Identifying Potential Risk to Groundwater from Hazardous Waste Injection Wells: A case study of seven counties in the Houston, Texas Area

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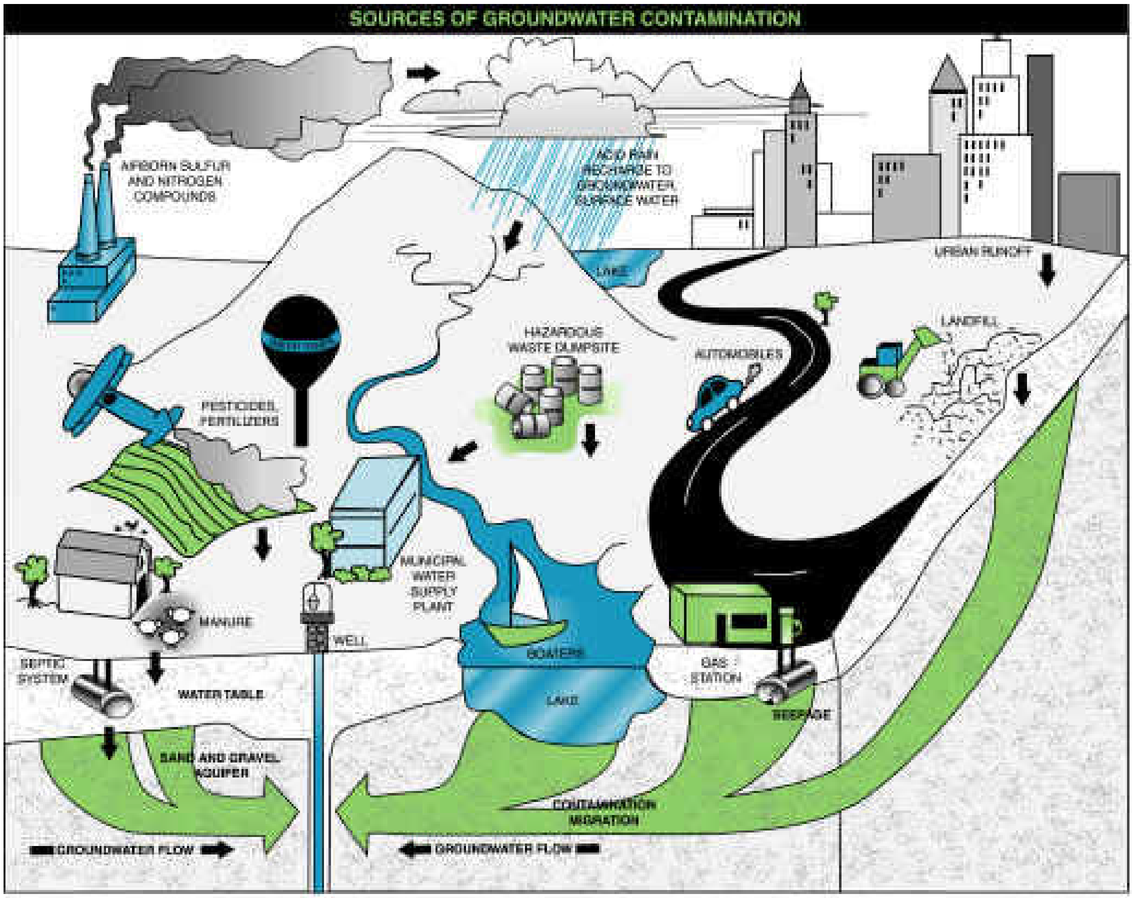
Introduction

Groundwater is a precious resource. It is the largest source of drinking water available, but only about 0.62% of the total amount of water on Earth. (Hudak 3) Contamination of this supply of water could be detrimental to areas that rely on groundwater as their primary source. Groundwater contamination can happen in many different ways and at many different levels. Figure 1, obtained from The Groundwater Foundation, shows some of the many ways groundwater can be contaminated.

Many industries create hazardous wastes. Some industries dispose of these wastes by injecting them into wells under high pressure. Some drilling wastes, like brine, are injected back into the ground at the drilling site, while others are taken to another location. This is a reasonable method of disposal, in most cases. However, if injection wells do not follow strict adherence to their rules and regulations, the result could be contaminated water supplies. Therefore, certain groundwater supplies could be at-risk to contamination from these hazardous wastes.

Figure 1. Sources of Contamination



Geographic Information Systems technology was used in order to assess the potential pollution risks associated with these hazardous waste injection sites within the Gulf Coast Aquifer of Texas. With this project, the questions asked were: is there a spatial relationship between the location of the hazardous waste injection sites and the public water supply and what areas of the aquifer are at-risk to contamination from these injection sites.

Review of Literature

Groundwater contamination:

Groundwater is considered contaminated when it is significantly altered from its original state. The origins of contamination can range from everyday activities like disposal of urban sewage and industrial wastes or use of pesticides to accidental releases like spills. (CRS) High levels of salinity in an aquifer can be generated through natural processes, like saltwater intrusion (common in coastal areas), or through industrial disposal of oil field brines. (Keller 201 and 237) Some aquifers naturally have a higher content of salinity than others do. However, the problems arise when this level of salinity has been increased by poor industrial disposal methods. Contamination of aquifers is density-dependant. Lower density contaminants will spread over the interface, while higher density contaminants are able to reach the bottom of an aquifer. (CRS)

Deep-Well Injection Disposal Methods:

All petroleum production brings, not only oil to the surface, but also a certain amount of salty water, or brine. (Keller 236) After the oil and salty water are separated, the latter must be disposed. Past disposal methods have included disposal wells, open pits, and lined reservoirs. (Todd 34 and Collins 419) Current disposal technology allows this to be accomplished through the use of a few common methods, which include deep-well disposal, evaporations in lined open pits, or by injection as part of the secondary recovery. (Keller 236) A certain level of risk to the groundwater is involved in these disposal methods. Deep-well injection of oil field brines is successful if carried out correctly, but abandoned oil and gas test wells, which are not plugged correctly, could allow the brines to move upward and contaminate the fresh groundwater. (Todd 35)

Groundwater Characteristics:

Groundwater flow is controlled by the following forces, hydraulic head, hydraulic conductivity, and effective porosity, and tends to flow in the direction of the steepest hydraulic gradient. (Hudak 75) Hydraulic gradient is measured by subtracting the differences between the hydraulic head of points A and B, and, then, dividing by the distance between the two points. In order to establish the direction of groundwater flow, at least three wells are required. (Hudak)

Regulations on Injection Wells:

The vulnerability of public water wells is an important concern. The revision of the Safe Drinking Water Act (or SDWA) established vulnerability assessments, as a way of fighting groundwater contamination. Computer programs are used to evaluate the environmental conditions surrounding public water supply wells. Several variables are analyzed in order to evaluate these conditions. Some variables included are location of wells, geology and soils, water quality, history of land usage, and potential sources of pollution. (TNRCC)

Injection wells are categorized into five classes (Figure 2.). These classes are based on the level of toxicity of the material being injected and the reason for injecting materials into the ground, whether it is for waste disposal or mineral extraction. (TNRCC)

Certain rules are set in place for the commission of injection operations. These standards provide the requirements for construction, operating, monitoring, reporting, and record keeping for all permitted injection operations. Class III and Class V injection operations are allowed some adjusted and less-stringent standards in specific instances, where the injection well is not into, above, or through a source of drinking water. (TNRCC and RCT) Failure to comply with these requirements can lead to enforcement actions, which can range anywhere from letters requesting corrective action to civil and criminal penalties by a court. (TNRCC)

Figure 2. Classification of Underground Injection Wells

Class	Description
Class I	Wells used by generators of hazardous wastes or owners/operators of hazardous waste management

	facilities. Other industrial and municipal waste disposal wells which inject fluid beneath the lowermost formation containing an aquifer within one-quarter mile of the well bore. This includes injection wells operated in conjunction with uranium mining activities. This class is regulated by the TNRCC through the use of permits.
Class II	Wells used to inject "oil and gas waste", a term that is defined to include waste arising out of or incidental to drilling for or production of oil, gas, or geothermal resources, the underground storage of hydrocarbons other then storage in artificial tanks or containers, or operation of gasoline plants, natural gas processing plants, or pressure maintenance or repressurizing plants. The injected waste fluid (usually salt water) may be combined with wastewaters from gas plants, unless those waters are classified as hazardous waste at the time of injection. Wells used for the enhanced recovery (secondary recovery) of oil or natural gas. Wells used for the underground storage of hydrocarbons which are liquid at standard temperature and pressure.
Class III	Wells used to inject fluids for extraction of minerals, exclusive of oil and natural gas. Brine injection wells are regulated by the RCT through permits. The TNRCC has full authority for regulating all other Class III injection wells, all of which are regulated by permit except uranium injection wells, which are regulated by a permit and production area authorization process.
Class IV	Wells used by generators of hazardous wastes or of radioactive wastes, by owners or operators of hazardous waste management facilities, or by owners or operators of radioactive waste disposal sites to dispose of hazardous wastes or radioactive wastes into or above a formation which contains an underground source of drinking water within one-quarter mile of the well bore.
Class V	Wells used for miscellaneous injection that are not included in the other class descriptions or are single family residential cesspools or septic system disposal wells.

Remediation of Contaminated Groundwater:

If groundwater contamination is found in a location, various methods may be used to clean up the polluted area. While digging up soil and trucking it to a landfill might be a relatively easy approach, it is not always the correct choice of action. Sometimes contamination may occur under buildings or to a much greater extent than can be excavated. Some of the alternative methods include: *In Situ* Physical or Chemical Treatment, Biological Treatment, and Electrokinetics. A common method is an In Situ method called air sparging. This consists of injecting gas (usually oxygen) under pressure into saturation zone wells to volatilize contaminants dissolved in groundwater, present as non-aqueous phase liquid, or sorbed to the soil matrix. These contaminants migrate upward and are removed upon reaching the vadose zone, typically through soil vapor extraction. (GWRTAC)

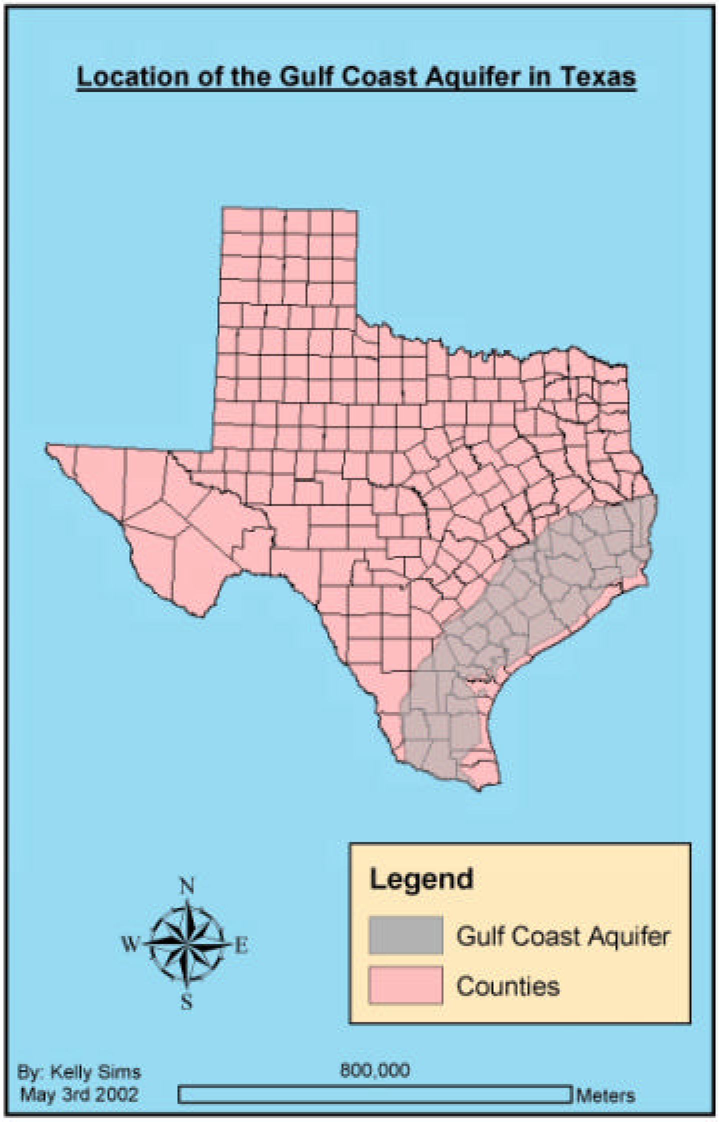
Methodology

The study area for this paper was first selected due to the location of the Gulf Coast Aquifer in Texas (Figure 3.) However, due to the size of this aquifer, the study area was scaled down to comprise of seven counties in the Houston area of Texas (Figure 5., see inset) These seven counties were chosen due to the high population density of the area, high density of industry, number of injection wells in the area, and the Gulf Coast Aquifer stretches underneath each of these counties.

After defining the study area, the next step was to obtain the data on the public water supply wells and the hazardous waste injection wells in Texas. Data were acquired from the Texas Natural Resource Conservation Commission (TNRCC) and the Texas Natural Resource Information System (TNRIS).

Once data were obtained, the layers were defined and projected into the same coordinates: UTM zone 14. They consisted of polygon and point layers. The polygons included: Texas counties and the Gulf Coast aquifer. The points included: Texas public water supply wells and Texas hazardous waste injection sites.

Figure 3. Gulf Coast Aquifer Region of Texas



The overlay of layers on the map was based on their new coordinate system. The point data was geocoded by latitude and longitude which allowed for the analysis of the sites by geographic location. Portions of the layers were selected based on whether they were within the study area. These selections were saved as new layers and named with the prefix "ha" for Houston Area. Buffers were created around the Houston Area public water supply wells. The hazardous waste injection sites that were within the buffers were saved into a new layer. While the public water supply wells that had hazardous waste injection wells within the buffer distance were also saved into a new layer. After these steps were completed, the data were ready for advanced spatial analysis.

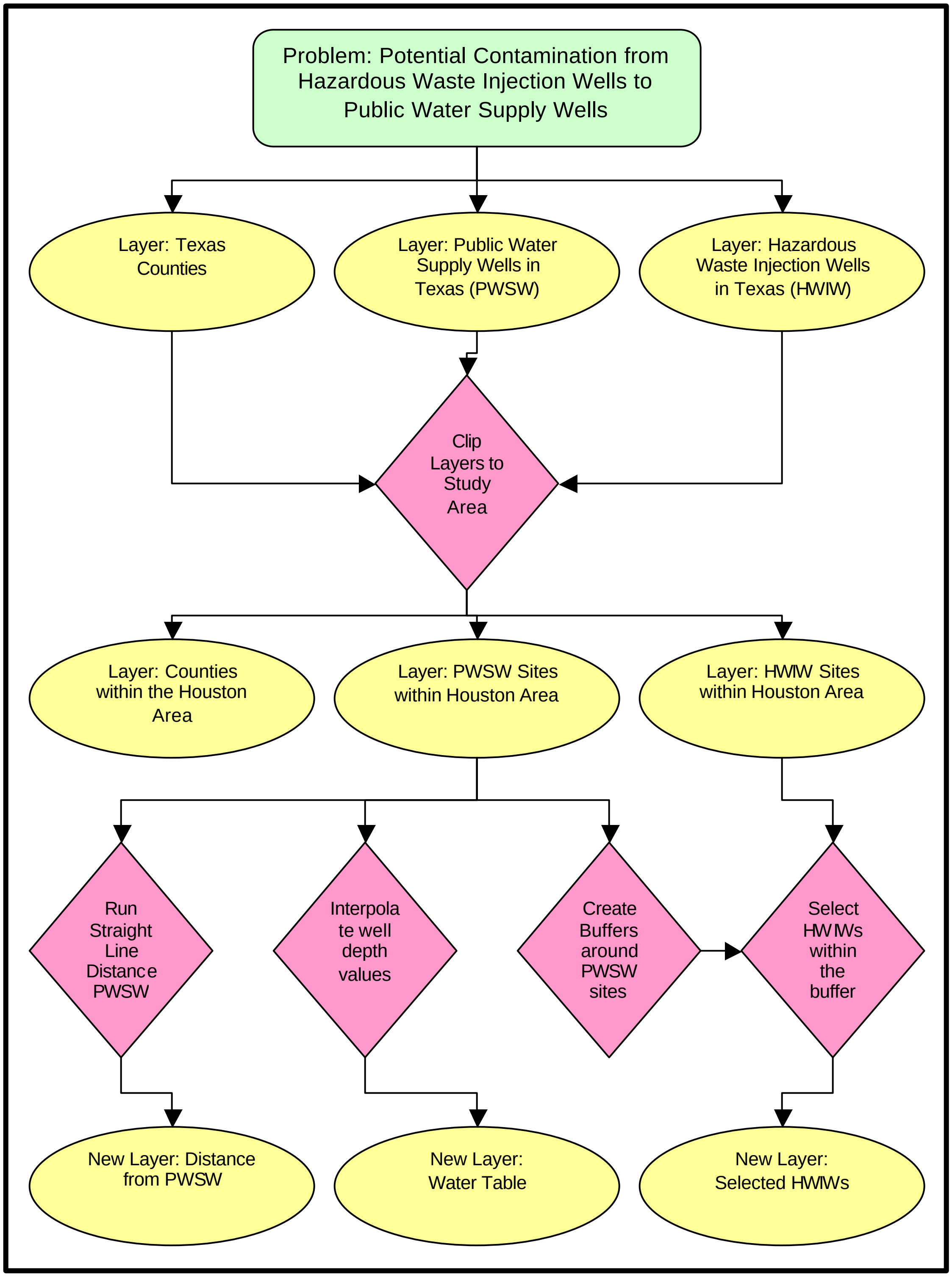
Analysis of Data

The spatial relationship between the public water supply wells and the hazardous waste injection sites was examined. Buffers of one-half mile were drawn around the injection sites and any public water supplies, within the buffers, were selected as potential sources of groundwater contamination. Hazardous waste injection wells were selected based on their distance to a water supply well. The hazardous waste injection wells that were within a 0.5 mile radius of a public water supply well were considered to be a potential contamination risk to the water supply. (Figure 5.)

The flowchart (Figure 4.) shows the necessary steps needed to implement my methodology using Geographic Information Systems.

Since the elevation head the Gulf Coast Aquifer was not available, the water table was estimated by interpolating the public water supply well depths. Even though this method was not completely accurate, the assumption was made that this interpolated surface would be a sufficient representation of the true water table. (Figure 6.) The assumption was also made that the groundwater direction would be toward the lowest elevation. Figure 6 shows the lowest water well depths in light purple and the greatest well depths in dark purple. Therefore, the darker areas are the most prone to contamination from hazardous waste injection operations.

Figure 4. Flowchart of Technical Procedure in this Project



A straight-line-distance correlation was executed to determine the areas of close distance to the public water supply wells. The concentrations of both the public water supply wells and the hazardous waste injection wells are shown by Figure 7. The hazardous waste injection sites that are within the 0.5-mile buffer are depicted in red and the remainder is green. This figure shows the high concentration of the hazardous waste injection wells near the city of Houston and near public water supply wells.

The greatest at-risk water wells within the study area were found to be those that are the deepest. This conclusion was reached for two reasons. One reason is that most contaminants flow in a down gradient direction. Therefore, as long as the contaminant does not react with the aquifer medium, it will follow the groundwater flow direction. The second reason is, since the hazardous wastes are being injected into deep-wells, contaminants will be closer to the deeper areas of the aquifer than to the near-surface areas.

Figure 5.

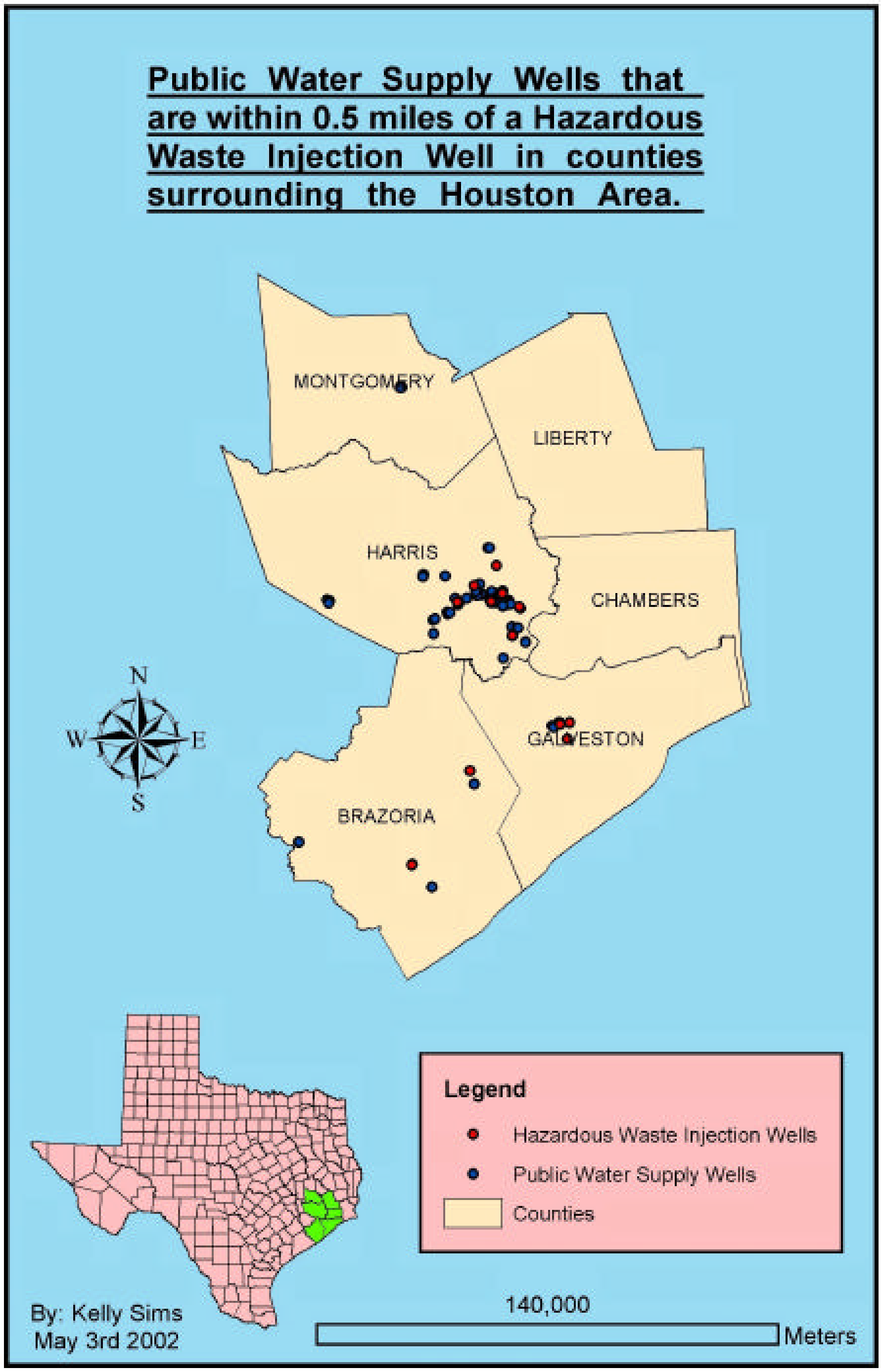
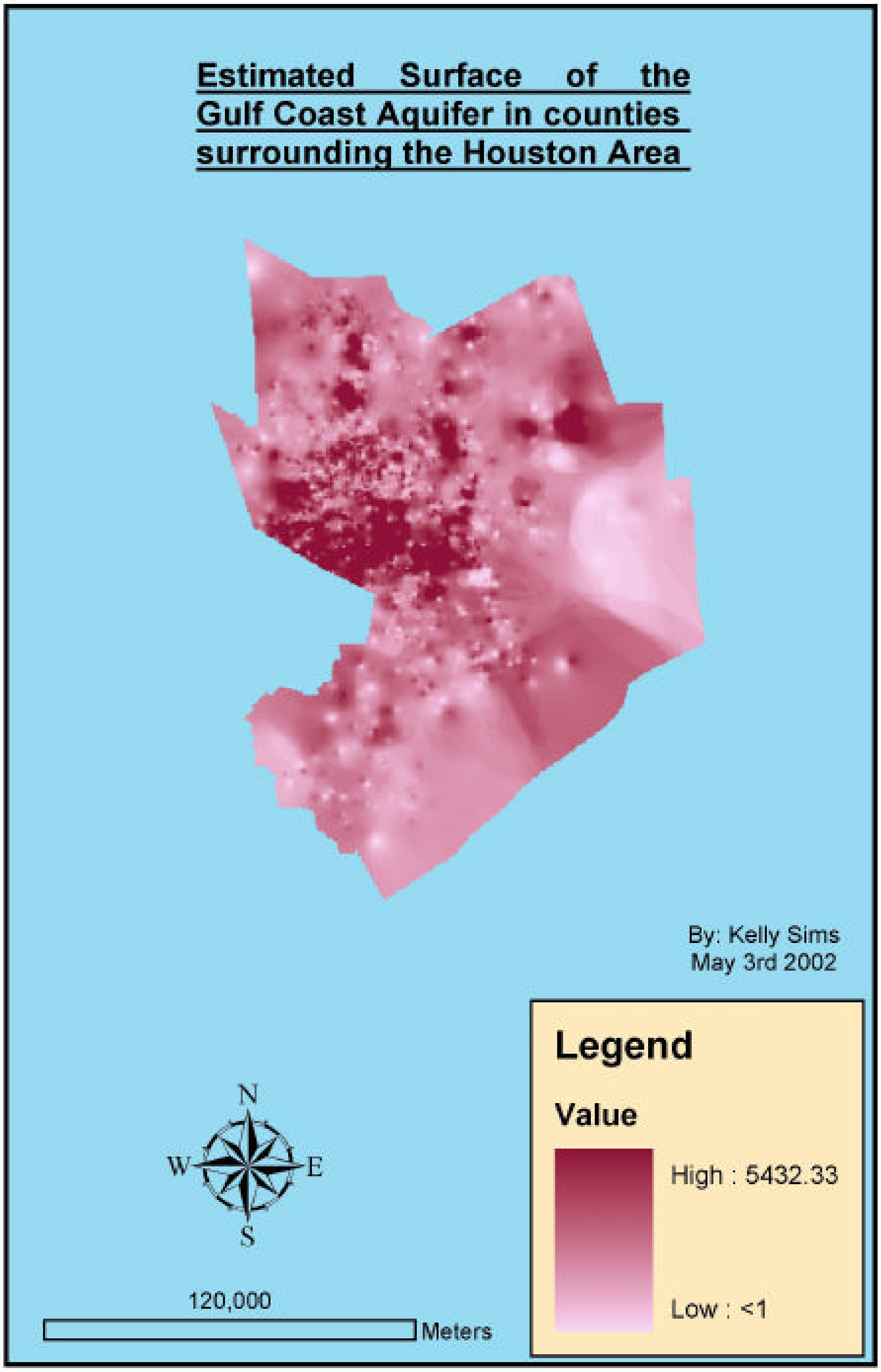

Public Water Supply Wells that are within 0.5 miles of a Hazardous Waste Injection Well in counties surrounding the Houston Area.
MONTGOMERY
LIBERTY
HARRIS
CHAMBERS
GALVESTON
BRAZORIA
N
S
E
W
Legend
Hazardous Waste Injection Wells
Public Water Supply Wells
Counties
140,000
Meters
By: Kelly Sims
May 3rd 2002

Figure 6.


Estimated Surface of the Gulf Coast Aquifer in counties surrounding the Houston Area
By: Kelly Sims
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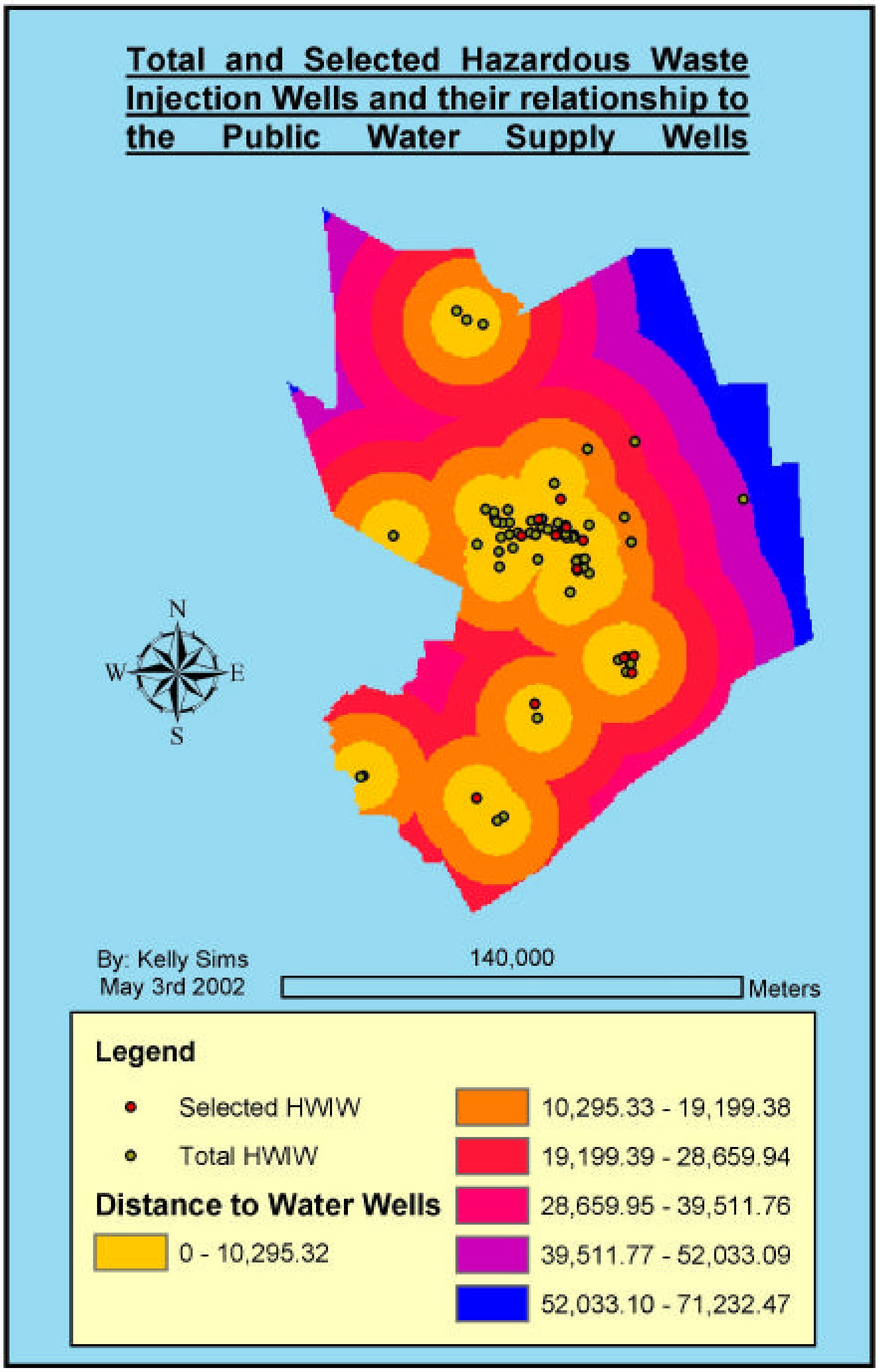
Legend
Value
High : 5432.33
Low : <1
N
W
E
S
120,000
Meters

Figure 7.


Total and Selected Hazardous Waste Injection Wells and their relationship to the Public Water Supply Wells
N
W
E
S
By: Kelly Sims
May 3rd 2002
140,000
Meters
Legend
Selected HWIW
Total HWIW
Distance to Water Wells
0 - 10,295.32
10,295.33 - 19,199.38
19,199.39 - 28,659.94
28,659.95 - 39,511.76
39,511.77 - 52,033.09
52,033.10 - 71,232.47

Conclusion

The research conducted by this paper is important to, not only the population living within the study area, but also to the waste-producing industry and state government. The general population will benefit from the knowledge gained about the potential sources of groundwater pollution from these hazardous waste injection wells that are placed too close to their public water supply wells. An informed public is a more productive public.

The waste-producing industries will benefit from the knowledge of whether their disposal methods have been implemented correctly, which could prevent unnecessary lawsuits in the future. Another entity that will benefit from this research would be the State of Texas. Since they handle the permits for the hazardous waste injection wells, they would be interested in knowing if any industry with poor disposal practices is being overlooked. In summary, this paper proved to be beneficial to several facets of Texas.

Even though some data was not obtainable, benefits still exist in the knowledge that these hazardous waste injection sites are located in close proximity, and in some cases, alarming proximity, to public water supply wells. These hazardous waste injection activities are not only putting precious groundwater at-risk to contamination, but also putting the high density population of the Houston area at-risk.

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