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# Aquifer Vulnerability Modeling in New Jersey Through the Use of Modified DRASTIC Methodology

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## Introduction

As the average global temperature has increased over last 50 years, sea level rise (SLR) has become an issue to monitor due to the fact that it makes coastal aquifers more susceptible to saltwater intrusion. Mapping aquifer vulnerability is possible with GIS through the use of a universal model created by the United States' Environmental Protection Agency (EPA) called the DRASTIC model. The DRASTIC model does not account for saltwater intrusion as a contaminant. It also does not take any other types of contaminants into account when mapping aquifer vulnerability. To ensure that saltwater intrusion as a contaminant is quantified, our project required the DRASTIC model to be modified to accommodate the inclusion of saltwater intrusion. This project sets out to investigate and compare the effectiveness of aquifer vulnerability mapping via the DRASTIC model and a modified DRASTIC model for the state of New Jersey.

## Definition of the DRASTIC Model

To better understand how aquifer vulnerability is mapped through the DRASTIC model, each of the parameter of the model need to be defined. Included are the two extra parameters used in the modified DRASTIC model.

- Depth to water table, *D*, depth from the ground surface to the water table. Original kriging was used to interpolate *D* for the entire state of New Jersey.
- Net Recharge, *R*, is the net groundwater recharge that replenishes the aquifer. The DRASTIC model calls for aquifer recharge, however with the data collected, groundwater recharge sufficed. This dataset from the NJ Bureau of GIS did not include two counties.
- Aquifer media, *A*, are the consolidated or unconsolidated rock that makes the aquifer confined or unconfined.
- Soil media, *S*, are the types of soil that are in the upper most vadose zone where biological activity occurs. Also taken into account is the ease at which water is able to transmit through the soil media type.
- Topography, *T*, depicts the slope and slope variability of the land surface. The lower the slope, the more likely water will not be running off and instead recharging the aquifer system.
- Impact vadose zone, *I*, is the area right above the water table that is either unsaturated or discontinuously saturated. It is much like aquifer media in relation to confined or unconfined aquifers.
- Hydraulic conductivity, *C*, measures the aquifer media's ability to transmit water through the different media zones and into the aquifer.
- Distance to the Coast, *DTCoast*, takes into account the potentiality of saltwater intrusion as a contaminant in the aquifer systems. This is the first of two parameters that were added to modify the DRASTIC model.
- Distance to Contaminants, *DTContaminants*, takes into account known contaminant areas within the state of New Jersey. These were chosen because we were looking at saltwater intrusion and other forms of contamination as well. This is the second of two parameters that were added to modify the DRASTIC model.

Literature sources: Ferreira, J.P.L., Chachad, A. G., Diamantino, C., Hendriques, M. J., 2005, Assessing aquifer vulnerability to seawater intrusion using GALDIT method: Part 1 – Application to the Portuguese Aquifer of Monte Gordo; Beevers, Michaels B., Cooper, Matthew J. P., Oppenheimer, Michael, 2008, The potential impact of sea level rise on the coastal region of New Jersey, USA

Data sources for mapmaking: New Jersey Bureau of GIS - http://www.nj.gov/dep/gis/listall.html;
New Jersey Geologic survey- http://www.nj.gov/dep/njgs/

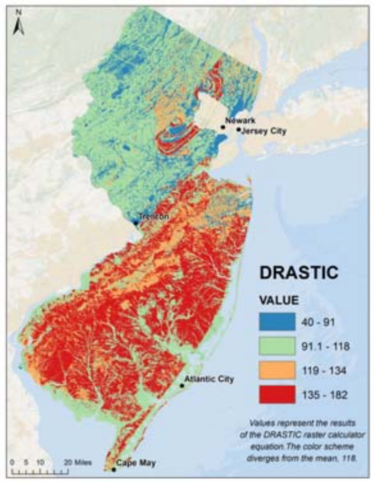


**Figure 1.** DRASTIC model of aquifer vulnerability in New Jersey.

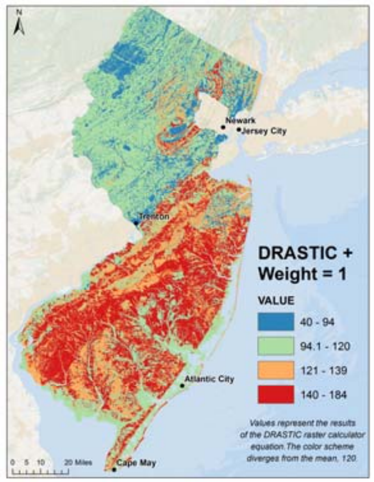


**Figure 2.** DRASTIC + DTCoast + DTContaminants model of aquifer vulnerability in New Jersey.

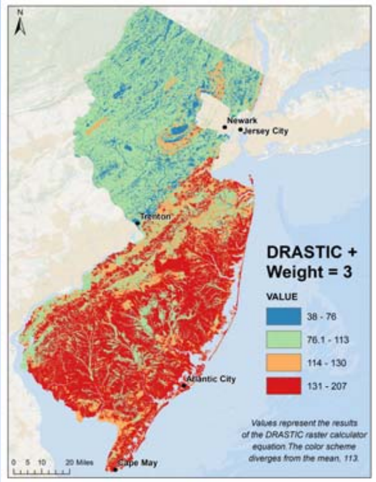


**Figure 3.** DRASTIC + 3DTCoast +3DTContaminants model of aquifer vulnerability in New Jersey.

## Methodology

**Depth to water table (*D*)** → Water table depths assigned to groundwater 273 test locations → Interpolated water table depth using ordinary kriging → Interpolated table depth is reclassified

| Depth to Water Table | |
|---|---|
| Depth in feet | Rank |
| 0 TO 5 | 10 |
| 5 TO 15 | 9 |
| 15 TO 30 | 7 |
| 30 TO 50 | 5 |
| 50 TO 75 | 3 |
| 75 TO 100 | 2 |
| 100 + | 1 |

**Groundwater Recharge (*R*)** → Recharge values per county converted from polygon to raster → Recharge raster reclassified

| Net Groundwater Recharge | |
|---|---|
| Recharge in inches | Rank |
| 0 TO 2 | 1 |
| 2 TO 4 | 3 |
| 4 TO 7 | 6 |
| 7 TO 10 | 8 |
| 10 + | 9 |

**Aquifer Media (*A*)** → Media types grouped into 7 media types → Converted polygon to raster → Reclassified aquifer types raster

| Aquifer Media | |
|---|---|
| Aquifer Media Type | Rank |
| Basalt | 9 |
| Sand and Gravel | 8 |
| Sand/Gravel/Silt/Clay | 7 |
| Sandstone/Limestone/Shale | 6 |
| Sandstone | 6 |
| Metamorphic or Igneous rock | 3 |
| Mudstone | 2 |

**Soil Media (*S*)** → 212 Soil types grouped into 22 soil types → Converted soil types from polygons to raster → Reclassified soil type raster

| Soil Media | |
|---|---|
| Soil Type | Rating |
| Fine sand | 9 |
| Sand | 9 |
| Loamy sand | 8 |
| Cobbly sandy laom | 8 |
| Gravelly sandy loam | 8 |
| Gravelly loam | 7 |
| Gravelly silt loam | 7 |
| Sandy loam | 6 |
| Cobbly loam | 6 |
| Sandy clay loam | 6 |
| Mucky sand | 5 |
| Channery loam | 5 |
| Loam | 5 |
| Channery silt loam | 4 |
| Silt loam | 4 |
| Westbrook, Ipswitch, Sandyhook | 4 |
| Mucky silt loam | 3 |
| Muck | 2 |
| Clay | 1 |
| Urban | 1 |
| Rock | 0 |
| Beach | 0 |
| Water | 0 |

**Topography (*T*)** → Slope generated from10m DEM → Slope raster reclassified

| Topography | |
|---|---|
| Percent slope | Rank |
| 0 TO 2 | 10 |
| 2 TO 6 | 9 |
| 6 TO 12 | 5 |
| 12 TO 18 | 3 |
| 18 + | 1 |

**Impact Vadose Zone (*I*)** → Utilized aquifer media type data and confining units → Converted polygon to raster → Reclassified raster

| Impact Vadose Zone | |
|---|---|
| Vadose Type | Rank |
| Basalt | 9 |
| Sandstone | 6 |
| Sandstone/Limestone/Shale | 6 |
| Sand/Gravel/Silt/Clay | 6 |
| Metamorphic/Igneous | 4 |
| Clay/Silt | 3 |
| Mudstone | 2 |
| Confining layer | 1 |

**Hydraulic Conductivity (*C*)** → Used aquifer media to determine and assign conductivity values → Converted conductivity polygon to raster → reclassified

| Hydraulic Conductivity | |
|---|---|
| Media type | Rank |
| Sand/Gravel | 7 |
| Sand/Gravel/Silt/Clay | 4 |
| Metamorphic/Igneous | 2 |
| Sandstone | 1 |
| Sandstone/Limestone/Shale | 1 |
| Mudstone | 1 |
| Clay/Silt | 1 |
| Basalt | 1 |

| EPA Conductivity Scale | |
|---|---|
| Conductivity in gal/day/sq. ft. | Rank |
| 1 TO 100 | 1 |
| 100 TO 300 | 2 |
| 300 TO 700 | 4 |
| 700 TO 1000 | 6 |
| 1000 TO 2000 | 8 |
| 2000 + | 10 |

**Distance from the coast (DTCoast)** → Used Euclidean distance to incrementally buffer coastline → Reclassified Euclidean distance results

| Distance to Shore | |
|---|---|
| Distance in meters | Rank |
| 0 TO 500 | 10 |
| 500 TO 750 | 7 |
| 750 TO 1000 | 5 |
| 1000 TO 2000 | 3 |
| 2000 TO 3000 | 1 |

**Distance from know contaminants (DTContaminant)** → Used Euclidean in similar interval to distance from coast → Reclassified Euclidean distance results

| Distance to Contaminants | |
|---|---|
| Distance in Meters | Rank |
| 0 TO 100 | 10 |
| 100 TO 250 | 7 |
| 250 TO 500 | 5 |
| 500 TO 750 | 3 |
| 750 TO 1000 | 1 |

**Figure 3.** Reclassified raster of ordinary kriging values of New Jersey's depth to water table.

**Figure 4.** Reclassified raster of groundwater recharge rate observed in New Jersey.

**Figure 5.** Reclassified raster of the aquifer media of New Jersey.

**Figure 6.** Reclassified raster of the soil media of New Jersey.

**Figure 7.** Reclassified raster of the topography, measured in percent slope, of New Jersey.

**Figure 8.** Reclassified raster of the impact vadose zones of New Jersey.

**Figure 9.** Reclassified raster of the hydraulic conductivity observed in New Jersey.

**Figure 10.** Reclassified raster of the Euclidean distance, up to 3000 meters, from the coast of New Jersey.

**Figure 11.** Reclassified raster of the Euclidean distance, up to 1000 meters, from known contamination sites in New Jersey.

Raster calculator equation: *D(5) + R(4) + A(3) + S(2) + T + I(5) + C(3) =* ***Figure 1***
*[+ DTCoast+ DTContaminants=* ***Figure 2****]*
*[+ DTCoast(3) + DTContaminants(3) =* ***Figure 3****]*

## Results

To the left are the aquifer vulnerability maps of New Jersey. These maps were used to investigate and compare which best mapped aquifer vulnerability, especially with regards to contamination by saltwater intrusion and known contaminant sources. Fig. 1 is the EPA's DRASTIC model with no modifications added. Fig. 2 is the DRASTIC model with two extra parameters added , *DTCoast* and *DTContaminants*, at a magnitude weight of 1. Fig. 3 is the DRASTIC model with two extra parameters added, *DTCoast* and *DTContaminants*, at a magnitude weight of 3.

## Discussion

From the model outputs we were able to compare, contrast and decide which model depicted aquifer vulnerability with respect to potentiality of contamination by saltwater intrusion. Below are observations that can be made from viewing the map:

The DRASTIC model in Fig. 1

- No potential contaminants are accounted for or included
- Fig. 1 shows that areas of the New Jersey coast ***would not*** experience effects to their aquifers due to saltwater intrusion while inland aquifers ***would***, which instinctually seems counterintuitive
- EPA's DRASTIC model does not properly answer the project question in regards to aquifer vulnerability to saltwater intrusion and other contaminants

The first modified model built, the DRASTIC + DTCoast + DTContaminants model in Fig. 2

- Magnitude weight of 1 was given to both *DTCoast* and *DTContaminants* because we needed to have an understanding of the baseline
- From literature review of the GALDIT model by Ferreira et al., the distance from coast measure (also known as D in GALDIT and DTCoast in our model) makes up for the lack of contamination potential seen in the DRASTIC model
- This model does a better job yet it still had a few gaps on portions of the coastal aquifers

The second and final modified model that we built, the DRASTIC + 3DTCoast + 3DTContaminants model in Fig. 3

- Demonstrated the best way to map aquifer vulnerability with respect to salt water intrusion and contaminants.
- Utilizing Ferreira et al., we set the contaminant weights both to 3 because if DTCoast was a measure of 3, then by extension DTContaminants should also be weighted similarly.
- This modified DRASTIC model demonstrated the importance of magnitude weighting within the model with respect to contamination potential.

## Conclusion

The DRASTIC model has the ability to evaluate aquifers' potential vulnerability to contamination, however as saltwater intrusion becomes a prevalent issue methods for assessing aquifer vulnerability that include vulnerability to saltwater intrusion are necessary. Including the distance to the coast, as well as known contaminants, is crucial to know the true vulnerability that aquifers face. In addition to adding these measures, the coefficient magnitude weight is necessary to properly scrutinize because it places the level of importance that the contaminants have on the vulnerability of the aquifer. From this study, we have found that utilizing a modified DRASTIC model that is aided by a weighted measure from the GALDIT model has better potential for mapping aquifer vulnerability than utilizing DRASTIC on its own.