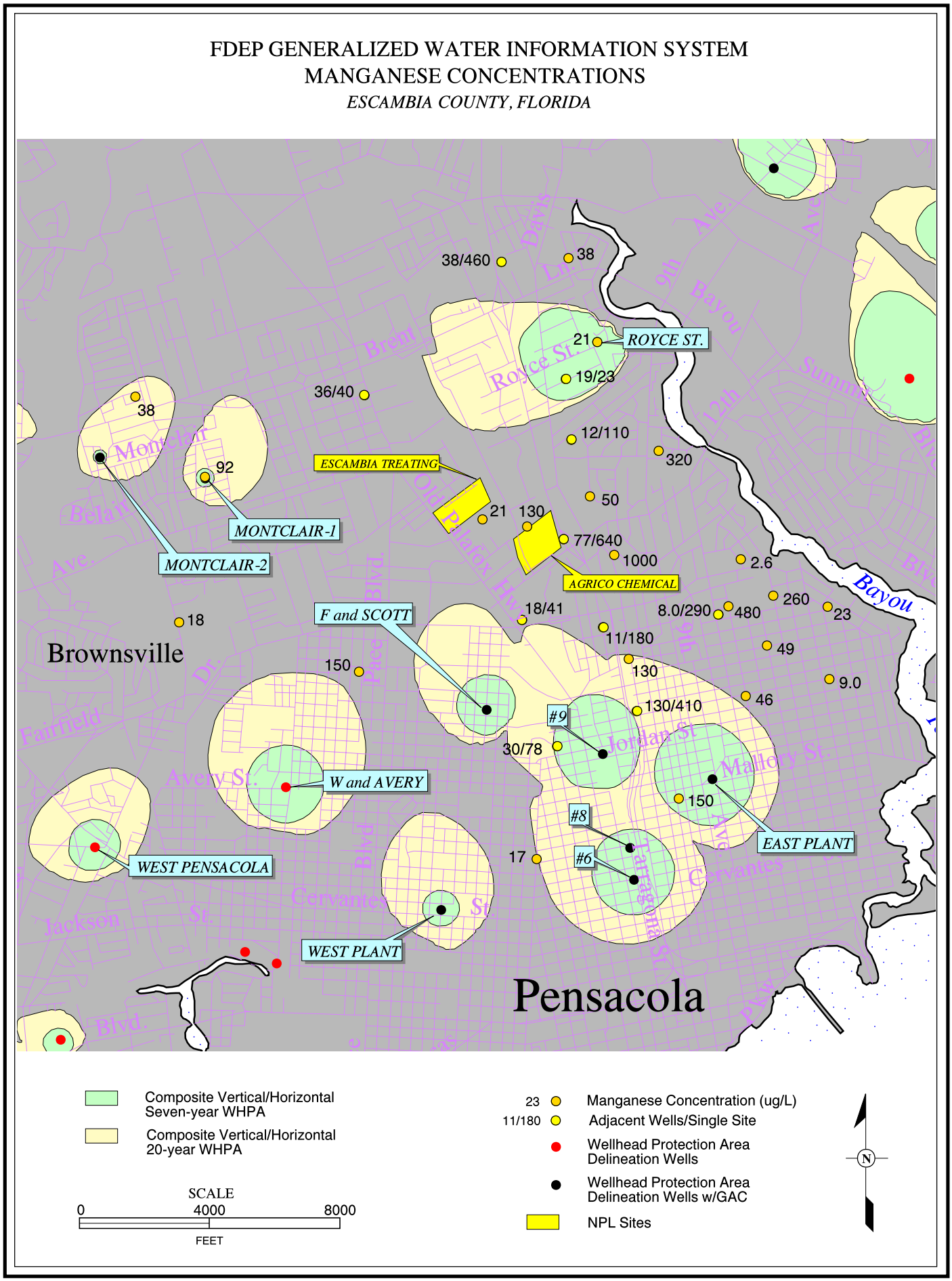


Figure 45. FDEP GWIS Manganese Concentrations.

GROUND WATER RISK ANALYSIS ARCVIEW EXTENSION

Functionality

A key purpose of this project was development of a ground water risk analysis decision-support tool. This purpose was achieved by development of an interactive tools which allows users to assess whether or not a particular point is at risk of eventually experiencing ground water contamination. The obvious utility of such a tool is the facilitation of new well siting. Southern Escambia County has many widely distributed sources of ground water contamination. A number of existing public supply wells have been effected by these sources. The likelihood that any well will be effected by contamination is controlled by a number of factors. These include the proximity of the source to the well (proposed or existing) and the particular aquifer hydraulic properties (hydraulic conductivities, unit thicknesses, gradients, etc.) lying between the well and the contamination. The main purpose of this project is to provide a means to assess whether a particular combination of aquifer hydraulic properties and proximity suggest a relatively greater or lesser risk of eventual impacts.

The required functionalities include viewing and mapping pertinent attributes of the hydrology and contamination history of southern Escambia County, interactively running the USEPA Wellhead Protection Area (WHPA) delineation model, and interactively running a project-developed ground water risk analysis module (RISK). Each of these tasks is performed from within the ArcView operating environment under an integrated Ground Water Risk Analysis System (GWRAS).

- *Mapping*

A total of 28 ArcView shape files were developed to describe the pertinent aspects of the ground water hydrology and contamination status of the Sand-and-Gravel Aquifer in southern Escambia County. Those shape files are available on the accompanying CD and have been previously described. They are available for viewing, mapmaking and visual spatial analysis.

- *WHPA*

The ArcView extension allows a user to interactively run the USEPA WHPA model from within the ArcView operating environment. Input data requirements are either obtained from the user interactively or from relevant ArcView shapefiles. This function uses user-specified time-of-travel (in years) and well pumping rate to calculate the horizontal time-of-travel in the main-producing zone. Output WHPA areas can be converted to a polyline data coverage within ArcView.

- *RISK*

The ArcView extension allows a user to interactively assess the relative risk from ground water contamination sources for any point in southern Escambia County. Input data requirements are either obtained from the user interactively or from relevant ArcView shapefiles. Output includes the site RISK score and a report of the number of contamination sources within specified radial distances of the point of interest.

WHPA Module

The source of ground water withdrawn by an individual pumping well is limited to a portion of the aquifer surrounding the well. This "portion" of the aquifer is referred to as the "zone of contribution" for that well. The USEPA (1987) defines the zone of contribution as "the area surrounding a pumping well that encompasses all areas or features that supply ground-water recharge to the well." The actual zone of contribution for a given well is controlled by the physical processes that control the behavior of ground water flow, the hydraulic conditions in the vicinity of the well and the pumping rate. With sufficient information, these physical processes can be simulated to delineate the surface expression of the zone of contribution for each well of interest.

In June 1986, the Amendments to the Safe Drinking Water Act (SDWA) initiated the State Wellhead Protection (WHP) Program. To facilitate local efforts at wellhead protection area delineation ″Guidelines for Delineation of Wellhead Protection Areas″ was published by the USEPA in 1987. In 1991 the USEPA released a wellhead protection area (WHPA) delineation model (Blandford & Huyakorn, 1991). With the WHPA model and certain hydrogeologic data, the spatial extent of the zone of contribution around a pumping well can be identified.

The WHPA model consists of four delineation modules. A description of each module is detailed in Blandford & Huyakorn (1991). For this effort, the numerical option of the General Particle Tracking Module (GPTRAC) was deemed to be most appropriate for inclusion in the RISK extension. GPTRAC, which delineates time-related capture zones around pumping wells in a steady ground-water flow field, was, therefore, incorporated into the GIS-based RISK system. Since this module performs particle tracking using a head field obtained from a numerical ground-water flow code, many types of boundary conditions, as well as aquifer heterogeneities and anisotropies, may be accounted for. The GPTRAC numerical option provides for the delineation of both pathlines and time-related capture zones. A rectangular finite-element or finite-difference grid, along with the hydraulic head values at the nodes of the grid, is required for calculation of the associated ground water velocity field. Pathlines can be delineated using particle tracking once the velocity field is determined.

The pathline of a fluid particle (beginning at a given initial location (x_0,y_0)) is determined by the integration of the following differential equations:

$$\frac{dx}{dt} = \mathrm{v_x} = \frac{q_x}{\theta} \qquad (1)$$

$$\frac{dy}{dt} = \mathrm{v_y} = \frac{q_y}{\theta} \qquad (2)$$

where (x,y) are coordinates of the fluid particle at time t; q_x and q_y are the specific flux in the x and y directions (determined using Darcy's law); and θ is the effective porosity of the aquifer.

RISK Module

The development of the RISK module utilized the results of the simulation of contaminant transport from the upper to lower part of a surficial aquifer where a semi-confined zone separates the two zones. Model output was used to derive a multivariate regression ground

water RISK model. It is considered that the physical set up of the model is similar to the surficial aquifer conditions in Escambia County. The use of a three-dimensional numerical flow and solute transport model provides insight into the influence of aquifer parameter interactions on the relative susceptibility of a pumping well to nearby contamination sources. A linear multiple regression analysis quantified the significance of each controlled aquifer hydraulic parameter considered in the numerical simulations.

Numerical Modeling of Contaminant Transport

The approach taken to identify the relative significance of various hydraulic parameters to a "risk" assessment entailed the implementation of a sensitivity analysis. Hydraulic parameters likely to influence contaminant transport within the Sand-and-Gravel Aquifer include horizontal and vertical hydraulic conductivity of the pumped aquifer, vertical hydraulic conductivity and thickness of the semi-confining unit, pumping rate, porosity, dispersivity, distance to the contaminant source, etc. In order to determine the relative significance of these properties, a series of numerical solute transport experiments were performed. These experiments form the basis of the sensitivity analysis. In turn, sensitivity analysis results form the basis of the multi-variate analysis lying at the center of the RISK analysis system.

The experiments consisted of simulating transient solute transport through a three-layer synthetic porous medium. The outcome of interest was the transient contaminant concentration history in a simulated pumping well. By varying hydraulic property values and observing the resultant pumped well concentration history, insight into the relative significance of the various properties was obtained. Although the physical setup of the model was not site-specific, it was similar to actual Escambia County conditions. Hence, the mechanisms of contaminant transport were expected to be similar to field conditions and to the question of ground water risk analysis in the county.

The experimental flow domain consisted of a surficial layer, a pumped aquifer and an intervening semi-confining unit. This is in keeping with the three-layer, leaky, confined conceptualization of the Sand-and-Gravel Aquifer. The thickness of the hypothetical aquifer (from the water table to the top of confining Intermediate System) was specified as 120 meters (m). A discharge well was simulated with the pumping rate of 0.0625 m^3/s (1,000 gpm). The well was screened from 75 to 80 m below the initial water table and was located in the basal portion of the synthetic medium (equivalent to the Sand-and-Gravel Aquifer main-producing zone). A constant input contaminant source was simulated as being situated at the top of the surficial zone. The concentration of discharged water was calculated by dividing the total mass of discharged solute during each time step by the total mass of water discharge during the same period. The maximum pore-water contaminant concentration was normalized to a dimensionless concentration of 1.00.

The physical system of the simulated volume in the X-Z, Y-Z, and X-Y planes and associated boundary conditions are shown in Figure 46. The hypothetical aquifer extends from 0 to 120 m in the Z direction and a 15-meter-thick semi-confining unit exists between 30 m to 45 m. The entire simulated volume is 4,405 m by 650 m by 120 m. This simulated volume is meshed by a 31 x 5 x 24 grid with variable spacing ranging from 400 m to 5 m in the X and Y directions and uniform spacing of 5 m in the Z direction.

To perform the experiments a density-dependent solute-transport approach was employed, and two nonlinear partial differential equations (the ground-water flow equation and the advection-

diffusion equation) are solved simultaneously by using a block-iterative, two-line, successive over-relaxation method (Varga, 1962). The finite difference model, SWIFT-II (Reeves et al., 1986), is employed to solve these two governing equations. Two governing differential equations, the ground-water flow equation and the transport equation, and the initial and boundary conditions used to describe the contaminant transport are briefly discussed herein.

Conservation of Fluid Mass

The conservation of mass expresses the balance of water and solute mass in a solid matrix. The ground-water equation is based on the conservation of mass coupled with Darcy's law for flow in a porous medium. The general equations are:

$$-\nabla \cdot (\rho \underline{u}) - Q_w + Rc' = \frac{\partial}{\partial t}(\phi \rho) \tag{3}$$

and

$$\nabla = \left| \frac{\partial}{\partial x} \right| i + \left(\frac{\partial}{\partial y} \right) j + \left(\frac{\partial}{\partial z} \right) k \tag{4}$$

where ρ is fluid density (ML^{-3}); $\underline{u}$ is fluid velocity vector (LT^{-1}); Q_w is sink or source [$(M(L^3T)^{-1}$]; a positive sign denotes a sink, a negative sign denotes a source; ϕ is the effective porosity; Rc' is the salt dissolution [$(M(L^3T)^{-1}$]; and *i, j*, and *k* are unit vectors in Cartesian coordinates.

The flow equation is Darcy's law:

$$\underline{u} = \left| \frac{\kappa}{\mu} \right| \cdot \left(\nabla p - \rho g \nabla z \right) \tag{5}$$

where κ is the solid matrix permeability (L^2), a vector quantity; μ is the fluid viscosity [$M(LT)^{-1}$]; g is the gravitational acceleration (L/T^2); and z is the potential head (L).

Fluid density is assumed to be a function of contaminant source concentration and pressure and effective porosity ϕ is a function of pressure p. The fluid viscosity μ depends on the contaminant source concentration and the temperature of the fluid.

Conservation of Solute Mass

The solute mass balance is expressed as:

$$-\nabla \cdot \left(\rho \hat{C} \underline{u} \right) + \nabla \cdot \left[\rho \left(D_{i,j} + D_m I \right) \cdot \nabla \hat{C} \right] - Q_w \hat{C}_I = \frac{\partial}{\partial t} \left(\phi \rho \hat{C} \right) \tag{6}$$

where D_m is the molecular diffusivity (L^2T^{-1}); $D_{i,j}$ is the dispersion tensor (L^2T^{-1}); and I is the identity tensor.

Equation 6 describes the rate of change of solute in the fluid phase in terms of the net dispersive and diffusive flux, the net advective flux, and the solute source or injection rate.

The dispersion coefficient is originally from Bear (1961) and Scheidegger (1961). For an isotropic porous medium, the dispersion tensor $D_{i,j}$ is a function of velocity of ground-water flow, and can be expressed by the longitudinal dispersivity α_L (m) and the transverse dispersivity α_T (m):

$$D_{ij} = \left(\alpha_L - \alpha_T\right) \frac{u_i\, u_j}{u} + \alpha_T u \delta_{ij} \tag{7}$$

$$u = \left(u_1^2 + u_2^2 + u_3^2\right)^{1/2} \tag{8}$$

where u_i(x,y,t) is the velocity in the *i* the direction; δ_{ij} is the Kronecker delta function; and *i* and *j* are unit vectors in the Cartesian coordinates.

Initial and Boundary Conditions

For the problem of interest, supplemental information (initial and boundary conditions) is required for solution of the above equations. The hydrostatic equilibrium is assumed for the initial pressure distribution. The boundary condition is to specify that the dependent variables are known functions of space and time in the simulated domain. The boundary conditions can be generally classified into three types, Dirichlet, Neumann, and Cauchy.

The initial and boundary conditions and the above two partial-different equations (Eqs. 3 and 6) are solved by the finite-difference scheme to determine the piezometric heads and the concentrations at nodes inside the aquifer boundary. Numerical procedures for solving the governing equations require an appropriate mesh in space and time steps. The set of linear equations generated by spatial discretization has to be solved repeatedly as the simulation time advances. To solve the partial-differential equations (Eqs. 3 and 6) by using the finite-difference technique, a two-line, successive over-relaxation method (Varga, 1962) is employed. It is a block-iterative method. The optimal over-relaxation factor is first estimated to increase convergence; then two neighboring lines of nodes are oriented and solved together by direct elimination. Once the optimal relaxation parameters and the optimal directions are determined at the time step for each transport equation, a convergent solution can be achieved.

Sensitivity Analysis Results

For the purposes of the sensitivity analysis, thirteen simulation cases were considered. A total of twelve different parameters were evaluated for their significance to solute transport; pumped aquifer horizontal hydraulic conductivity, pumped aquifer vertical hydraulic conductivity, longitudinal dispersivity, transverse dispersivity, well screen location, porosity, recharge, pumping rate, semi-confining unit thickness, semi-confining unit vertical hydraulic conductivity, water-table gradient and contaminant source location (Table 6). As a basis for comparison, a

reference case was established (case #1). Hydraulic properties that define the reference case are given in Table 7.

For each of the twelve parameters of interest, a series of solute transport simulations were performed. Transport was simulated for a period of ten years, and was time-stepped in ten-day increments. One by one the twelve parameters were varied through a range of values, transport simulations were performed, and the outcomes compared to the reference case. Results are presented as a series of dimensionless concentration breakthrough curves (Figures 47 through 58). In each figure the breakthrough curve for the reference case is compared to curves obtained from the permutations of the parameter of interest. The greater the deviation of a given curve from the reference case, the more significant is the impact of the parameter value on contaminant transport.

Case Results

In simulation case #2, the effect of horizontal conductivity of the pumped aquifer (K_h) was investigated. The values of horizontal conductivity varied from 0.864 m/d to 86.4 m/d. Similarly, to investigate the effect of vertical conductivity (K_v) of the pumped aquifer (case #3), the values of vertical conductivity varied from 0.00864 m/d to 8.64 m/d. Hydraulic conductivity can vary several orders of magnitude and is usually considered to be a highly uncertain parameter in simulations. The mixing of waters of varying concentrations is dominated by the horizontal conductivity and this process will dilute the contaminant concentration. Increasing the vertical hydraulic conductivity will increase the vertical velocity; consequently, the movement of contaminant can also be increased. The computed temporal variations of the dimensionless concentration of pumped water are shown in Figures 47 and 48, respectively.

Case #4 is to investigate the effect of longitudinal dispersivity, α_L, by changing the values of α_L from 0.1 m to 10 m. Case #5 is to investigate the effect of transverse dispersivity, α_T, by changing the values of α_T from 0.01 m to 1 m. The results for cases #4 and #5 are shown in Figures 49 and 50, respectively. The migration of plume in general is controlled by the combination of advection, dispersion and diffusion. The dispersion and diffusion are not critical since the dominant factor is the advection. The dispersion tensor, ***D*** (Eq. 7), is a function of flow velocity and is used to represent the mixing phenomenon.

Case #6 is to investigate the effect of well screen location by shifting the location of well screen by 10 meters both up and down. The shifting of well screen depth changes the distance from the well screen to the contaminant source. Flow velocity is inversely proportional to the distance to the pumping well; therefore, the movement of plume will become less significant if the distance between the well screen and the contaminant source becomes larger. This can be clearly demonstrated from the results shown in Figure 51.

Case #7 is to investigate the effect of porosity, ϕ, by changing the values of ϕ from 0.05 to 0.5. The average velocity, *V*, is given by the specific discharge obtained from Darcy's law (Eq. 3) divided by the effective porosity, that is, *V* is inversely proportional to the porosity. The plume is mainly transported by advection, therefore, the transport of plume will be less significant if a high porosity value is used, and vice versa. This is demonstrated from the results shown in Figure 52.

Case #8 is to investigate the effect of recharge by imposing 0.05 m/yr, 0.127 m/yr, and 0.254 m/yr (2 in/yr, 5 in/yr, and 10 in/yr) of recharge uniformly distributed into the aquifer. Increasing recharge can, potentially, alleviate a contamination problem; however, the recharge rate to each cell in the simulation model is much lower than the discharge rate (1,000 gpm) and will not significantly relax the contamination problem. These results are shown in Figure 53.

Case #9 is to investigate the effect of pumpage by changing the pumping rate from 6.25×10^{-4} m^3/s to 0.1875 m^3/s (10 gpm to 3,000 gpm). The large increase in concentration as the pumping rate increases is expected. The variations of the concentration of discharged water during 10 years of continuous pumping are shown in Figure 54.

Case #10 is to investigate the effect of the thickness of semi-confining zone. A continuous semi-confining zone with thickness ranges from 5 m to 50 m is considered and compared with the reference case. Case #11 is to investigate the effect of the vertical hydraulic conductivity in the semi-confining zone (K_Z) by varying the values between 8.64×10^{-6} m/d and 0.864 m/d (2.85×10^{-5} ft/d and 2.85 ft/d). The results of both cases are shown in Figures 55 and 56. As can be seem from the simulation results, the thickness and hydraulic conductivity of semi-confining zone greatly retard the movement of plume from the surficial zone to the main-producing zone and are considered as critical control parameters in the migration of plume.

Case #12 is to investigate the effect of regional flow by changing the slope of water table from 0 to 0.0034. Because of the resistance of the matrix, ground water flow is a slow process and the influence of regional flow to the migration of plume is much less significant than the local pumping activity. The results shown in Figure 57 indicate that the influence of regional flow is relatively insignificant and, practically, can be ignored.

Case #13 is to investigate the effect of contaminant source location located at both upstream and downstream. The separation distances, d, considered in this simulation vary from 100 meters to 500 meters upstream and downstream. The results of above three cases are shown in Figure 58.

An additional test of parameter significance was performed by comparing concentrations at the end of the ten-year simulation period. Discharged concentrations at the end of the period were compared to the reference case based on the following formula (Table 8).

$$\text{contaminant - concentration change (\%)} = \frac{\text{model output} - \text{reference output}}{\text{reference output}} \times 100 \qquad (9)$$

A negative percentage in concentration change indicates a decrease in concentration as compared to the reference case. Conversely, a positive percentage change indicates an increase in concentration at period end. In the case of a positive percentage change, the prescribed combination of parameter values was more effective at delivering contaminants to the well than was the reference case. By inference, this parameter combination poses a greater "risk." For example, vertical hydraulic conductivity of the semi-confining unit has percentage changes as high as 13,000 percent. Higher K_Z values allow contaminants to more readily leak across the semi-confining unit and, hence, more readily reach the pumping well. This outcome is not particularly surprising. Conversely, screen location, transverse dispersivity, recharge and contaminant source location all have relatively little impact on discharged concentration at period end and, hence, little significance to the assessment of "risk."

On the basis of these results, contaminant transport is believed to be influenced by the following factors (in descending order of significance): vertical hydraulic conductivity of the pumped aquifer; vertical hydraulic conductivity of the semi-confining unit; effective porosity; horizontal hydraulic conductivity of the pumped aquifer; thickness of semi-confining unit; pumping rate; water-table gradient; contaminant source distance; recharge rate; longitudinal and transverse dispersivities and well screen location.

Multi-Variate Analysis

Sensitivity analyses conducted in this study quantify the factors governing solute transport in the subsurface. The results are utilized to develop a relatively simple ground water risk model. With this model, the relative risk of a well being effected by ground water contamination can be identified. Results from previous numerical simulations indicate that the vertical hydraulic conductivity (K_Z) (both the pumped aquifer and the semi-confining unit) is the major factor controlling the movement of plume from the surficial zone to the main producing zone. The remaining parameters considered in the sensitivity analysis are of relatively equal important.

Subsequent to the sensitivity analysis, a linear multiple regression analysis was conducted to quantify the significance of controlled parameters and to develop a relationship between discharged ground water quality and these parameters. On the basis of the regression analysis, a series of simple ground water risk assessment models were developed. These models, based on knowledge of the study area, the sensitivity analysis, and results from a multiple regression analysis, can be used to provide technical support for current and future ground water use.

Linear Multiple Regression Analysis

K_X and K_Z, effective porosity, thickness of semi-confined zone, pumping rate, water table gradient, contaminant source distance, surface recharge, longitudinal and transverse dispersivity and well screen location are the independent variables used to develop a linear multiple regression water quality model. The dependent variable is the calculated dimensionless concentration at the end of 10-year simulation. The SPSS/PC+ backward regression analysis (Norusis, 1990) is adopted to determine the smallest number of independent variables. The results of this backward-elimination procedure are summarized in Table 9. The coefficient of determination, R_{sq}, is the square of the multiple correlation coefficient, Mult*R*, which indicates how good does the regression model explain the observed data. Adj R_{sq} is similar to R_{sq}; however, it takes into account the different number of degrees of freedom (Plane and Oppermann, 1977).

The coefficients for each independent variable listed in Table 9 do not represent the actual weight since uniform units do not apply to each variable. The β coefficient concept, which adjusts the regression coefficients to eliminate the difference caused by the difference in units, is adopted. The β coefficients for each independent variable are tabulated in Table 10. In addition, the variance inflation factor, VIF, is also computed to check the multi-co-linearity between independent variables. The value of VIF equal or close to 1 indicates that there is no redundant information in the other independent variables. The results of VIF shown in Tables 11 to 15 shows that all the variables are independent of each other.

Models of Ground Water Risk

All regression equations derived from the backward-elimination procedure at each step (Table 10) are considered to develop the RISK models. Each independent variable is further classified into the same number of data classes, and summarized in Table 16. Note that for the variables negatively related to concentration, the higher the variable values, the lower the class rank assigned. The reverse is true for the positively related variables. For each step, the β coefficients are normalized to 1, and used to weigh the class ranking of each independent variable.

The higher the ranking, the greater the contamination hazard. In addition, in analyzing the significance of separation distance between the contaminant source and the pumping well only a single contaminant source was considered. In reality, multiple contaminant sources are expected to be found near the site of interest. To account for the effect of multiple contaminant sources, β coefficients (determined for CSDIS) are further multiplier by the total number of contaminant sources (N). Five selected ground water RISK models that are derived to calculate risk scores are as follows.

1. $$\text{Risk} = \beta_1\times(K_x \text{ class rank}) + \beta_2\times(K_z \text{ class rank}) + N\times\beta_3\times(\text{CSDIS class rank}) + \beta_4\times(Q_p \text{ class rank}) + \beta_5\times(SCK_z \text{ class rank}) + \beta_6\times(\text{SCTHC class rank}) + \beta_7\times(\phi \text{ class rank}) + \beta_8\times(\text{WTG class rank}) + \beta_9\times(\text{UREC class rank}) + \beta_{10}\times(\alpha_L \text{ class rank}) + \beta_{11}\times(\alpha_V \text{ class rank}) + \beta_{12}\times(\text{SCREEN class rank}) \quad (10)$$

2. $$\text{Risk} = \beta_1\times(K_x \text{ class rank}) + \beta_2\times(K_z \text{ class rank}) + N\times\beta_3\times(\text{CSDIS class rank}) + \beta_4\times(Q_p \text{ class rank}) + \beta_5\times(SCK_z \text{ class rank}) + \beta_6\times(\text{SCTHC class rank}) + \beta_7\times(\phi \text{ class rank}) + \beta_8\times(\text{WTG class rank}) + \beta_9\times(\text{UREC class rank}) \quad (11)$$

3. $$\text{Risk} = \beta_1\times(K_x \text{ class rank}) + \beta_2\times(K_z \text{ class rank}) + N\times\beta_3\times(\text{CSDIS class rank}) + \beta_4\times(Q_p \text{ class rank}) + \beta_5\times(SCK_z \text{ class rank}) + \beta_6\times(\text{SCTHC class rank}) + \beta_7\times(\phi \text{ class rank}) \quad (12)$$

4. $$\text{Risk} = \beta_1\times(K_x \text{ class rank}) + \beta_2\times(K_z \text{ class rank}) + N\times\beta_3\times(\text{CSDIS class rank}) + \beta_4\times(Q_p \text{ class rank}) + \beta_5\times(SCK_z \text{ class rank}) + \beta_6\times(\text{SCTHC class rank}) \quad (13)$$

5. $$\text{Risk} = \beta_1\times(K_x \text{ class rank}) + \beta_2\times(K_z \text{ class rank}) + N\times\beta_3\times(\text{CSDIS class rank}) + \beta_4\times(Q_p \text{ class rank}) \quad (14)$$

where $n\beta_i = \dfrac{\beta_i}{\sum_{i=1}^{n}\beta_i}$

The choice among the above RISK models depends on the availability of data. If more field data are available, more reliable prediction can be given. Use of model 1 (Eq. 10) is expected to be more reliable than the use of model 5 (Eq. 14). However, the results from any of the five

models should only be used to provide general guidance for selecting new well locations and for comparing sites. This is due to relatively large uncertainties involved in the ground water system, specifically, in the distribution of both contaminants and aquifer hydraulic properties.

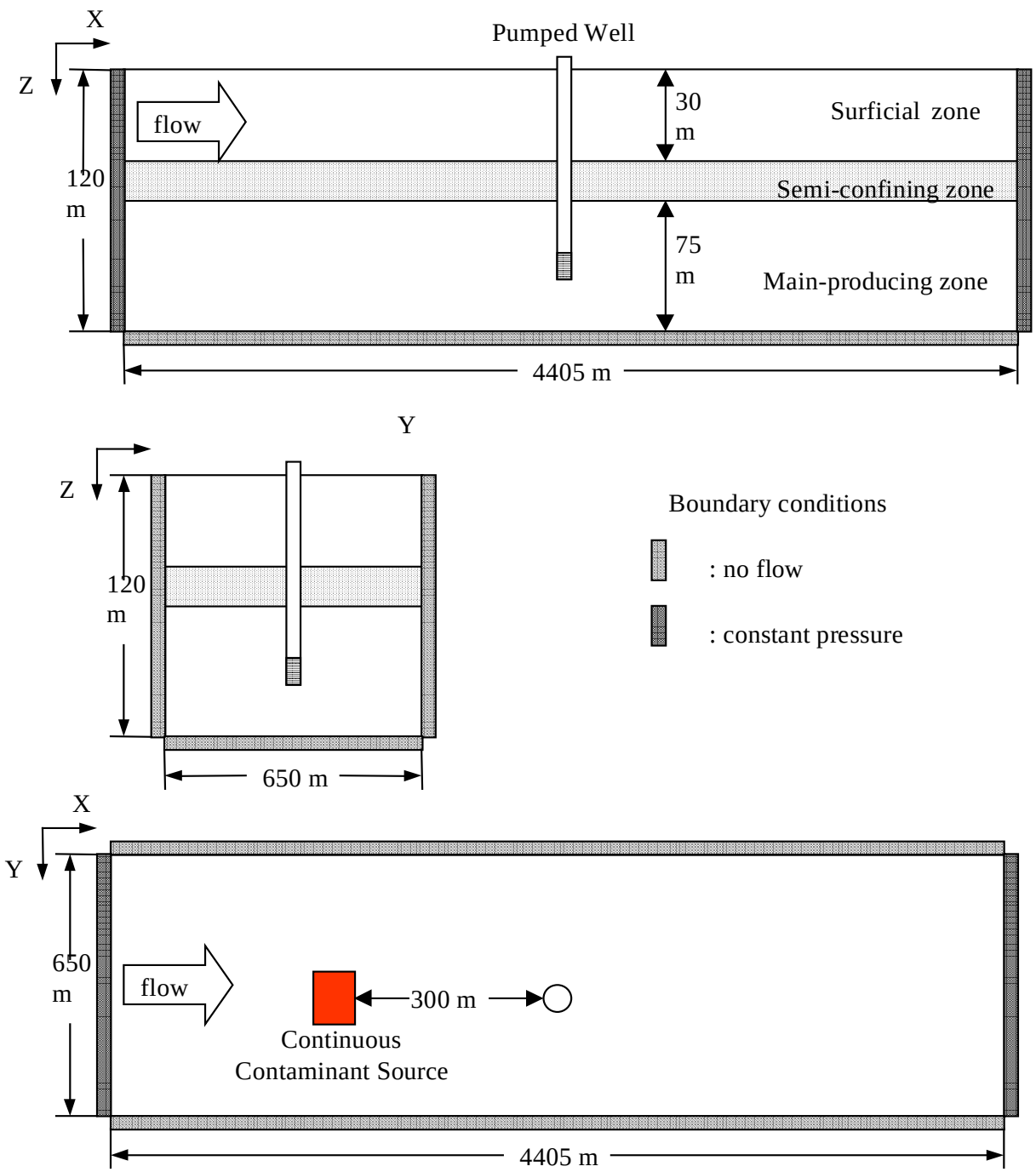


Figure 46. Physical System and Boundary Conditions for Conceptual Model.

Figure 47. Effect of Pumped Aquifer Horizontal Hydraulic Conductivity on Discharged Water Quality.

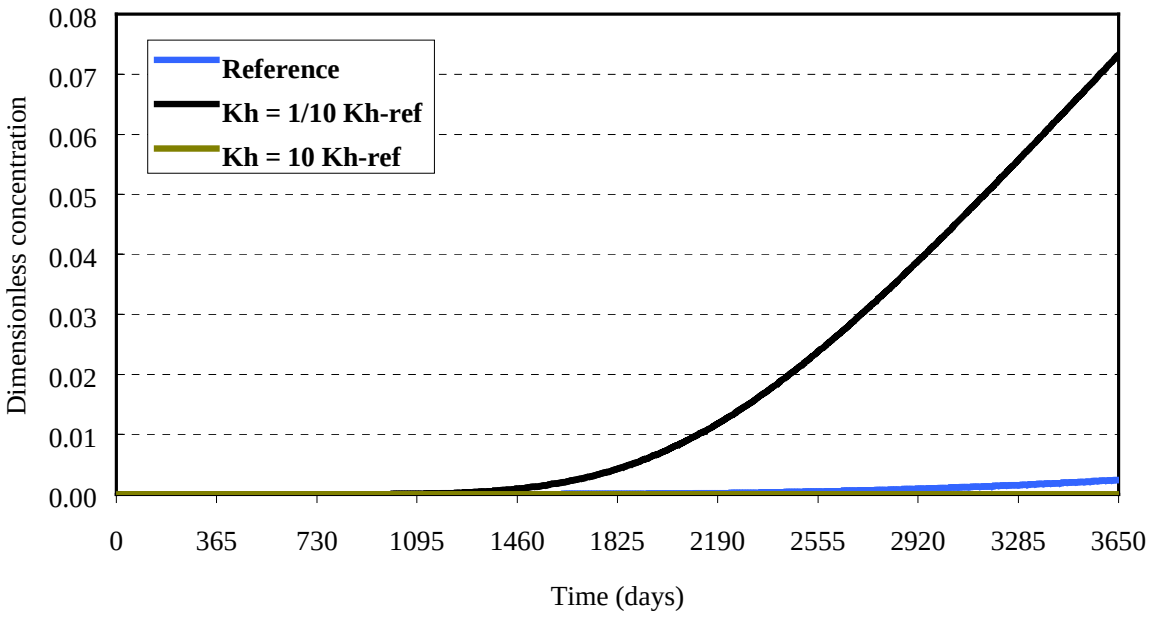


Figure 48. Effect of Pumped Aquifer Vertical Hydraulic Conductivity on Discharged Water Quality.

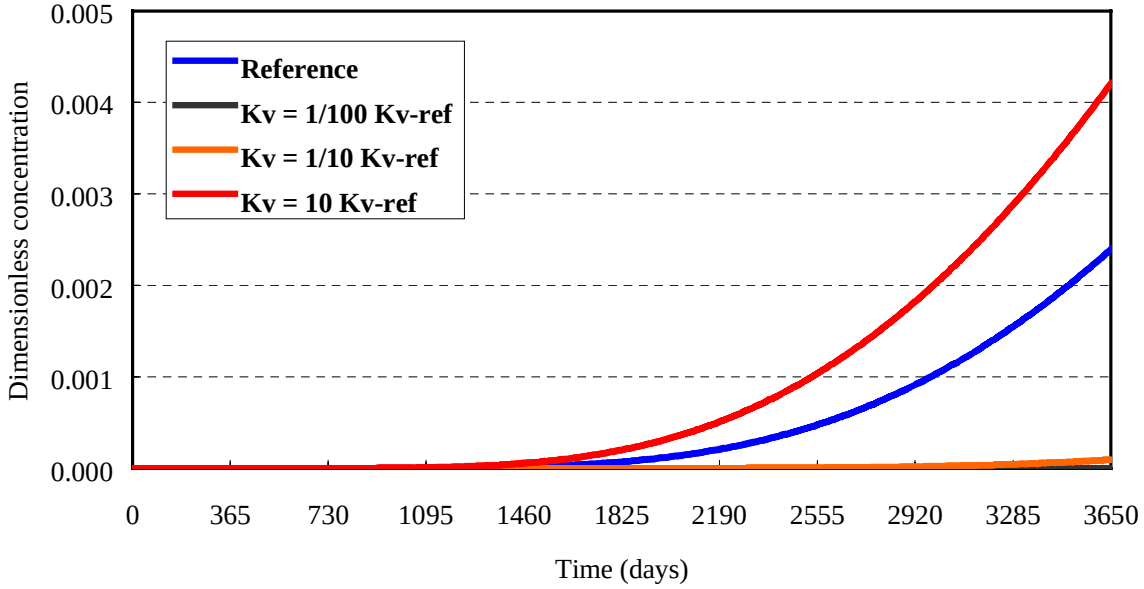


Figure 49. Effect of Longitudinal Dispersivity on Discharged Water Quality.

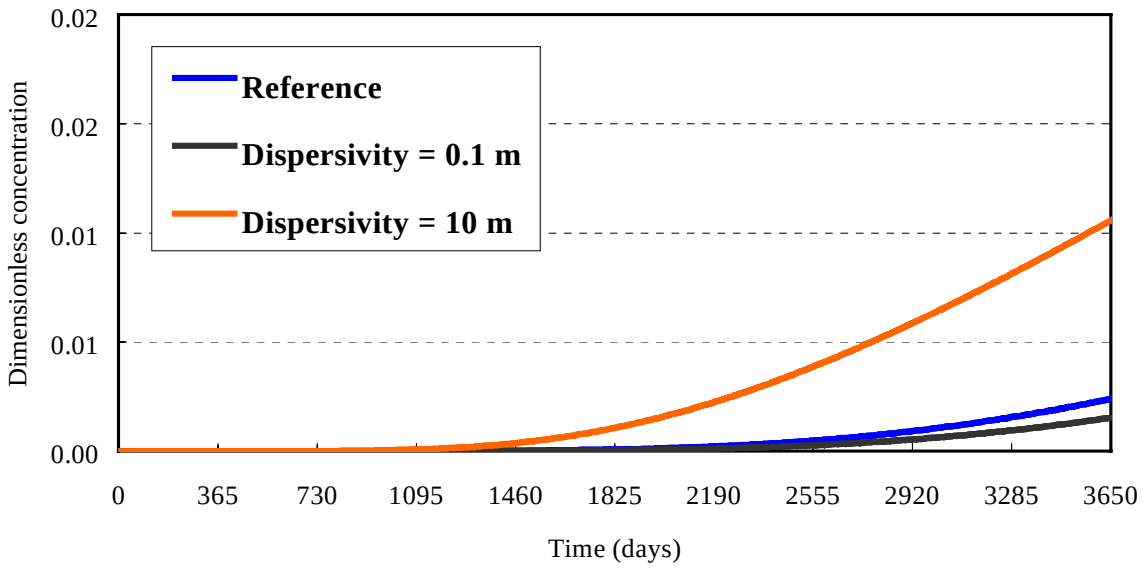


Figure 50. Effect of Transverse Dispersivity on Discharged Water Quality.

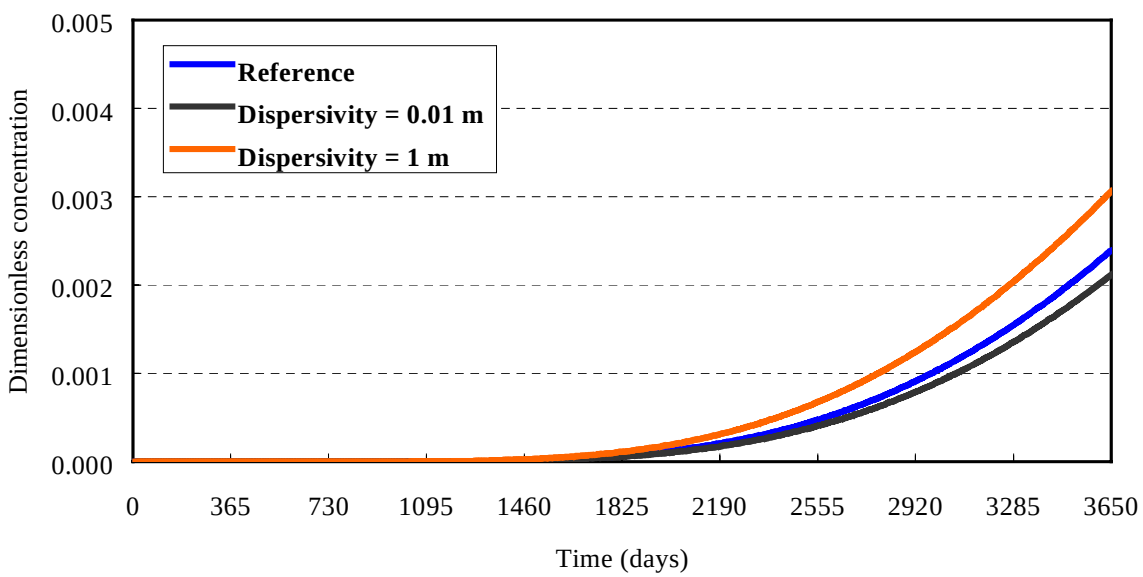


Figure 51. Effect of Well Screen Location on Discharged Water Quality.

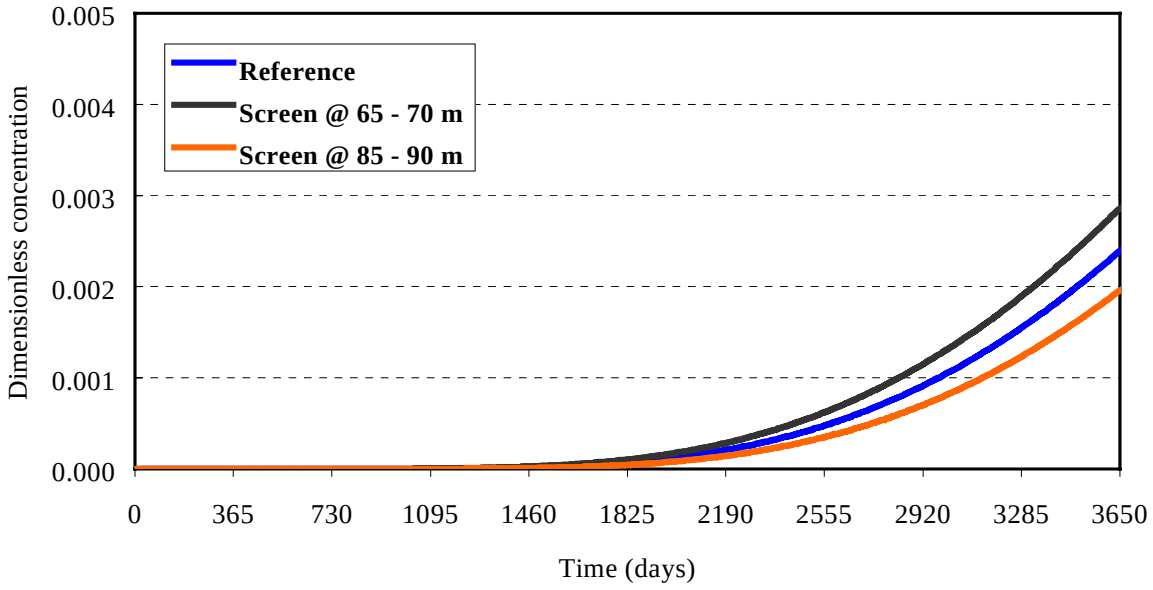


Figure 52. Effect of Porosity on Discharged Water Quality.

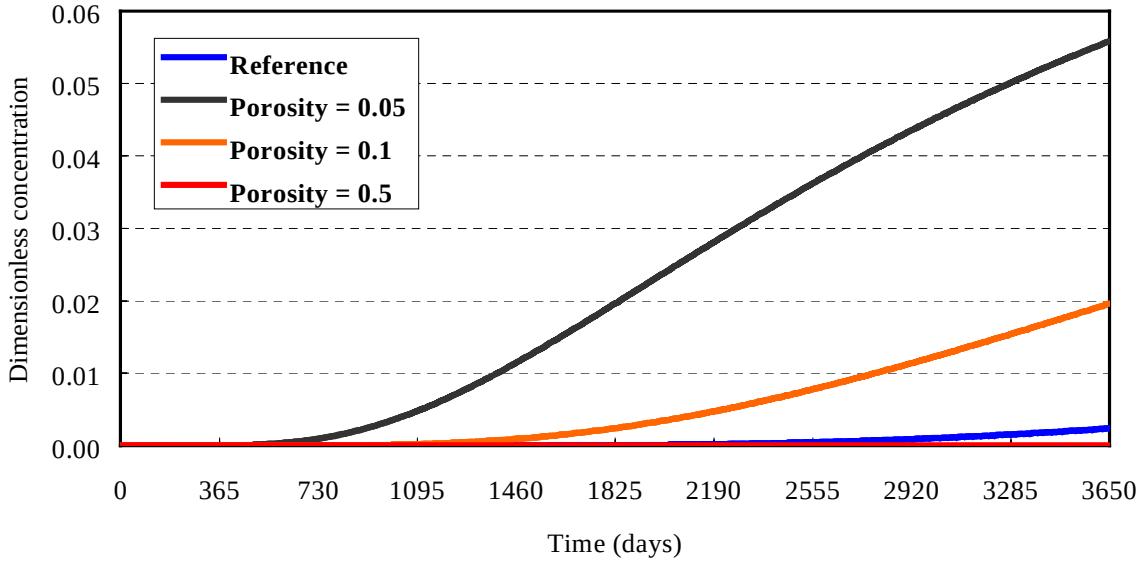


Figure 53. Effect of Recharge on Discharged Water Quality.

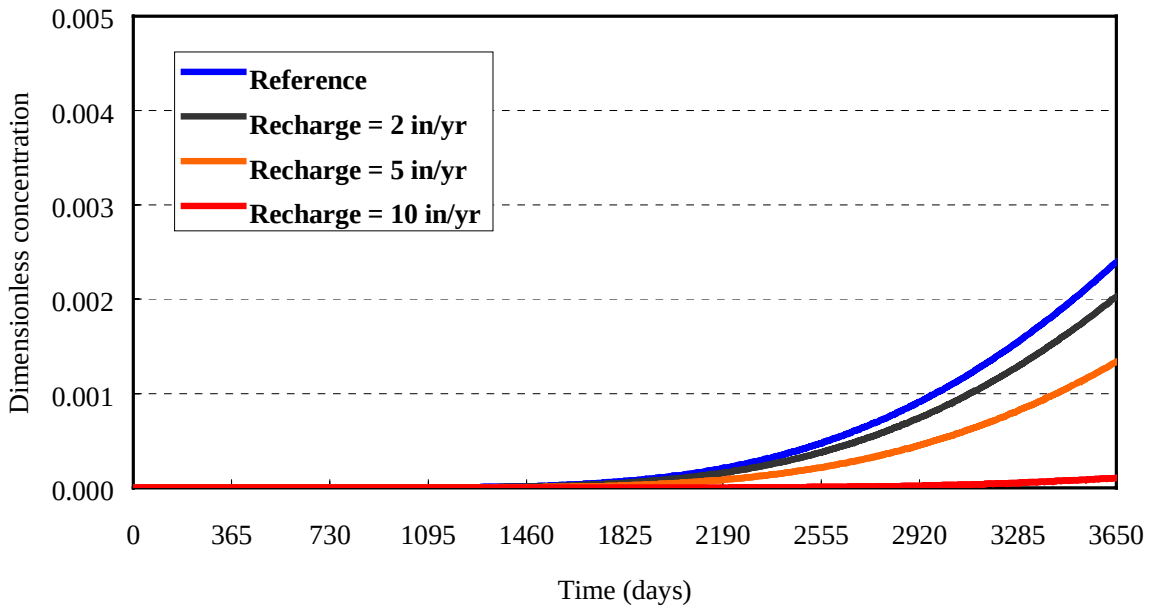


Figure 54. Effect of Pumping Rate on Discharged Water Quality.

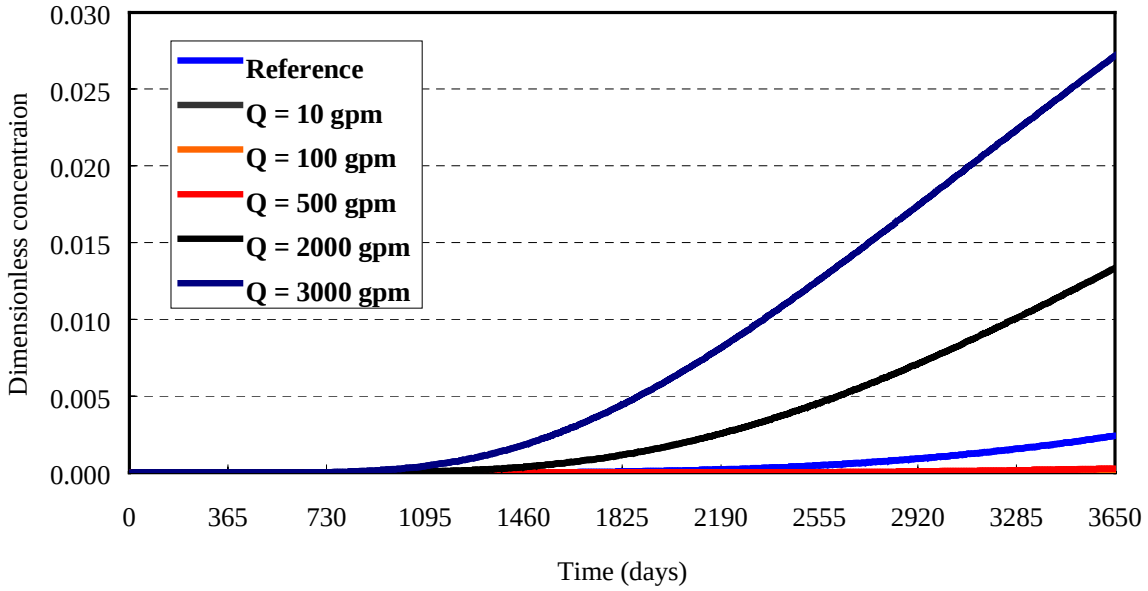


Figure 55. Effect of Semi-Confining Unit Thickness on Discharged Water Quality.

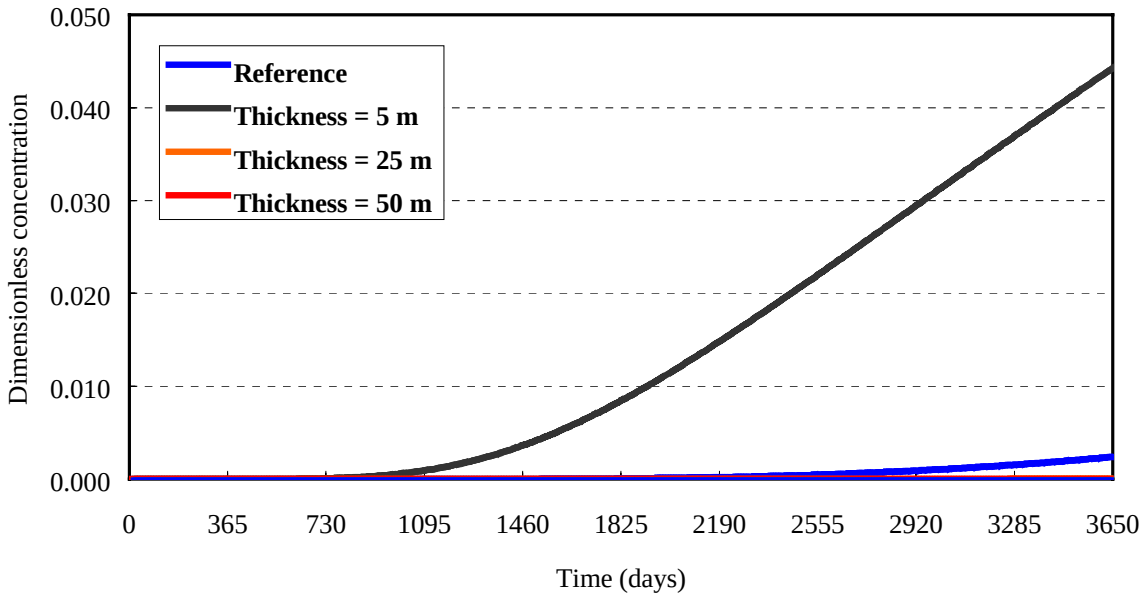


Figure 56. Effect of Semi-Confining Unit Vertical Hydraulic Conductivity on Discharged Water Quality.

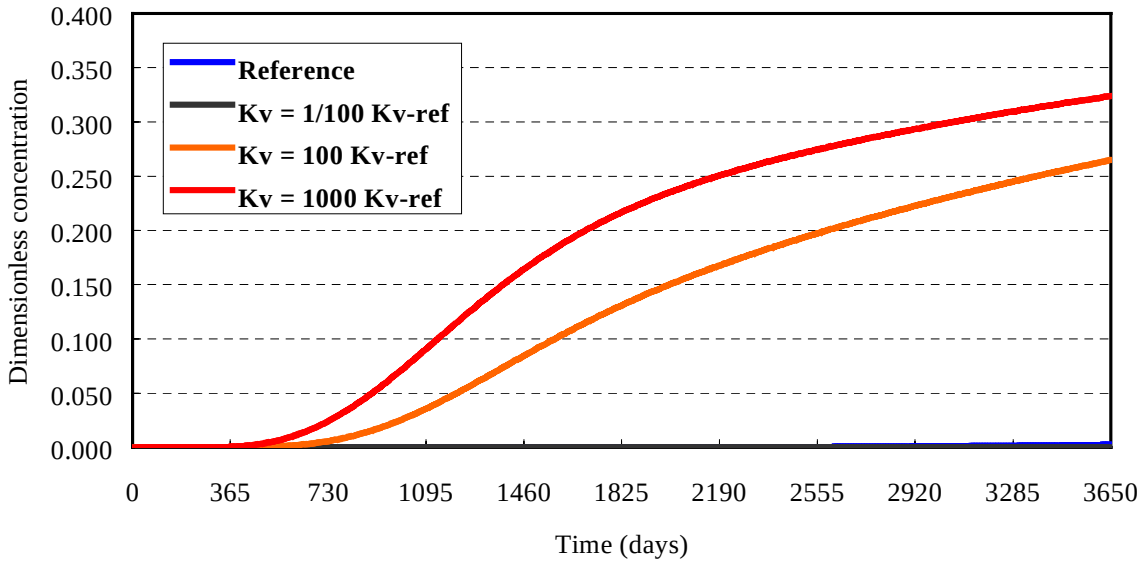


Figure 57. Effect of Water-Table Gradient on Discharged Water Quality.

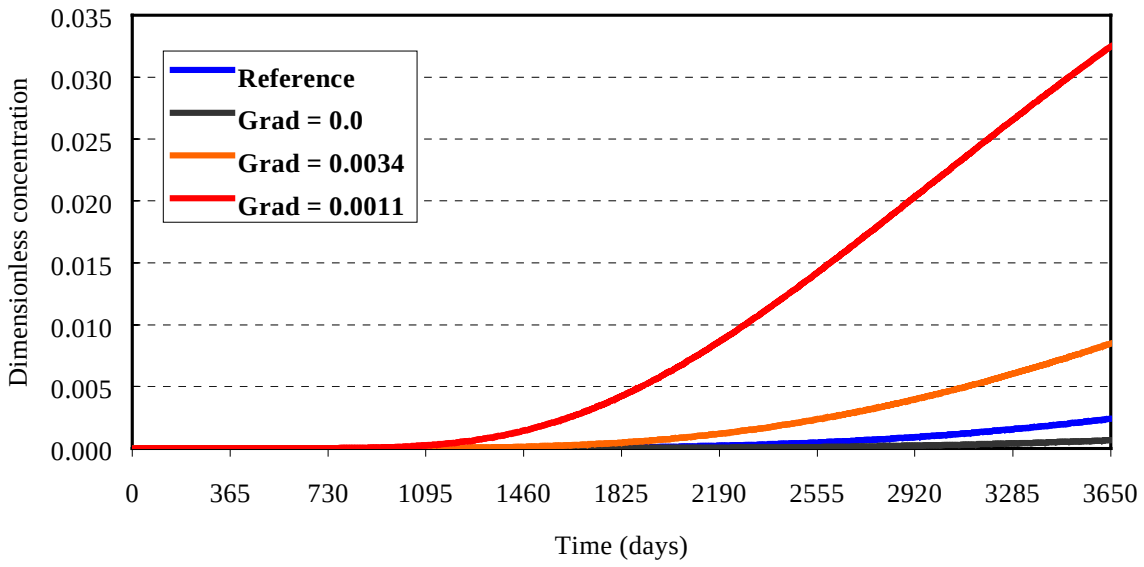


Figure 58. Effect of Contaminant Source Location on Discharged Water Quality.

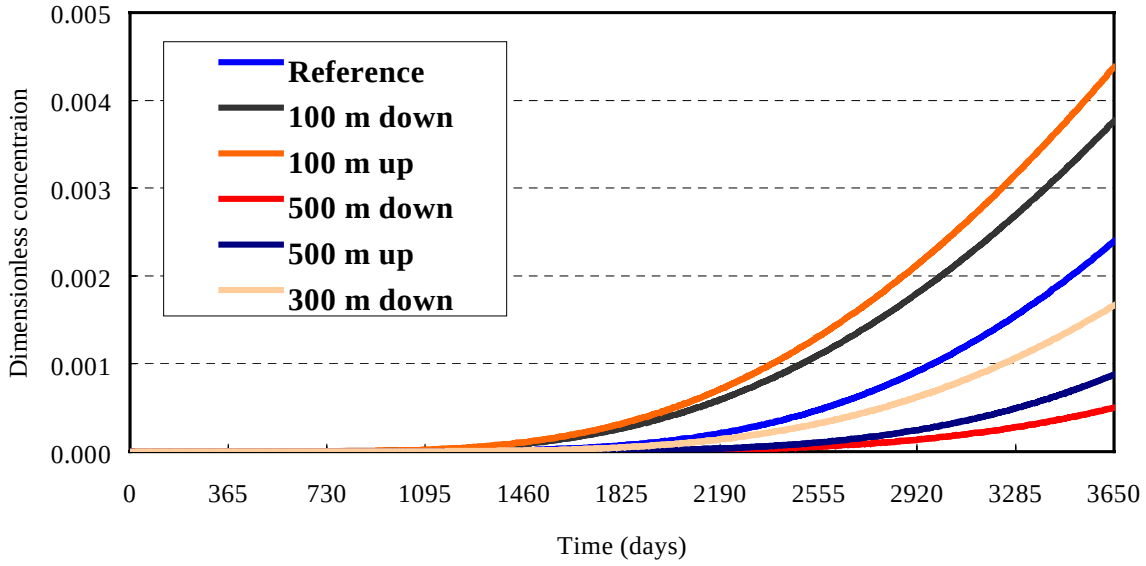


Table 6. Simulation Cases in the Three-dimensional Numerical Solute Transport Model.

Case No.	Descriptions
1.	Single pumping well (reference case). The input parameters, variables, and boundary conditions are described in Table 7 and Figure 44, respectively.
2.	Investigation of the effect of the horizontal conductivity, K_X and K_Y, by ranging K_X and K_{YZ} between 0.864 m/d and 86.4 m/d (2.85 ft/d to 285 ft/d).
3.	Investigation of the effect of the vertical conductivity, K_Z, by ranging K_Z between 0.00864 m/d and 8.64 m/d (0.0285 ft/d to 28.5 ft/d).
4.	Investigation of the effect of the longitudinal dispersivity, α_L, by changing the α_L from 0.1 m to 10 m (0.33 ft to 33 ft).
5.	Investigation of the effect of the transverse dispersivity, α_T, by changing the α_T from 0.01 m to 1 m (0.033 ft to 3.3 ft).
6.	Investigation of the effect of well screen location by elevating the well screen 10 m up and 10 m down from the reference model.
7.	Investigation of the effect of the porosity, ϕ, by changing the ϕ from 0.05 to 0.5.
8.	Investigation of the effect of various recharge amounts by uniformly imposing 0.05, 0.127, and 0.254 m/yr (2 in/yr, 5 in/yr, and 10 in/yr) recharge to the aquifer.
9.	Investigation of the effect of the pumpage by ranging the pumpage between 6.25×10^{-4} m^3/s and 0.1875 m^3/s (10 gpm and 3,000 gpm).
10.	Investigation of the effect of the thickness of semi-confining zone by ranging the thickness between 5 m and 50 m.
11.	Investigation of the effect of the vertical conductivity, K_Z, in semi-confining zone by ranging K_Z between 8.64×10^{-6} m/d and 0.864 m/day (2.85×10^{-5} ft/d and 2.85 ft/day).
12.	Investigation of the effect of water-table gradient by ranging the slope of water table between 0 and 0.0034.
13.	Investigation of the effect of the contaminant source location by changing the distance from 500 m upstream to 500 m downstream of the pumping well. The base case placed the contaminant source at a distance of 300 m upstream of the pumping well.

Table 7. Parameter Values Used in Reference Model.

Aquifer Parameters	
Horizontal hydraulic conductivity	K_X & K_Y = 8.64 m/d (28.5 ft/d)
Vertical hydraulic conductivity	K_Z = 0.864 m/d (2.85 ft/d)
Porosity	ϕ = 0.2
Bulk porous matrix compressibility	$\alpha = 2.58 \times 10^{-7}$[kg/(m s^2)]$^{-1}$
Longitudinal dispersivity	α_L = 1 m
Transverse dispersivity	α_T = 0.1 m
Properties of water and containment	
Density of water	ρ_o = 1,000 kg/m^3
Density of brine	ρ = 1,000 kg/m^3
Coefficient of viscosity of water	$\mu = 1.0 \times 10^{-3}$ kg/(m s)
Solute molecular diffusivity	$D_m = 1.0 \times 10^{-10}$ m^2/s
Properties of semi-confined zone	
Location (m)	30-45
Thickness (m)	15
K_X & K_Y (m/d)	0.00
K_Z (m/d)	8.64×10^{-4}
Porosity	0.05

Table 8. Percentage Change of Pumped Water Concentration Relative to Reference Model.

Parameters		Percentage change (%)
K_Z *(pumped aquifer)* = 0.00864 m/d	(0.0285 ft/d)	-100.0
K_Z *(pumped aquifer)* = 0.0864 m/d	(0.285 ft/d)	-96.1
K_Z *(isotropic pumped aquifer)* = 8.64 m/d	(28.5 ft/d)	21951
K_Z *(semi-confining zone)* = 8.64×10^{-6} m/d	(2.85×10^{-5} ft/d)	-100.0
K_Z *(semi-confining zone)* = 0.0864 m/d	(0.285 ft/d)	10959
K_Z *(semi-confining zone)* = 0.864 m/d	(2.85 ft/d)	13424
ϕ = 0.05		2232
ϕ = 0.1		718.6
ϕ = 0.5		-99.4
$K_X = K_Y$ *(pumped aquifer)* = 0.864 m/d	(2.85 ft/d)	2960
$K_X = K_Y$ *(pumped aquifer)* = 86.4 m/d	(285 ft/d)	-99.9
Thickness of semi-confined zone: 5 m		1749
Thickness of semi-confined zone: 25 m		-98.1
Thickness of semi-confined zone: 50 m		-100.0
$Q_p = 6.25 \times 10^{-4}$ m^3/sec	(10 gpm)	-100.0
$Q_p = 6.25 \times 10^{-3}$ m^3/sec	(100 gpm)	-99.9
$Q_p = 3.125 \times 10^{-2}$ m^3/sec	(500 gpm)	-88.6
$Q_p = 0.125$ m^3/sec	(2,000 gpm)	457.3
$Q_p = 0.1875$ m^3/sec	(3,000 gpm)	1034.7
water-table gradient: 0.00		-72.4
water-table gradient: 0.0034		253.8
contaminant source 100 m upstream of pumped well		82.9
contaminant source 500 m upstream of pumped well		-63.4
contaminant source 100 m downstream of pumped well		57.2
contaminant source 300 m downstream of pumped well		-30.5
contaminant source 500 m downstream of pumped well		-79.1
recharge = 0.05 m/yr	(2 in/yr)	-15.3
recharge = 0.127 m/yr	(5 in/yr)	-44.3
recharge = 0.254 m/yr	(10 in/yr)	-95.6
α_L = 0.1 m		-36.2
α_L = 10 m		341.6
α_T = 0.01 m		-11.6
α_T = 1 m		28.0
screen area 10 meters up		19.6
screen area 10 meters down		-18.1

Table 9. Backward-Selection Regression Equations and Diagnostics.

STEP	K_X	K_Z	*CSDIS*	Q_p	SCK_Z	*SCTHC*	ϕ
1	-3.04E-04	-1.30E-03	2.38E-05	1.48E-06	3.78E-01	-7.62E-04	-9.18E-02
2	-2.95E-04	-1.22E-03	2.26E-05	1.49E-06	3.79E-01	-7.42E-04	-9.15E-02
3	-2.87E-04	-1.15E-03	2.16E-05	1.51E-06	3.80E-01	-7.25E-04	-9.12E-02
4	-2.85E-04	-1.14E-03	2.14E-05	1.51E-06	3.80E-01	-7.21E-04	
5	-3.98E-04	-2.12E-03	3.57E-05	1.35E-06			

STEP	*WTG*	*UREC*	α_L	α_V	*SCREEN*	*Constant*
1	1.26E+00	-2.33E-03	-6.74E-04	-1.63E-03	-4.51E-05	3.93E-02
2	1.34E+00	-2.23E-03				3.40E-02
3						3.45E-02
4						1.61E-02
5						1.39E-02

Step summary

STEP	MultR	R_{sq}	$AdjR_{sq}$	F(Eqn)	SigF
1	0.8187	0.6703	0.5121	4.2360	0.0011
2	0.8177	0.6686	0.5621	6.2773	0.0001
3	0.8147	0.6637	0.5852	8.4562	0.0000
4	0.8109	0.6575	0.5912	9.9194	0.0000
5	0.1329	0.0177	-0.1014	0.1484	0.9624

Q_p	: pumping rate	(m^3/day)
ϕ	: effective porosity	
K_v	: vertical conductivity	(m/day)
K_h	: horizontal conductivity	(m/day)
α_h	: horizontal dispersivity	(m)
α_v	: vertical dispersivity	(m)
CSDIS	: contaminant source distance to discharged well	(m)
WTG	: water-table gradient	
UREC	: recharge	(m/day)
SCK_v	: vertical conductivity in semi-confining unit	(m/day)
SCTHC	: thickness of semi-confined zone	(m)
SCREEN	: screen location	(m)

Table 10. Re-weighted β Coefficients for Each Step Used in RISK Model.

STEP	K_X	K_Z	*CSDIS*	Q_p	*SCKZ*	*SCTHC*
1	-4.47E-02	-1.93E-02	4.86E-02	4.04E-02	6.15E-01	-5.41E-02
2	-4.56E-02	-1.90E-02	4.86E-02	4.28E-02	6.48E-01	-5.54E-02
3	-4.82E-02	-1.95E-02	5.05E-02	4.69E-02	7.07E-01	-5.89E-02
4	-5.16E-02	-2.07E-02	5.38E-02	5.05E-02	7.60E-01	-6.30E-02
5	-2.93E-01	-1.57E-01	3.66E-01	1.84E-01		

STEP	ϕ	*WTG*	*UREC*	α_L	α_V	*SCREEN*
1	-6.12E-02	2.51E-02	-4.89E-02	-1.15E-02	-3.04E-02	-1.21E-03
2	-6.40E-02	2.80E-02	-4.90E-02			
3	-6.95E-02					
4						
5						

Table 11. Regression Equation Variables at Step 1.

Variable	Beta	VIF	F	SigF
K_X	-0.05764	1.009	0.25	0.6216
K_Z	-0.02485	1.007	0.047	0.831
CSDIS	0.062684	1.023	0.291	0.5942
Q_p	0.052035	1.001	0.205	0.6545
SCK_Z	0.792353	1.012	47.032	0
SCTHC	-0.069748	1.009	0.366	0.5509
ϕ	-0.078827	1	0.471	0.4988
WTG	0.032292	1.012	0.078	0.7821
UREC	-0.063012	1.021	0.295	0.5919
α_L	-0.014796	1.009	0.016	0.8989
α_V	-0.03923	1.012	0.115	0.737
SCREEN	-1.56E-03	1	0	0.9892
Constant			0.024	0.8773

Table 12. Regression Equation Variables at Step 2.

Variable	Beta	VIF	F	SigF
K_X	-0.055885	1.007	0.262	0.6126
K_Z	-0.023314	1.005	0.046	0.8323
CSDIS	0.059594	1.017	0.295	0.5913
Q_p	0.05249	1	0.233	0.6333
SCK_Z	0.794483	1.009	52.845	0
SCTHC	-0.067932	1.007	0.387	0.5388
ϕ	-0.078544	1	0.521	0.4763
WTG	0.034405	1.009	0.099	0.7552
UREC	-0.060136	1.015	0.301	0.5876
Constant			0.73	0.4002

Table 13. Regression Equation Variables at Step 3.

Variable	Beta	VIF	F	SigF
K_X	-0.054358	1.004	0.263	0.6121
K_Z	-0.021978	1.003	0.043	0.8372
CSDIS	0.056905	1.008	0.287	0.5963
Q_p	0.052886	1	0.249	0.6211
SCK_Z	0.796337	1.005	56.287	0
SCTHC	-0.066352	1.004	0.391	0.5364
ϕ	-0.078297	1	0.547	0.4654
Constant			0.825	0.371

Table 14. Regression Equation Variables at Step 4.

Variable	Beta	VIF	F	SigF
K_X	-0.054047	1.004	0.263	0.6114
K_Z	-0.021706	1.003	0.043	0.838
CSDIS	0.056357	1.008	0.285	0.597
Q_p	0.052966	1	0.254	0.6179
SCK_Z	0.796715	1.005	57.177	0
SCTHC	-0.06603	1.004	0.393	0.5352
Constant			0.319	0.5761

Table 15. Regression Equation Variables at Step 5.

Variable	Beta	VIF	F	SigF
K_X	-0.075535	1.002	0.191	0.6647
K_Z	-0.040505	1.002	0.055	0.816
CSDIS	0.094189	1.003	0.297	0.5893
Q_p	0.047394	1	0.075	0.7853
Constant			0.15	0.7009

Table 16. Ranking of the Independent Variables Used in RISK Model.

Class Rank	K_X (m/day)	K_Z (m/day)	CSDIS (meter)	Q_p (gpm)	SCK_Z (m/day)	SCTHC (meter)
1	< 1	< 0.1	> 500	< 100	< 0.001	> 50
2	1 ~ 33.3	0.1 ~ 3.33	300~ 500	100 ~ 500	0.001 ~ 0.033	25 ~ 50
3	33.3 ~ 66.7	3.33 ~ 6.67	100 ~ 300	500 ~ 1500	0.033 ~ 0.067	10 ~ 25
4	66.7 ~ 100	6.67 ~ 10	50 ~ 100	1500 ~ 3000	0.067 ~ 0.1	3 ~ 10
5	> 100	> 10	< 50	> 3000	> 0.1	< 3

Class Rank	ϕ	WTG	UREC (in/year)	α_L (meter)	α_V (meter)	SCREEN (meter)
1	> 0.35	< 0.001	> 10	< 0.1	< 0.01	> 100
2	0.25 ~ 0.35	0.001 ~ 0.002	6.7 ~ 10	0.1 ~ 1	0.01 ~ 0.1	85 ~ 100
3	0.15 ~ 0.25	0.002 ~ 0.005	3.3 ~ 6.7	1 ~ 5	0.1 ~ 0.5	65 ~ 85
4	0.05 ~ 0.15	0.005 ~ 0.01	1 ~ 3.3	5 ~ 10	0.5 ~ 1	50 ~ 65
5	< 0.05	> 0.01	< 1	> 10	> 1	< 50

Integrated GIS-Based Ground Water Risk Analysis

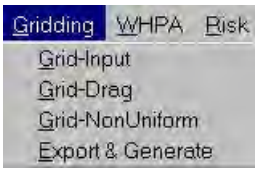
Three distinct elements 1) a GIS database of important environmental data, 2) a numerical wellhead protection areas model (WHPA), and 3) five multi-variate regression risk models are integrated through a customized ArcView Graphical User Interface (GUI). Figure 59 is a schematic diagram showing the components of the integrated risk system. The whole system is designed to facilitate risk analysis in the prevention of ground water pollution and to prioritize contaminant source remediation. Advantages of this system are 1) the system is interactive and user-friendly, 2) laborious and time-consuming tasks in data handling are avoided, 3) results are visually displayed for comparison, 4) the system can easily include any other numerical models for solving problems of user's interest, and 5) the proposed system has state-wide applicability with modifications. Details of the ground water risk analysis system (GWRAS) and an application of the integrated system are discussed below.

Interactive Ground Water Risk Analysis System

RISK.APR is a customized interface and is saved as an ArcView project. Three menus, "**Gridding**", "**WHPA**" and "**Risk**" on the menu bar and a "**WQ**" button on the tool bar will appear when a View is opened.

Menu - Gridding

Gridding is used to generate uniform and non-uniform grid shape files and to export the generated grid shape files and generate point coverage in ArcView. Four items, "**Grid-Input**", "**Grid-Drag**", "**Grid-Nonuniform**", and "**Export and Generate**" are programmed to perform the required functionality.



Item - Grid-Input

Grid-Input can create two grid shape files. One is the shape file with a specified uniform grid size and the other is the corresponding shape file of grid center points. The user has to follow the interactive processes to enter the coordinates of the lower left and upper right corners and the width and height of the grid cell, and determine if a grid center point shape file is needed when this function is executed. The script is "**Grid-Input**".

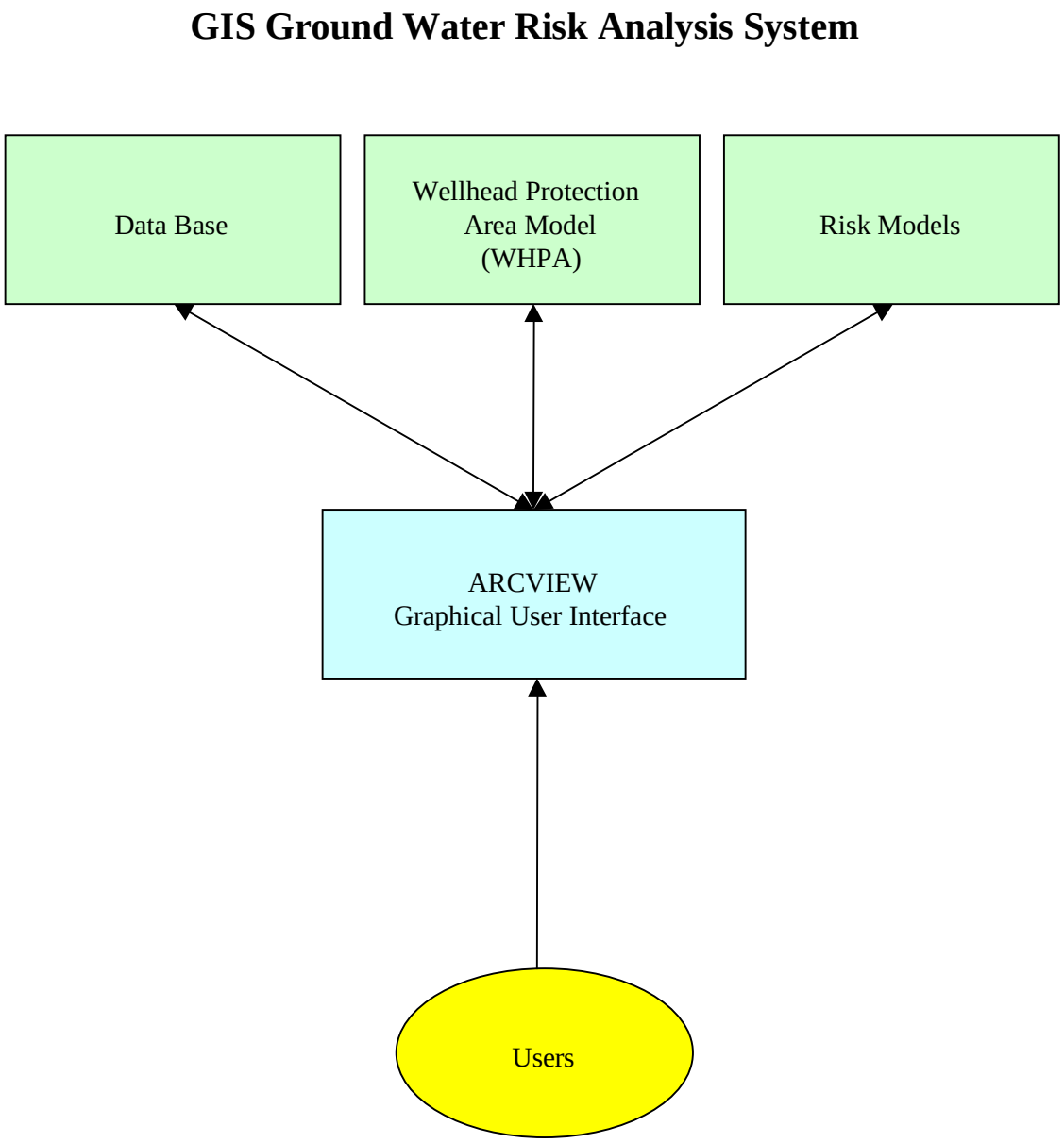
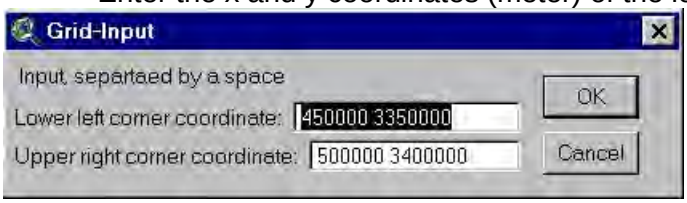
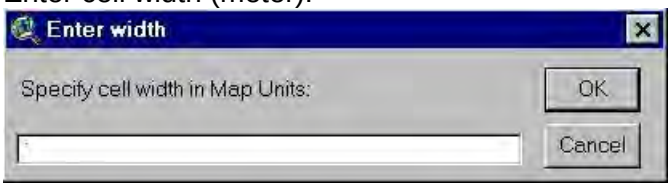


Figure 59. Components of the Integrated Ground Water Risk Analysis System (GWRAS).

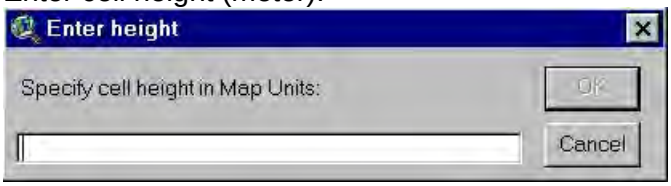
Enter the x and y coordinates (meter) of the lower left and upper right corners.



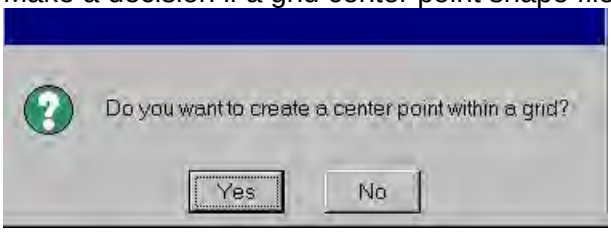
Enter cell width (meter).



Enter cell height (meter).



Make a decision if a grid center point shape file is needed.

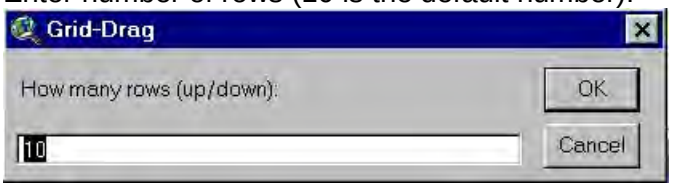


Item - Grid-Drag

This function is similar to the Grid-Input. The grid is determined by dragging a rectangle over the area of interest instead of entering the corner coordinates. The number of rows and columns of the grid and the generation of grid center points are determined by the user. A shape file of uniform grid size and a shape file of grid center points can be generated. This function has to be executed by clicking the button "**D**" on the tool bar and the associated script of this function is "**Grid-Drag**".

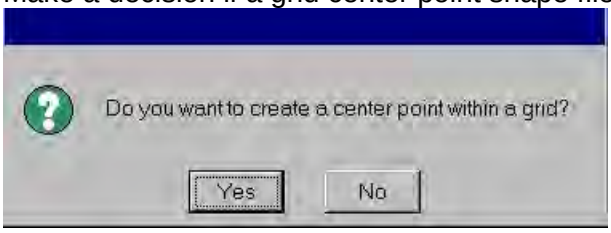
D button on the tool bar is used to execute the script.

Enter number of rows (10 is the default number).



Enter number of columns (10 is the default number).

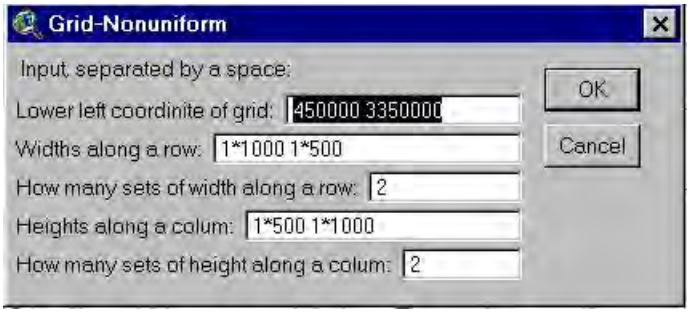
Make a decision if a grid center point shape file is needed.



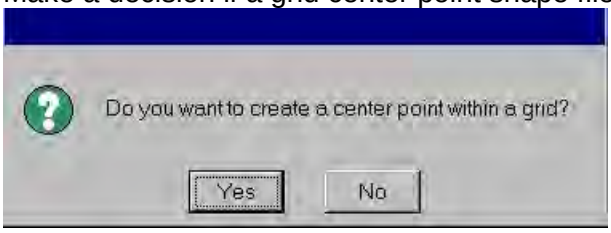
Item - Grid-Nonuniform

This function is used to generate non-uniform grid cell sizes. The coordinates of the lower left corner, the number of row and column, and the number of grid-cell sizes along a row and a column have to be specified. A shape file of uniform grid size and a shape file of grid center points can be generated. The script of this function is "**Grid-Nonuniform**".

Enter the x and y coordinates (meter) of the lower left corner, variable width along a row, variable height along a column, and number of rows and columns. All the numbers shown below are the defaults.



Make a decision if a grid center point shape file is needed.

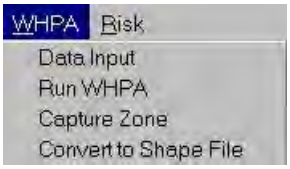


Item - Export and Generate

This function is used to export the generated grid shape files and generate point coverage in ArcView. User has to specify the path and name of the file to be generated. The script of this function is "**Exp and Gen**".

Menu - WHPA

WHPA is used to identify the wellhead protection areas. It can prepare input data file for WHPA model, execute WHPA model, extract the simulated pathline from WHPA model and find the wellhead protection area, and convert the extracted wellhead protection area to a shape file. Four items "**Data Input**", "**Run WHPA**", "**Capture Zone**", and "**Convert to Shape File**" are programmed to perform the required functionality.



Item - Data Input

Data Input is used to prepare the input data file for the execution of WHPA model. Ten grid systems, which cover the current water supply wells in Escambia County, have been build into the GWRAS as shown in Figure 60. Grids 7 & 72 and grids 8 & 82 are two identical grid systems. Both grids cover the Cantonment and the Molino areas, respectively; however, they represent different aquifer layers. Details of the grid systems are discussed in Richards et al., 1997. The user has to choose the grid system, the associated hydraulic head distribution file, time of simulation (days), number of wells in the study area, and the associated information of each well. An output file, "**gptrac.sav**", will be generated under C:\GWRISK\BIN\ directory and ready for the execution of WHPA model. The script for this function is "**whpafile**".

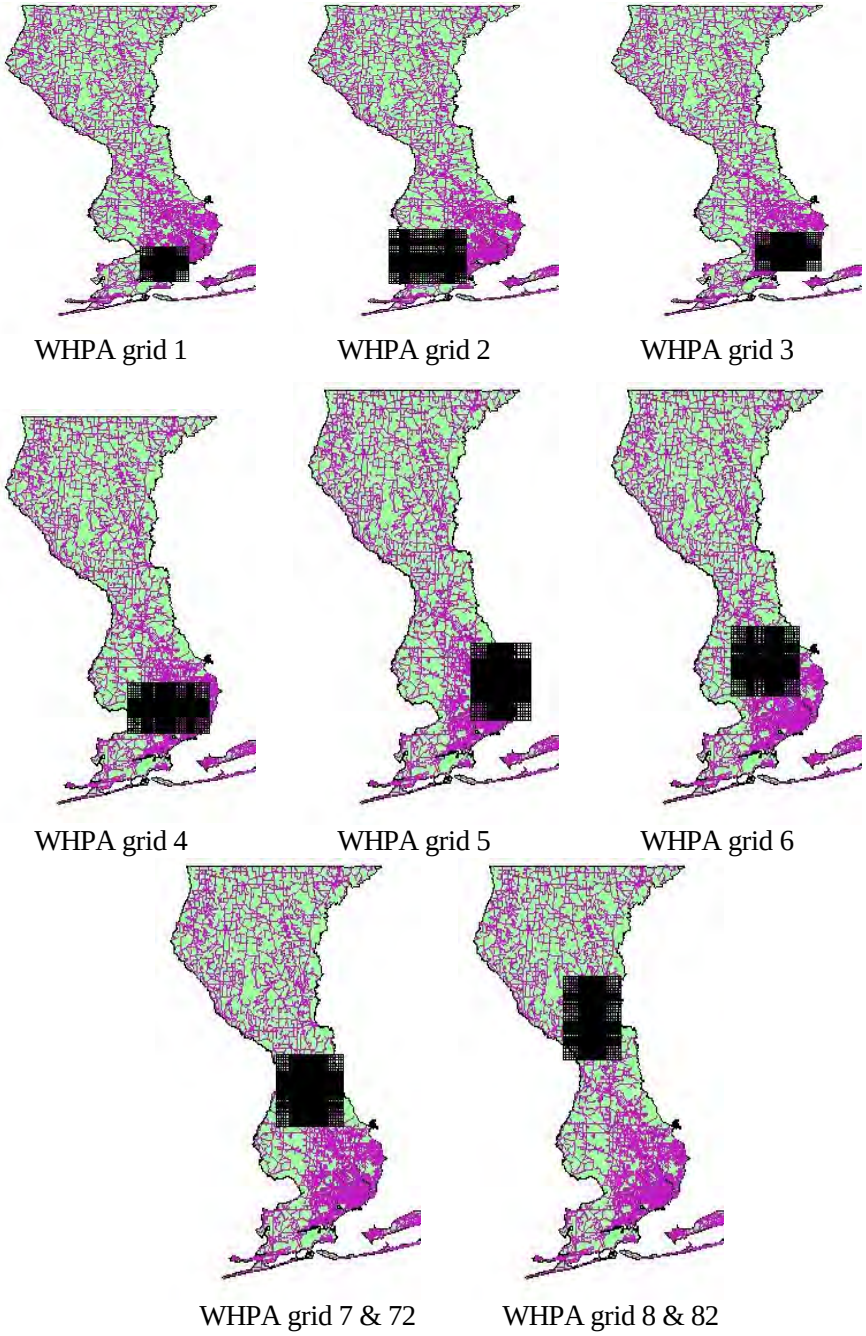
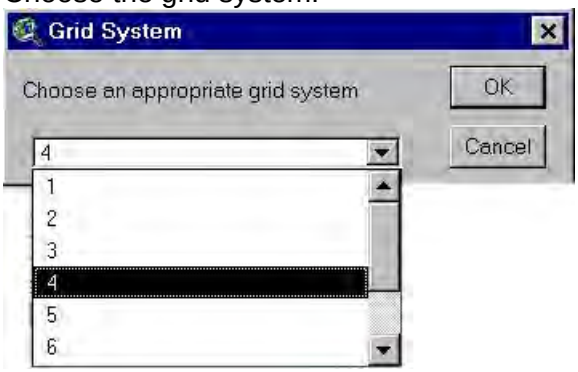
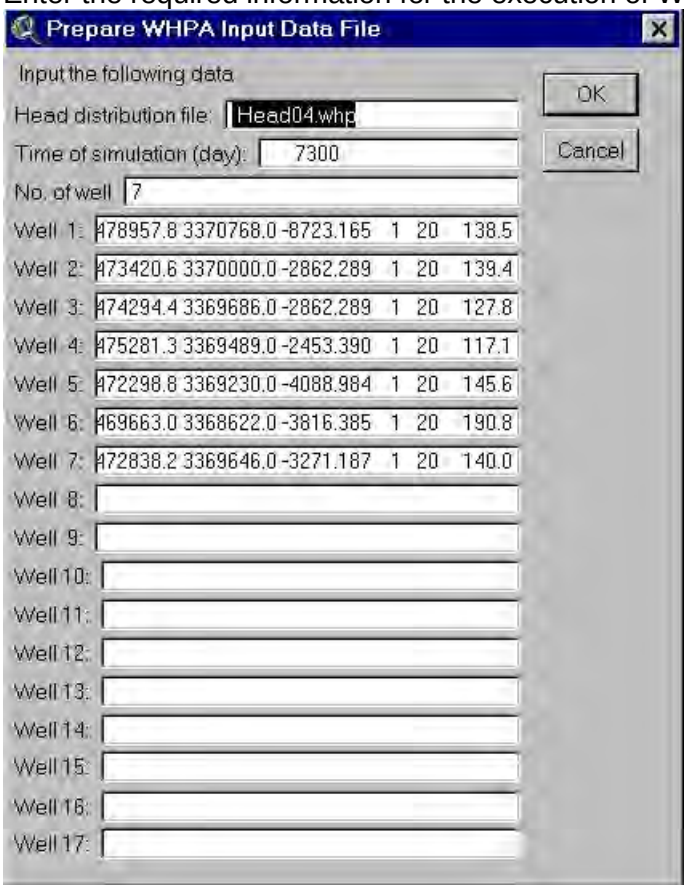


Figure 60. 10 Pre-Generated Flow Model Grids Used in GWRAS.

Choose the grid system.



Enter the required information for the execution of WHPA model.



Item - Run WHPA

This function is used to execute the WHPA model (**whpa.exe**) which is located under C:\GWRISK\BIN directory. WHPA model reads the **gptrac.sav** file generated from **Data Input** and two output files (**gptrac.out** and **whpa.plt**) are given under the directory of C:\GWRISK\OUTPUT. **Gptrac.out** is the standard output from the WHPA model and **whpa.plt** contains the coordinates of the simulated pathline. The associated script for this function is "**Whpa**".

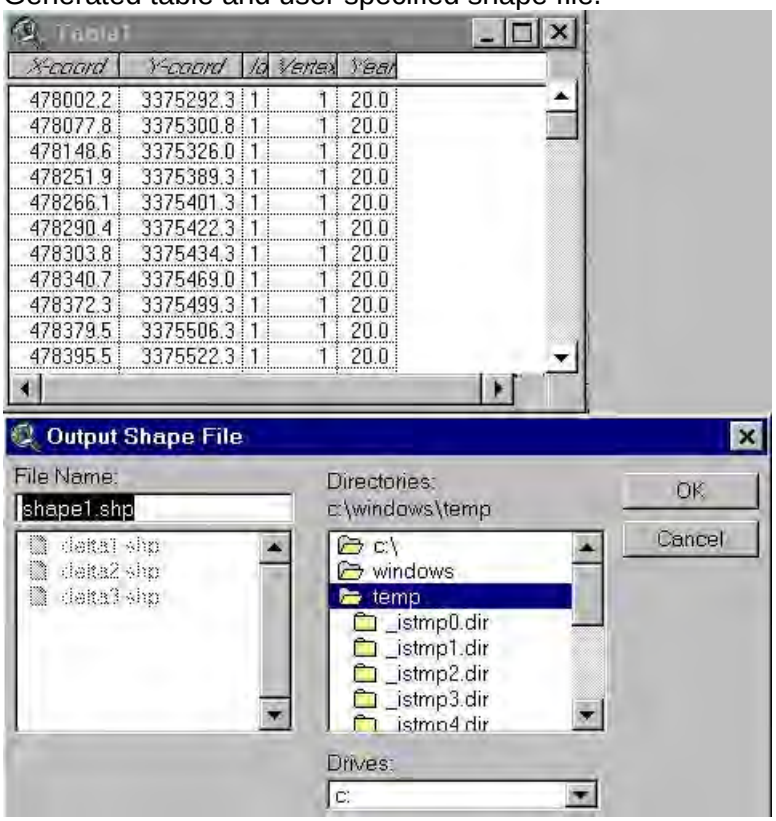
Item - Capture Zone

This function is used to execute the envelope.exe under C:\GWRISK\BIN directory. It reads the **whpa.plt** generated from **Run WHPA** and a wellhead protection area file (**capture.dat**) is generated under the directory of C:\GWRISK\OUTPUT. The associated script for this function is "**Envelope**".

Item - Convert To Shape File

This function is used to convert the **capture.dat** generated from **Capture Zone** to a polyline shape file. A table and a polyline shape file will be created. User has to enter the name and path to output the shape files. The associated script is "**Convert**".

Generated table and user specified shape file.



Menu - RISK

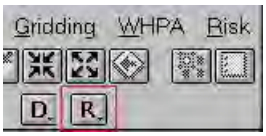
RISK contains two items, "**Risk Search**" and "**Risk Model**." "**Risk Search**" is designed to search the contaminant sources near the selected site and extract pertinent data from the database for the execution of multi-variate regression risk model. "**Risk Model**" is to execute the multi-variate regression risk model developed from the multi-variate regression analysis.

Item - Risk Search

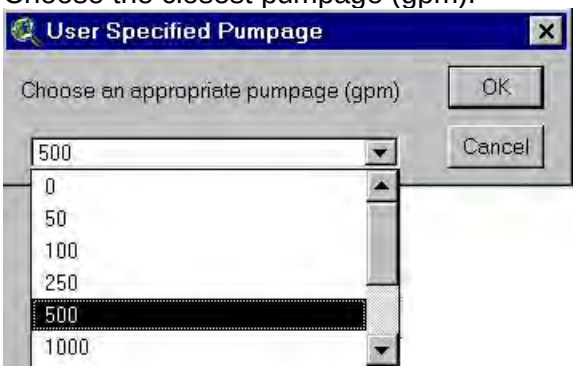
This function is executed by clicking the button **R** on the tool bar. Any contaminant sources that the user wishes to consider in the risk assessment have to be activated before the execution of this function. Once **R** button is clicked and the site of interest is selected, user has to enter the pumpage (gpm) at the selected site and determine an appropriate field for each contaminant sources to report. All the selected contaminant sources around the selected site will be searched and the available data for an appropriate multi-variate regression risk model will be extracted from the database. A **test.dat** output file will be generated under C:\GWRISK\OUTPUT directory.

Arrange.exe will be executed to sort the **test.dat** into two output files, **csoutput.dat** and **riskdata.dat**. All the activated contaminant sources within the radius of 1000 meters (m) to 500 m, 500 m to 300 m, 300 m to 150 m, 150 m to 50 m, and less than 50 m to the selected site will be listed in the **csoutput.dat**. The available data for the GWRAS model to perform the risk assessment is stored in **riskdata.dat**. The associated script for this function is "**Risk Search**."

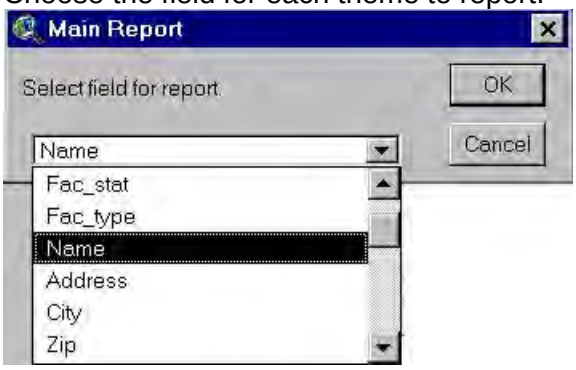
Click the **R** button on the tool bar to activate the search function.



Choose the closest pumpage (gpm).



Choose the field for each theme to report.



Item - Risk Model

This function is used to execute the multi-variate regression risk model (**risk.exe**). RISK model reads the **riskdata.dat** generated from the **Risk Search**. The number of model used for the assessment, available risk data, risk score, and level of risk will be given in a pop up message box. The associated script is "**Risk Score**".

Water Quality Button

The water quality data shape files can be added as a Theme to the active View by clicking on the "**WQ**" button located on the toolbar. A message box appears listing the two Ambient Monitoring sub-networks for which analytical data are available. User can select either the "**Background Sub-Network**" or the "**VISA Sub-Network**". Selecting a sub-network produces a list of parameters. Only parameters that exhibited numerous detection, exceeded State standards, and/or are potential contaminates by local industry (i.e. gas stations, dry cleaners, etc.) were included. The resulting Theme displays well locations and includes the most recent analytical values for the selected parameter.

Volatile Organic Contamination Status of ECUA Public Supply Wells

The likelihood that a given well will be impacted by ground water contamination is influenced, in part, by the well's proximity to a source of contamination. Obviously, the closer a well is to a plume, the greater the likelihood plume constituent(s) will eventually show up in the well. As a test of the utility of the GWRAS analysis system, ground water quality data were obtained from the ECUA for selected wells. ECUA was selected for this evaluation because its wells are widely distributed around the southern half of the county and because it has a number of contaminant-effected wells.

Data were obtained for volatile organic constituents (Tim Haag, personal communication, 1999). Volatiles were selected because, to date, the most significant impacts have been related to the presence of these compounds in ground water. At present, 10 of 34 ECUA wells have granular, activated carbon (GAC) treatment vessels in operation. GACs are designed to remove organic contaminants. An additional three ECUA wells were previously equipped with GACs. An additional five wells have levels of volatile organic contaminants below the regulatory thresholds requiring action. Other water suppliers also utilize GACs. Peoples Water Service has GACs on two of its six wells, primarily to remove PCE. The U.S. Navy has GACs on all ten wells at Corry Station. These GACs remove organochlorine pesticides (dieldrin and chlordane) and pesticide derivatives (heptachlor epoxide) from Sand-and-Gravel Aquifer water. The primary source of organic contaminants effecting ECUA wells appears to be leaking gasoline storage tanks and dry-cleaning solvents. Data coverages for both of these classes of contamination sources were developed as a part of GWRAS development.

Data were obtained for the recent past (1997 and 1998) and were evaluated to determine which constituents were the "primary" contaminants of concern. Primary was somewhat subjectively

defined as a contaminant that persistently appeared in the analytical results for a well of interest. The actual concentrations were of lesser interest than was repetitive occurrence. Many of the "primary" contaminants were present in every sample. During the period some of these wells were sampled as many as 30 times.

Eighteen of 34 ECUA wells have a history of organic contamination. The remaining 16 wells have no significant organic contamination history. All 18 ECUA organic-effected wells have a history of PCE (a dry-cleaning solvent) contamination. In some wells the concentration is presently below the established maximum contaminant level of 3 μg/L. Nine of the PCE-effected wells also contain TCE, a degradation product of PCE. Nine of the organic-effected wells contain either gasoline components or additives. The gasoline components present are one or more of benzene, toluene, ethylbenzene and xylene (BTEX). In some wells other, minor gasoline components are present. The gasoline additive methyl-tert-butyl-ether (MTBE) is present in six wells.

By juxtaposing the ECUA organic contaminant data against the spatial distribution of underground storage tanks and dry-cleaning facilities, insight into the causes of well vulnerability is possible. Table 17 identifies whether or not a well has a GAC, the contaminants principally responsible for the presence of the GAC, the number of FDEP DSCP program sites within the delineated 20-year WHPA and the number of NWFWMD cleaning business inventory sites (from Table 4) within the seven-year WHPA. DSCP program sites all have a history of solvent release to the environment. Table 18 summarizes the number of NWFWMD cleaning business inventory sites and the number of FDEP STCM underground storage tanks within the 20-year WHPA.

Regarding PCE, the positive correlation between proximity to either a DSCP PCE-contaminated site and/or a cleaning business location(s) and a history of PCE contamination is striking. In the case of DSCP sites, 13 of 36 contaminated sites are located within (or immediately adjacent to) the 20-year WHPAs of ECUA wells. Further, all 13 sites are associated with ECUA wells having a history of PCE contamination.

The same trend holds for the NWFWMD cleaning business inventory. A total of 34 sites fell within a seven-year WHPA. Of these, 31 (91 percent) were within the WHPA of a well having a history of PCE contamination. Eighty-five sites from the NWFWMD cleaning inventory fell within the 20-year WHPA of an ECUA well. Of these 79 (93 percent were associated with wells having a history of PCE contamination.

Near proximity to a dry-cleaning facility imparts a distinct risk of PCE-contamination. Conversely, a good strategy to avoid PCE contamination is to avoid placing new wells in proximity to dry-cleaning sites. Implementation of this strategy requires several actions. First, new well sites must be evaluated for their proximity to existing cleaning business locations. This may be done with the WHPA and RISK functionalities of the ArcView application presented here. Second, a database of cleaning business locations is required. The information presented here is a good point-of-beginning. A key recommendation is the acquisition of cleaning business locations by real-time, differentially corrected GPS.

Among all public water suppliers, 14 DSCP contaminated sites (eligible and not eligible) are located within (or immediately adjacent to) 20-year WHPAs. Of the eligible sites, only four have been tasked to contractors for action. The remaining eight eligible sites have the following

Table 17. Relationship between PCE Contamination and Clothes Cleaning Business Locations.

Well Name	RISK score	GAC unit installed (as of 1999)	Primary organic contaminants present in raw water	Number of DSCP program sites in 20-year composite WHPA	Number of NWFWMD cleaning business sites in 7-year composite WHPA
ECUA #23-ENSLEY[1]		**yes**	**PCE**	**1**	
ECUA #18-MCALLISTER		**yes**	**PCE, TCE**	**1**	**2**
ECUA #17-9TH AVENUE[3]		**yes**	**PCE, BTEX, MTBE**	**1**	**5**
ECUA #38-ROYCE ST[1]		**yes**	**PCE, TCE, BTEX, MTBE**	**1**	**4**
ECUA #14-MONTCLAIR #2		**yes**	**PCE, TCE**	**1**	
ECUA #9-F & SCOTT ST[1]		**yes**	**PCE, BTEX, MTBE**	**1**	**2**
ECUA #4-EAST PLANT[1]		**yes**	**PCE, TCE, BTEX**	**1**	**3**
ECUA #1-(#6)		**yes**	**PCE, TCE, MTBE**	**2**	**4**
ECUA #10-LILLIAN		**yes**	**PCE, MTBE**	**1**	**1**
ECUA #5-WEST PLANT		**yes**	**PCE, TCE**		**2**
ECUA #13-MONTCLAIR #1		**previously**	**PCE[2], BTEX[2]**		
ECUA #3-(#9)		**previously**	**PCE, TCE, BTEX**	**2**	**5**
ECUA #2-(#8)		**previously**	**PCE, TCE**	**no whpa**	**no whpa**
ECUA #40-CANTONMENT		no			
ECUA #42-MCCRORY		no			
ECUA #22-SWEENEY		no	**PCE[2]**		
ECUA #28-OLF 4A[1]		no	**PCE[2], MTBE**	**1**	
ECUA #27-UNIVERSITY		no			
ECUA #39-ELLYSON		no			
ECUA #24-BROAD ST		no			**1**
ECUA #20-OLIVE RD		no			
ECUA #25-DUNAWAY		no			
ECUA #21-DAVIS HWY		no			**1**
ECUA #19-AIRPORT NORTH		no	**PCE[2]**		
ECUA #6-HAGLER		no			
ECUA #15-MONTCLAIR #3		no			
ECUA #29-CARRIAGE HILLS		no			
ECUA #41-TENNANT		no			
ECUA #30-AVONDALE		no			
ECUA #8-W & AVERY ST		no	**PCE[2], TCE[2]**		**2**
ECUA #7-WEST P'COLA		no	**PCE[2]**		**1**
ECUA #37-VILLA DR		no			**1**
ECUA #11-BRONSON #1		no			
ECUA #12-BRONSON #2		no		**no whpa**	**no whpa**
Totals				**13**	**34**

Water quality data provided by ECUA; data for 1997 and 1998.
"previously" denotes that GAC was installed at one time and subsequently removed.
"no whpa" denotes that a wellhead protection area has not been delineated for this well.
[1] denotes that DCSP site is considered within the 20-year composite WHPA, even though it is slightly outside the WHPA.
[2] denotes that concentrations were below regulatory thresholds during 1997/1998.
[3] denotes that seven-year composite WHPA also contains Fashion Cleaners, a state-funded action site.
PCE is tetrachloroethylene, a dry-cleaning solvent.
TCE is trichloroethylene, a degradation product of PCE.
BTEX denotes one or more of benzene, toulene, ethylbenzene, xylene or other gasoline constituents.
MTBE is methyl-tert-butyl-ether, a gasoline additive.

Table 18. Relationship between BTEX Contamination and Storage Tank Locations.

Well Name	RISK score	GAC unit installed (as of 1999)	Primary organic contaminants present in raw water	Number of NWFWMD cleaning business sites in 20-year composite WHPA	Number of USTs in 20-year composite WHPA
ECUA #23-ENSLEY		**yes**	**PCE**	**1**	**1**
ECUA #18-MCALLISTER		**yes**	**PCE, TCE**	**4**	**4**
ECUA #17-9TH AVENUE		**yes**	**PCE, BTEX, MTBE**	**5**	**5**
ECUA #38-ROYCE ST		**yes**	**PCE, TCE, BTEX, MTBE**	**4**	**5**
ECUA #14-MONTCLAIR #2		**yes**	**PCE, TCE**	**1**	**2**
ECUA #9-F & SCOTT ST		**yes**	**PCE, BTEX, MTBE**	**3**	**10**
ECUA #4-EAST PLANT		**yes**	**PCE, TCE, BTEX**	**8**	
ECUA #1-(#6)		**yes**	**PCE, TCE, MTBE**	**24**	**11**
ECUA #10-LILLIAN		**yes**	**PCE, MTBE**	**1**	**2**
ECUA #5-WEST PLANT		**yes**	**PCE, TCE**	**10**	**2**
ECUA #13-MONTCLAIR #1		**previously**	**PCE[2], BTEX[2]**		
ECUA #3-(#9)		**previously**	**PCE, TCE, BTEX**	**10**	**7**
ECUA #2-(#8)		**previously**	**PCE, TCE**	**no whpa**	**no whpa**
ECUA #40-CANTONMENT		no			
ECUA #42-MCCRORY		no			
ECUA #22-SWEENEY		no	**PCE[2]**		
ECUA #28-OLF 4A		no	**PCE[2], MTBE**	**1**	**1**
ECUA #27-UNIVERSITY		no			
ECUA #39-ELLYSON		no			
ECUA #24-BROAD ST		no		**3**	**5**
ECUA #20-OLIVE RD		no			**4**
ECUA #25-DUNAWAY		no			
ECUA #21-DAVIS HWY		no		**2**	**2**
ECUA #19-AIRPORT NORTH		no	**PCE[2]**		
ECUA #6-HAGLER		no			
ECUA #15-MONTCLAIR #3		no			**1**
ECUA #29-CARRIAGE HILLS		no			
ECUA #41-TENNANT		no			**1**
ECUA #30-AVONDALE		no			**1**
ECUA #8-W & AVERY ST		no	**PCE[2], TCE[2]**	**2**	**3**
ECUA #7-WEST P'COLA		no	**PCE[2]**	**5**	**4**
ECUA #37-VILLA DR		no		**1**	
ECUA #11-BRONSON #1		no			
ECUA #12-BRONSON #2		no		**no whpa**	**no whpa**
Totals				**85**	**71**

Water quality data provided by ECUA; data for 1997 and 1998.
Number of sites in 20-year WHPA includes sites within the imbedded seven-year WHPA.
"previously" denotes that GAC was installed at one time and subsequently removed.
"no whpa" denotes that a wellhead protection area has not been delineated for this well.
[2] denotes that concentrations were below regulatory thresholds during 1997/1998.
PCE is tetrachloroethylene, a dry-cleaning solvent.
TCE is trichloroethylene, a degradation product of PCE.
BTEX denotes one or more of benzene, toulene, ethylbenzene, xylene or other gasoline constituents.
MTBE is methyl-tert-butyl-ether, a gasoline additive.

statewide tasking ranks; 82, 527, 540, 553, 554, 562, 576 and 598. Two contaminated sites were determined to be not eligible for participation in the program.

Regarding BTEX, the relationship between proximity and contamination is not as clear-cut as was the case for PCE. A total of 71 underground storage tanks were located within the 20-year wellhead protection area of ECUA wells. Of these, only 41 (58 percent) were within a WHPA having BTEX or MTBE contamination. The remaining 30 were within the WHPA of wells with no history of BTEX/MTBE contamination. Regardless, leaking gasoline storage tanks are the source of the BTEX and MTBE seen in ECUA wells. By avoiding placement of new well zones-of-contribution in downgradient proximity to storage tanks, BTEX and MTBE contamination can be minimized. Real-time, differentially corrected GPS locational data is crucial to implementation of this strategy.

Demonstration and Application of GWRAS

A demonstration of a site-specific risk assessment is presented here. The 34 existing ECUA wells were selected for this analysis. 343 dry-cleaning facilities (*NWFWMD_cleaners.shp*) and 476 underground storage tanks (*STCM_tanks.shp*) were considered as the main contaminant sources (Figure 61). Locations of dry-cleaning facilities and gasoline stations were obtained using the address geocoding function in ArcView.

Verification of the geocoded addresses was performed using real-time differentially corrected Global Positioning System (GPS). Fieldwork was conducted to determine the locations of selected dry-cleaning facilities and gasoline stations with GPS. Verification of the geocoded locations was undertaken to assess uncertainty associated with using these locations for risk assessment. Twenty-three dry-cleaning facilities and 56 gasoline stations were located in the field, GPSed and cross-referenced with their respective databases. Statistical comparisons of the two sets of locational data are presented in Tables 19 and 20. The statistics indicate that locations obtained from address geocoding procedure give a fairly reasonable accuracy, especially in the metropolitan area. The mean errors between the geocoded and GPSed locations for dry-cleaning facility and gasoline station are 138.5 m and 200.2 m, respectively.

Table 19. Statistics of the Geocoded and GPSed Dry-Cleaning Facility Locations.

Statistics	
Mean	138.51
Standard Deviation	83.93
Sample Variance	7044.94
Minimum	32.23
Maximum	324.06
Sum	23

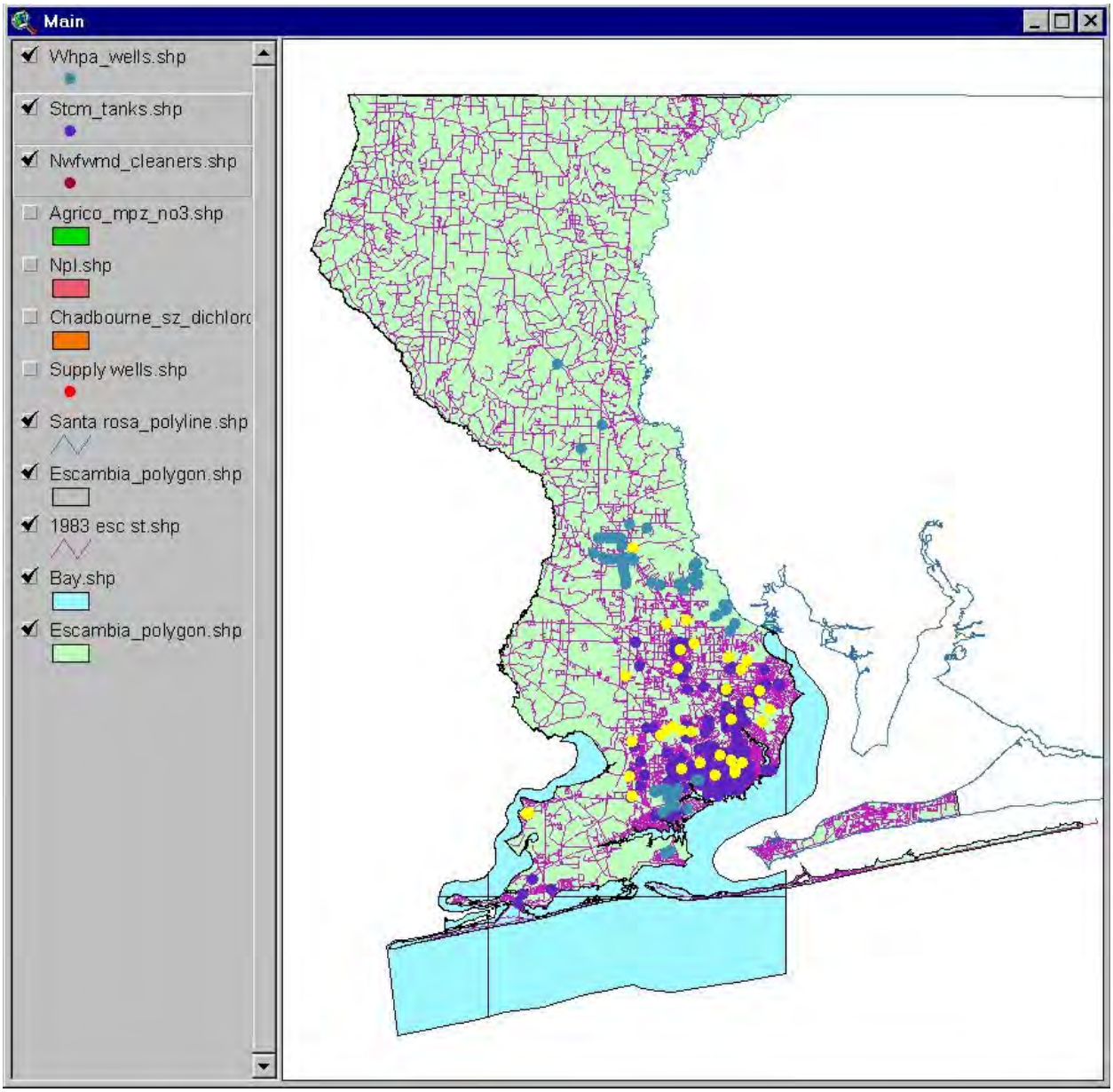


Figure 61. ECUA Wells, Dry-Cleaning Facilities and Gasoline Stations in Escambia County.

Table 20. Statistics of the Geocoded and GPSed Gasoline Station Locations.

Statistics	
Mean	200.19
Standard Deviation	250.33
Sample Variance	62667.00
Minimum	11.90
Maximum	1425.74
Sum	56

For the purposes of illustration, the GWRAS is applied to the location of ECUA#40-CANTONMENT. All other wells and locations can be assessed using the same procedures. The location of ECUA#40-CANTONMENT well can be identified by highlighting ECUA#40-CANTONMENT in the attribute table of *Whpa_wells.shp*. To do so, the water supply well theme (*Whpa_wells.shp*) has to be activated and the Open Theme Table button on the tool bar has to be clicked. The location of ECUA#40-CANTONMENT well will turn yellow as shown in Figure 62.

All the themes of contaminant sources considered in GWRAS have to be activated before the start of search. Simultaneously pressing SHIFT key and clicking Themes in the Main view can activate multiple themes. Once the *NWFWMD_cleaners.shp* and *STCM_tanks.shp* are activated (Figure 61), click the Risk Search in Risk menu to start the search of contaminant sources. Pumpage (gpm) of the well and field to be reported have to be chosen to complete the interactive processes as shown in Figures 63 and 64.

Two output files are generated under C:\GWRISK\OUTPUT\ directory. **Csoutput.dat** contains the contaminant sources information within a radius of 1,000 m of the selected well and **riskdata.dat** contains the available data needed for GWRAS. Examples of **csoutput.dat** and **riskdata.dat** are shown in Tables 21 and 22, respectively. The “-1” value in Table 22 indicates no data available.

Table 21. **Csoutput.dat** for ECUA#40-CANTONMENT.

```
TOTAL SELECTED CONTAMINANT SOURCES :     2
  1  Gas_tanks.shp
WITHIN RADIUS 1000. METER, TOTAL CONTAMINANT SOURCES :       1
ESCAMBIA CNTY SHERIFF'S DEPT-SUB STA
WITHIN RADIUS  500. METER, TOTAL CONTAMINANT SOURCES :       0
WITHIN RADIUS  300. METER, TOTAL CONTAMINANT SOURCES :       0
WITHIN RADIUS  150. METER, TOTAL CONTAMINANT SOURCES :       0
WITHIN RADIUS   50. METER, TOTAL CONTAMINANT SOURCES :       0
  2  Dry cleaning.shp
WITHIN RADIUS 1000. METER, TOTAL CONTAMINANT SOURCES :       0
WITHIN RADIUS  500. METER, TOTAL CONTAMINANT SOURCES :       0
WITHIN RADIUS  300. METER, TOTAL CONTAMINANT SOURCES :       0
WITHIN RADIUS  150. METER, TOTAL CONTAMINANT SOURCES :       0
WITHIN RADIUS   50. METER, TOTAL CONTAMINANT SOURCES :       0
```

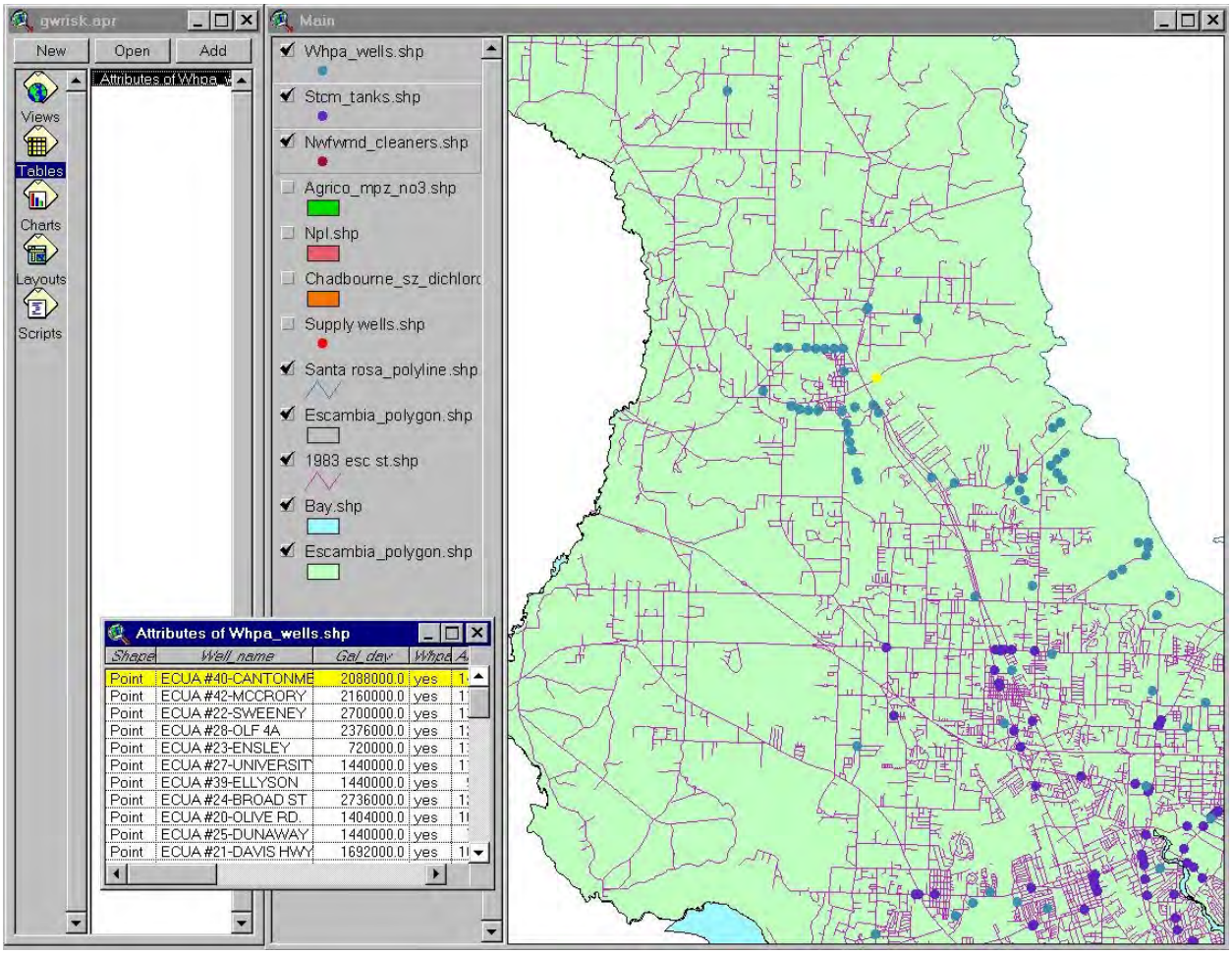


Figure 62. ECUA#40-CANTONMENT is Identified by Selecting from Whpa_wells.shp Attributes.

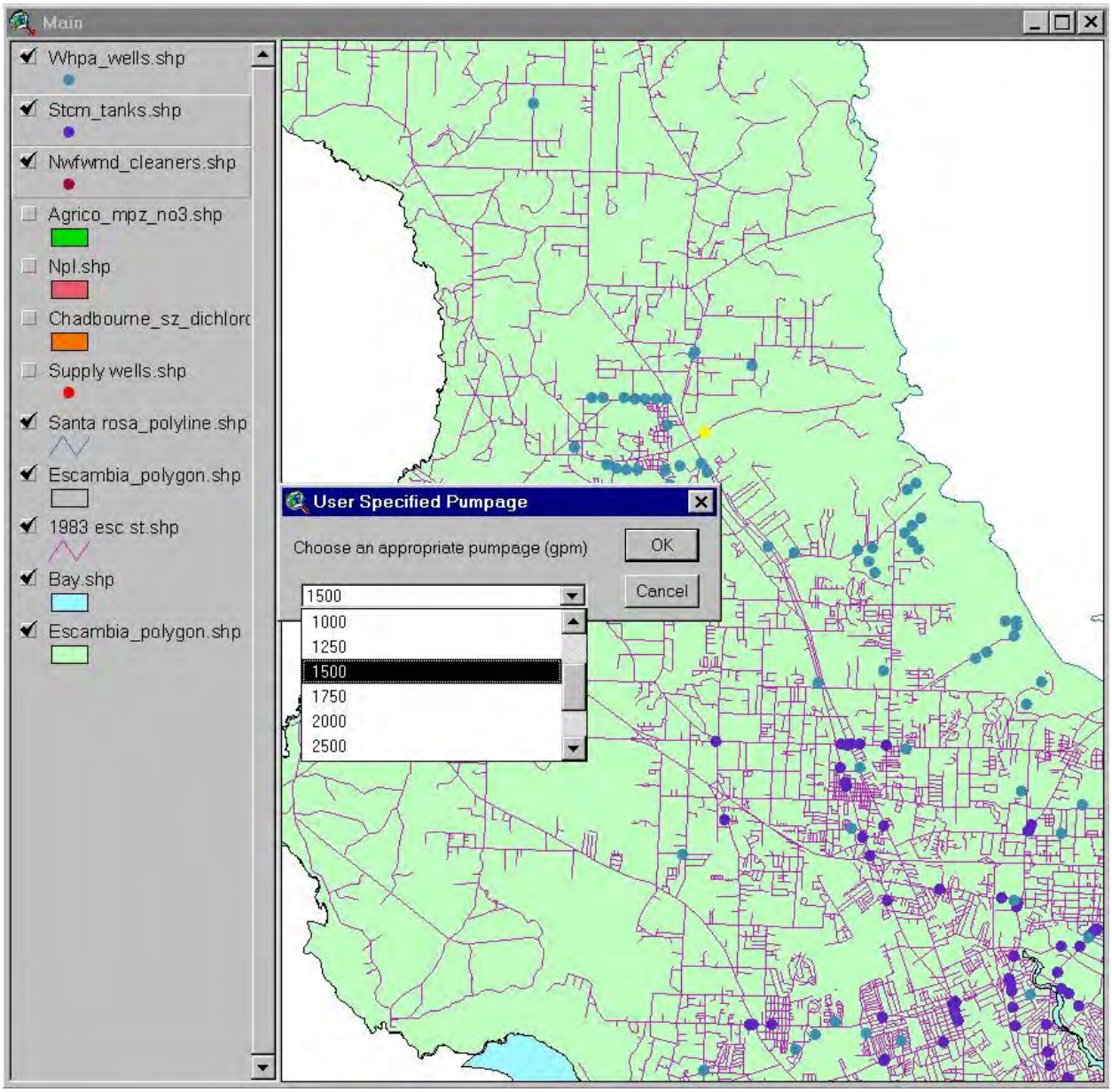


Figure 63. Example of GWRAS Pumpage Selection Functionality.

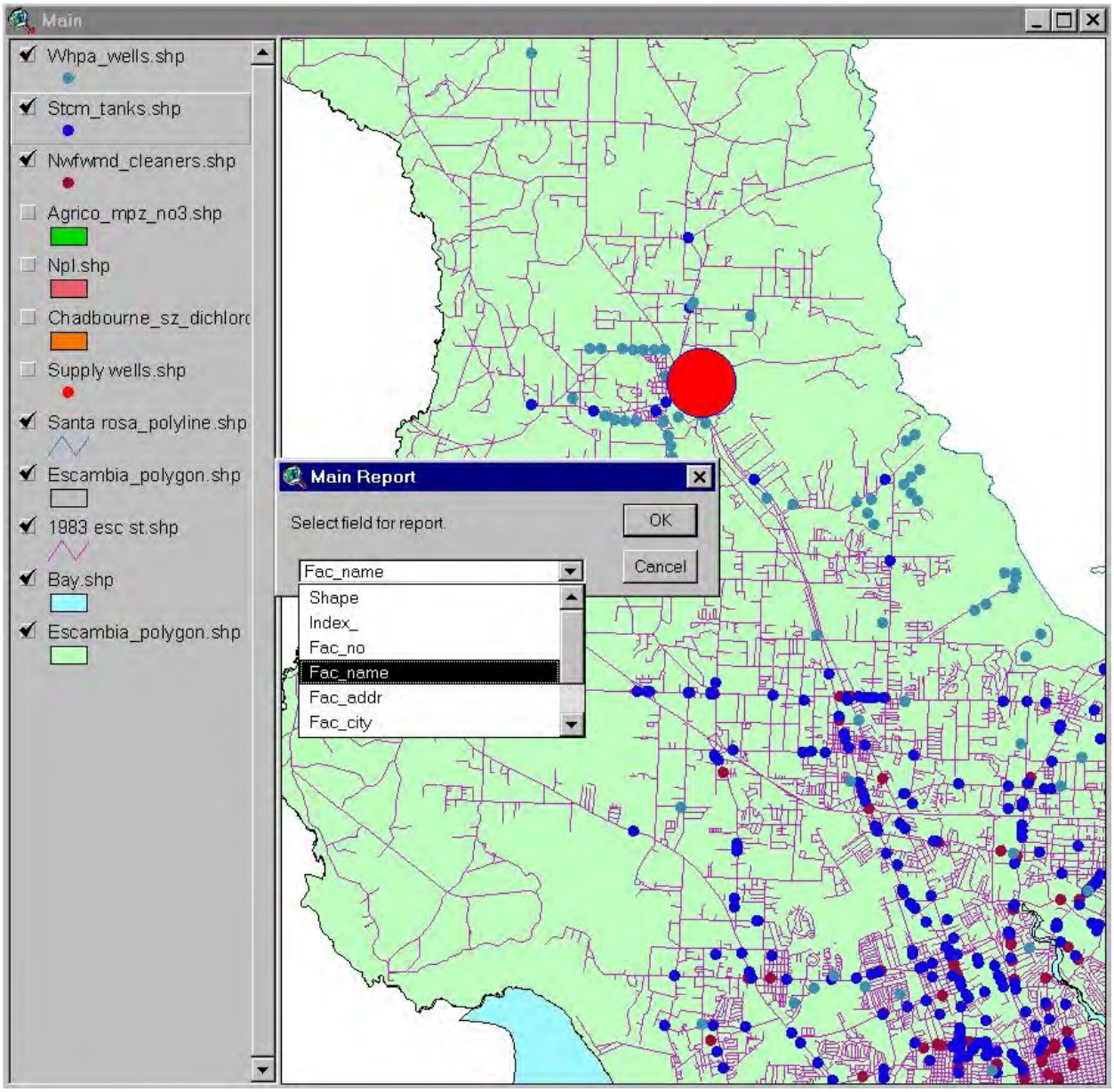


Figure 64. Example of GWRAS Report Generation Functionality.

Table 22. **Riskdata.dat** for ECUA#40-CANTONMENT.

```
45.00
          4.50
1     0     0     0     0
  1500.00
            .01
         71.00
         -1.00
         -1.00
         -1.00
         -1.00
         -1.00
         -1.00
         -1.00
```

After the completion of Risk Search, the generated **riskdata.dat** will be used for a site specific risk assessment. Clicking the **Risk Model** in the **RISK** menu performs the risk assessment. A message box appears and information of which model, what variables used in the risk model, risk score, and level of risk are given as shown in Figure 65. The risk score is calculated by one of the five multi-variate regression risk models and re-scaled to 100. The level of risk is based on the calculated risk score as shown in Table 23.

Table 23. Risk Score and Level of Risk.

Risk Score	Level of Risk
< 40	Low Risk
40 ~ 55	Low to Moderate Risk
55 ~ 65	Moderate Risk
65 ~ 80	Moderate to High Risk
> 80	High Risk

The risk score of the ECUA#40-CANTONMENT well (45.6) suggests that this well is at low to moderate risk based on the combination of one gasoline tank and moderate leaky semi-confined zone.

The rest of 33 ECUA wells were assessed in the same manner. The risk score of the total 34 ECUA wells is listed in Table 24. From Table 24, the risk score is mainly proportional to the vertical hydraulic conductivity of the semi-confined zone. The second important factor is the number of contaminant sources and the distance between contaminant source and site of interest. Among all the wells, ECUA #1-(#6) and ECUA #2-(#8) received the highest scores (71.7 and 70.2, respectively). Both wells are located in a moderated semi-confined zone area; however, the large number of dry-cleaning facilities and gasoline stations within a radius of 1,000 meters contribute to the high scores of these sites.

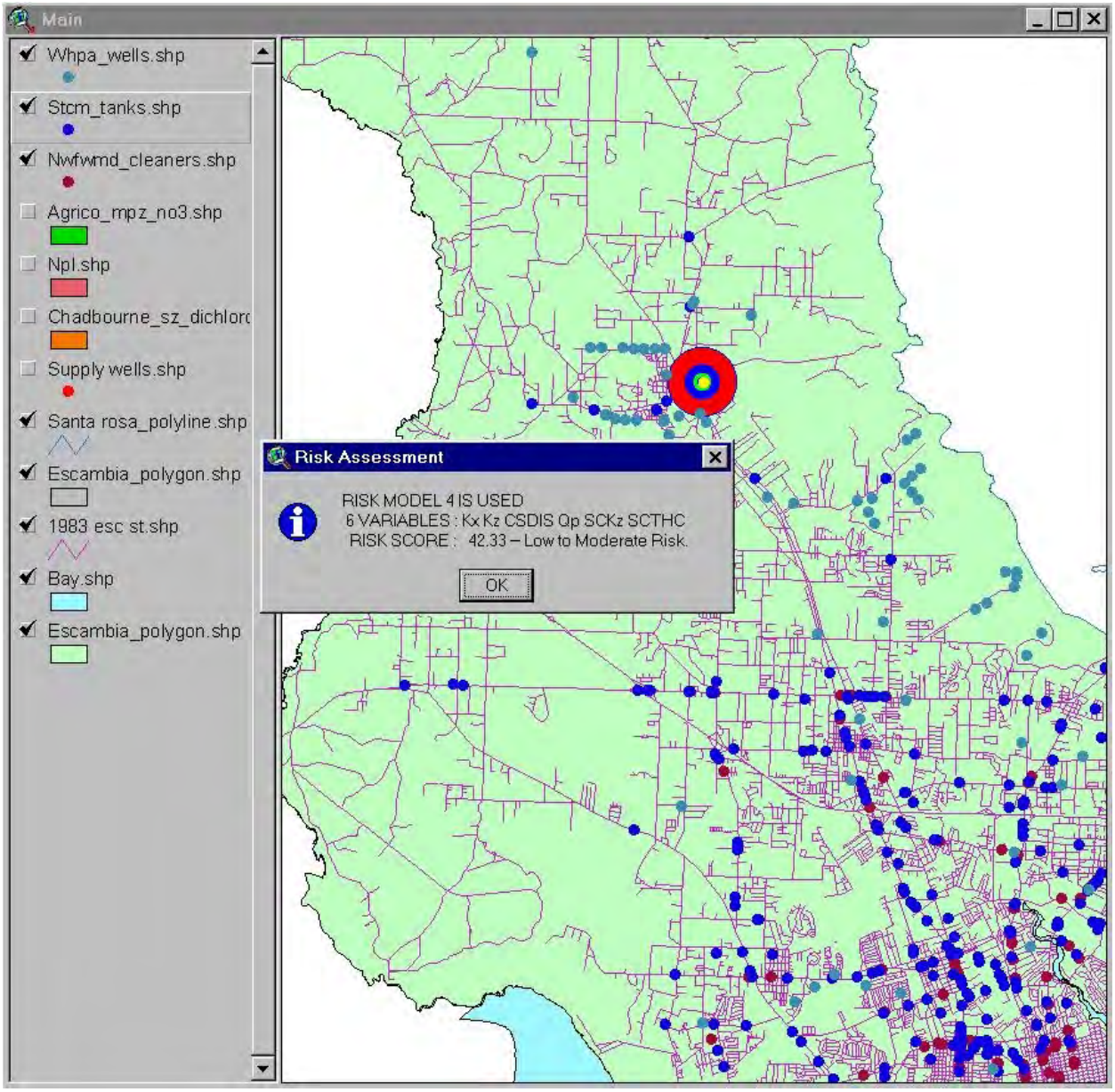


Figure 65. Example of RISK Assessment Score Output.

Table 24. RISK Scores for ECUA Supply Wells.

WELL NAME	GAC UNIT (as of 1999)	GWRAS PUMPAGE (gpm)	TOTAL # SOURCES	LPZ THICKNESS (m)	LPZ Kz (m/d)	RISK SCORE	REMARK
ECUA #1-(#6)	**yes**	1300	70	23.6	0.03	71.7	M to H
ECUA #2-(#8)	**yes***	0	62	23.6	0.03	70.2	M to H
ECUA #3-(#9)	**yes***	1300	44	21.5	0.03	67.3	M to H
ECUA #20-OLIVE RD	no	1000	9	10.9	0.052	65.8	M to H
ECUA #28-OLF 4A	no	1650	7	7.3	0.052	64.9	M
ECUA #39-ELLYSON	no	1000	2	10	0.052	64.3	M
ECUA #18-MCALLISTER	**yes**	1375	23	7.9	0.015	63.7	M
ECUA #5-WEST PLANT	**yes**	825	34	27	0.03	63.2	M
ECUA #19-AIRPORT NOR.	no	1000	0	8.5	0.061	62.9	M
ECUA #17-9TH AVENUE	**yes**	1000	22	14.6	0.015	62.9	M
ECUA #6-HAGLER	no	2150	0	10.6	0.061	62.6	M
ECUA #9-F & SCOTT ST	**yes**	800	38	23.6	0.03	62.6	M
ECUA #42-MCCRORY	no	1500	0	5.5	0.055	62.4	M
ECUA #7-WEST P'COLA	no	875	30	21.2	0.03	62.4	M
ECUA #27-UNIVERSITY	no	1000	0	10	0.052	61.3	M
ECUA #4-EAST PLANT	**yes**	1450	29	22.1	0.03	59.4	M
ECUA #23-ENSLEY	**yes**	500	25	9.4	0.015	56.5	M
ECUA #21-DAVIS HWY	no	1175	12	12.1	0.015	54.5	L to M
ECUA #38-ROYCE ST	**yes**	1600	17	5.2	0.03	54.3	L to M
ECUA #8-W & AVERY ST	no	1550	15	26.1	0.03	53.7	L to M
ECUA #24-BROAD ST	no	1650	11	8.5	0.003	52.7	L to M
ECUA #13-MONTCLAIR #1	**yes***	450	14	21.2	0.015	51.9	L to M
ECUA #10-LILLIAN	**yes**	1200	5	13.9	0.015	51.3	L to M
ECUA #14-MONTCLAIR #2	**yes**	525	11	19.7	0.015	51.0	L to M
ECUA #30-AVONDALE	no	750	4	12.7	0.015	47.2	L to M
ECUA #15-MONTCLAIR #3	no	525	2	17	0.015	46.2	L to M
ECUA #37-VILLA DR	no	1150	1	16.7	0.015	45.7	L to M
ECUA #41-TENNANT	no	750	3	16.4	0.015	45.6	L to M
ECUA #40-CANTONMENT	no	1450	1	21.5	0.03	45.6	L to M
ECUA #29-CARRIAGE HILL	no	600	2	18.5	0.015	45.1	L to M
ECUA #22-SWEENEY	no	1875	0	13.9	0.015	45	L to M
ECUA #11-BRONSON #1	no	525	0	13.3	0.015	43.9	L to M
ECUA #25-DUNAWAY	no	1000	0	16.1	0.003	43.9	L to M
ECUA #12-BRONSON #2	no	0	0	13.3	0.015	41.2	L to M

Demonstration of the Identification of Wellhead Protection Areas

The GPTRAC module (Blandford & Huyakorn, 1991) was incorporated into GWRAS to delineate time-related capture zones around pumping wells. Richards et al. (1997) constructed 10 sub-regional model grids to accurately accommodate the WHPA wells. 10 steady ground-water flow fields were simulated to provide the needed head field information in GPTRAC module. The head fields of Richards et al. are incorporated into GWRAS to approximate horizontal times-of-travel within the main-producing zone of the Sand-and-Gravel Aquifer in southern Escambia County.

Grid 3 (Figure 60) is used to demonstrate the identification of a WHPA. There are four steps required to complete the process.

Step - 1

By clicking the **Data Input** in **WHPA** menu, the user will go through two interactive processes and enter the needed information to prepare an input data required for execution of WHPA model. First, system will ask the user to choose a grid system (Figure 66) and the well information associated with the selected grid system will appear (Figure 67) for further modification, if required. In Figure 67, head03.whp is the simulated flow field file for grid 3 and 7,300 days (20 years) is the default time of simulation. Seven is the number of WHPA wells within grid 3.

The first number in well 1 to 7 is the well number. The following two numbers are the x and y coordinates (meter) of well position. The fourth number is the pumpage (m^3/d). A minus sign indicates a pumping well and a plus sign indicates an injection well. The fifth number is a control parameter to indicate pumping wells for which capture zones are to be delineated. The sixth number is the number of pathlines. Twenty is the default. The last number is the maximum radius of influence of pumping well (in meters). In this demonstration, all default numbers are adopted without any modification. An output file, gptrac.sav is generated under C:\GWRISK\BIN\ directory and is ready for execution of the WHPA model.

Step - 2

By clicking the **Run WHPA** in **WHPA** menu, WHPA model reads the gptrac.sav and generates two output files (gptrac.out and whpa.plt) under C:\GWRISK\OUTPUT. Whpa.plt contains the coordinates of the simulated pathlines and is needed for determination of the wellhead protection area.

Step - 3

By clicking the **Capture Zone** in **WHPA** menu, a WHPA file (capture.dat) is generated under C:\GWRISK\OUTPUT directory.

Step - 4

By clicking the **Convert To Shape File** in **WHPA** menu, a table which contains the coordinates of WHPA will pop up and the user will be asked to specify an appropriate directory and name to store the polyline shape file (Figure 68). It takes a few minutes for the script to convert the capture.dat to a shape file. Once it is complete, the user will be asked to choose an appropriate

View to display the converted WHPA shape file (Figure 69). Figure 70 is the calculated WHPA in the area covered by grid 3.

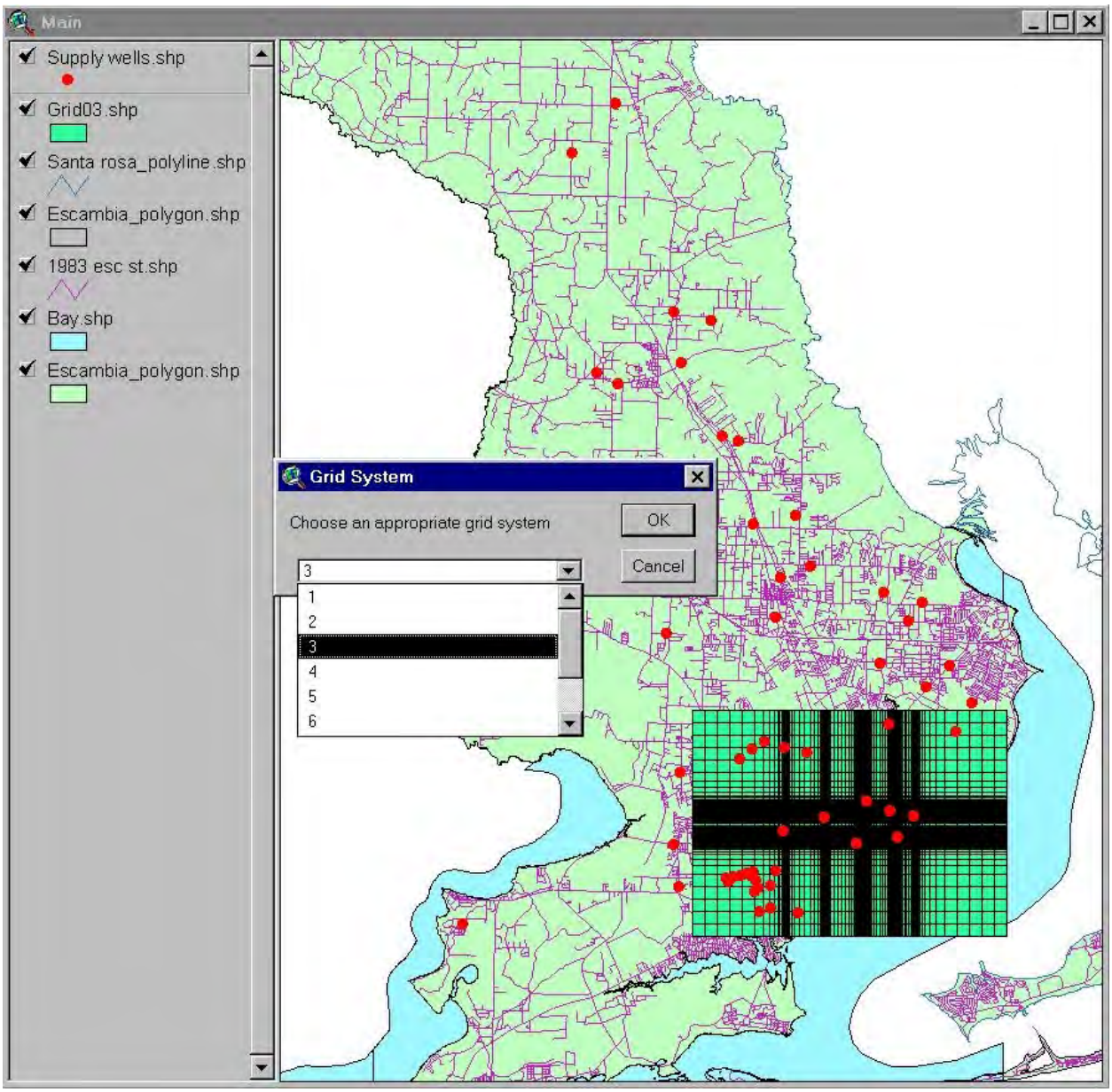


Figure 66. Example Grid System Selection.

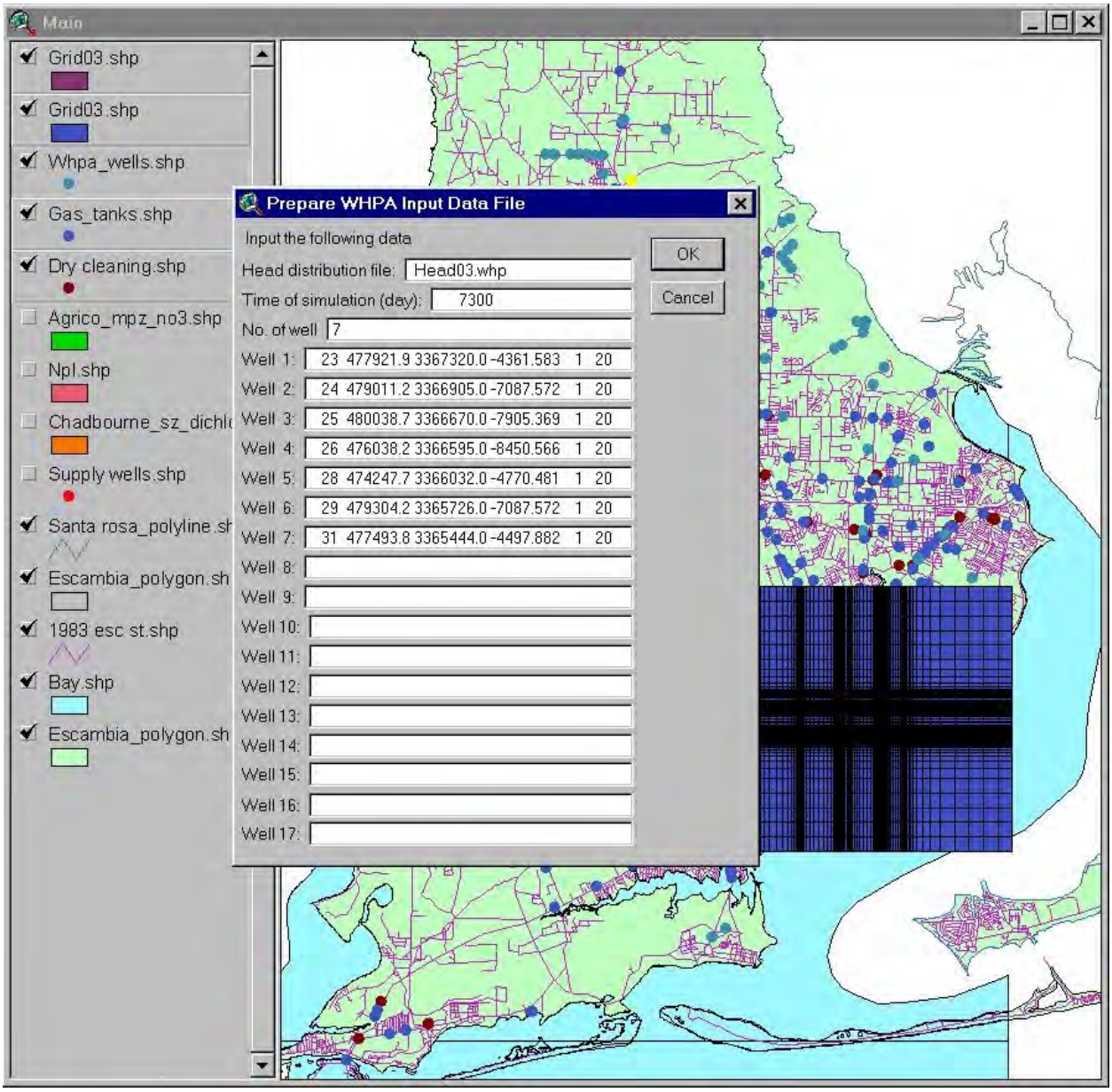


Figure 67. Example Well Information Input.

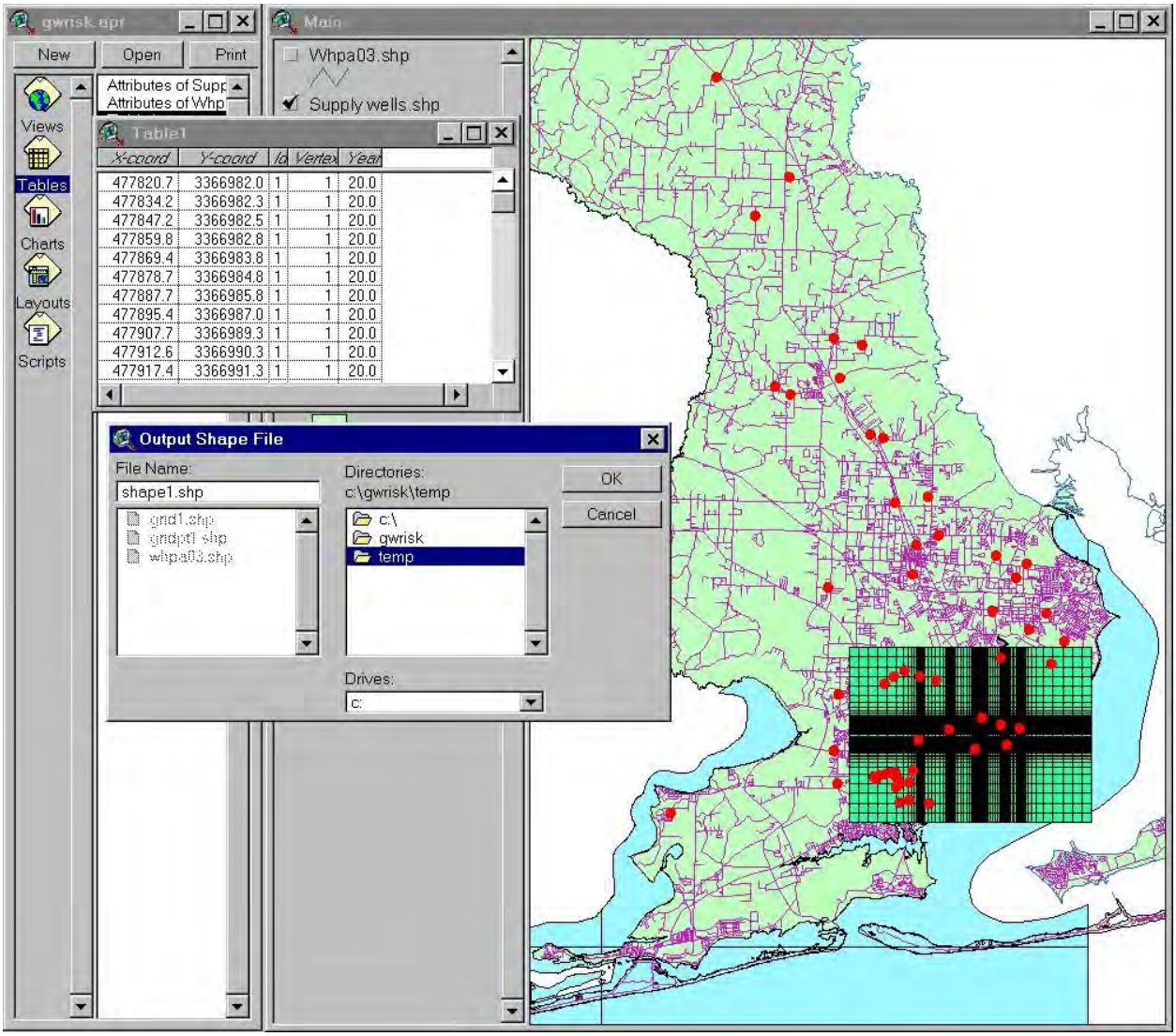


Figure 68. Example of WHPA Shape File Directory Specification.

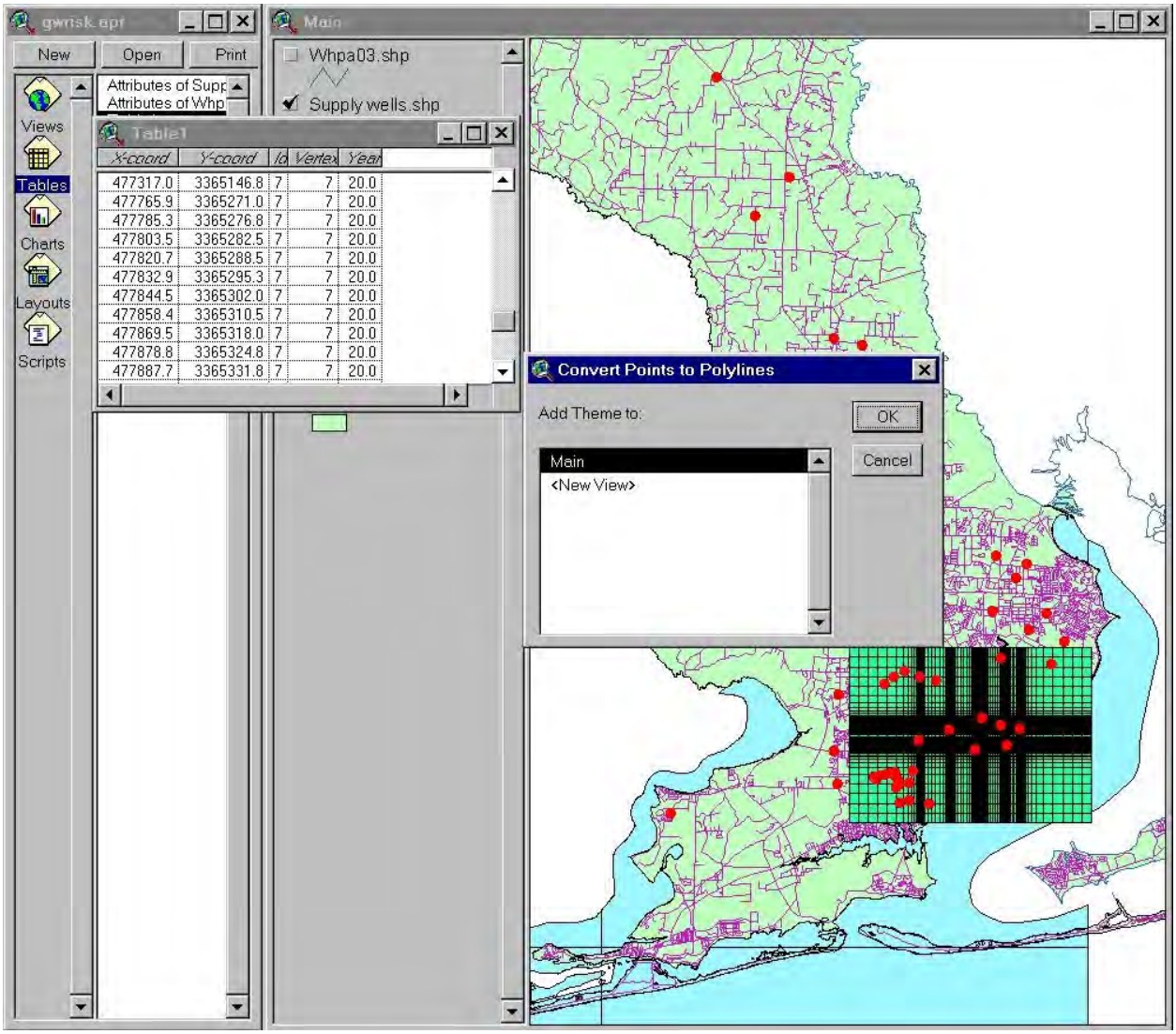


Figure 69. Example of WHPA Shape File View Selection.

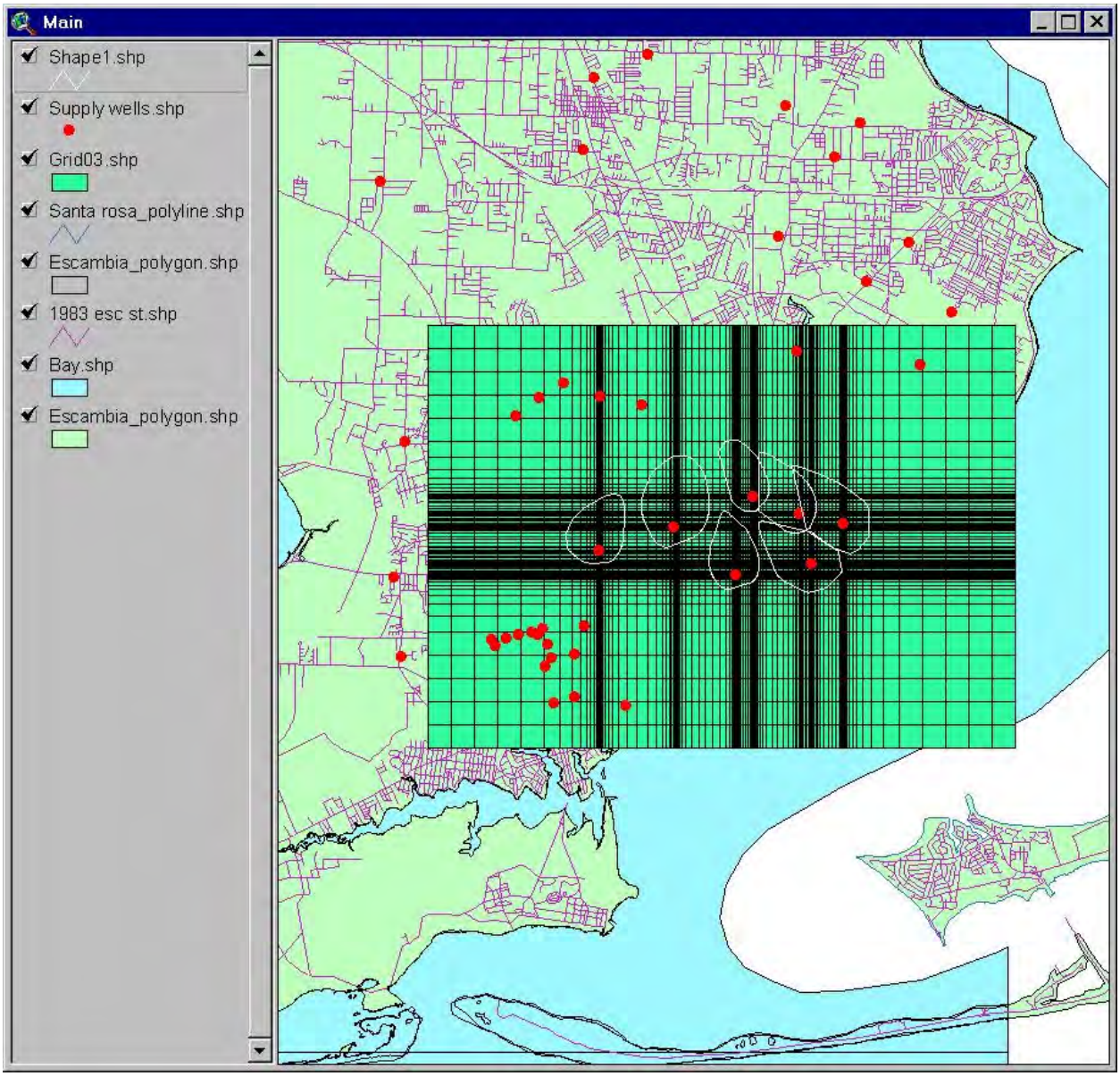


Figure 70. Simulated 20-year Horizontal Wellhead Protection Areas.

CONCLUSIONS AND RECOMMENDATIONS

- *Advection of contaminants in the Sand-and-Gravel Aquifer is strongly influenced by the vertical hydraulic conductivity of the aquifer. This includes all units that comprise the aquifer (surficial zone, low-permeability zone and main-producing zone). Additional quantification of this hydraulic property by multi-well aquifer testing is extremely useful, is worth the expense and should be encouraged.*

- *Based solely on hydraulic properties, wells in southern Escambia County are at roughly comparable risk. This derives from the relatively greater significance of vertical hydraulic conductivity in risk assessment and the relatively narrow range of values for this property in the southern half of the county.*

- *New public supply wells should be sited such that the zone of contribution does not lie under any major transportation corridor.*

- *New public supply wells should be sited such that the zone of contribution does not, to the greatest extent practicable, lie under any underground storage tank or clothes cleaning facility. This particularly includes dry-cleaning sites enrolled in the FDEP DSCP cleanup program and which have demonstrated releases of solvents.*

- *Good locational information is crucial to understanding the relationship between sources of contamination and effected wells. Accordingly, regulated underground storage tanks in southern Escambia County should be located with real-time differentially corrected GPS. Cleaning businesses addresses (Table 4) known or believed to be located in the 20-year composite wellhead protection areas should also be located with real-time differentially corrected GPS.*

- *The FDEP should review DSCP cleanup rankings for sites within or immediately adjacent to 20-year time-of-travel wellhead protection areas to assure itself that the current rankings are appropriate. Sites of sufficiently close proximity to existing wells should be moved up in the statewide rankings.*

- *Public water suppliers should familiarize themselves with FDEP DSCP program activities being conducted at sites within the 20-year wellhead protection areas of their wells. Of particular interest should be site monitoring (and associated contaminant analytical data) and site remediation status.*

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Escambia County

Article 7 PERFORMANCE STANDARDS

7.12.02. Definitions.

A. *Aquifer.* A groundwater bearing geologic formation, or formations, that contain enough saturated permeable material to yield significant quantities of water. In Escambia County, most potable water is extracted from the "sand and gravel" aquifer, a shallow aquifer separated by impermeable matter from the deeper, and more protected, Floridan Aquifer.

B. *Cone of depression.* An area of reduced water levels which results from the withdrawal of groundwater from a point of collective source such as a well, wellfield, dewatering site of a quarry, etc. The area, extent and depth of the depression is a function of the hydraulic properties of the aquifer, the pumpage rates and recharge rates.

C. *Groundwater.* Water that fills all the unblocked voids of underlying material below the ground surface, which is the upper limit of saturation, or water which is held in the unsaturated zone by capillarity.

D. *Protected wellhead.* Those wellheads with a permitted capacity of 100,000 GPD or more.

E. *Public utility.* Any privately owned, municipally owned, special district-owned, or state-owned system providing water or wastewater service to the public which has at least 15 service connections or regularly serves at least 25 individuals daily for at least 60 days of the year.

F. *Regulated substances.*

1. Those deleterious substances and contaminants, including degradation and interaction products which, because of quality, concentration, or physical, chemical (including ignitability, corrosivity, reactiveness and toxicity), or infectious characteristics, radioactivity, mutagenicity, carcinogenicity, teratogenicity, bioaccumulative effect, persistence (nondegradability) in nature, or any other characteristic, may cause significant harm to human health and the environment (including surface water and groundwater, plants, and animals).

2. Regulated substances shall include, but are not limited to, those substances set forth in the lists, as amended from time to time, entitled Lists of Hazardous Wastes (40 CFR Part 261, Subpart D), 40 CFR, Part 261, Appendix VIII--Hazardous Constituents, and EPA Designation Reportable Quantities and Notification Requirements for Hazardous Substances Under Circular (40 CFR 302, effective July 3, 1986); provided, however, that this article shall only apply whenever the aggregate sum of all quantities of any one time exceeds five gallons where said substance is a liquid, or 25 pounds where said substances is a solid.

3. These regulations shall also apply if no single substance exceeds the above-referenced limits but the aggregate sum of all regulated substances present at one facility/building at any one time exceeds 100 gallons if said substances are liquids, or 500 pounds if said substances are solids.

4. These regulations shall apply to all underground storage facilities for petroleum projects which are not regulated by F.S. § 376.317 and F.A.C. ch. 17-61.

G. *Travel time contour.* Locus of points from which water takes an equal amount of time to reach a given destination such as a well or other point of withdrawal.

H. *Travel time zones.* The areas bounded by travel time contours.

I. *Wellhead protection area.* All land within a 200-foot radius of an existing or designated protected wellhead. WHPA or all land within the seven-year and 20-year travel time contour (whichever is more protective of the wellhead) as shown on the maps provided herein as composite exhibit "A," attached hereto and incorporated by reference herein and defined for the composite vertical and horizontal travel time analysis in the project report entitled "Wellhead Protection Area Delineation in Southern Escambia County, Florida." Any wells north of Barrineau Park Road (County Road 196) shall have a 500-foot radius zone in lieu of the seven-year and 20-year travel time contour. Within the 200 feet of any well, the only activities allowed are those associated with

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the well or existing single-family residential uses, open spaces and recreation facilities, but not including impervious surfaces.

7.12.03. Restrictions on development.

A. *[Seven-year wellhead protection area.]* The following land uses are prohibited within the seven-year travel time contour as shown on attached exhibit "A" or within the 500-foot radius of any well north of County Road 196.

1. Sanitary landfills plus construction and debris pits.
2. Facilities for the bulk storage, handling or processing of materials on the Florida substance list (F.S. ch. 442).
3. Activities that require the outside storage, use, production or bulk transportation of regulated substances: agricultural chemicals, petroleum products, hazardous/toxic wastes, industrial chemicals, medical wastes, etc.
4. Feedlots or other concentrated animal facilities.
5. Wastewater treatment plants, and related percolation ponds; septic tank or other on-site treatment facilities for commercial and industrial uses.
6. Mines or resource extraction.
7. Excavation of waterways or drainage facilities which intersect the water table.
8. Drainage wells or other facilities which provide for the disposal of stormwater directly into the aquifer absent normal percolation.
9. Discharges to ground water of industrial wastewater.
10. Phosphogypsum stacks and lateral expansions of phosphogypsum stack systems.
11. Class I and Class III underground injection control wells.
12. Class V underground injection control wells.
13. Aboveground and underground tankage of hazardous wastes.

B. *Twenty-year wellhead protection area.* Within the 20-year travel time contour as shown on Exhibit "A," all site plans or change of use applications involving the land uses listed in A. above shall be subject to review by one representative each of the Escambia County Utilities Authority and the county department of neighborhood and environmental services. In the case of site plans, this shall be part of the DRC process. A report is required as outlined in 7.12.04.D.

C. *Abandoned wells.* Where wells have been abandoned or no longer function, such wells shall be sealed and plugged in accordance with the requirements of the NWFWMD and F.A.C. ch. 17.28.

7.12.04. Development standards.

A. *New on-site wells.* All applications for development approval must specify whether new protected wellheads will be required to service the development. When such new protected wellheads are to be required, the applicant shall demonstrate that:

1. There will be no significant adverse impact on minimum groundwater levels at the protected wellhead;
2. There will be no significant adverse impact from saltwater intrusion at the protected wellhead.

B. *Area of water resources concern.* Whenever adverse groundwater withdrawal impacts have been identified through water quality monitoring activities, all development approvals for activities which require the use of groundwater wells shall be coordinated with the NWFWMD, the Escambia County Utilities Authority and other public supply systems. Among other things, lower permit thresholds, maximum and minimum withdrawal levels, other stipulated conditions regarding water use, and any provisions of the Florida Administrative Code including relevant portions of F.A.C. 40A-2.801 et seq., may be employed to regulate, control or restrict water resource withdrawal activities.

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C. *Site plan requirements.* Where applicable, all site plans which accompany applications for development approval shall depict the location of all active and inactive or protected wellheads within 500 feet of the property, and the development approvals shall be conditioned upon the submission of a management plan which provides for the proper abandonment of existing unused wells, in conformance with requirements of the NWFWMD and the public supply systems.

D. *Groundwater/wellhead impact report.* Within the 20-year travel time contours, all proposed development excluding single-family homes shall prepare and submit a groundwater/wellhead impact report. The purpose of this report is to provide evidence of the probable impact of the proposed development on the groundwater supply and recharge potential of the area and existing or designated wellhead locations.

(Ord. No. 97-51, § 1, 10-2-1997; Ord. No. 99-34, § 1, 7-1-1999)

7.13.00. Wetlands and environmentally sensitive lands.

7.13.01. Findings and purpose. The Escambia County Board of County Commissioners (hereinafter "board") finds that wetlands and environmentally sensitive lands are indispensable and fragile resources that provide many public benefits including maintenance of surface and groundwater quality through nutrient cycling and sediment trapping, as well as flood and stormwater runoff control through temporary water storage, slow release, and groundwater recharge. In addition, wetlands and environmentally sensitive lands provide open space; passive outdoor recreation, education, and scientific study opportunities; critical wildlife habitat for fish, amphibians, reptiles, migratory waterfowl, and rare, threatened or endangered animal and plant species; and pollution treatment by serving as biological and chemical oxidation basins.

A considerable number of these important natural resources in Escambia County have been lost or impaired by draining, dredging, filling, excavating, building, pollution, and other acts. Preservation of the remaining Escambia County wetlands and environmentally sensitive lands in a natural condition shall be and is necessary to maintain hydrological, economic, recreational, and aesthetic natural resource values for existing and future residents of Escambia County. Therefore, the board desires to achieve a long-term goal of net gain of wetlands and environmentally sensitive lands to be accomplished through review of degraded or destroyed wetlands and environmentally sensitive lands in Escambia County, and through cooperative work with landowners, using incentives and agreements to restore and purchase wetlands and environmentally sensitive lands.

To achieve these goals, it is therefore necessary for the board to ensure maximum protection for wetlands and environmentally sensitive lands by discouraging development activities that may adversely affect wetlands and environmentally sensitive lands, while encouraging development activities which avoid and minimize adverse impacts to wetlands and environmentally sensitive lands.

The purpose of this section is to promote wetland and environmentally sensitive land protection, while taking into account varying ecological, economic development, recreational, and aesthetic values. Activities that may damage wetlands or environmentally sensitive lands should be located on upland sites to the greatest degree practicable as determined through a permitting process. The objective of this ordinance is to protect wetlands and environmentally sensitive lands from alterations that will adversely impact or reduce their primary functions for water quality improvement, floodplain and erosion control, groundwater recharge, educational and aesthetic nature, and wildlife habitat, especially for species listed as threatened, endangered, or of special concern by local, state or federal agencies. Provided that when insufficient uplands exist for construction of one single-family dwelling unit on a lot of record less than five acres in size, applications for a building permit shall be exempt from the wetland review and permitting requirements of this ordinance, provided the total area of dredging or filling in wetlands for the residence and associated residential improvements shall not exceed 4,000 square feet, and the total area of clearing in wetlands (including the dredging and filling for the residence and associated residential improvements) shall not exceed 6,000 square feet on the contiguous property owned by the applicant. The board of county commissioners may also exempt utilities when necessary.

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No. 90-2

PINELLAS COUNTY WELLHEAD PROTECTION ORDINANCE

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PINELLAS COUNTY WELLHEAD PROTECTION ORDINANCE

Sec. 166-191. Definitions

The following words, terms and phrases, when used in this article, shall have the meanings ascribed to them in this section, except where the context clearly indicates a different meaning:

Aquifer means a groundwater bearing geologic formation, or formations, that contains enough saturated permeable material to yield a minimum of 100 gallons per minute quantities of water.

Classification of groundwater, usage, reclassification. All groundwater of the county is classified by the board of county commissioners according to designated uses as follows:

(1) *Class G-1:* Potable water use, groundwater in aquifers which has a total dissolved solids content of less than 3,000 mg/l in an unconfined or leaky confined aquifer and is restricted to zones of protection around major public community drinking water supplies, and has been classified as G-1 by the board of county commissioners.

(2) *Class G-II:* Potable water use, groundwater in aquifers which has a total dissolved solids content of less than 10,000 mg/l, unless otherwise classified by the board.

(3) *Class G-III:* Nonpotable water use, groundwater in unconfined aquifers which has a total dissolved solids content of 10,000 mg/l or greater, or which has total dissolved solids of 3,000--10,000 mg/l and which has been classified by the board as having no reasonable potential as a future source of drinking water, or has been designated by the county water system as an exempted aquifer using the standards contained in section 17-28.130(C), Florida Administrative Code (F.A.C.).

(4) *Class G-IV:* Nonpotable water use, groundwater in confined aquifers which has a total dissolved solids content of 10,000 mg/l or greater.

Closure permit means that permit required by activities which must cease operation pursuant to the provisions of section 166-195 of this article, the criteria for which are set forth under section 166-196 of this article.

Completed application means an application which includes all materials and documents which are necessary to support the application and which has been accepted as complete by the county water system.

County administrator means the county administrator of Pinellas County or the administrator's designee.

Designated public utility means that public utility which has been designated by federal, state, regional or local law, regulation, resolution, rule, ordinance or requirement as having jurisdiction to provide potable water or residential wastewater service to the property on which the nonresidential activity is located.

Discharge to groundwater means treated or untreated wastewater, stormwater leachate, leachate from a solid waste facility, or leaked product generated by the construction or operation of an installation and discharging directly or indirectly to groundwater.

Emergency hazardous situation means a situation which exists whenever there is an immediate and substantial danger to human health, safety, or welfare or to the environment.

EPA means the United States Environmental Protection Agency.

Facility means main structures, accessory structures and activities which store, handle, use or produce regulated substances. Where contiguous facilities exist and such facilities are separate in the nature of the businesses, they shall remain separate under this article.

FDEP means the Florida Department of Environmental Protection.

Generic substance list means those general categories of substances set forth in Appendix A to Ordinance No. 90-2 and incorporated herein by reference. This list is equivalent to the regulated substances.

Groundwater means water that fills all the unblocked voids of underlying material below the ground surface, which is the upper limit of saturation, or water which is held in the unsaturated zone by capillarity.

Laboratory means a designated area or areas used for testing, research, experimentation, quality control, or prototype construction, but not used for repair or maintenance activities (excluding laboratory equipment), the manufacturing of products for sale, or pilot plant testing.

Major public community drinking water supply means those community water systems as defined in section 17-550.200(7), F.A.C., that are permitted by consumptive use permit to withdraw an average daily amount of 100,000 gallons or greater of groundwater.

New discharge means, for the purpose of the zone of protection, a discharge from a new installation, or a discharge for which a permit is required which is significantly different and causing a negative impact on groundwater, from the permit conditions as of the effective date of the zone of protection classification for the chemical, microbiological, physical quality, quantity, or point of discharge.

New installation means, for the purpose of the zone of protection, facilities located in areas receiving protection through classification by the board of county commissioners within the zone of protection that have neither filed a complete permit application nor received an appropriate permit prior to the effective date of classification.

Nonresidential activity means any activity which occurs in any building, structure or open area which is not used primarily as a private residence or dwelling.

Open interval of a well means the uncased or screened length of the well within the saturated zone of an aquifer.

Operating permit means the permit required of certain activities under section 166-195 to operate, the criteria for which are set forth under section 166-196.

Person means any natural person, individual, public or private corporation, firm, association, joint venture, partnership, municipality, governmental agency, political subdivision, public officer, owner, lessee, tenant or any other entity whatsoever or any combination of such, jointly or severally.

Potable water means water that is intended for drinking, culinary or domestic purposes, subject to compliance with county, state or federal drinking water standards.

Public utility means any privately owned, municipally owned, county-owned, special district-owned, or state-owned system providing water or resident wastewater service to the public which has at least 15 service connections or regularly serves at least 25 individuals daily for at least 60 days of the year.

Regulated substances means those deleterious substances, contaminants, priority pollutants (in accordance with chapter 17-22, F.A.C.), and potable water quality primary and secondary standards parameters (in accordance with chapter 3, part 4, F.A.C., and appendices A and E), which, because of

quality, concentration, or physical, chemical, including ignitability, corrosivity, reactiveness, synergistic, and toxicity; or infectious characteristics, radioactivity, mutagenicity, carcinogenicity, teratogenicity, bioaccumulative effect, persistence, or nondegradability in nature, or any other characteristic, may cause significant harm to human health and the environment, including surface water and groundwater, plants, and animals.

Spill means the unpermitted release or escape of a regulated substance directly or indirectly to soils, surface waters or groundwaters.

Underground facilities for transportation of wastewater of industrial chemical products means underground facilities for transportation of waste effluent of industrial chemical products, including piping, sewer lines, and ducts or other conveyances designed to transport industrial pollutants as defined in F.S. § 376.301(12), and contaminants as defined in F.S. § 403.031(1).

Underground storage facility means and includes any enclosed structure, container, tank or other enclosed stationary devices used for storage or containment of pollutants as defined in F.S. § 376.301(18) or any contaminant as defined in F.S. § 403.031(1). Nothing in this definition is intended to include septic tanks, enclosed transformers or other similar enclosed underground facilities.

Utility means a public utility (power company or telephone company) which serves the general public.

Variance means a grant of relief to a person or entity from the requirements of this article, which permits construction in a manner otherwise prohibited by this article where specific enforcement would result in inequitable hardship. The county administrator shall have the authority to grant variances.

Water table means the surface between the vadose zone and the groundwater, that surface of a body of unconfined groundwater at which the pressure is equal to that of the atmosphere.

Well means a pit or hole sunk into the earth to reach a resource of potable supply, such as water, to be used for domestic purposes by municipalities. Irrigation wells and privately owned wells for domestic consumption are not included in the scope of this article.

Wellfield means an area of land which contains more than one well for obtaining water.

Zone of protection means the total area contributing water to a well under a given set of circumstances. This area changes over time in response to changes in the water table or potentiometric surface, well pumpage, and other withdrawals in the vicinity. It is determined by the construction of a flow net, based on potentiometric surface contours.

Zone of protection map means the map at the scale determined by the county administrator showing the location on the ground of the outer limits of the zone of protection for present and future public potable water supply wells and wellfields of 100,000 gallons per day or more. This zone is described in section 166-194.

(Ord. No. 90-2, § 3, 1-30-90; Ord. No. 90-62, § 3, 7-24-90; Ord. No. 93-12, § 2, 2-16-93)

Cross references: Definitions generally, § 134-2.

Sec. 166-192. Authority.

(a) This article is adopted in compliance with, and pursuant to, the local government comprehensive planning and land development regulation act, F.S. § 163.3161 et seq. This article is adopted pursuant to the constitutional and home rule powers of article VIII, Florida Constitution, F.S. ch. 125, and article II of the Pinellas County Home Rule Charter.

(b) All provisions of this article shall be effective within the incorporated and unincorporated areas of the county, as delineated by a zone of protection map, and shall set restrictions, constraints and prohibitions to protect present and future public potable water supply wells and wellfields from degradation by contamination from regulated substances.

(Ord. No. 90-2, § 1, 1-30-90; Ord. No. 90-62, § 1, 7-24-90)

Charter references: Conflicts between county and municipal ordinances, §§ 2.01, 2.04.

Sec. 166-193. Purpose and intent.

(a) In order to properly protect existing and future potable water supply sources within the zone of protection area, the board of county commissioners declares that the storage, handling, use, disposal, or production of hazardous or toxic substances in close proximity to public potable water supply wells is potentially harmful to the drinking water of the county, and that certain land uses and activities involving regulated or generic substances are hereby prohibited or regulated within the defined zone of protection area.

Therefore, the intent of this article is to protect and safeguard the health, safety, and welfare of the residents and visitors of the county by providing criteria for regulating and prohibiting the use, handling, production, disposal, and storage of certain regulated substances which may impair present and future public potable water supply wells and wellfields.

It is the intent of the board of county commissioners to augment the policies within the adopted comprehensive plan that protect the wells and wellfields through land use controls and environmental regulations. It is essential to protect the environmentally sensitive area adjacent to wells and wellfields from disruption and encroachment in order to preserve vital natural functions relating to water quality, water quantity and other elements of aquatic ecosystems.

(b) It is the intent of the county to enter into interlocal agreements with Pasco County and Hillsborough County to exercise jointly any power, privilege or authority to protect from degradation all potable water wells within the zone of protection. The agreements shall be construed as accomplishing a joint use of powers subject to the terms and conditions stated in this article, in addition to any ordinance and regulations of Pasco County and/or Hillsborough County if the development proposal lies within their jurisdiction.

The agreement shall at a minimum include provisions for administration and enforcement of label development regulations within any area of the zone of protection and shall be undertaken by the jurisdiction within whose boundaries that area is located. With respect to the issuance of any development order or development permit within the zone of protection, the nonjurisdictional counties shall receive notice prior to any decision or determination on an application for development with adequate time for the nonjurisdictional counties to review and comment on the development permit application.

(c) The generic substance list attached to Ordinance No. 90-2 and incorporated in this article as Appendix A is provided for informational and regulatory purposes and may be amended from time to time by the board of county commissioners. Persons using, handling, producing or storing a substance on the generic list may be using, handling, producing or storing a regulated substance as defined by this article. Persons unsure as to whether they are subject to this article may wish to consult with the county water system.

(Ord. No. 90-2, § 2, 1-30-90; Ord. No. 90-62, § 2, 7-24-90)

Sec. 166-194. Maps delineating zone of protection.

(a) The zone of protection maps developed as described in subsection (b) are incorporated herein and made a part of this article. These maps shall be on file and maintained by the county administrator's designated departments. Any amendments, additions or deletions to such maps shall be approved by amendment to this article pursuant to the provisions established by F.S. § 125.66(5).

(b) The zone of protection map is developed by the following procedure:

(1) The historic water level data is obtained for each of the U.S. Geological Survey and county water system Floridan monitor wells shown on the zone of protection map and listed in Appendix I.

(2) The average water level is calculated for each well for the period of record available for each well.

(3) Potentiometric surface contours are then constructed based on these average water levels.

(4) A flow net is then constructed across the potentiometric contours by constructing flow lines perpendicular to potentiometric contours.

(5) The zone of protection is delineated by extending a line along the convergence of those flow lines that enter the wells or wellfields (flow lines converge in areas of discharge and diverge in areas of recharge).

(6) As additional Floridan monitor wells are constructed in the map area, this additional water level data will be incorporated into the zone of protection map. Accumulated annual water level data may be evaluated annually and adjustments to the zone of protection will be made as the data dictates.

(7) Measurement of the zone around a wellfield will be established for the entire wellfield by calculating the zone of protection for the wellfield as a whole. In the case of unclustered wells, individual zones of protection around each well will be calculated.

(8) Rebuttable presumption: Affected parties wanting to challenge the county's determination of the zone of protection may do so during the public hearings by generating more precise site-specific data concerning potentiometric levels that would allow more accurate calculations of the zone.

(9) The county administrator may change the zone of protection based on reconfiguration of a wellhead or wellfield, changes in open interval, proper abandonment of a well pursuant to rule 17-522, F.A.C., or permitted increase in the permitted average daily pumping rate. Such changes in the zone of protection shall follow the requirements as described in subsection (c) of this section. The zone of protection may be established for newly approved/permitted well(s) or wellfield(s), after the appropriate hydrogeologic testing and impact analyses have been performed in accordance with Southwest Florida Water Management District permitting consumptive use from the wells or wellfields.

(c) The zone of protection maps may be reviewed at least on an annual basis. However, failure to conduct such review shall not affect the validity of the existing approved map. The basis for updating such map may include, but is not limited to, the following:

(1) Changes in the technical knowledge concerning the applicable aquifer.

(2) Changes in pumping rates of wellfields.

(3) Wellfield reconfiguration.

(4) Designation of new wellfields.

(d) In determining the location of properties and facilities within the zones depicted on the zone of protection map, the following rules shall apply:

(1) Properties located partially within the zone of protection reflected on the applicable zone of protection maps shall be governed by the restrictions applicable to that zone.

(2) Where a zone of protection contour passes through a facility, the entire facility shall be considered to be in the more restrictive zone.

(e) The legal description of the area of the county zone of protection is as follows:

Commence at the intersection of the centerline at East Lake Road (C.R. 77) and the northern boundary line of Pinellas County; thence run easterly along said northern boundary line of Pinellas County to its intersection with the eastern boundary line of Pinellas County; thence run southerly along said eastern boundary line of Pinellas County to its intersection with the easterly extension of the Florida Power Corporation right-of-way, said intersection being 1290'+ north of the southeast corner of Section 12, Township 28 South, Range 16 East; thence westerly along the easterly extension of the centerline and the centerline of said Florida Power Corporation right-of-way to its intersection with the centerline of Tampa Road (S.R. 584); thence northwesterly along the centerline of Tampa Road (S.R. 584) to its intersection with the centerline of the aforementioned East Lake Road (C.R. 77); thence northerly along the centerline of East Lake Road (C.R. 77) to the point of beginning.

(Ord. No. 90-2, § 4, 1-30-90; Ord. No. 90-62, § 4, 7-24-90; Ord. No. 92-67, § 1, 10-27-92)

Sec. 166-195. Conditions of permitting, planning, and zoning within zone of protection.

(a) The use, handling, production, disposal, and storage of regulated substances associated with nonresidential activities is prohibited in the zone of protection, except as provided under the general exemptions and special exemptions provisions of this article (sections 166-200 and 166-201). All existing nonresidential activities within the zone of protection which store, handle, use, dispose of, or produce any regulated substance are prohibited from doing so unless they qualify as a general exemption, obtain a special exemption, or receive an operating permit from the county administrator. The owners or operators of such activities within the zone of protection shall be notified in writing, by certified mail, or hand delivery, within 90 days of the effective date of this article, as to the requirements to cease the use, handling, storage, disposal, and production of regulated substances. All existing nonresidential activities within the zone of protection which store, use, handle, or produce regulated substances shall file an application for an operating permit, or an operating permit with a general exemption application, or an operating permit with special exemption application, or a closure permit, within 90 days of receipt of notice from the county administrator. Such permit application shall be prepared and signed by a professional registered engineer and a geologist certified in the state, or either if the applicant can demonstrate to the county administrator that conditions will only require an engineer or a geologist. Within 30 days of receipt of such notice, the owner or operator shall file with the county administrator proof of retention of such engineer and geologist, or submit to the county administrator a written notice to obtain either an engineer or geologist.

(b) Any nonresidential activity in the zone of protection which is allowed to continue or commence in accordance with the general exemptions or special exemptions set forth in sections 166-200 and 166-201 shall obtain an operating permit which shall indicate the special conditions to be instituted and the dates on which such conditions shall be instituted. No expansions, modifications or alterations which would

increase the storage, handling, use or production of regulated substances shall be permitted in the zone of protection. An owner or operator that is denied a special exemption shall be issued a closure permit as part of the denial process. Any operating permit required in this article shall be filed with the applications for general exemption or special exemption.

(c) All new nonresidential discharges, new nonresidential activities, and installations shall be prohibited subject to conditions including but not limited to the following:

(1) No nonresidential installation shall discharge into groundwater, either directly or indirectly, any contaminant that causes a violation in the water quality standards and criteria for the receiving groundwater as established in chapter 17-3, part IV, F.A.C.

(2) Discharges through natural or manmade conduits, such as wells and sinkholes, that allow direct contact with class G-1 and class G-2 groundwater are prohibited, except for projects designed to recharge aquifers with surface water of comparable quality, or projects designed to transfer water across or between aquifers of comparable quality for the purpose of storage or conservation, or residential stormwater discharging through wet retention/detention ponds.

(3) Industrial stormwater discharges to retention/detention ponds are prohibited.

(4) New discharge to groundwater of industrial waste that contains hazardous constituents listed in the department of environmental protection's publication, G-1, Modified Hazardous Constituents List (December 1, 1986), which is hereby adopted and incorporated by reference, shall be prohibited.

(5) There will be no new industrial land use zoning within the zone of protection.

(6) Construction and operation of new sanitary landfills as defined by applicable state rules shall be prohibited. Operation of all existing sanitary landfills will be terminated within one year and a permanent leachate monitoring system installed to monitor movement of leachate.

(7) Commercial or industrial septic tank disposal systems are prohibited in the zone of protection.

(8) Construction of interstate highway system is prohibited for construction within one-half mile of public supply wells, unless stormwater drainage is collected and piped beyond the half-mile radius of the wellhead. There will be no stormwater retention within this half-mile radius around the zone of the wellhead.

(d) New and existing nonresidential discharge to groundwater within the zone of protection shall comply with the primary and secondary standards at the end of the discharge pipe. Additionally, more stringent monitoring requirements than the existing state law may be implemented. More stringent monitoring requirements may include increased monitoring frequency, increased number of parameters, or increased number of monitoring wells. Such determinations will be made by the county on a case-by-case basis by considering soil conditions, quality and volume of the waste stream, and the point of discharge.

(1) Stormwater discharge within the zone of protection: Direct and indirect discharge from new stormwater facilities serving an area ten acres or larger with a 40 percent impervious surface excluding building tops shall be required to monitor the discharge to groundwater according to section 17-28.700(6), F.A.C. Such facilities may be required to implement more stringent monitoring requirements which may include increased monitoring frequency, increased number of parameters, or increased number of wells. Such determination will be made by the county administrator on a case-by-case basis by considering soil conditions, quality and volume of the waste stream, and the point of discharge.

(2) Commercial stormwater runoff will be required to have a double pond detention/retention system for new facilities. The first pond will be off line and lined to prevent leakage and be designed to hold the first inch of runoff. Sludge from the first pond will be disposed of in accordance with FDEP rules and regulations. The second retention pond will accept overflow from the detention pond. Existing facilities will be required to obtain an operating permit and perform groundwater quality monitoring for groundwater pollution.

Variance. In order to authorize any variance to the stormwater runoff requirements of this subsection (d)(2), the county administrator shall consider the following criteria:

a. *Special conditions:* That special conditions and circumstances exist which are peculiar to the land, structure, or building involved, including the nature of and to what extent these special conditions and circumstances may exist as direct results from actions by the applicant.

b. *No special privilege:* That granting the variance requested will not confer on the applicant any special privilege that is denied by this article to other similar lands, buildings, or structures in the zone of protection.

c. *Unnecessary hardship:* That literal interpretation of the provisions of this article would deprive the applicant of rights commonly enjoyed by other properties under the terms of this article.

d. *Minimum variance necessary:* That the variance granted is the minimum variance that will make possible the reasonable use of the land, building, or structure.

e. *Purpose and intent compliance:* That the grant of the variance will be in harmony with the general intent, purpose, and spirit of this article, and with the comprehensive plan adopted pursuant to state law.

f. *No detriment to public welfare:* That such variance will not be injurious to the area involved or otherwise detrimental to the public welfare.

g. *Establishing conditions or safeguards:* That in granting any variance, the county administrator may prescribe appropriate conditions and safeguards to ensure proper compliance with the general spirit, purpose, and intent of this article. Noncompliance with such conditions and safeguards, when made a part of the terms under which the variance is granted, shall be deemed a violation of this article.

h. *Expiration:* All variances granted by the County Administrator shall be deemed to automatically expire in the event a structure or use of land which is the subject of the variance has been discontinued.

(3) New underground storage facilities within the zone of protection shall meet the following requirements:

a. Double-walled tank and piping with a continuous leak detection system in between the walls; or

b. An impervious secondary containment having monitoring well(s) or detector located therein; and

c. For each of the above options, it is required that the facility install, maintain, and monitor a groundwater program approved by the County.

(4) Existing underground storage facilities within the zone of protection not meeting the construction retrofit requirements of chapter 17-61, F.A.C., on the effective date of aquifer classification as class G-1 by the Board of County Commissioners shall be retrofitted in accordance with chapter 17-61, F.A.C., and shall also meet the requirements for new facilities under subsection (d)(3) of this section.

(5) Existing underground storage facilities within the zone of protection meeting the construction retrofit requirements of chapter 17-61, F.A.C., on the effective date of aquifer classification within the zone of protection by the Board of County Commissioners are exempt from the requirements above, with the exception of being required to increase their groundwater monitoring programs. Nothing herein shall be construed to relieve facilities subject to chapter 17-61, F.A.C., requirements from complying with the requirements of that chapter.

(6) New underground facilities for transportation of domestic raw wastewater within the zone of protection shall be constructed not to allow leakage of more than 25 gallons per inch of pipe diameter per mile per day into the soil or groundwater. These facilities, however, shall not cause violations of groundwater quality standards (as referenced in applicable state rules).

(7) New underground facilities for transportation of chemical products within the zone of protection shall be constructed to ensure no leakage into the soil or groundwater.

(8) Discharge to groundwater from the state department of environmental protection approved remedial corrective actions for contaminated sites located within the zone of protection shall not be subject to the G-1 discharge criteria.

(9) New discharge to groundwater of treated domestic waste effluent meeting domestic wastewater plant class I reliability; daily monitoring to assure proper treatment plant process control; and 24-hour-a-day attendance by a wastewater operator as required by chapter 17-16, F.A.C., and under the general supervision of a class A certified wastewater operator, shall be allowed to operate provided that the discharge from such plant shall meet the groundwater criteria as specified in section 17-520.420, F.A.C., prior to contact with groundwater (end of pipe). Treated domestic waste effluent discharge employing land application shall be restricted to slow-rate infiltration methods. At no time will an effluent disposal area be within 500 feet of potable supply wells.

(10) New single-family residential septic tanks will be exempt from this article, provided they meet the minimum criteria of one unit per two acres.

(e) A notice to cease, or a permit or an exemption issued under this article shall not relieve the owner or operator of the obligation to comply with any other applicable federal, state, regional or local regulation, rule, ordinance or requirement, nor shall such notice, permit, or exemption relieve any owner or operator of any liability for violation of such regulations, rules, ordinances or requirements.

(Ord. No. 90-2, § 5, 1-30-90; Ord. No. 90-62, § 5, 7-24-90; Ord. No. 93-12, § 2, 2-16-93)

Sec. 166-196. Permits.

(a) *Compliance with article required.* The permit conditions shall ensure compliance with all the prohibitions, restrictions, and requirements as set forth in this article. Such conditions may include, but are not limited to, monitoring wells, periodic groundwater analysis reports, and compliance schedules. Such conditions may also include requirements in a closure permit to reduce the risk in the interim of contamination of the groundwaters, taking into account cost, likely effectiveness and degree of risk to the groundwater.

(b) *Requirements for issuance of other permits.*

(1) No site plan approval, building permit, or certificate of occupancy for any nonresidential activity shall be issued by the County or any city located within the County that would allow development or construction in the zone of protection, that is contrary to the restrictions and provisions provided in this article. Permits issued in violation of this section confirm no right or privilege on the grantee.

(2) The requirements and provisions of this article shall apply immediately on February 17, 1990, to all new nonresidential activities.

(3) An existing activity is one for which a building permit had been issued by the appropriate jurisdiction prior to February 17, 1990, and which had not expired on or before February 17, 1990, or for which a completed building permit application had been filed and accepted with the appropriate jurisdiction prior to February 17, 1990. All other activities shall be deemed new.

(4) Any application for a nonresidential or residential development greater than 25 units for a site plan approval, building permit or nonresidential development subject to review by an advisory planning body and approval by the local governing authority or Zoning Board of Appeals that includes property wholly or partially within the zone of protection of a wellfield shall include the following:

a. Notification by the local governing authority of the location of the property in the zone of protection and a notarized letter from the applicant admitting acceptance of notification; notification shall be prepared by the County Administrator providing details of zones, prohibitions, and measures required for compliance; or

b. Any application submitted for site plan approval or certification of occupancy for any use within the zone of protection shall require certification by the County Administrator that the use meets the applicable requirements of this article.

(5) It shall be the duty of each local agency to screen all applications for the zone of protection site plans.

(6) The County Administrator shall provide a list to all local agencies of potentially prohibited operations in the zone of protection.

(7) Copies of building permits of residential activities larger than 25 units, all nonresidential projects, and all site plans, or nonresidential certificates of occupancy issued for the zone of protection shall be submitted to the County Administrator on a weekly basis.

(c) Change of ownership. In the event there is a change of ownership, a new lease, or an assignment of a lease, a sublease or any other change in regard to the person conducting the operation regulated, the County Administrator shall be notified by the property owner upon payment of the appropriate application fee and completion of processing of an application. In the event of leasing of space, the lessee will obtain the permit, but the property owner will be liable for the on-site activities relative to the conditions of the permit. The property owner will be notified by the County Administrator regarding the permit application or condition.

(d) Issuance, fees, inspections.

(1) An application which satisfied the requirements of the applicable zone of protection, section 166-195, and this section and, if applicable, section 166-194, shall be approved and a permit issued. In addition to the failure to satisfy these requirements, the County Administrator may deny a permit based on repeated violations of this article.

(2) An operating permit shall remain valid provided the permittee is in compliance with the terms and conditions of the permit

(3) Permittees shall not be required to pay annual renewal fees until March 1, 1991. Beginning March 1, 1991, all current and future permittees are subject to an annual renewal license fee as adopted by the Board of County Commissioners.

(4) The County Administrator shall have the right to make inspections of facilities at reasonable times to determine compliance with this article.

(5) All of the facilities owned and/or operated by one person, when these structures and activities are located on contiguous parcels of property, even where there are intervening public or private roads, may be covered under one permit.

(e) *Requirements and liabilities.*

(1) Leakproof trays under containers, floor curbing or other containment systems to provide secondary liquid containment shall be installed. The containment shall be of adequate size and design (no less than 150 percent of container volume) to handle all spills, leaks, overflows, and precipitation until appropriate action can be taken. The specific design and selection of materials shall be sufficient to preclude any regulated substance loss to the external environment. Containment systems shall be sheltered so that the intrusion of precipitation is effectively prevented. The owner/operator may choose to provide adequate and appropriate liquid collection methods rather than sheltering only after approval of the design by the County Administrator. These requirements shall apply to all areas of use, production, and handling, to all storage areas, to loading and off-loading areas, and to aboveground and underground storage areas. The containment devices and liquid collection systems shall be certified in the operating permit application by a professional engineer certified in the State.

(2) Vacuum suction devices, absorbent scavenger materials or other devices approved by the County Administrator shall be present on-site or available within four hours in the zone of protection 24 hours per day and seven days per week by contract with a cleanup company approved by the County Administrator, in sufficient magnitude so as to control and collect the total quantity of regulated substances present. To the degree feasible, emergency containers shall be present and of such capacity as to hold the total quantity of regulated substances plus absorbent material. The presence of such emergency collection devices shall be certified annually in the operating permit applications for existing activities. Such certification for new activities shall be provided to the County water system prior to the presence of regulated substances on the site. Certification shall be provided by a professional registered engineer certified in the State.

(3) An emergency plan shall be prepared and filed with the operating permit application indicating the procedures which will be followed in the event of spillage of a regulated substance so as to control and collect all such spilled material in such a manner as to prevent it from reaching any storm or sanitary drains or the ground.

(4) A responsible person designated by the permittee who stores, handles, uses or produces the regulated substances shall check, on every day of operation, for breakage or leakage or any container holding the regulated substances. Electronic sensing devices may be employed as part of the inspection process, if approved by the County Administrator, and provided the sensing system is checked daily for malfunctions. The manner of daily inspection shall not necessarily require physical inspection of each container provided the location of the containers can be inspected to a degree which reasonably assures the County Administrator that breakage or leakage can be de-tected by the inspection. Monitoring records shall be kept, submitted quarterly, and made available to the County Administrator within 24 hours, upon

request. Quarterly, each facility will be inspected, its monitoring procedures reviewed, and quality water samples taken.

(5) Procedures shall be established for the quarterly in-house inspection and maintenance of containment and emergency equipment. Such procedures shall be in writing, a regular checklist and schedule of maintenance shall be established, and a log shall be kept of inspections and maintenance. Such logs and records shall be available for inspection by the County Administrator.

(6) Any spill of a regulated substance shall be reported by telephone to the County health unit and designated public utility within one hour, and the County Administrator within one hour of discovery of the spill. Cleanup shall commence immediately upon discovery of the spill. A full written report including the steps taken to contain and clean up the spill shall be submitted to the County Administrator within 15 days of discovery of the spill.

(7) The County water system will establish a schedule of raw water analysis if inspection of a facility indicates signs of contamination, in which case the County Administrator shall require a sampling schedule. The analysis shall be for all substances which are listed on the operating permit. The analytical reports shall be prepared by a state certified laboratory, certified for the applicable analyses. The analytical reports shall be reviewed by the County water system.

(8) Groundwater monitoring wells shall be provided at the expense of the permittee in a manner, number and location approved by the County Administrator as shown in Appendix G, Exhibit A. Except for existing wells found by the County Administrator to be adequate for this provision, the required well or wells shall be designed by a professional registered engineer or a state certified geologist, and installed by a state-licensed water well contractor under the supervision of a professional registered engineer or a state certified geologist. On completion of well construction, a report will be submitted by the geologist or engineer to the County Administrator detailing final well construction geology and a map of the facility showing well location. Quarterly, water quality samples shall be taken by a state certified laboratory during the quarterly inspection of each facility. Analytical reports prepared by a certified laboratory of the quantity present in each monitoring well of the regulated substances listed in the activity's operating permit shall be filed at least annually, or more frequently as determined by the County Administrator, based upon site conditions and operations.

(9) The County Administrator shall be notified in writing prior to the expansion, alteration or modification of a business or individual holding an operating permit. Such expansion, alteration, or modification may result from increased square footage of production or storage capacity, or increased quantities of regulated substances, or changes in types of regulated substances beyond those square footages, quantities, and types upon which the permit was issued. Excluded from notification prior to alteration or modification are changes in types of regulated substances used in a laboratory or laboratories designed as such in the currently valid permit and which are within the generic substances listed in such permit based upon the generic substance list incorporated in this article as Exhibit A. Should a facility add new regulated substances, it shall notify the County Administrator on a quarterly basis of the types and quantities of such substances added and the location of the use, handling, storage, and production of such substances. Any such expansion, alteration or modification shall be in strict conformity with this article. Further, except as provided in this article, any existing operating permit shall be amended to reflect the introduction of any new regulated substances resulting from the change. However, the introduction of any new regulated substance shall not prevent the revocation or revision of any existing operating permit if, in the opinion of the County Administrator, such introduction substantially or materially modifies, alters or affects the conditions upon which the existing operating permit was granted or the ability to remain qualified as a general exemption, if applicable, or to continue to satisfy any conditions that have been imposed as part of a special exemption, if applicable. The County Administrator shall

notify the permittee in writing within 60 days of receipt of the permittee's notice that the County Administrator proposes to revoke or revise the permit and stating the grounds therefor.

(10) Reconstruction of any portion of a structure or building in which there is any substance or facility subject to the provisions of this article which is damaged by fire, vandalism, flood, explosion, collapse, wind, war or other catastrophe shall be in strict conformity with this article.

(11) All existing nonresidential activities in the zone of protection which use, handle, store, dispose, or produce regulated substances shall file an application for an operating permit within 90 days or a closure permit, general exemption application or special exemption application within 90 days of the receipt of written notice from the County Administrator. Such permit application shall be prepared and signed by a professional registered engineer and a geologist certified in the State, or either at the option of the County Administrator if conditions dictate. Within 30 days of receipt of such notice, the owner or operator shall file with the County Administrator proof of retention of such engineer and geologist or submit to the County Administrator a written notice to obtain either an engineer or geologist, in accordance with FDEP statutes. If application is made for an operating permit, such a permit shall be issued or denied within 60 days of the filing of the completed application. If the application for an operating permit is denied, then the activity shall cease within one year of the denial and an application for a closure permit shall be filed within 120 days of the denial of the operating permit.

(f) *Operating permit applications.* Operating permit applications, as a minimum, shall provide the following information:

(1) A list of all regulated substances and substances on the generic substance list which are to be stored, handled, used, disposed of, or produced in the nonresidential activity being permitted, including their quantities.

(2) A detailed description of the nonresidential activities that involve the storage, handling, use, disposal, or production of the regulated substances indicating the unit quantities in which substances are contained or manipulated.

(3) A description of the containment, the emergency collection devices and containers and copy of the emergency plan that will be employed to comply with the restrictions required for the zone of protection.

(4) A description of the daily monitoring activities that have been or will be instituted to comply with the restrictions for the zone of protection.

(5) A description of the maintenance that will be provided for the containment facility, monitoring system, and emergency equipment required to comply with the restrictions of the zone of protection.

(6) A description of the groundwater monitoring wells, including the latitude and longitude, location map, construction design, geology log and water quality analysis that have been or will be installed and the arrangements made or which will be made for certified quarterly analyses for specified regulated substances in the zone of protection.

(7) Evidence of arrangements made with the appropriate designated public utility for sampling analysis of the raw water from the potable water well.

(8) An agreement to indemnify and hold the County harmless from any and all claims, liabilities, causes of action, or damages arising out of the issuance of the permit. The County shall provide reasonable notice to the permittee of any such claims.

(9) The application for the operating permit shall be filed with the County Administrator within 90 days of receipt of written notification from the County Administrator of the requirement for the facility to obtain an operating permit. In the event of verification of groundwater contamination at a facility within the zone of protection, the Board of County Commissioners will have the option of requiring the bond or letter of credit with a corporate surety in the amount required by Appendix B, incorporated in this article, to ensure that:

a The permittee will operate its nonresidential activities and/or closure of such nonresidential activities, as applicable, in accordance with the conditions and requirements of this article and permits issued under this article.

b. Before a bond or letter of credit is accepted by the County Administrator as being in compliance with this section, the bond or letter of credit shall be reviewed and approved by the County Insurance and Risk Management Department and the County Attorney's Office and shall be filed with the Clerk of the Board of County Commissioners. A corporate bond shall be executed by a corporation authorized to do business in the State as a surety. A cash bond shall be deposited with the Clerk of the Board of County Commissioners, who shall give receipt therefor.

c. Any person subject to regulation under this article shall be liable with respect to regulated substances emanating on or from the person's property for all costs of removal or remedial action incurred by the County and damages for injury to, destruction of, or loss of natural resources, including the reasonable costs of assessing such injury, destruction or loss resulting from the release or threatened release of a regulated substance as defined in this article. Such removal or remedial action by the County may include, but is not limited to, the prevention of further contamination of groundwater, monitoring, containment, and cleanup or disposal of regulated substances resulting from the spilling, leaking, pumping, pouring, emitting or dumping of any regulated substance or material which creates an emergency hazardous situation or is expected to create an emergency hazardous situation.

(g) *Closure permit applications.* Closure permit applications shall provide the following information:

(1) A schedule of events to complete the closure of a facility that does or did store, handle, use, dispose, or produce regulated substances. At a minimum, the following actions shall be addressed:

a. Disposition of all regulated substances and contaminated containers

b. Cleanup of the activity and environs to preclude leaching of unacceptable levels or residual regulated substances into the aquifer.

c. Certification by a professional registered engineer or a geologist certified in the State that disposal and cleanup have been completed in a technically acceptable manner.

d. An appointment for an inspection by the County Administrator.

e. An agreement to indemnify and hold the County harmless from any and all claims, liabilities, causes of action, or damages arising out of the issuance of the permit. The County shall provide reasonable notice to the permittee of any such claims.

(2) The issue of well reconfiguration shall be evaluated by the County Administrator and the affected public utility as an alternative to a closure permit during the permit application process.

(3) The County water system shall be advised in writing of each closure permit application.

(h) *Fee schedule*

(1) The fee for an operating permit under this article shall be as shown in Appendix C, incorporated in this article. A late fee shall be charged if the application for a permit or renewal is late. The operating permit fee shall be used to defray the cost of monitoring compliance with this article.

(2) The fee for a closure permit under this article regulation shall be as shown in Appendix C.

(3) The fee for a transfer of an operating permit or closure permit shall be in accordance with the fee schedule set out in Appendix C to defray the cost of processing the transfer. Application for transfer permit is to be made within 60 days of transfer of ownership of the activity.

(4) The fee schedule may be revised from time to time by resolution of the Board of County Commissioners.

(i) *Revocation or revision of permits, general exemption or special exemption.*

(1) Any permit issued under the provisions of this article shall not become vested in the permittee. The County Administrator will revoke any permit by first issuing a written notice of intent to revoke by certified mail, return receipt requested, or hand delivery, if he finds that the permit holder:

a. Has failed or refused to comply with any of the provisions of this article, including but not limited to permit conditions and bond requirements in this article;

b. Has submitted false or inaccurate information in his application;

c. Has failed to submit operational reports or other information required by this article;

d. Has refused lawful inspection; or

e. Is subject to revocation.

(2) The County Administrator may revise any permit by first issuing a written notice of intent to revise, sent by certified mail, return receipt requested, or hand delivery.

(3) In addition to the provisions of subsections (i)(1) and (i)(2) of this section, within 30 days of any spill of a regulated substance in the zone of protection, the County Administrator shall consider revocation or revision of the permit or revise the bond amount. Upon such consideration the County Administrator may issue a notice of intent to revoke or revise which shall be subject to the provisions of section 166-199, or elect not to issue such notice. In consideration of whether to revoke or revise the permit, the County Administrator may consider the intentional nature or degree of negligence, if any, associated with the spill, and the extent to which containment or cleanup is possible, the nature, number and frequency of previous spills by the permittee, and the potential degree of harm to the groundwater and surrounding wells due to such spill.

(4) For any revocation or revision by the County Administrator of a special exemption or general exemption that requires an operating permit as provided under the terms of this article, the County Administrator shall issue a notice of intent to revoke or revise which shall contain the intent to revoke or revise both the applicable exemption and the accompanying operating permit.

(5) The written notice of intent to revoke or revise shall contain the following information:

a. The name and address of the permittee, if any, and property owner, if different.
b. A description of the facility which is the subject of the proposed revocation or revision.

c. Location of the spill, if any.

d. Concise explanation and specific reasons for the proposed revocation or revision.

e. A statement that "Failure to file a petition within 30 days after the date upon which permittee receives written notice by certified or registered letter to the lessor and landowner of the intent to revoke or revise shall render the proposed revocation or revision final and in full force and effect."

(6) Failure of the permittee to file a petition shall render the proposed revocation or revision final and in full force and effect.

(7) Nothing in this section shall preclude or be deemed a condition precedent to the County Administrator seeking a temporary or permanent injunction.

(Ord. No. 90-2, § 6, 1-30-90; Ord. No. 90-62, § 6, 7-24-90; Ord. No. 92-67, § 6, 10-27-92; Ord. No. 98-24, § 1, 2-10-98)

Sec. 166-197. Powers and duties of county administrator.

(a) The County Administrator or the administrator's designee shall have the power and duty to:

(1) Administer and enforce the provisions of this article.

(2) Investigate complaints, study and observe pollution conditions, and make recommendations as to the institution of action necessary to abate nuisances caused by pollution, and as to prosecution of any violation of this article.

(3) Make appropriate surveys, tests, and inspections of property, facilities, equipment, and processes operating under the provisions of this article to determine whether the provisions of this article are being complied with; interact with the state department of environmental protection, and make recommendations for methods by which pollution may be reduced or eliminated. Inspections shall be conducted in accordance with subsection (b) of this section.

(4) Maintain, review, and supervise all operating records required to be filed with the county administrator by persons operating facilities subject to the provisions of this article.

(5) Render all possible assistance and technical advice to persons owning and/or operating regulated facilities, except that the county administrator and/or his employees shall not design the facility systems for any person.

(6) Perform such other administrative duties as may be assigned by the board of county commissioners.

(7) Issue or deny permits.

(b) Inspections shall be conducted as follows:

(1) Any duly authorized representative of the county administrator may, at any reasonable time, enter and inspect for the purpose of ascertaining the state of compliance with this article, any property, premises, or place, except a building which is used exclusively for a private residence,

on or at which a regulated facility is located or is being constructed or installed or where records which are required under this article are kept.

(2) Any duly authorized representative may, at reasonable times, have access to and copy any records required under this article; inspect any monitoring equipment or method; sample for any hazardous material which the owner or operator of such source may be discharging or which may otherwise be located on or underlying the owner's or operator's property; and obtain any other information necessary to determine compliance with permit conditions or other requirements of this article.

(3) No person shall refuse reasonable entry or access to any authorized representative of the county administrator who requests entry for purposes of inspection and who presents appropriate credentials; nor shall any person obstruct, hamper, or interfere with any such inspection. The owner or operator of the premises shall receive a report, if requested, setting forth all facts found which relate to compliance status.

(4) Install and sample monitor wells in facilities suspected of causing groundwater pollution. All costs associated with these activities will be borne by the facility if they are proved to be the source of pollution, or the facility is in noncompliance with its operating permit.

(Ord. No. 90-2, § 7, 1-30-90)

Sec. 166-198. Protection of future wellfields.

The prohibitions and restrictions set forth in this article and in regulations promulgated pursuant hereto shall apply to any sites officially designated by the board of county commissioners as future wellfields. Such prohibitions and restrictions shall become effective upon approval by the board of county commissioners of the zone of protection maps for the designated future wellfield. Prior to final action by the board of county commissioners in designating a future wellfield or approving the zone of protection map for those wellfields, all property owners and discernable operating activities within the area affected shall receive notice pursuant to the provisions established by F.S. § 125.66(5).

(Ord. No. 90-2, § 8, 1-30-90)

Sec. 166-199. Appeals.

a) Any applicant or permittee affected by a decision of the county administrator in the enforcement or interpretation of any of the terms or provisions of this article may appeal such decision to the board of county commissioners. Such appeal shall be taken by filing written notice thereof with the clerk of the board of county commissioners, within ten days after notice of the decision of the county administrator.

(1) Upon receipt of a timely filed appeal, the clerk to the board of county commissioners shall schedule and properly notice a public hearing to be held before the board of county commissioners as soon as practicable.

(2) At the public hearing, the board of county commissioners may consider the record developed in proceedings before the county administrator, as well as all testimony and evidence presented at the public hearing.

(3) The board of county commissioners shall make its determination based upon this record in light of the standards and factors outlined in this article and such other factors as the board of county commissioners may deem relevant.

(4) An applicant or permittee denied relief may seek judicial review of the board of county commissioners' determination by the timely filing of an action in a court of competent jurisdiction.

(b) Any person may appeal to the board of county commissioners for the following reasons:

(1) To appeal the county administrator's permit conditions, denial of a permit, general exemption or nondisclosure of a trade secret.

(2) To appeal an intent to revoke or revise an operating permit and a general or special exemption.

(3) To request a special exemption. When requesting special exemption, written petitions for relief shall be filed with the clerk of the board of county commissioners and the factual basis for the relief requested. Such petitions shall include all materials and documents which are necessary to support the specific relief requested. Except in the case of an application for special exemption, a written request for relief shall be filed with the clerk of the board of county commissioners within 20 days after the date upon which the petitioner receives a permit, or written notice of an intent to revoke or revise his permit, general exemption, or that trade secret protection has been denied. Failure to file within 20 days shall constitute a waiver of the person's right to an administrative hearing. The filing of a petition authorized by this section shall stay all proceedings with respect to the matters that are contained in the petition until there is a final decision of the board of county commissioners as provided in this section.

(c) Hearing date

(1) All appeals and applications shall be heard within 45 days of the date from which the petition and supporting data are filed with the clerk of the board of county commissioners. An extension of time for the hearing may be granted by the board for good cause shown.

(2) Notice of hearing shall be served upon the applicant or permittee and property owner, if different, by hand delivery or by certified mail, return receipt requested, no less than ten days prior to the hearing. When the owner or responsible individuals are not present or are avoiding service of the notice of hearing, service shall be accomplished by posting copies of the notice of hearing in a conspicuous place on the premises of the facility that is the subject of the appeal.

(d) The notice of hearing provided for in this section shall contain the following information:

(1) Name and address of the petitioner and property owner, if different:

(2) Description of the facility;

(3) Ordinance section (of this article) or regulation section alleged to have been the basis of the denial or proposed revocation or revision;

(4) Time, date and place of the hearing;

(5) A statement that "Failure to attend may result in an order being issued adverse to your interest";

(6) A statement that all parties shall be given the opportunity to present witnesses and evidence in support of their position; and

(7) A statement reflecting the requirements of F.S. ch. 286, regarding a verbatim record of the proceedings.

(e) In computing the period of time within which an appeal must be taken from the permit conditions, denial of a permit, general exemption or application for nondisclosure or from intent to revoke or revise a permit, general exemption or special exemption, the day of receipt of notice of such denial or intent to revoke or revise shall not be included. In computing the period of time in which the board of county commissioners must set a hearing date, the date on which the clerk of the board receives the written petition and accompanying information shall not be included. In computing the period within which notice shall be provided prior to the hearing, the date of the hearing shall not be included. The last day of any period of time provided in this article shall be counted, unless it is a Saturday, Sunday or a legal holiday, in which event the period shall run until the end of the next day which is neither a Saturday, Sunday or a legal holiday. Intermediate Saturdays, Sundays and legal holidays shall be excluded in the computation when any period of time prescribed in this article is less than ten days; where such period is ten days or greater, Saturday, Sunday and legal holidays shall be included.

(f) Hearing procedure. The procedure for hearing of appeals under this article shall be as follows:

(1) All testimony shall be under oath and shall be recorded.

(2) If there is a proper notice of hearing as provided in subsection (c)(2) of this section, the hearing may proceed in the absence of the alleged petitioner and property owner, if different.

(3) Irrelevant, immaterial, or unduly repetitious evidence shall be excluded, but all other evidence of a type commonly relied upon by reasonably prudent persons in the conduct of their affairs shall be admissible, whether or not such evidence shall be admissible in a trial in the courts of the state. Any part of the evidence may be received in written form. Hearsay evidence may be used for the purpose of supplementing or explaining other evidence, but it shall not be sufficient in itself to support a finding unless it would be admissible over objection in civil actions.

(4) Documentary evidence may be received in the form of a copy or excerpt if the original is not readily available.

(5) The rules of privilege shall be effective to the same extent that they are now or hereafter may be recognized in civil actions.

(6) Each party shall have the following rights:

a. To be represented by counsel;

b. To call and examine witnesses;

c. To introduce Exhibits;

d. To cross examine opposing witnesses on any relevant matter, even though the matter was not covered under direct examination;

e. To impeach any witness, regardless of which party called the witness to testify;

f. To rebut the evidence.

(7) Any interested party or person whose substantial interests are affected may make application, and upon good cause shown, may be allowed by the board of county commissioners to intervene in a pending proceeding.

(8) In an appeal of an intent to revoke or revise a special exemption or general exemption that also requires an operating permit under the terms of this article, the appeal of both the intent to revoke or revise the applicable exemption and the accompanying permit shall be consolidated into one hearing.

(g) At all hearings under this article, the board of county commissioners shall hear and consider all facts material to the appeal or application for special exemption and shall thereafter issue a decision based on the competent and substantial evidence presented at the hearing. Such decision may affirm, reverse or modify the action or proposed action of the county administrator.

(h) The decision of the board of county commissioners, as applicable, shall be the final administrative action on behalf of the county administrator and the county. Any person who is a party to the proceeding before the board of county commissioners, if applicable, may appeal to the circuit court of the county in accordance with applicable Florida Appellate Rules.

(Ord. No. 89-69, § IX, 12-19-89; Ord. No. 90-62, § 7, 7-24-90; Ord. No. 92-67, § 7, 10-27-92)

Sec. 166-200. General exemptions.

(a) Facilities and activities qualifying for a general exemption include public utilities, commercial lawn maintenance businesses that use regulated substances, parks, maintenance of office facilities, and retail sales.

(1) A general exemption application and operating permit in compliance with the provisions of section 166-195(d) shall be required for any nonresidential activity claiming a general exemption under this section and shall be filed with the county administrator.

(2) Such application shall contain a concise statement by the applicant detailing the circumstances upon which the applicant believes would entitle him to an exemption.

(3) A fee as listed in Exhibit C shall be filed with the application to defray the costs of processing such application.

(4) Within 30 working days of receipt of an application for general exemption, the county administrator shall inform the applicant whether such application contains sufficient information for a proper determination to be made. If the application is found to be insufficient, then the county administrator shall provide to the applicant a written statement by certified mail or hand delivery requesting the additional information required. The applicant shall inform the county administrator within ten working days of the date of the written statement of his intent to furnish the information. The applicant has 30 days to furnish the required information after so informing the county administrator. The county administrator shall have 90 working days from either the rendering of a sufficiency determination or receipt of additional information making an application sufficient to make a decision.

(b) Existing fire, police, emergency medical services and county emergency management center facilities are required to obtain an operating permit and general exemption.

(c) Utilities as defined in this article shall be exempt from the zone of protection prohibitions as set forth in section 166-195(c). However, an operating permit and special exemption shall be obtained pursuant to section 166-195(d) for the refueling facilities within the zone of protection.

(d) The transportation of any regulated substance through the zone of protection shall be exempt from the provisions of this article, provided the transporting motor vehicle is in continuous transit. The transport of such substances through existing permanent pipelines is also exempt, provided that the currently authorized use or uses are not changed and provided that leak detection and monitoring as approved by the county administrator are employed. No general exemption or operating permit application is required except that an operating permit is required to establish the leak detection and monitoring requirements for such existing pipelines.

(e) The use in a residential vehicle, commercial lawn service vehicle or residential lawn maintenance equipment of any regulated substance solely as fuel in that vehicle or equipment fuel tank or as lubricant in that vehicle or equipment shall be exempt from the provisions of this article. No general exemption or operating permit application is required.

(f) The commercial or residential application on residential lawn or commercial landscaping of those regulated substances used as pesticides, herbicides, fungicides, and rodenticides in recreation, agriculture, pest control and aquatic weed control activities shall be exempt from the provisions of this article, provided that:

(1) In the zone of protection, the application is in strict conformity with the use requirement as set forth in the substances' EPA registries and as indicated on the containers in which the substances are sold.

(2) In the zone of protection, the application is in strict conformity with the requirements as set forth in F.S. chs. 482 and 487, and chapters 5E-2 and 5E-9, Florida Administrative Code.

(3) In the zone of protection, the application of any of the pesticides, herbicides, fungicides, and rodenticides shall be flagged in the records of the certified operator supervising the use. The certified operator shall provide specific notification in writing to the applicators under his supervision that they are working at a site located in the zone of protection for which particular care is required. Records shall be kept of the date and amount of these substances applied at each location and such records shall be available for inspection at reasonable times by the county administrator.

(4) In the zone of protection, the pesticides, herbicides, fungicides, and rodenticides for lawn, golf courses or agricultural application shall not be handled during application in a quantity exceeding 700 gallons of formulation.

(5) All nonresidential applicators of pesticides, herbicides, fungicides, and rodenticides who apply those substances within the zones of protection shall obtain an operating permit covering all application operations under one permit using these materials and shall comply with all the requirements of section 166-195.

This exemption applies only to the application of pesticides, herbicides, fungicides, and rodenticides.

(g) Retail sales establishments in the zone of protection that store and handle regulated substances for resale in their original unopened containers shall be exempt from the prohibition in the zone of protection provided that those establishments obtain an operating permit pursuant to the provisions of section 166-195.

(h) Office uses, including the use of regulated substances for the maintenance and cleaning of office buildings in volumes less that ten gallons, shall be exempt from the provisions of this article. No general exemption or operating permit applications are required.

(i) The activities of constructing, repairing or maintaining any facility or improvement on lands within the zone of protection shall be exempt from the provisions of this article, provided that all contractors, subcontractors, laborers, material men and their employees when using, handling, storing or producing regulated substances in the zone of protection use those applicable best management practices set forth in Appendix D, incorporated in this article. No general exemption or operating permit applications are required.

(j) Residential development greater than 25 units shall be required to file a general exemption application and an operating permit application with the county administrator; however, the annual renewal application is not required.

(Ord. No. 89-69, § X, 12-19-89; Ord. No. 90-62, § 8, 7-24-90; Ord. No. 92-67, §§ 8, 9, 10-27-92)

Sec. 166-201. Special exemptions.

(a) An affected person in the zone of protection may petition the board of county commissioners for a special exemption from the prohibitions and monitoring requirements set out in section 166-195. In order to obtain such an exemption such person must demonstrate by a preponderance of competent, substantial evidence that:

(1) Special or unusual circumstances and adequate technology exist to isolate the facility or activity from the potable water supply.

(2) In granting the special exemption, the board of county commissioners may prescribe any additional appropriate conditions and safeguards which are necessary to protect the wellfield.

(b) Activities claiming special exemption with adequate technology to isolate the facility or activity from the potable water supply and protect the wellfield must submit:

(1) A special exemption application claiming special or unusual circumstances and adequate protection technology shall be filed with the county administrator. It shall be signed by the applicant and by a professional engineer and certified geologist registered in the state.

(2) Such application shall contain a concise statement by the applicant detailing the circumstances which the applicant feels would entitle him to an exemption pursuant to subsection (b)(1) of this section.

(3) A nonrefundable fee as listed in Exhibit C shall be filed with the application to defray the costs of processing such application.

(4) The application for special exemption shall contain but not be limited to the following elements:

a. A description of the situation at the site requiring isolation from the wellfield, including:

1. A list of the regulated substances in use at the site;

2. A site plan of the facility including all storage, piping, dispensing, shipping, etc., facilities;

3. What operations at the facility involve regulated substances which must be isolated from the wellfields;

4. The location of all operations involving regulated substances;

5. A sampling and analysis of the groundwater on the site of the activity seeking a special exemption shall be performed to the satisfaction of the county to determine if any regulated substances are already present which constitute a threat to the water supply;

6. An analysis of the affected well showing whether or not such well is already contaminated by any regulated substances and the extent of such contamination;

7. A hydrogeologic assessment of the site which shall address, at a minimum, soil characteristics and groundwater levels, directional flow, and water quality and which shall be performed by a registered geologist, certified by the state.

b. A technical proposal to achieve the required isolation, including;

1. Components to be used and their individual functions;

2. Systems tying the components together

3. A discussion and documentation, such as published technical articles, substantiating the performance and reliability of the components individually and the system as a whole; if the system has not been field tested, a discussion and laboratory test documentation to substantiate the proposed performance and reliability of the system;

4. Details of the specific plans to install the system at the site

c. Testing procedures: If the proposed system does not have a proven history of successful in-field operation, it may still be proposed using proven components. A test plan for the system as installed shall be provided to prove that the proposed system works in the field.

d. A technical proposal for backup detection of regulated substances that may elude the isolation system and escape to outside a perimeter to be established by the county administrator. Such proposal shall include emergency measures to be initiated in case of escape of regulated substances.

e. Criteria for success: Site-specific, system performance criteria shall be proposed to ascertain the success of the system. Such criteria shall include but shall not be limited to:

1. Performance;

2. Reliability;

3. Level of maintenance;

4. Level of sensitivity to regulated substances;

5. Effect of rain, flood, power failure or other natural disaster.

f. Precautions in event of failure: The applicant shall provide information on the on-site availability of substance removal technologies sufficient to remediate any introduction of regulated substances into the water table at the site. Where water is removed from on-site wells during the remedial process, a plan shall be proposed for the disposal of such water.

g. A closure plan shall be provided in the event the system does not prove successful in the testing required by subsection (b)(4)c of this section.

h. Any other reasonable information deemed necessary by the county water system due to site-specific circumstances.

(5) Within 30 working days of receipt of an application for special exemption, the county administrator shall inform the applicant whether such application contains sufficient information for a proper determination to be made. If the application is found to be insufficient, then the county administrator shall provide to the applicant a written statement by certified mail or hand delivery requesting the additional information required. The applicant shall inform the county administrator within ten working days of the date of the written statement of his intent to furnish the information. The applicant has 30 days to furnish the required information or have the application processed as it stands. At the end of such 30-day period, the county administrator

shall have 14 days to inform the board of county commissioners of such application and shall transfer all information accompanying the application to the board of county commissioners, who shall then proceed with the hearing procedures as provided under section 166-199.

(c) Granting special exemptions:

(1) Any special exemption to this article granted by the board of county commissioners shall be subject to the applicable conditions of sections 166-195 and 166-196 and any other reasonable and necessary special conditions imposed by the board of county commissioners. An operating permit shall be issued by the department with the applicable conditions of sections 166-195 and 166-196 and any other reasonable and necessary special conditions imposed by the board of county commissioners. Such special exemptions shall be subject to revocation or revision by the department for violation of any condition of such special exemption by first issuing a written notice of intent to revoke or revise by certified mail, return receipt requested, or hand delivery. Upon revocation or revision, the activity will immediately be subject to the enforcement provisions of this article.

(2) Special exemptions for the zone of protection are for existing nonresidential facilities only. No new nonresidential activity shall be permitted into the zone of protection after February 17, 1990, if the new nonresidential facility stores, handles, produces, disposes of, or uses any regulated substance.

(Ord. No. 89-69, § XI, 12-19-89; Ord. No. 90-62, § 9, 7-24-90; Ord. No. 92-67, § 7, 10-27-92)

Sec. 166-202. Trade secrets.

The department shall not disclose any trade secrets of the permittee under this article that are exempted from such disclosure by federal or state law; provided, however, that the burden shall be on the permittee to demonstrate entitlement to such nondisclosure. Decisions by the county administrator as to such entitlement shall be subject to challenge by the permittee by filing a petition with the county administrator pursuant to section 166-199.

(Ord. No. 89-69, § XII, 12-19-89; Ord. No. 90-62, § 10, 7-24-90)
Secs. 166-203--166-240. Reserved.

APPENDIX A

GENERIC SUBSTANCES LIST

The Generic Substance List is provided for informational and regulatory purpose and may be amended from time to time by the Board of County Commissioners. Some of the regulated substances are listed below. For additional regulated substances, see Appendix E of the Wellhead Protection Ordinance.

Acids and basic cleaning solutions
Antifreeze and coolants
Arsenic and arsenic compounds
Bleaches and peroxides
Brake and transmission fluids
Brine Solutions
Casting and foundry chemicals
Caulking agents and sealants
Cleaning solvents
Corrosion and rust prevention solutions
Cutting fluids
Degreasing solvents
Disinfectants
Electroplating solutions
Explosives
Fertilizers
Fire extinguishing chemicals
Food processing wastes
Formaldehyde
Fuels and additives
Glues, adhesives and resins
Greases
Hydraulic fluids
Indicators
Industrial and commercial janitorial supplies
Industrial sludges and stillbottoms
Inks, printing and photocopying chemicals
Laboratory chemicals
Liquid storage batteries
Medical, pharmaceutical, dental, veterinary and hospital solutions
Mercury and mercury compounds
Metal finishing solutions
Oils
Paints, primers, thinners, dyes, stains, wood preservatives and varnishing and cleaning compounds
Painting solvents
PCBs
Pesticides and herbicides
Plastic resins, plasticizers and catalysts
Photo development chemicals
Poisons
Polishes
Pool chemicals
Processed dust and particulates
Radioactive sources
Reagents and standards
Refrigerants
Roofing chemicals and sealers
Sanitizers, disinfectants, bactericides and algaecides, soaps, detergents and surfactants
Solders and fluxes
Stripping compounds
Tanning industry chemicals
Transformer and capacitor oils/fluids
Water and wastewater treatment chemicals

APPENDIX B

OPERATING AND CLOSURE PERMITS*

Zone of Protection

Cash Bond	$20,000
Rate Bond	$20,000
Letters of Credit	$20,000

*Amounts reflected on this table are for each Operating and Closure Permit issued and may be adjusted by the Pinellas County Risk Management Department upon further risk/loss analysis.

APPENDIX C

FEE SCHEDULE

1. FILING FEE - All applicants for a Wellhead Protection Operating Permit shall pay a nonrefundable filing fee of twenty-five dollars ($25.00). The filing fee shall be applied against other fees prescribed for the issuance of a permit. The filing fee shall be paid prior to acceptance of the permit application for review.

2. WELLHEAD PROTECTION OPERATING PERMIT FEE - The fee for a Wellhead Protection Operating Permit under this regulation shall be twenty-five dollars ($25.00). The Wellhead Protection Operating Permit shall be used to defray the cost of administering this Ordinance.

3. CLOSURE PERMIT FEE - The fee for a Closure Permit under this regulation shall be one hundred dollars ($100.00).

4. PERMIT TRANSFER FEE - The fee for transfer of Wellhead Protection Operating Permit shall be twenty-five dollars ($25.00) to defray the cost of processing the transfer.

5. SPECIAL EXEMPTION FEE - Any person seeking a special exemption shall pay a fee of two hundred dollars ($200) to defray the cost of processing the exemption request.

6. ANNUAL RENEWAL LICENSE FEE - Beginning March 1, 1991, an annual renewal license fee shall be collected to defray cost of administering of this Ordinance. The fee shall be twenty-five dollars ($25.00) per year.

7. GENERAL EXEMPTION FEE - Any person seeking a general exemption shall pay a fee of one hundred dollars ($100.00) to defray the cost of processing the exemption request.

8. SAMPLING FEE - The required groundwater quality sampling of permitted facilities within the Zone of Protection will be assessed a fee of $50.00 /sample by the Pinellas County Utilities Department to withdraw and transport each groundwater sample. The cost of the sampling will be assessed to the permittee.

9. WATER QUALITY ANALYSIS FEE - The cost for cash analysis to be borne by the permittee, will be seven hundred dollars ($700) /sample.

APPENDIX D

“BEST MANAGEMENT PRACTICES” FOR THE CONSTRUCTION INDUSTRY

A. The general contractor, or if none, the property owner, shall be responsible for assuring that each contractor or subcontractor evaluates each site before construction is initiated to determine if any site conditions may pose particular problems for the handling of any regulated substances. For instance, handling regulated substances in the proximity of water bodies or wetlands may be improper.

B. If any regulated substances are stored on the construction site during the construction process, they shall be stored in a location and manner which will minimize any possible risk of release to the environment. Any storage container of 30 gallons, or 250 pounds, or more containing regulated substances shall have constructed below them an impervious containment system constructed of material of sufficient thickness, density and composition that will prevent the discharge to the land, groundwaters, or surface waters of any pollutant which may emanate from said storage tank or tanks. Each containment system shall be able to contain 150% of the contents of all storage containers above the containment system.

C. Each contractor shall familiarize himself with the manufacturer’s safety data sheet supplied with each material containing a regulated substance and shall be familiar with procedures required to contain and clean up any releases of the regulated substance. Any tools or equipment necessary to accomplish same shall be available in case of a release.

D. Upon completion of construction, all unused and regulated waste substances and containment systems shall be removed from the construction site by the responsible contractor and shall be disposed of in a proper manner as prescribed by law.

APPENDIX E

PRIORITY POLLUTANTS REFERRED TO IN

THIS ORDINANCE REFERENCING 17-22 F.A.C.

FLORIDA DEPARTMENT OF ENVIRONMENTAL REGULATION
GROUND WATER GUIDANCE CONCENTRATIONS*
FEBRUARY 1989

CAS #	Parameter	Guidance* Concentration (ug/L)	Practical Quantitation Level (ug/L)	Basis/Comment
83-32-9	Acenaphthene	20	10	Organoleptic (AWQCD)
208-96-8	Acenaphthylene	10	10	PQL
67-64-1	Acetone	700	5-10 A	IRIS
5094-66-6	Acifluorfen (Blazer)	10	5-10 A	PQL / 1ug/L = 10^{-6} cancer risk (H.A.)
107-02-8	Acrolein (Propenal)	110	5	EPA PPCL
79-06-1	Acrylamide (2-Propeneamide)	1	1	PQL / 0.01ug/L=10^{-6} cancer risk (CAG)
107-13-1	Acrylonitrile	2.5	2.5	PQL / 0.063ug/L=10^{-6} cancer risk (AWQCD)
15972-60-8	Alachlor	1.5	1	Lifetime Health Adv.
116-06-3	Aldicarb (Temik)	10	5	Lifetime Health Adv.
	Aldicarb sulfoxide	10	5	Lifetime Health Adv.
1646-88-4	Aldicarb sulfone	40 **	5	Lifetime Health Adv.
309-00-2	Aldrin	0.05	0.05	PQL / RPC= 0.013 ug/L
	Alpha, gross ****	15 pCi/L		Primary D.W. Standard
834-12-8	Ametryn	60	5-10 A	Lifetime Health Adv.
7773-06-0	Ammonium sulfamate	2,000	5-10 X	Lifetime Health Adv.
120-12-7	Anthracene	10	10	PQL
7440-36-0	Antimony	29	20	EPA PPCL (ADI)
	Arsenic ****	50	5	Primary D.W. Standard
1332-21-4	Asbestos ***	7 million fibers/L	0.1 million fibers/L	Proposed EPA MCL
1912-24-9	Atrazine	3	0.25	Lifetime Health Adv.
	Barium ****	1,000	500	Primary D.W. Standard
114-26-1	Baygon (Propoxur)	10	5-10 A	PQL / 3ug/L=Lifetime Health Advisory
25057-89-0	Bentazon	20	5-10 A	Lifetime Health Adv.
71-43-2	Benzene ****	1	1	Primary D.W. Standard
	Benzenehexachloride (See Hexachloro-cyclohexane)			
92-87-5	Benzidine	10	10	PQL / 0.00015ug/L=10^{-6} cancer risk (AWQCD)
56-55-3	Benzo(a)anthracene	10	10	PQL
205-99-2	Benzo(b)fluoranthene	10	10	PQL
207-08-9	Benzo(k)fluoranthene	10	10	PQL

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CAS #	Parameter	Guidance* Concentration (ug/L)	Practical Quantitation Level (ug/L)	Basis/Comment
191-24-2	Benzo(g,h,i)perylene	10	10	PQL
50-32-8	Benzo(a)pyrene	10	10	PQL / 0.003ug/L=10^{-6} cancer risk (AWQCD)
7440-41-7	Beryllium	5	5	PQL / 0.004ug/L=10^{-6} cancer risk (AWQCD)
	BHC (See Hexachloro-cyclohexane)			
92-52-4	Biphenyl	10	5-10 A	PQL / 0.5ug/L = organoleptic (RPC)
314-40-9	Bromacil	90	10	Lifetime Health Adv.
75-27-4	Bromodichloromethane (See Trihalomethane)			
75-25-2	Bromoform (See Trihalomethane)			
74-83-9	Bromomethane (Methyl bromide)	20	10	RPC
101-55-3	4-Bromophenyl phenyl ether	10	10	PQL
78-93-3	2-Butanone (See Methyl ethyl ketone)			
123-86-4	n-Butyl acetate	43	5-10 X	Organoleptic (RPC)
2008-41-5	Butylate	700	5-10 A	Lifetime Health Adv.
85-68-7	Butyl benzyl phthalate	1,400	10	IRIS
85-70-1	Butyl phthalyl butyl glycolate	120,000	5-10 A	Water solubility limit (AWQCD ADI=350,000ug/L)
	Cadmium ****	10	10	Primary D.W. Standard
63-25-2	Carbaryl (Sevin)	700	5	Lifetime Health Adv.
1563-66-2	Carbofuran	36	5	Lifetime Health Adv.
108-95-2	Carbolic acid (See Phenol)			
56-23-5	Carbon tetrachloride **** (Tetrachloromethane)	3	1	Primary D.W. Standard
5234-68-4	Carboxin	700	5-10 A	Lifetime Health Adv.
133-90-4	Chloramben	100	5-10 A	Lifetime Health Adv.
57-74-9	Chlordane	0.1	0.1	PQL / 0.027 ug/L=10^{-6} cancer risk (H.A.)
	Chloride ****	250,000	1000	Secondary D.W. Std.
108-90-7	Chlorobenzene	10	1	Organoleptic (H.A.)
124-48-1	Chlorodibromomethane (See Trihalomethane)			

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CAS #	Parameter	Guidance* Concentration (ug/L)	Practical Quantitation Level (ug/L)	Basis/Comment
106-89-8	1-Chloro-2,3-epoxypropane (See Epichlorohydrin)			
75-00-3	Chloroethane (Ethyl chloride)	6,300	2.5	RPC
111-91-1	bis(2-Chloroethoxy) methane	10	10	PQL
75-01-4	Chloroethylene **** (Vinyl chloride)	1	1	Primary D.W. Standard
111-44-4	bis(2-Chloroethyl)ether (Dichloroethyl ether)	10	10	PQL / 0.031ug/L=10^{-6} cancer risk (AWQCD)
110-75-8	2-Chloroethyl vinyl ether (Vinyl 2-chloroethyl ether)	1	1	PQL
67-66-3	Chloroform (See Trihalomethane)			
108-60-1	bis(2-Chloroisopropyl) ether	10	10	PQL / 7ug/L=EPA PPCL ADI
74-87-3	Chloromethane (Methyl chloride)	3,800	1	EPA PPCL (ADI)
542-88-1	bis(Chloromethyl) ether	10	5-10 A	PQL/ 3.8x10^{-6}ug/L= 10^{-6} cancer risk (AWQCD)
59-50-7	4-Chloro-3-methyl phenol (p-chloro-m-cresol)	3,000	10	Organoleptic (AWQCD)
94-74-6	4-Chloro-2-methyl-phenoxy acetic acid (See MCPA)			
91-58-7	2-Chloronaphthalene	10	10	PQL
108-43-0	3-Chlorophenol	10	10	PQL / 0.1ug/L = organoleptic (AWQCD)
106-48-9	4-Chlorophenol	10	10	PQL / 0.1ug/L = organoleptic (AWQCD)
7005-72-3	4-Chlorophenyl phenyl ether	10	10	PQL
76-06-2	Chloropicrin	7.3	5	Organoleptic (RPC)
1897-45-6	Chlorothalonil (Bravo)	2	1	10^{-6} cancer risk, Health Advisory
	Chromium ****	50	50	Primary D.W. Standard
218-01-9	Chrysene	10	10	PQL
	Color ****	15 (color units)		Secondary D.W. Std.
	Copper ****	1000	100	Secondary D.W. Std.
21725-46-2	Cyanazine	30	30	PQL / 10 ug/L= Lifetime Health Advisory

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CAS #	Parameter	Guidance* Concentration (ug/L)	Practical Quantitation Level (ug/L)	Basis/Comment
57-12-5	Cyanide	154	40	Lifetime Health Adv.
94-75-7	2,4-D ****	100	5	Primary D.W. Standard
861-32-1	Dacthal (DCPA)	4,000	1	Lifetime Health Adv.
75-99-0	Dalapon (2,2-Dichloro-propionic acid)	200	5-10 A	Lifetime Health Adv.
50-29-3	DDT	0.1	0.1	PQL / 0.004 ug/L=10^{-6} cancer risk (AWQCD)
303-16-4	Diallate	10	10	PQL / 0.045 ug/L=10^{-6} cancer risk (AWQCD)
333-41-5	Diazinon	10	5-10 A	PQL / 0.6 ug/L= Lifetime Health Adv.
53-70-3	Dibenzo(a,h) anthracene	10	10	PQL
124-48-1	Dibromochloromethane (See Trihalomethane)			
96-12-8	1,2-Dibromo-3-chloropropane(DBCP)	0.025	0.025	Lifetime Health Adv.
106-93-4	1,2-Dibromoethane **** (Ethylene Dibromide, EDB)	0.02	0.02	Primary D.W. Standard
84-74-2	Di-n-butyl phthalate	700	10	IRIS
918-00-9	Dicamba	200	1	Lifetime Health Adv.
95-50-1	o-Dichlorobenzene (1,2-Dichlorobenzene)	10	2	Organoleptic (H.A.)
541-73-1	m-Dichlorobenzene (1,3-Dichlorobenzene)	10	2	Organoleptic (H.A.)
106-46-7	p-Dichlorobenzene **** (1,4-Dichlorobenzene)	75	2	Primary D.W. Standard
91-94-1	3,3-Dichlorobenzidine	20	20	PQL / 0.021ug/L=10^{-6} cancer risk (AWQCD)
75-27-4	Dichlorobromomethane (See Trihalomethane)			
75-71-8	Dichlorodifluoro-methane(Freon 12)	1,400	5	IRIS
75-34-3	1,1-Dichloroethane	2,400	1	RPC
107-06-2	1,2-Dichloroethane **** (Ethylene dichloride)	3	1	Primary D.W. Standard
75-35-4	1,1-Dichloroethylene **** (Vinylidene chloride)	7	1	Primary D.W. Standard
156-59-2	cis-1,2-Dichloro-ethylene	4.2	1	Organoleptic (RPC)
156-60-5	trans-1,2-Dichloro-ethylene	4.2	1	Organoleptic (RPC)

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CAS #	Parameter	Guidance* Concentration (ug/L)	Practical Quantitation Level (ug/L)	Basis/Comment
111-44-4	Dichloroethyl ether (See bis(2-Chloroethyl) ether)			
108-60-1	Dichloroisopropyl ether (See bis (2-Chloroisopropyl) ether)			
75-09-2	Dichloromethane (See Methylene chloride)			
542-88-1	Dichloromethyl ether (See bis(Chloromethyl ether)			
576-24-9	2,3-Dichlorophenol	10	10	PQL / 0.04ug/L = organoleptic (AWQCD)
120-83-2	2,4-Dichlorophenol	10	10	PQL / 0.3ug/L = organoleptic (AWQCD)
583-78-8	2,5-Dichlorophenol	10	10	PQL / 0.5ug/L = organoleptic (AWQCD)
87-65-0	2,6-Dichlorophenol	10	10	PQL / 0.2ug/L = organoleptic (AWQCD)
95-77-2	3,4-Dichlorophenol	10	10	PQL / 0.3ug/L = organoleptic (AWQCD)
78-87-5	1,2-Dichloropropane	1	1	PQL / 0.56 ug/L=10^{-6} cancer risk (H.A.)
542-75-6	1,3-Dichloropropene (DCP, Telone)	1	1	PQL / 0.2 ug/L=10^{-6} cancer risk (H.A.)
60-57-1	Dieldrin	0.05	0.05	PQL / 0.002ug/L=10^{-6} cancer risk (H.A.)
117-81-7	Di(2-ethylhexyl) phthalate	14	10	RPC
84-66-2	Diethyl phthalate	5,600	10	IRIS
239-16-1	Dimethrin	2,000	5-10 A	Lifetime Health Adv.
105-67-9	2,4-Dimethyl phenol (2,4-Xylenol)	400	10	Organoleptic (AWQCD)
131-11-3	Dimethyl phthalate	70,000	10	EPA PPCL (ADI)
534-52-1	4,6-Dinitro-o-cresol (2-Methyl-4,6-dinitrophenol)	50	50	PQL
51-28-5	2,4-Dinitrophenol	70	50	EPA PPCL (ADI)
121-14-2	2,4-Dinitrotoluene	10	10	PQL / 0.11ug/L=10^{-6} cancer risk (AWQCD)
608-20-2	2,6-Dinitrotoluene	10	10	PQL

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CAS #	Parameter	Guidance* Concentration (ug/L)	Practical Quantitation Level (ug/L)	Basis/Comment
88-85-7	Dinoseb	7	0.5	Lifetime Health Adv.
117-84-0	Di-n-octyl phthalate	10	10	PQL
123-91-1	p-Dioxane (1,4-Dioxane)	10	5-10 A	PQL / 7ug/L= 10^{-6} cancer risk (CAG)
1746-01-6	Dioxin (See 2,3,7,8-Tetra chlorodibenzo-p-dioxin)			
957-51-7	Diphenamid	200	5-10 A	Lifetime Health Adv.
122-66-7	1,2-Diphenyl hydrazine	10	10	PQL / 0.045ug/L=10^{-6} cancer risk (AWQCD)
298-04-4	Disulfoton	10	5-10 A	PQL / 0.3 ug/L= Lifetime Health Adv.
330-54-1	Diuron	10	5-10 A	Lifetime Health Adv.
15-29-7	Endosulfan (alpha + beta)	0.4	0.05	IRIS
1031-07-8	Endosulfan sulfate	0.3	0.3	PQL
145-73-3	Endothall	100	5-10 X	Lifetime Health Adv.
72-20-8	Endrin ****	0.2	0.03	Primary D.W. Standard
7421-93-4	Endrin aldehyde	0.1	0.1	PQL
106-89-8	Epichlorohydrin (unstable in H_2O)	10	5-10 A	PQL / 3.5ug/L=10^{-6} cancer risk (H.A.)
75-21-8	1,2-Epoxyethane (See Ethylene oxide)			
563-12-2	Ethion	14	0.5	RPC
141-78-6	Ethyl acetate	100	5-10 X	Organoleptic (RPC)
100-41-4	Ethylbenzene	2	2	PQL / 1.6 ug/L = organoleptic (RPC)
75-00-3	Ethylchloride (See Chloroethane)			
166-93-4	Ethylene dibromide **** (EDB, 1,2-Dibromo-ethane)	0.02	0.02	Primary D.W. Standard
107-06-2	Ethylene dichloride **** (1,2-Dichloroethane)	3	1	Primary D.W. Standard
107-21-1	Ethylene glycol	7,000	5-10 X	Lifetime Health Adv.
75-21-8	Ethylene oxide (unstable in H_2O)	10	5-10 A	PQL / 0.028ug/L=10^{-6} cancer risk (EPA PPCL)
96-45-7	Ethylene thiourea (2-imidazoli-dinethione)	0.5	0.5 X	PQL / 0.2 ug/L=10^{-6} cancer risk (H.A.)
84-72-0	Ethyl phthalate ethyl glycolate	17,500	5-10 A	EPA PPCL (ADI)
22224-92-6	Fenamiphos	10	5-10 X	PQL / 2 ug/L= Lifetime Health Adv.

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CAS #	Parameter	Guidance* Concentration (ug/L)	Practical Quantitation Level (ug/L)	Basis/Comment
2164-17-2	Fluometuron	90	50	Lifetime Health Adv.
206-44-0	Fluoranthene (Idryl)	42	10	EPA PPCL (ADI)
86-73-7	Fluorene	10	10	PQL
	Fluoride ****	4,000	10	Primary D.W. Standard
	Fluoride ****	2,000	10	Secondary D.W. Std.
75-69-4	Fluorotrichloromethane (See Trichloromono fluoromethane)			
	Foaming agents ****	500	100	Secondary D.W. Std.
944-22-9	Fonofos	10	5-10 A	Lifetime Health Adv.
50-00-0	Formaldehyde	50	50	PQL / 4.1 ug/L = RPC
1071-83-6	Glyphosate (Roundup)	700	25	Lifetime Health Adv.
76-44-8	Heptachlor	0.076	0.05	10^{-6} cancer risk, H.A.
1024-57-3	Heptachlor epoxide	0.1	0.1	PQL / 0.038 ug/L=10^{-6} cancer risk (H.A.)
118-74-1	Hexachlorobenzene (HCB)	10	10	PQL / 0.02ug/L=10^{-6} cancer risk (CAG)
87-68-3	Hexachlorobutadiene	10	10	PQL / 0.45ug/L=10^{-6} cancer risk (AWQCD)
319-84-6	alpha-Hexachloro-cyclohexane (BHC)	0.05	0.05	PQL / 0.0035ug/L = 10^{-6} cancer risk (CAG)
319-85-7	beta-Hexachloro-cyclohexane (BHC)	0.05	0.05	PQL / 0.01ug/L = 10^{-6} cancer risk (CAG)
58-89-9	gamma-Hexachloro-cyclohexane **** (Lindane)	4	0.05	Primary D.W. Standard
319-86-8	delta-Hexachloro-cyclohexane (BHC)	0.05	0.05	PQL
77-47-4	Hexachlorocyclo-pentadiene	10	10	PQL / 1 ug/L= organoleptic (AWQCD)
67-72-1	Hexachloroethane	10	10	PQL / 3.4ug/L=10^{-6} cancer risk (AWQCD)
110-54-3	n-Hexane	10	5-10 A	PQL / 6.4ug/L = organoleptic (RPC)
51235-04-2	Hexazinone (Velpar)	200	5	Lifetime Health Adv.
206-44-0	Idryl (See Fluoranthene)			
96-45-7	2-Imidazoli-dinethione (See Ethylene thiourea)			
193-39-5	Indeno(1,2,3-cd) pyrene	10	10	PQL
	Iron ****	300	150	Secondary D.W. Std.

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CAS #	Parameter	Guidance* Concentration (ug/L)	Practical Quantitation Level (ug/L)	Basis/Comment
78-59-1	Isoacetophorone (See Isophorone)			
78-59-1	Isophorone	1,050 #	10	AWQCD (ADI)
98-82-8	Isopropyl benzene (Cumene)	10	5-10 A	PQL / 0.8ug/L = organoleptic (RPC)
	Lead ****	50	50	Primary D.W. Standard
58-89-9	Lindane ****	4	0.05	Primary D.W. Standard
330-55-2	Linuron	22	0.05	RPC
123-33-1	Maleic hydrazide	4,000	5-10X	Lifetime Health Adv.
2327-38-2	Maneb	75	75	PQL / 14 ug/L = RPC
	Manganese ****	50	25	Secondary D.W. Std.
94-74-6	MCPA (4-Chloro-2-methylphenoxy acetic acid)	1,000	1,000 A	PQL / 4 ug/L= Lifetime Health Adv.
	Mercury ****	2	0.2	Primary D.W. Standard
1265-92-6	Methamidophos	18	5-10 X	RPC
7752-77-5	Methomyl	200	50	Lifetime Health Adv.
72-43-5	Methoxychlor ****	100	0.5	Primary D.W. Standard
74-83-9	Methyl bromide (See Bromomethane)			
74-87-3	Methyl chloride (See Chloromethane)			
534-52-1	2-Methyl-4,6-dinitrophenol (See 4,6-Dinitro-o-cresol)			
75-09-2	Methylene chloride (Dichloromethane)	5	1	10^{-6} cancer risk (Health Advisory)
78-93-3	Methyl ethyl ketone (MEK, 2-Butanone)	170 #	10	Lifetime Health Adv.
60-34-4	Methyl hydrazine	10	5-10 A	PQL / 0.03ug/L=10^{-6} cancer risk (EPA PPCL)
108-10-1	Methyl isobutyl ketone (4-Methyl-2-pentanone)	350 #	5	IRIS
298-00-0	Methyl parathion	10	5-10 A	PQL / 2ug/L= Lifetime Health Adv.
218-45-2	Metolachlor	100	5-10 A	Lifetime Health Adv.
087-64-9	Metribuzin	200	2	Lifetime Health Adv.
385-85-5	Mirex	3.5	0.1	RPC
91-20-3	Napthalene	10	10	PQL 6.8ug/L = organoleptic (RPC)
440-02-0	Nickel	150	50	Lifetime Health Adv.
	Nitrate (as N) ****	10,000	5	Primary D.W. Standard
	Nitrite (as N)	1,000	100	Health Advisory

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CAS #	Parameter	Guidance* Concentration (ug/L)	Practical Quantitation Level (ug/L)	Basis/Comment
98-95-3	Nitrobenzene	30	10	Organoleptic (AWQCD)
88-75-5	2-Nitrophenol (o-Nitrophenol)	20	20	PQL
100-02-7	4-Nitrophenol (p-Nitrophenol)	10	10	PQL
924-16-3	N-Nitrosodi-n-butylamine	10	5-10 A	PQL / 0.0064ug/L=10^{-6} cancer risk (AWQCD)
55-18-5	N-Nitrosodi-ethylamine	10	5-10 A	PQL / 0.0008ug/L=10^{-6} cancer risk (AWQCD)
62-75-9	N-Nitrosodi-methylamine	20	20	PQL / 0.0014ug/L=10^{-6} cancer risk (AWQCD)
86-30-6	N-Nitrosodi-phenylamine	10	10	PQL / 0.0001ug/L=10^{-6} cancer risk (EPA PPCL)
759-73-9	N-Nitroso-N-ethylurea	10	5-10 X	PQL / 0.001ug/L=10^{-6} cancer risk (EPA PPCL)
684-93-5	N-Nitroso-N-methylurea	10	5-10 X	PQL / 0.0001ug/L=10^{-6} cancer risk (EPA PPCL)
621-64-7	N-Nitrosodi-n-propylamine	10	10	PQL
930-55-2	Nitrosopyrrolidine	10	10	PQL / 0.016ug/L=10^{-6} cancer risk (AWQCD)
	Odor ****	3 T.O.N.		Secondary D.W. Std.
23135-22-0	Oxamyl (Vydate)	175	10	Lifetime Health Adv.
75-21-8	Oxirane (See Ethylene oxide)			
1910-42-5	Paraquat	30	5-10 X	Lifetime Health Adv.
608-93-5	Pentachlorobenzene	120	10	EPA PPCL (ADI)
87-86-5	Pentachlorophenol (PCP)	30	10	Organoleptic (RPC)
127-18-4	Perchloroethylene **** (Tetrachloro-ethylene	3	1	Primary D.W. Standard
	pH ****	6.5-8.5 (standard units)		Secondary D.W. Std.
85-01-8	Phenathrene	10	10	PQL
108-95-2	Phenol (Carbolic acid)	20	10	Organoleptic (RPC)
103-85-8	N-Phenylthiourea	1,400	5-10 A	EPA PPCL (ADI)
1918-02-1	Picloram	500	5-10 A	Lifetime Health Adv.
1336-36-3	Polychlorinated Biphenyls (PCBs)	0.5	0.5	PQL ' 0.008 ug/L=10^{-6} cancer risk (H.A.)
1610-18-0	Prometon	100	5-10 A	Lifetime Health Adv.
23950-58-5	Pronamide	50	5-10 A	Lifetime Health Adv.
1918-16-7	Propachlor	90	5-10 A	Lifetime Health Adv.
139-40-2	Propazine	10	5-10 A	Lifetime Health Adv.

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CAS #	Parameter	Guidance* Concentration (ug/L)	Practical Quantitation Level (ug/L)	Basis/Comment
107-02-8	Propenal (See Acrolein)			
76-06-1	2-Propeneamide (see Acrylamide)			
122-42-9	Propham	100	5-10 A	Lifetime Health Adv.
129-00-0	Pyrene	10	10	PQL
	Radium-226+228 ****	5 pCi/L		Primary D.W. Standard
	Selenium ****	10	5	Primary D.W. Standard
	Silver ****	50	50	Primary D.W. Standard
93-72-1	Silvex (2,4,5-TP) ****	10	1	Primary D.W. Standard
122-34-9	Simazine	10	5-10 A	PQL / 4ug/L=Lifetime H.A.
	Sodium ****	160,000	500	Primary D.W. Standard
100-42-5	Styrene (Vinyl benzene)	1	1	PQL / 0.01 ug/L=10^{-6} cancer risk (H.A.)
	Sulfate ****	250,000	500	Secondary D.W. Std.
93-76-5	2,4,5-T (See 2,4,5-Trichlorophenoxy-acetic acid)			
	TDS (Total Dissolved Solids) ****	500,000		Secondary D.W. Std.
34014-18-1	Tebuthiuron	500	5-10 A	Lifetime Health Adv.
116-06-3	Temik (See Aldicarb)			
5902-51-2	Terbacil	90	5-10 A	Lifetime Health Adv.
13071-79-9	Terbufos	10	5-10 A	PQL / 0.9 ug/L= Lifetime Health Adv.
95-94-3	1,2,4,5-Tetrachloro-benzene	35	10	EPA PPCL (ADI)
1746-01-6	2,3,7,8-Tetrachloro-dibenzo-p-dioxin (TCDD, Dioxin)	0.01	0.01	PQL/ 2.2 X 10^{-7}ug/L= 10^{-6} cancer risk (Health Advisory)
79-34-5	1,1,2,2-Tetra-chloroethane	1	1	PQL / 0.8 ug/L = RPC
127-18-4	Tetrachloroethylene **** (Perchloroethylene)	3	1	Primary D.W. Standard
56-23-5	Tetrachloromethane **** (Carbon-tetrachloride)	3	1	Primary D.W. Standard
7440-28-0	Thallium	10	10	PQL / 3.7ug/L=EPA PPCL
108-88-3	Toluene	24	1	Organoleptic (RPC)
636-21-5	o-Toluidine hydrochloride	10	5-10 X	PQL / 0.146ug/L=10^{-6} cancer risk (EPA PPCL)
	Total Dissolved Solids (TDS) ****	500,000		Secondary D.W. Std.
8001-35-2	Toxaphene ****	5	1	Primary D.W. Standard

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CAS #	Parameter	Guidance* Concentration (ug/L)	Practical Quantitation Level (ug/L)	Basis/Comment
73-72-1	2,4,5-TP (Silvex) ****	10	1	Primary D.W. Standard
75-25-2	Tribromomethane (see Bromoform)			
120-82-1	1,2,4-Trichloro-benzene	140	10	IRIS
71-55-6	1,1,1-Trichloro-ethane ****	200	20	Primary D.W. Standard
79-00-5	1,1,2-Trichloro-ethane	1	1	PQL / 0.61ug/L=10^{-6} cancer risk (AWQCD)
79-01-6	Trichloroethene **** (Trichloro-ethylene, TCE)	3	1	Primary D.W. Standard
67-66-3	Trichloromethane (See Chloroform)			
75-69-4	Trichloromono-fluromethane	2,400	1	EPA PPCL (ADI)
95-95-4	2,4,5-Trichloro-phenol	10	10	PQL / 1ug/L = organoleptic (AWQCD)
88-06-2	2,4,6-Trichloro-phenol	10	10	PQL / 1.2ug/L = 10^{-6} cancer risk (AWQCD)
93-76-5	2,4,5-Trichloro-phenoxyacetic acid (2,4,5-T)	70	1	Lifetime Health Adv.
1582-09-8	Trifluralin	10	5-10 A	PQL / 2ug/L= Lifetime Health Adv.
	Trihalomethanes **** (total)	100		Primary D.W. Standard
	Trimethyl benzenes (total)	10	5-10 A	PQL / 0.24ug/L = organoleptic (RPC)
786-19-6	Trithion	12	5-10 X	RPC
100-42-5	Vinyl benzene (See Styrene)			
75-01-4	Vinyl chloride **** (Chloroethylene)	1	1	Primary D.W. Standard
110-75-8	Vinyl 2-chloroethyl ether (See 2-Chloro-ethyl vinyl ether)			
107-13-1	Vinyl cyanide (See Acrylonitrile)			
75-35-4	Vinylidene chloride **** (1,1-Dichloro-ethylene)	7	1	Primary D.W. Standard
1330-20-7	Xylenes (total)	50	5	Organoleptic (RPC)
105-67-9	2,4-Xylenol (See 2,4-Dimethyl phenol)			
	Zinc ****	5,000	25	Secondary D.W. Std.
12122-67-7	Zineb	14	5-10 X	RPC

SYMBOLS AND ABBREVIATIONS

* - The concentrations in this table are only to be used as a screening guideline for ground water contamination. These concentrations are not standards and without further justification can not be used as standards.

** - Guidance Concentration for Aldicarb Sulfone in the presence of Aldicarb or Aldicarb Sulfoxide is 10 ug/L.

*** - Guidance Concentration applies to asbestos fibers exceeding 10 um in length.

**** - Florida Primary or Secondary Drinking Water Standard: Chapter 17-550.310-320, F.A.C.

\# - Organoleptic threshold data may necessitate a lower Guidance Concentration

A - Practical Quantitation Level of 5-10 ug/L based on gas chromotograph detection with mass spectrometer confirmation. Estimated by Tom Presely, Methodology Department, EPA Laboratory, Cincinnati, and Geoffrey Watts, Bureau of Waste Cleanup DER, Tallahassee.

ADI - Acceptable Daily Intake

AWQCD - Ambient Water Quality Criteria Documents, EPA 1980.

CAG - Carcinogen Assessment Group, EPA 1980.

CAS # - American Chemical Society's Chemical Abstract Service, 8th Collective Index

EPA - Environmental Protection Agency.

H.A. - Health Advisory, EPA Office of Drinking Water.

IRIS - Intergrated Risk Information System, EPA January 1989

MCL - Maximum Contaminant Level, EPA.

OPP - Office of Pesticide Programs, EPA, 1984.

Organoleptic - taste and odor.

PPCL - Preliminary Protective Concentration Limits, EPA Draft, 1984.

PQL - Practical Quantitation Level; the lowest level that can be reliably achieved within specified limits of precision and accuracy during routine laboratory operating conditions. The Practical Quantitation Level can be estimated to be five (5) times the method detection limit. Federal Register: Vol.52, No.131, Thursday, July 9, 1987, pgs. 25947-25953.

RPC - Recommended Protective Concentration: Toxicant Profiles, Center for Biomedical and Toxicological Research, Florida State University, 1985-1988.

T.O.N. - Threshold Odor Number

X - An EPA approved method for the analysis of this chemical in water has not been established at this time. Routine analyses for this chemical is not recommended unless its presence is suspected.

APPENDIX F

TANK PITS - A SAFEGUARD TO PREVENT CONTAMINATION OF WATER SUPPLY AQUIFER BY CHEMICAL SPILLS

1. Pits constructed of concrete for portable or future tank installations shall have a certifiable dead load of sufficient weight to prevent floatation (Exhibit A) or a combined thickness of floor and roof equal to 73% of the inside depth of the pit of 73% of the distance from finished ground level to tank floor (Exhibit B) whichever is the lesser.

2. Pits constructed with the tank in place and anchored to the floor shall have combined dead load of pit and empty tank equal to the weight of the volume of water displaced by that part of the pit below finished grade.

3. Pit shall be of sufficient size to retain all contents of the tank plus a 12 -inch free board. A minimum clearance of 24 inches shall be provided on all sides of the tank and its supports. Floor shall have 1/4 inch per foot fall to an 18" x18" x6" sump (centered under an access on covered pits for pumping equipment).

4. Covered pits subject in any part to vehicular traffic shall be designed to sustain an H-20 loading. Covers shall be removable (Exhibit C).

5. Open pits shall extend 12 inches above the highest point of the finished grade at the pit.

6. Pit walls shall be constructed of water-proofed reinforced concrete or reinforce hollow unit masonry with all cells grout-filled. Pit cover (where used) and floor shall be constructed of water-proofed reinforced concrete. All concrete shall have a minimum compressive strength 3000 psi in 28 days. Working stresses for reinforced masonry shall conform to SB CC Standards Building Code. Plans and specifications shall be prepared and sealed by an Engineer or Architect registered in the State of Florida. Upon completion of construction, the Engineer/Architect shall certify in writing to the City Building and Zoning Department that construction conforms to these requirements.

7. Vents for covered pits shall have the same venting system as required for the tank placed in the pit - both as to capacity, location and arrangement.

8. Pit opening other than vents shall be liquid-tight, and every connection through which liquid can normally flow shall have a valve located as close as possible to the pit.

9. Vent, fill and withdrawal piping shall not pass through floor or walls of pit, and connections shall be made to preclude breakage form settlement, vibration or contraction.

10. Paint interior of concrete pit (both sides of masonry walls if used with two coats of water proofing compound inert to the storage tank contents.

11. Leakage shall be monitored weekly, and log recording the inspection results shall be maintained. Report leakage and spills to the Pinellas County Utilities Director and Environmental Director, and in the case of flammable and combustible liquids, also report to the Fire Department. Do not pump pits! Wait for disposal instructions.

12. Open tank inspections may be visual. Covered tanks may have a manual gauge, magnetic, hydraulic or hydrostatic remote reading device, or a sealed float gauge.

13. Other containment devices may be submitted for considerations provided that the tank is restrained from floatation under all conditions, that the containing device permits inspection, and if required- withdrawal of the spill without6 removal of tank.

14. In all instances the regulations of the National Fire Protection Association as administered by the Pinellas County Fire Department shall prevail.

EXHIBIT A

FLOATATION PREVENTION

Pit Dead Load must equal Buoyance

Pit Dead Load lbs.* = 144 (Vol. cubic feet roof + walls + floor)

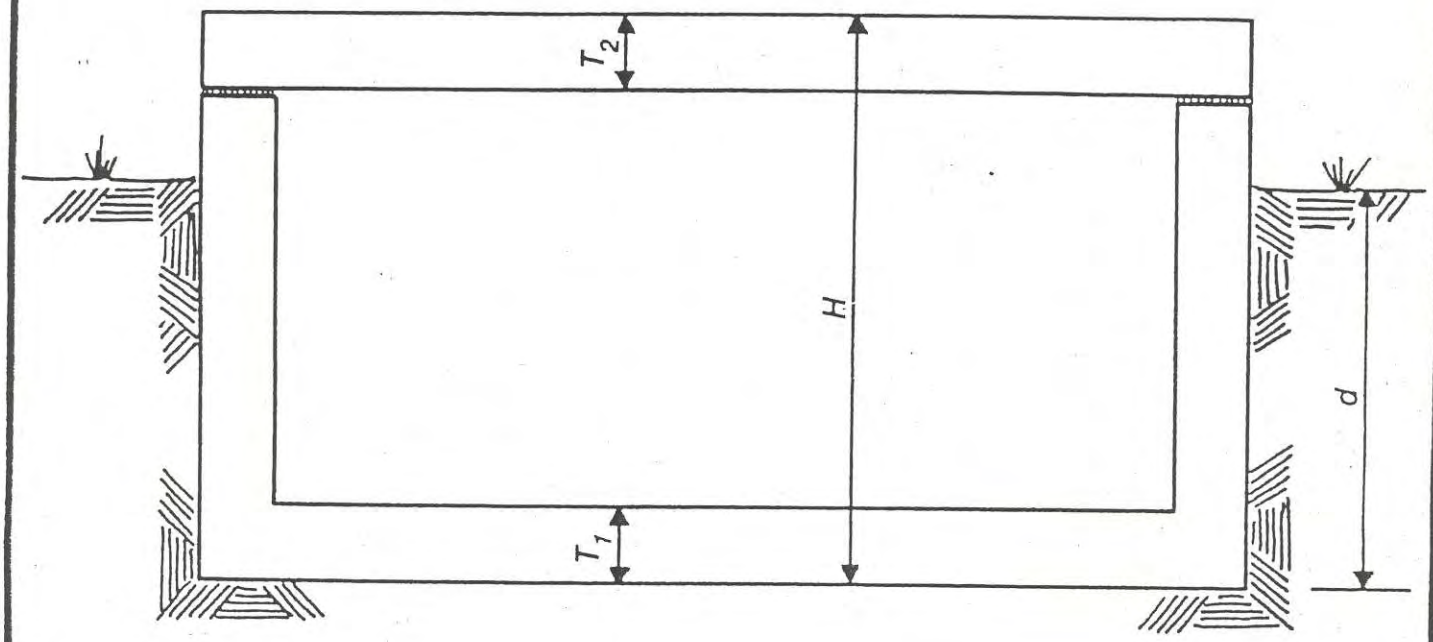
* Add weight of empty tank if permanently anchored.

Buoyance lbs. = 62.35 x Out to Out area of floor x least depth to finished grade.
(all measurements in feet)

Exhibit B

FLOTATION PREVENTION

(Alternate Calculation)



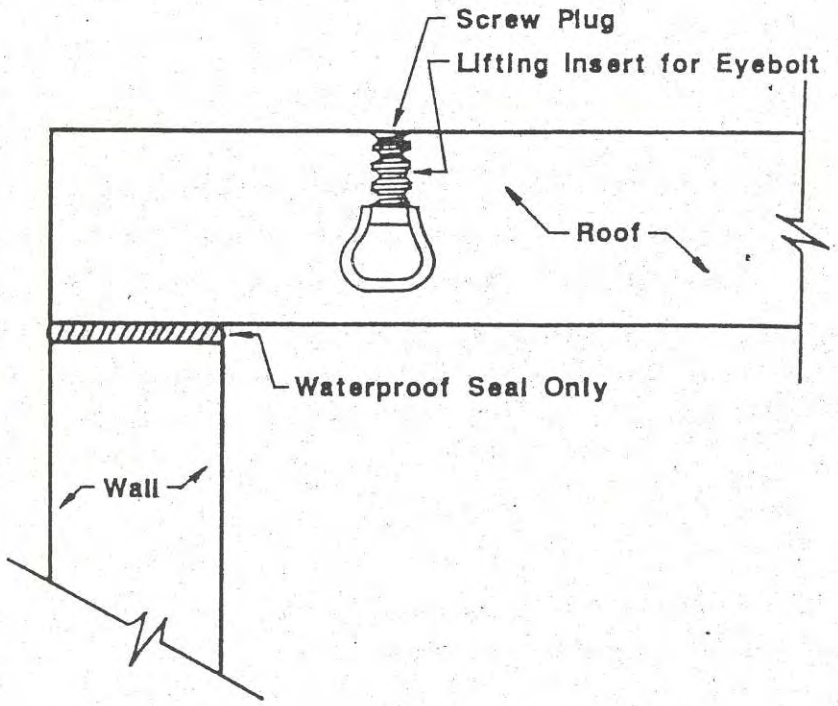
$$d_{max.} = H$$

$$T_1 + T_2 = 0.73d \quad \text{Covered Pit}$$

$$T_1 = 0.73d \quad \text{Open Pit}$$

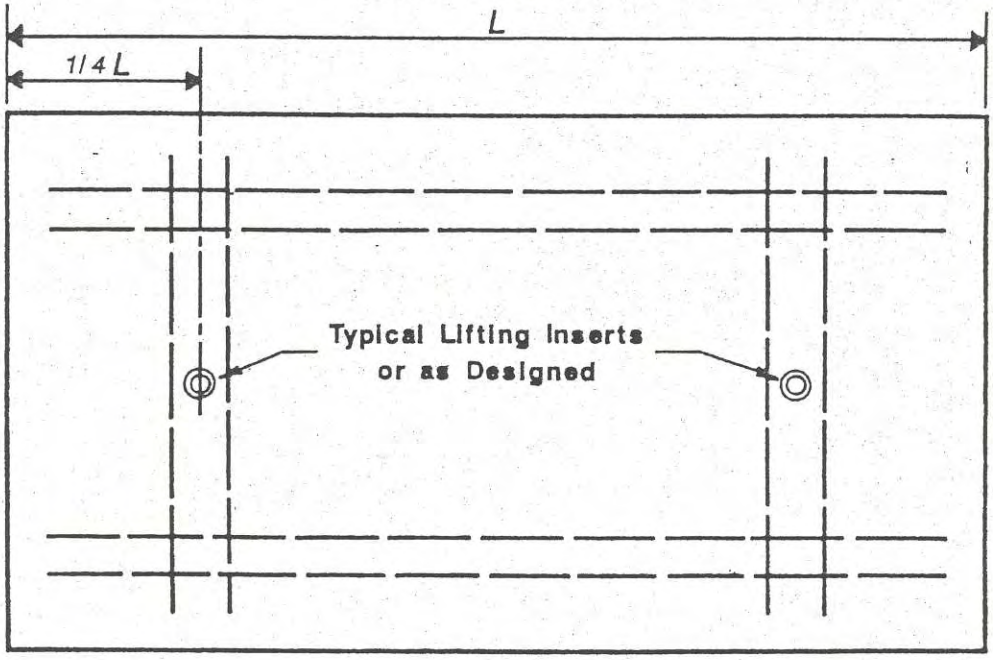
Exhibit C

REMOVABLE ROOF SLABS - COVERED PITS



Removable Pit Cover Lifting Inserts

(Submit Calculations)



APPENDIX G

OBSERVATION AND MONITORING WELLS

Observation wells, located in tank excavations and collection sumps of secondary containment systems, typically extend two feet below the level of the land or hold-down pad. Monitoring wells, located outside of the tank excavations, enable sampling groundwater in areas with permeable soil, where the water table is below the bottom of the tanks but within forty feet of the surface.

Comments:

a) The size, number, and location of wells is largely dictated by building codes and physical conditions.

b) Wells should be constructed of factory perforated or slotted PVC, galvanized or coated metallic pipe with .020 inch openings and permeable backfill material to permit water or released product to flow freely into the well.

c) Access covers and well construction should restrict infiltration of surface water.

d) Wells should be clearly marked with a black equilateral triangle on a white background and a durable label, warning against the accidental or intentional introduction of petroleum products in the well.

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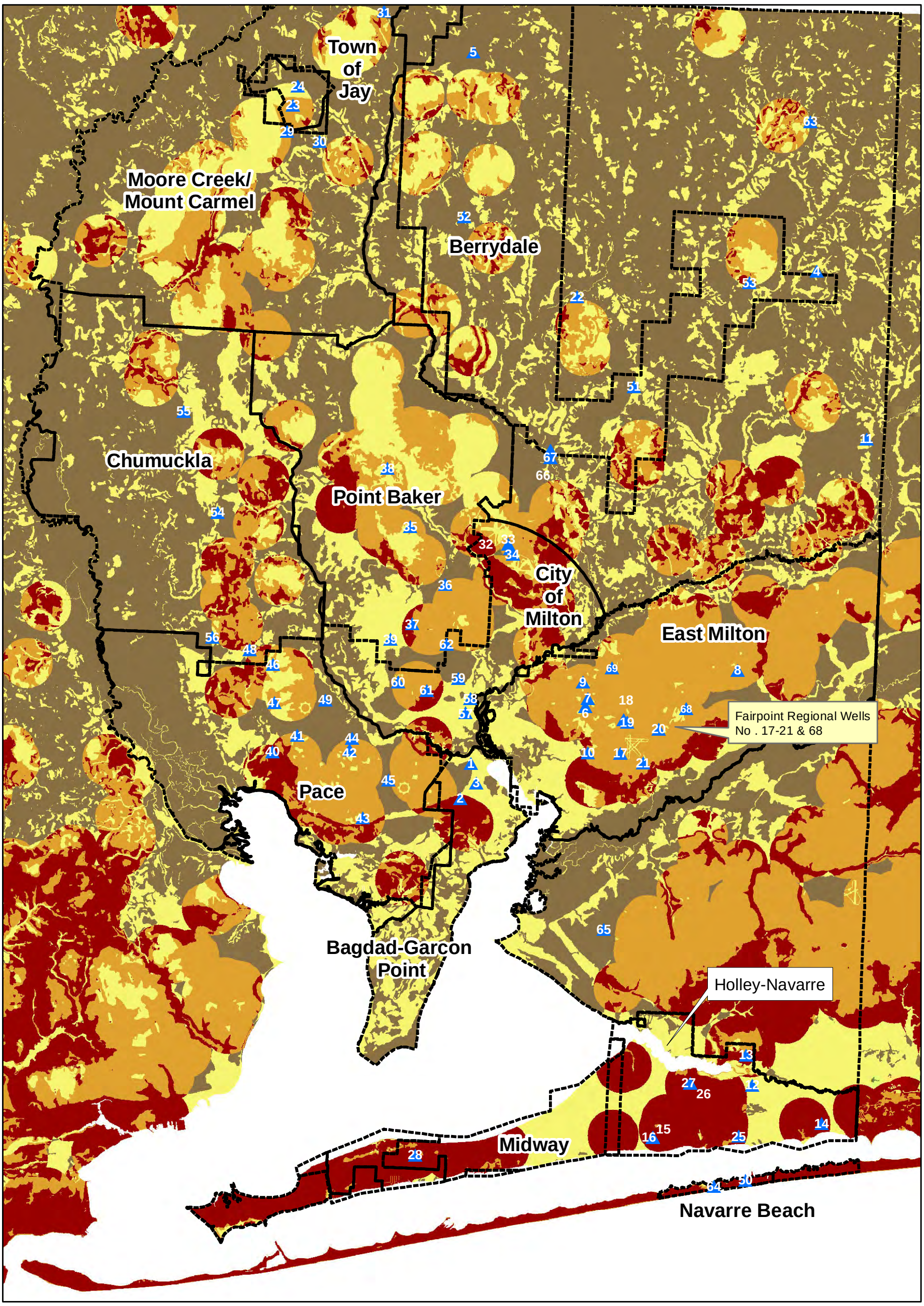
Sand & Gravel Acquifer - Relative Acquifer Vulnerability Map with Active Well Locations



Legend

- Wells
- Water Franchise Areas

Surficial Acquifer - Relative Vulnerability

- Less Vulnerable
- More Vulnerable
- Most Vulnerable
- Vulnerable

Note 1: Wells 4, 11, 22, 53, 63, 65, 66 and 67 Are Non-Community Wells

Note 2: Wells 15 & 16, 18 & 19, 32, 33 & 34 and 66 & 67 are close to each other and the well labels are difficult to see; text added in plain white to visualize general location.

Map Document: (C:\mav's-d-drive\mav\work \WellfieldProtectionARea\Relative Vulnerability MapAll SRC.mxd)
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