Water Sources for Hydraulic Fracturing in the Barnett Shale

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Term Paper

Introduction:

As the global population continues to grow and countries continue to industrialize, there is a continued, growing need for new energy sources. Unfortunately, as our energy usage as surged exponentially over the past two centuries, so has atmospheric pollution. Given our current energy demands and infrastructures, an immediate, complete switch to renewable energy (i.e. wind and solar) is not the most feasible plan. We need an intermediate source that can produce the energy needed while lessening the amount of pollutions, especially carbon dioxide, emitted into the atmosphere. The most likely candidate for our next primary energy source is natural gas.

Fossil Fuel Emission Levels
- Pounds per Billion Btu of Energy Input

Pollutant	Natural Gas	Oil	Coal
Carbon Dioxide	117,000	164,000	208,000
Carbon Monoxide	40	33	208
Nitrogen Oxides	92	448	457
Sulfur Dioxide	1	1,122	2,591
Particulates	7	84	2,744
Mercury	0.000	0.007	0.016

Table 1. Emitted contaminants from various fossil fuels. (EIA - Natural Gas Issues and Trends 1998)

In the above comparison table among the three fossil fuels – oil, coal, and natural gas – it is clear to see that natural gas is the ‘cleanest.’ Except for carbon monoxide, which is than oil emissions but still much less than that of coal, natural emits much less pollutants than coal or oil.

There are many natural gas reserves located throughout the United States, as shown in figure 1, and one of the largest, the Barnett Shale formation, is located in Texas. Being able to extract the gas and use it as an alternative to coal and oil would not only help to reduce pollution, it would also lessen our demand on foreign oil. Extraction and processing of the natural gas would also give cause for more jobs. So besides being better (it is still polluting, just not as much) for the environment, incorporating more natural gas into our energy sources could potentially have great economic effects as well. One of the issues, however, with natural gas, is that most of the reserves are found in shale formations that have low permeability, thus making it difficult to extract the gas. A proposed solution is to fracture the formations by injecting water under high pressure. In Texas, water is becoming a scarce resource, and so water that will be used for this fracturing process or ‘fracking’ as it has been dubbed should not come from any potable source of water. The purpose of this project is to analyze well logs and construct datasets and maps that display the best locations for well placements in four counties (Montague, Wise, Hood, and Parker) that can extract water to be used for fracking in the Barnett Shale.

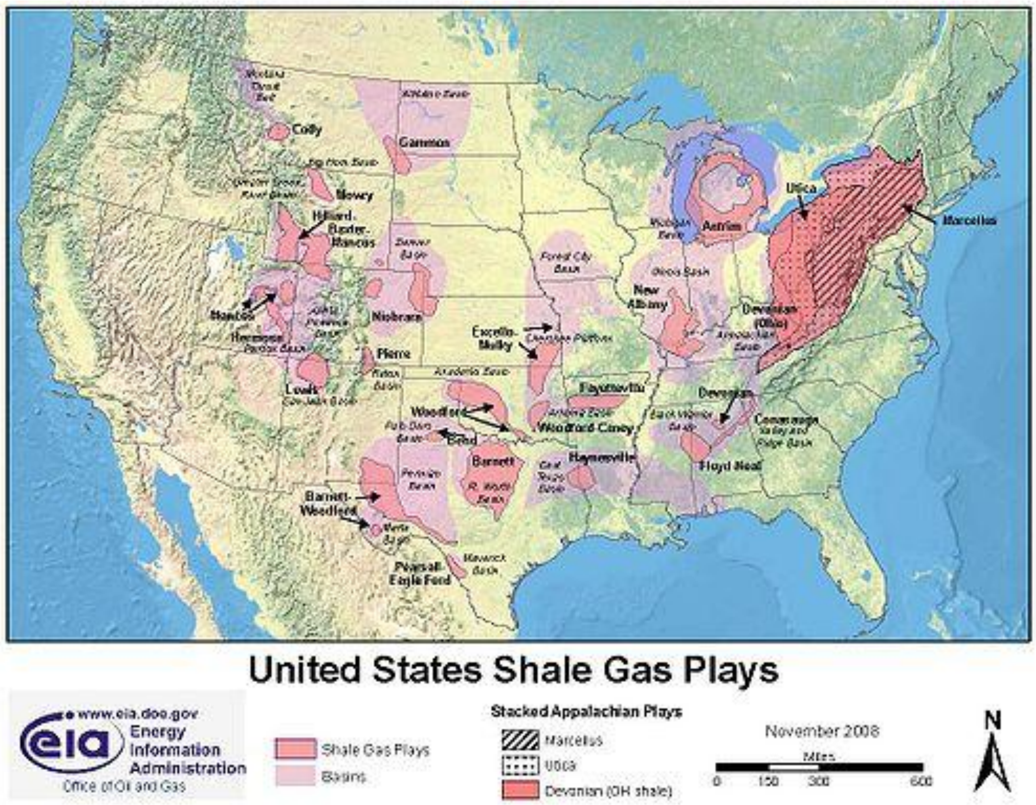

Figure 1. Location of natural gas reserves in the United States. (Energy Information Administration)

Background Information:

Barnett Shale

The Barnett Shale is located in the Bend Arch-Fort Worth Basin in northern-central Texas. It is now estimated that potential production area covers 5,000 square miles, throughout over 20 counties (Fig. 2) (Bruner and Smosna). The formation primarily consists of shales and other sedimentary rocks of Mississippian-age (~350-325 Ma). It was first discovered in 1980 that the Barnett Shale contained natural gas in its pore space. As geophysical technologies have evolved, so has the estimated amount of hydrocarbons, primarily natural gas, in the shale.

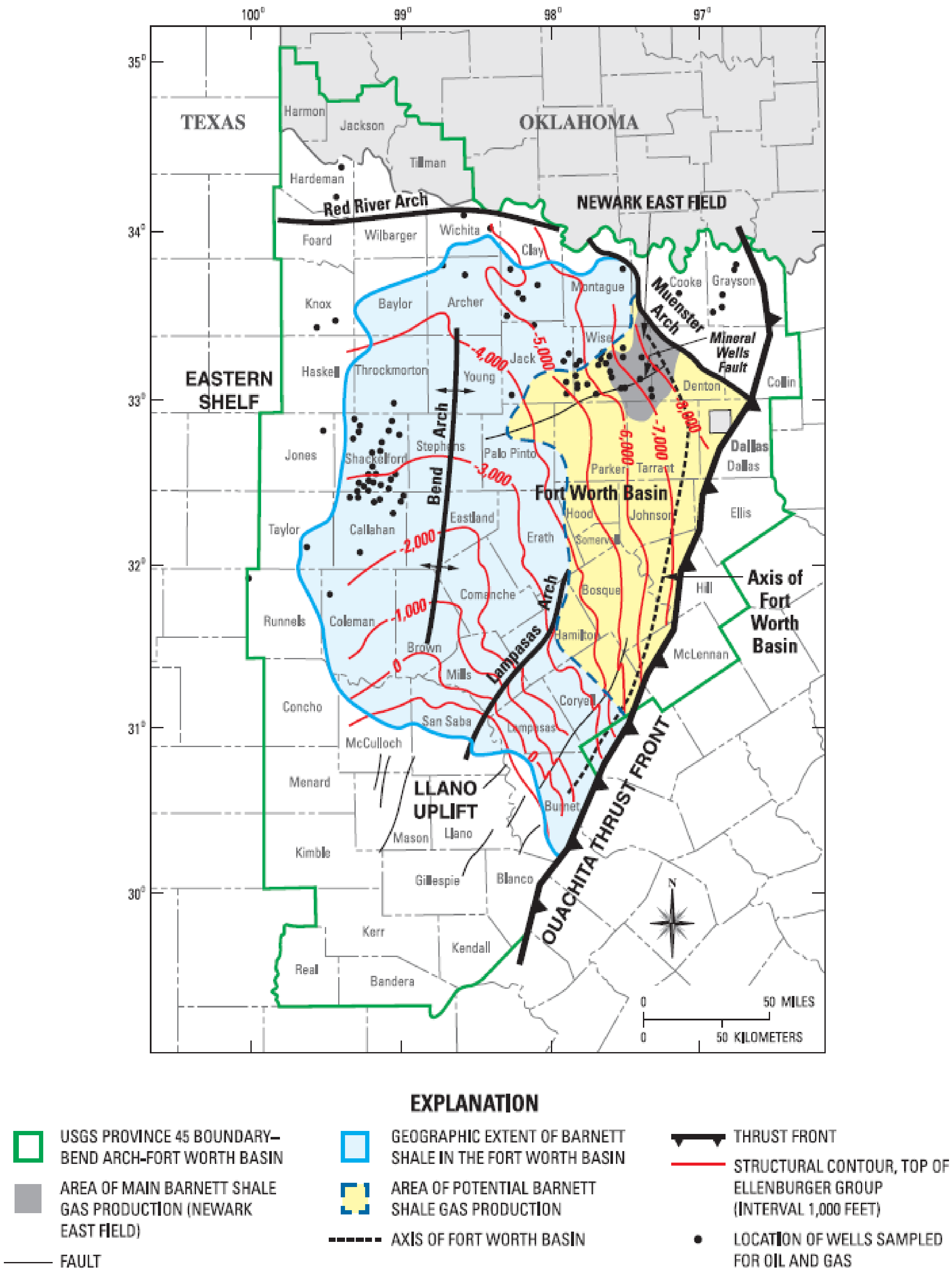

Figure 2. Estimated extent of the Barnett Shale production area. (Bruner and Smosna)

Estimates for the total amount of gas in the shale vary greatly. Some estimate the total capacity to be around 250 trillion cubic feet (TRC), but the majority of that will probably not be able to be recovered. Recoverable amount estimates range anywhere between 2.5 to 30 TCF. Given the exponential growth (Fig. 3) in production and continuous advancements in drilling and extraction techniques, it is hard to make a definitive estimate, as that number always seems to be increasing.

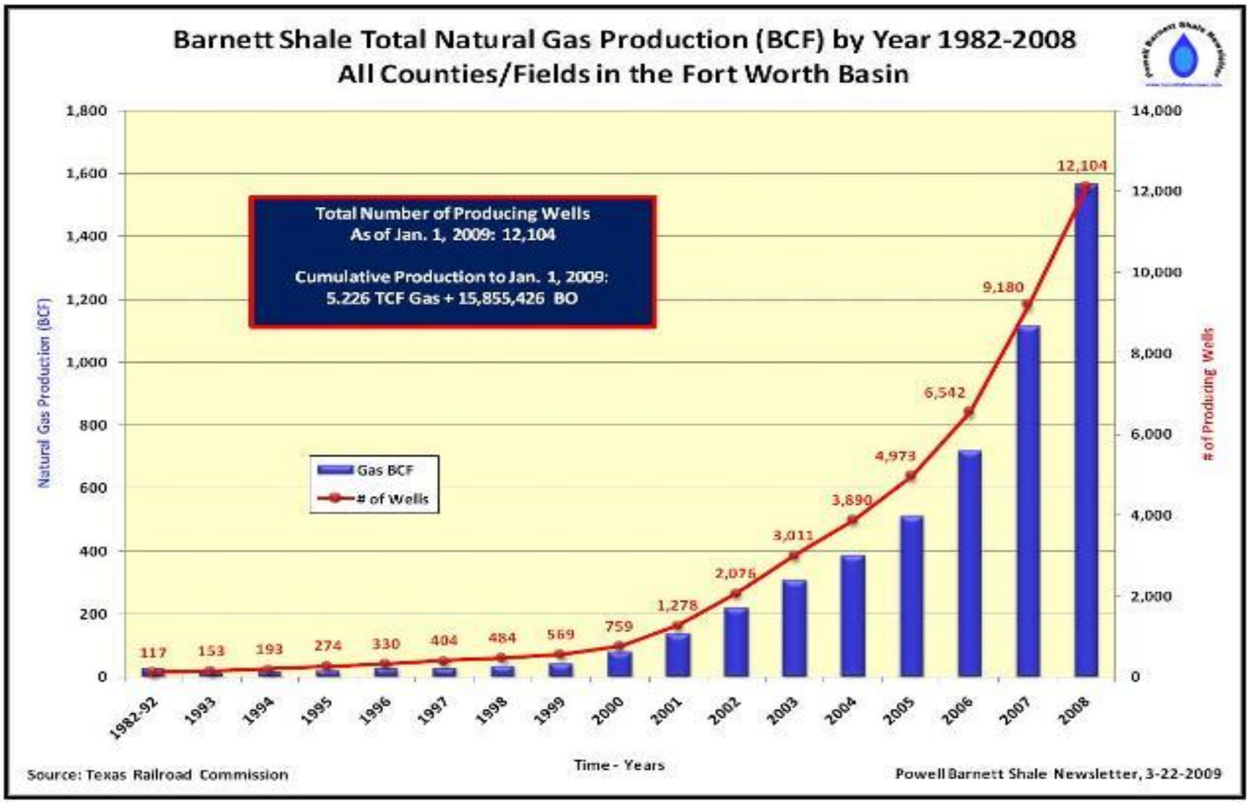

Figure 3. Production history of the Barnett Shale. (Texas Railroad Commission)

Hydraulic Fracturing ("Fracking")

As previously mentioned, most gas reserves are tied up in shale formations. Shale is a microporous (i.e. very small spaces in between grains), sedimentary rock, but it has a low permeability, meaning the pores are not always connected (Brauner and Smosna). While shale formations contain large amounts of gas, because of their low permeability, drilling a single vertical well would not yield a high production. During the past couple decades however, two drilling techniques have emerged that help to overcome this problem – horizontal drill and hydraulic fracturing ("fracking") (US DOE).

Fracking is the process in which water is injected through a well into a formation and higher pressure than the rock strength in order to break apart the rock, propagating fractures to connect the once sealed off pores (US DOE). Once these pores are connected and the permeability is increased, a production well then can be used to extract a much greater amount of hydrocarbons. Controversies have risen over this practice. When water is injected, it sometimes contains chemicals that help to dissolve the rocks. Once the hydrocarbons have been extracted this water is also extracted. Since fracking is a rather new practice, strict regulations have not been put in play to assure of the proper and safe treatment and disposal of this water. Some people have fears about this water contaminating their drinking water, along with the fear the fracking will allow methane to leak up into their aquifer systems as well. As it seems that fracking is a necessary technique for much gas extraction, it is imperative that strict regulations are implemented and enforced in order to assure the safety of drinking water.

Data Acquisition and Analysis

The data used for calculating water availability and location came from the extensive database of well logs kept by the Texas Commission for Environmental Quality (TCEQ). The TCEQ keeps records of all water wells drilled in the state; however the information that is recorded during the drilling processes is not regulated very strictly, meaning even though there may be records available, they may not be useful due to lack of information.

The well log database was downloaded in Microsoft Access and then the selected counties were transferred into an Excel spreadsheet. Since GPS is a rather recent invention, well locations are based off of a USGS gridding system. For each county, a grid number is provided that has links to PDFs of all the well logs in that grid. The properties that were used for this project included depth to water, pumping rate, and drawdown. Only data from wells that extend past the base of the Trinity Aquifer were used as to limit the risk of extracting water from one of the major potable aquifer systems in Texas. Also, wells that had complete information for the above mentioned properties were entered into the spreadsheet (Fig. 4).

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	County	Grid Num	Depth to Bottom of Trinity Aquifer	Date Drilled (completed)	Well Diameter (in)	Well Depth (ft)	Pump Depth (ft)	Gravel Packed (Yes=1)	Number of Screens	Screen Data ? (Yes=1)	Casing1 Diameter (inch)	Screen1 Top (ft)	Screen1 Bottom (ft)	Screen1 Type	Depth to Water (ft), neg = below land surface	Pump rate (gpm)	Drawdown (ft)	Pumping Time (hr)	Test Type1	Page Number; Comments and Notes
866	MONTAGUE	19-34-6	64	4/13/1998	7.5	260	-	1	0	-	4.5			SCH40	100	20	160	1	J	P. 3/5
867	MONTAGUE	19-34-6	64	1/9/1995	7.25	200	-	1	0	-	4.5			PVC40	40	25	100	1	J	P. 4/5
868	MONTAGUE	19-34-6	64	8/23/2000	7.5	130	100	1	1	1	4.5	120	130	SCH40	70	15	70	2	J	P. 1/49
869	MONTAGUE	19-34-6	64	8/24/2000	7.5	125	100	1	1	1	4.5	105	125	SCH40	70	20	77	3	J	P. 3/49
870	MONTAGUE	19-34-6	64	5/10/2000	7.875	400	340	1	1	1	4	360	400	SCH40	200	30	60	1	J	P. 5/49
871	MONTAGUE	19-34-6	64	5/15/1997	7.25	340	-	1	0	-	4.5			SCH40	180	40	190	1	J	P. 11/49
872	MONTAGUE	19-34-6	64	9/12/1997	7.25	460	-	1	1	1	4.5	300	460	SDR17	250	50	240	1	J	P. 12/49

Figure 4. Snippet of the spreadsheet with well log information entered.

Once all well logs were analyzed, averages of the depth to water, drawdown, and pumping rates were computed for each grid cell. Then the average specific capacity was calculated by dividing the average pumping rate by the average drawdown.

GIS Processing

The first thing done in GIS was to create a base of the counties of interest and then overlay that with the USGS gridding system. Maps of the counties in Texas and of the gridding system were downloaded from the Texas Parks and Wildlife and Texas Water Development Board websites and then imported into Arc GIS. In order to focus only on the counties of interest, I used the attribute table to select Montague, Wise, Parker and Hood and then created a new feature layer of only those counties. I cropped the grid system map by using the “Select by Polygon” tool and once again created a new layer. Figure 5 is the result of this.

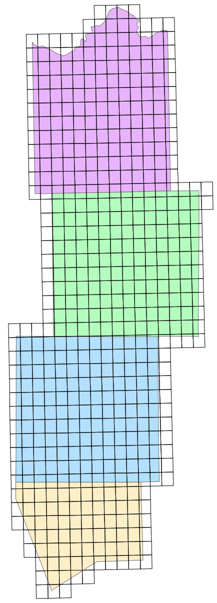

Figure 5. Counties of interest: Montague (purple), Wise (green), Parker (blue), Hood (orange)

The Excel spreadsheet containing the averaged properties was then imported into ArcMap. I joined the imported table and grid attribute table by linking the grid numbers. I then altered the symbology display fields in order to produce two maps, one showing depth to water (Fig. 6) and another showing specific capacity (Fig. 7).

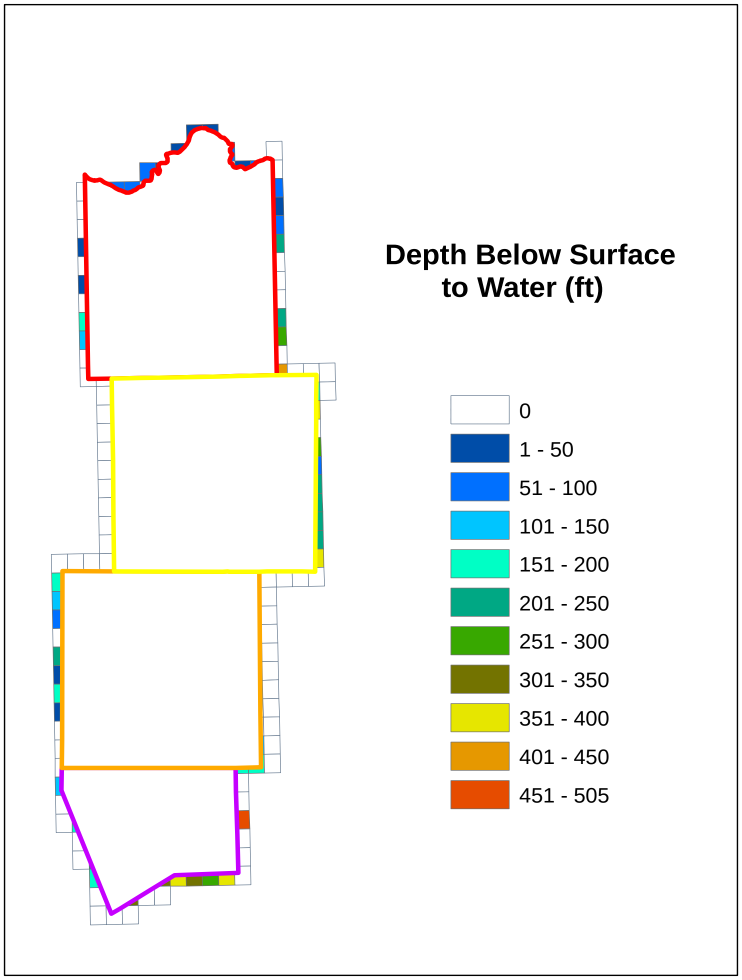

Figure 6. Constructed map showing the average depth to usable water (0 = no data).

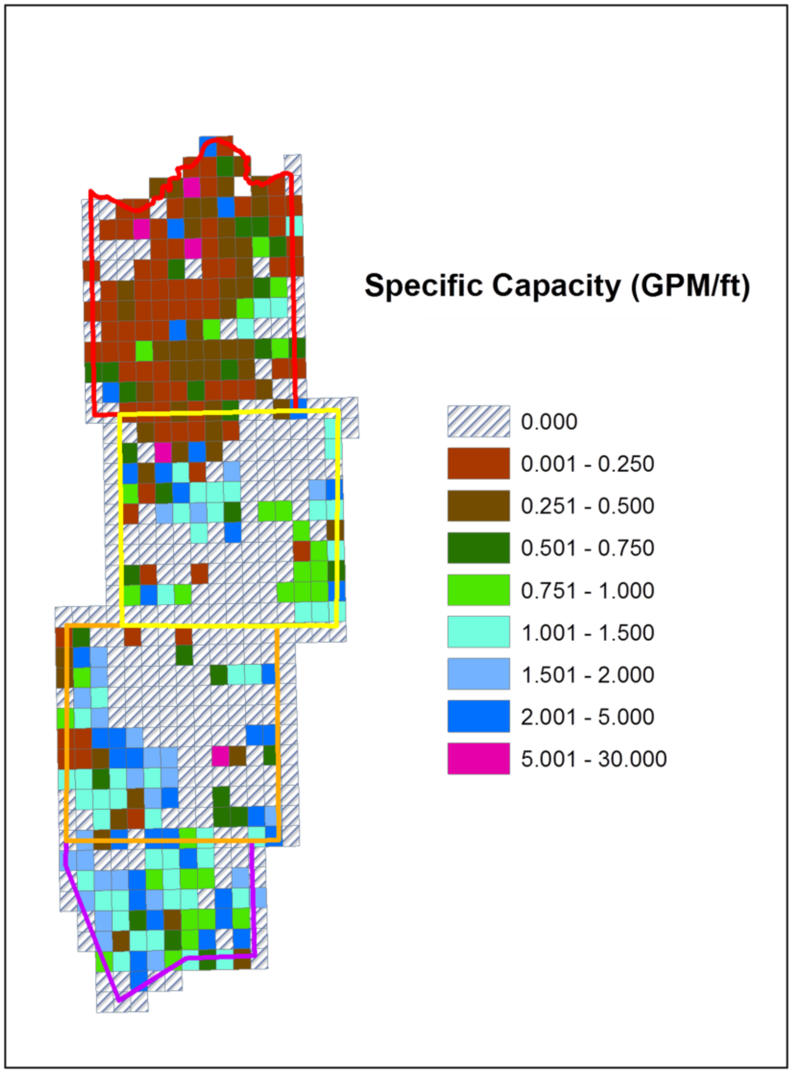

Figure 7. Constructed map showing average specific capacity (0 = no data).

Next, I created two new columns in the grid attribute tables and use the calculator to write an 'If then' statement that would assign ranking values based on water level and specific capacity; specific capacity was weighted more because I considered it to be more important. I then created a third column that summed the ranking values and created my final map (Fig. 8) that shows where, based on my ranking, are the best spots to drill.

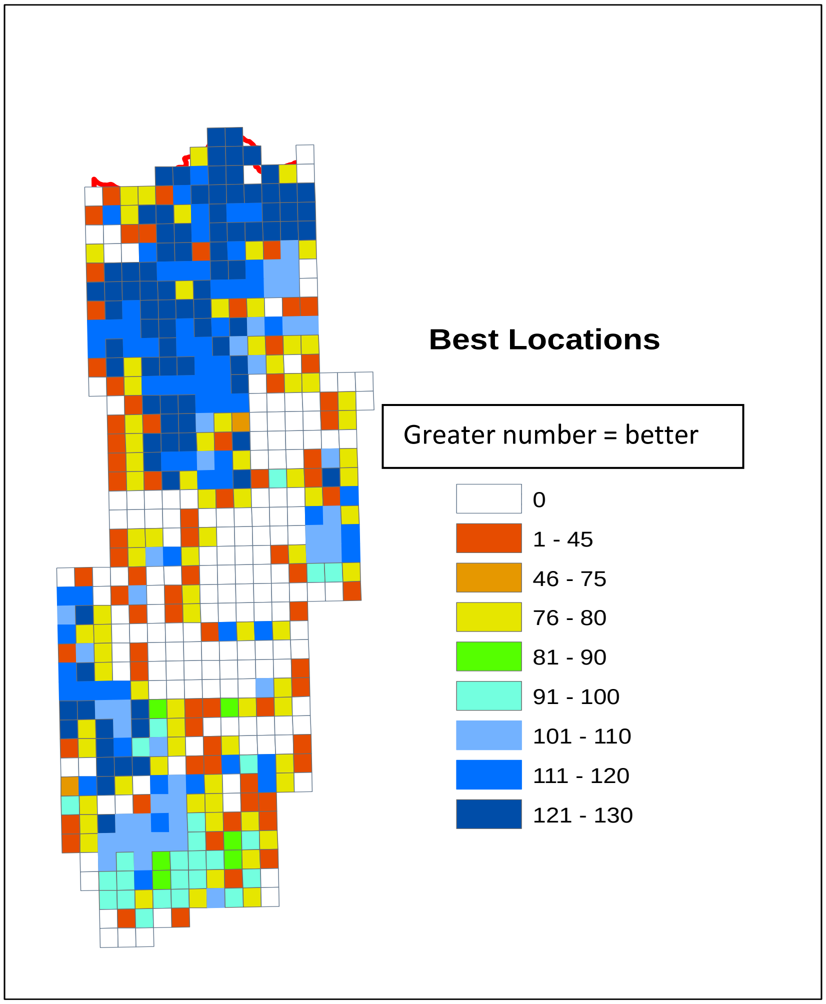

Figure 8. Constructed map showing best places to drill (0 = no data).

Results

As shown in the above figures, Montague has the shallowest depths to water, while Hood has the greatest specific capacities. With the ranking system I used, despite giving more weight to higher specific capacities, Montague was shown to be the best area for drilling wells.

Data interpolation was not used to fill in the missing grid cell data because subsurface geology can be so heterogeneous that a geostatistical analysis would have to be performed first in order to get an applicable result. When drilling a well that will cost much money, you would want to base your location off of more concrete data and not rough estimations. If the missing data was known, it may change the drilling location results.

Conclusions

Drilling in Montague would require shallower wells, but you would not extract that much water. Hood has higher capacities, but wells would have to be over 400 feet deep. Not having exact GPS coordinates also skews these results to give a greatly averaged display. Given the amount of missing data due to incomplete well logs and then a significant amount of the pumping rates and drawdowns were based off of estimations, these maps could be very inaccurate with regards to specific capacity. Also, some of these well logs were from over 40 years ago and so those wells may now be dry. To construct a more accurate map, it may be better to base it off core logs and incorporate more hydrogeological data.

References and Sources

Energy Information Administration

TCEQ Water Well Reports

Texas Parks and Wildlife GIS Lab Map Downloads

Texas Water Development Board GIS Data

Texas Railroad Commission

US Dept. of Energy, Energy Citations Database – Mechanics of hydraulic fracturing

Bruner, K. R., and Smosna, R. "A comparative study of the Mississippian Barnett Shale, Fort Worth Basin, and Devonian Marcellus Shale, Appalachian Basin." URS Corp. National Energy Technology Lab., US DOE. 2011.