Mapping changes in water consumption in Texas river basins due to changes in water demand by Electricity Generating Units (Power Plants) in the wake of highly volatile Natural Gas Prices.

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Introduction:

The production of natural gas and natural gas co-products is increasing dramatically in the United States, enabled by technologies such as horizontal drilling and hydraulic fracturing of shale formations. This transformation in the production of shale gas is directly impacting US fuel distribution, electrical generation, and water distribution infrastructures, and is expanding fuel exports. These collective changes in electricity and fuel infrastructures have impacts on water consumption & thus affect its availability. This happens because the water is used for cooling etc. by Electricity Generating Units, also called as Power Plants, to generate electricity. These power plants have different water requirement depending upon the energy source they use to generate electricity such as coal, Natural Gas, Nuclear, Petroleum Products etc. Moreover, water finds great demand while employing the techniques such as hydraulic fracturing which are used extensively to extract oil and natural gas. Now, in the scenario when Natural Gas is being extracted extensively using hydraulic fracturing, it has resulted in a huge pressure on the available water resources. Moreover, given the rapid fall in natural gas prices over the past 10-15 years, the entire fuel economy of US has seen a great amount change. This is easily evident from the fact that today natural gas contributes to around 35 % of the net electricity generation as compared to around 15% almost two decades ago. Now given the large percentage contribution of natural gas towards total electricity generation, even slight fluctuation in its prices has significant effects on the overall fuel consumption & electricity generation patterns.

Talking about the state of Texas, this effect is even more pronounced. In Texas, the percentage contribution of various energy sources towards total electricity generation can be depicted in the form of a pie chart as follows:

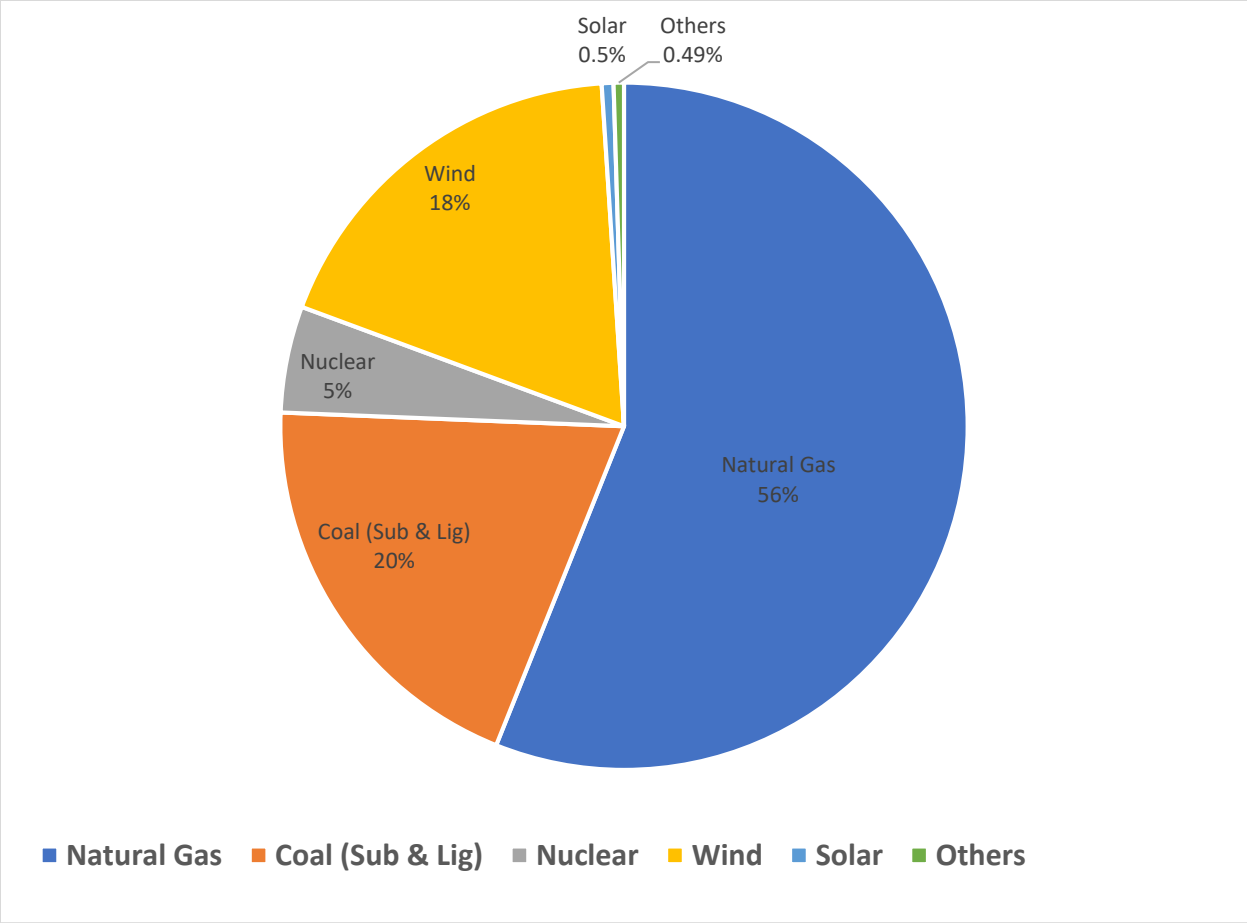

Fig. 1 (2017 Scenario for the State of Texas, US Energy Information Administration, Form EIA-860)

The pie chart in Fig. 1 reveals that in 2017, the electricity generation scenario was governed majorly by natural gas & in fact huge thrust is being given to wind & solar which is bound to result in even more quick changes in the electricity generation scenario in years to come. All these changes ultimately effect the water consumption in the river basins as already discussed above.

Objectives and Scope:

This project aims to map & thus highlight the impacts of changing water consumption in different river basins of the state of Texas due to changing water usage by the power plants, which is further dependent upon availability & price variability of natural gas vis a vis other fuel type. As the data pertaining to the water consumption in different river basins is mapped using ArcGIS Pro over the period of years, & it is simultaneously compared to the relative percentage contribution of different energy sources to generate electricity, we can expect to observe a pattern of the effect of such activities (i.e. hydraulic fracturing & too much use of natural gas to generate electricity) on the water availability in the river basins. Accordingly, we can reasonably & hopefully reliably as well, predict the future variations in water availability in basins viz a viz the percentage utility of different fuels to generate electricity. This study thus aims to address the broader concern of suitably managing the water resources & thus lead to an equal society where everyone has reasonable access to required water resources. Through this study, it is envisaged that we can strive for a scenario where we can minimize the negative effects of anthropogenic activities such as hydraulic fracturing and electricity generation, through efficient & intelligent water resource use.

Data Sources and Procedure:

Firstly, the shapefile for the 23 major U.S.G.S. river basins in the state of Texas was downloaded from the official website of the Texas Water Development Board (TWDB). Additionally, the shape file for various major rivers in Texas (Data extracted from NHD, 1:100,000 layer) was also downloaded from TWDB website. Not to forget, the Texas State boundary shapefile that was downloaded from the home of the US Govt's open data i.e. the data.gov website. These shapefiles were then added to a topographic base map in ArcGIS Pro as shown in Fig. 2. Thereafter, historical data for the shapefile of the power plants was downloaded from the website of the US Energy Information Administration for the period of study (year 2008-09). These are the power plants that were operating, on standby, or short- or long-term out of service with a combined nameplate capacity of 1 MW or more during that period. 'Clip'- Analysis tool was used to clip & thus get only those power plants lying within the State of Texas. Some modifications in the labelling representation of power plants was done to make them clearly visible & distinguishable from one another as shown in Fig. 3.

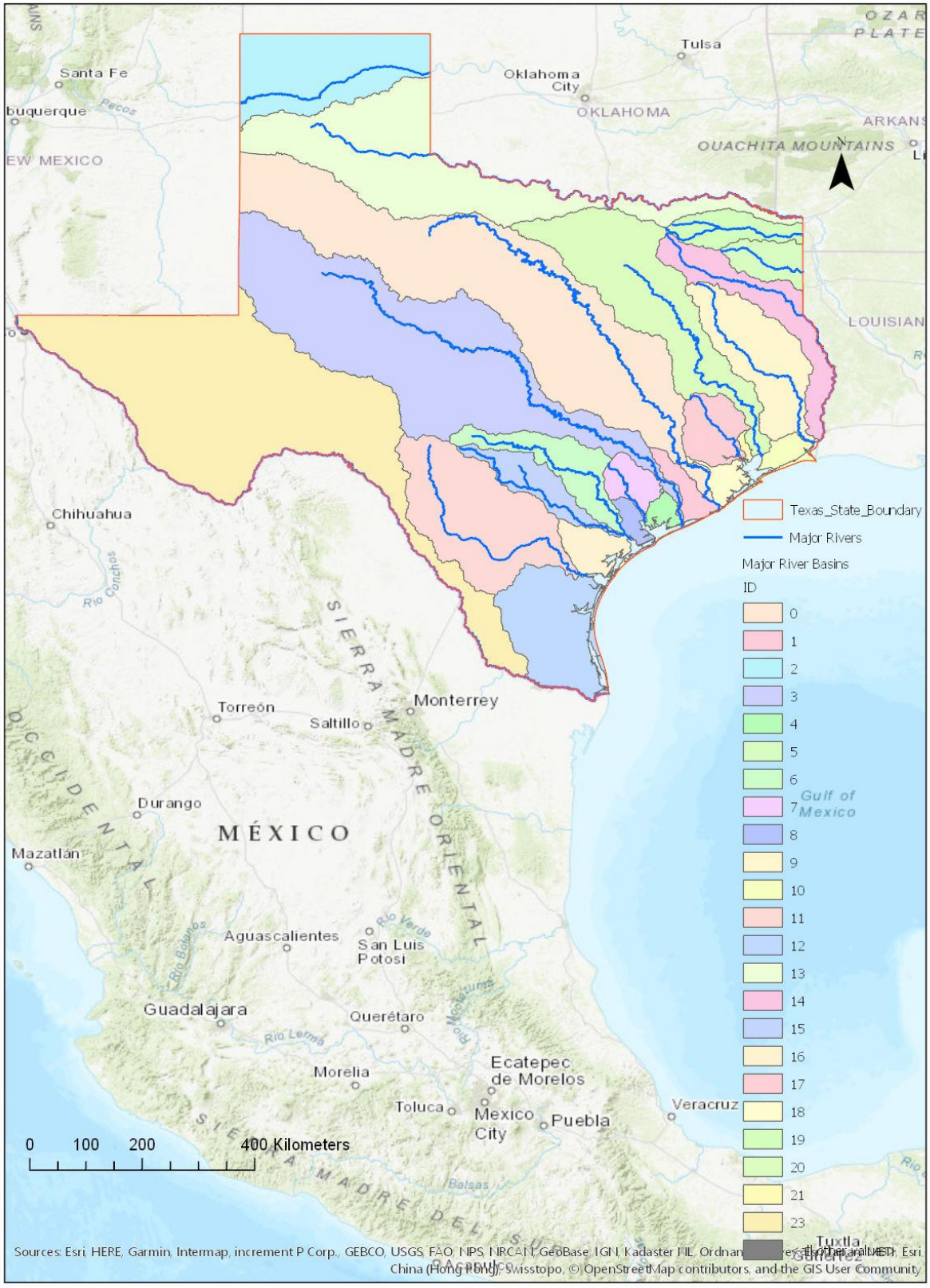

Fig. 2: Map of the State of Texas showing the major USGS rivers & 23 major river basins.

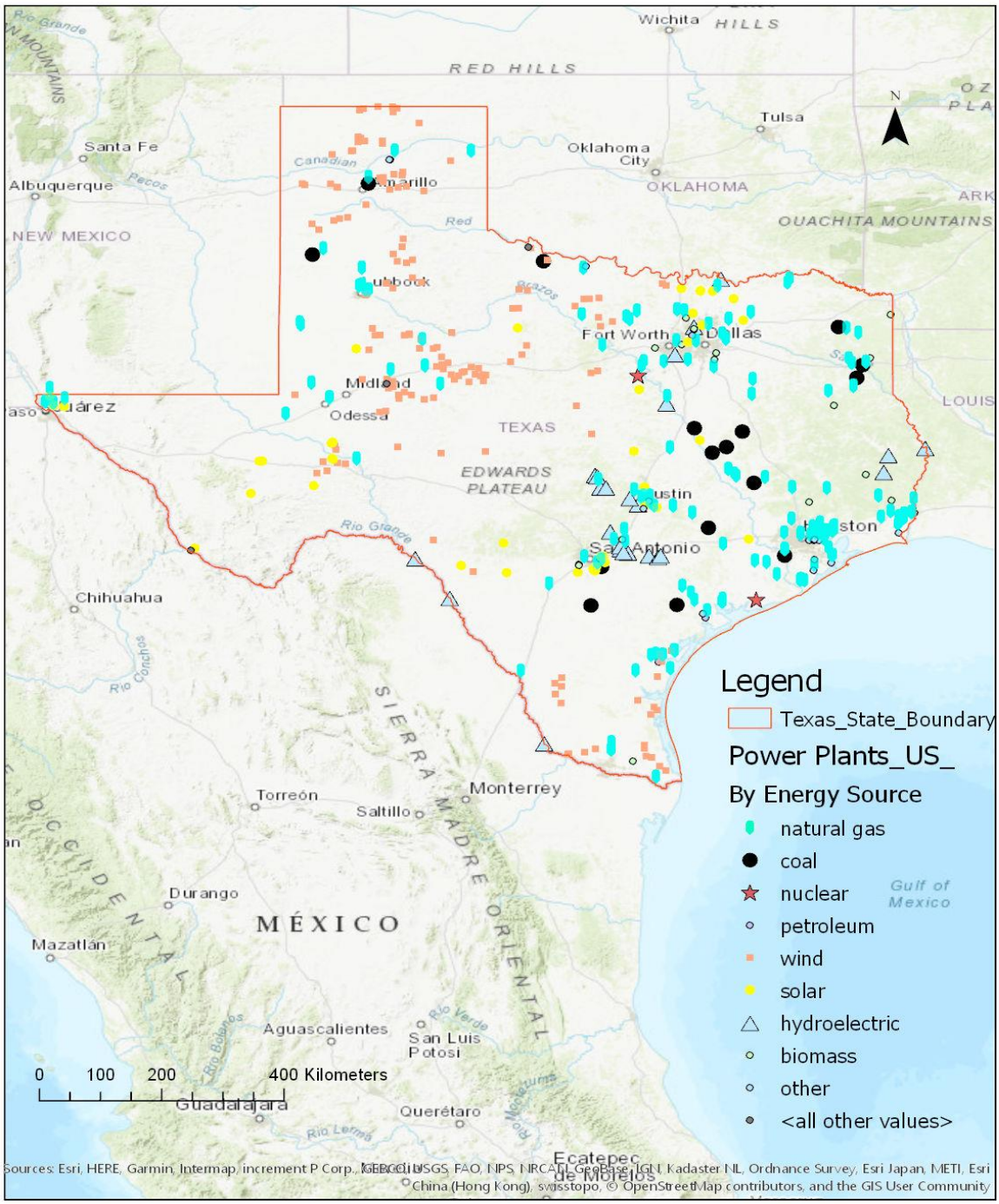

Fig. 3: Map showing the locations of the power plants based on the source of energy they use as the fuel to generate electricity, in the State of Texas.

Thereafter, the rivers, river basins & power plants were plotted together (Fig. 4) in the ArcGIS map to see whether there is any pattern observable regarding the locations of these power plants. An important observation that can be made from this map is that most of the thermal power plants i.e. the ones based on coal, natural gas and petroleum and also the nuclear power plants, happen to be situated usually near the major rivers. This is because of the obvious reason that these power plants require water in enough quantity for purposes like cooling etc. in order to carry out their operations smoothly.

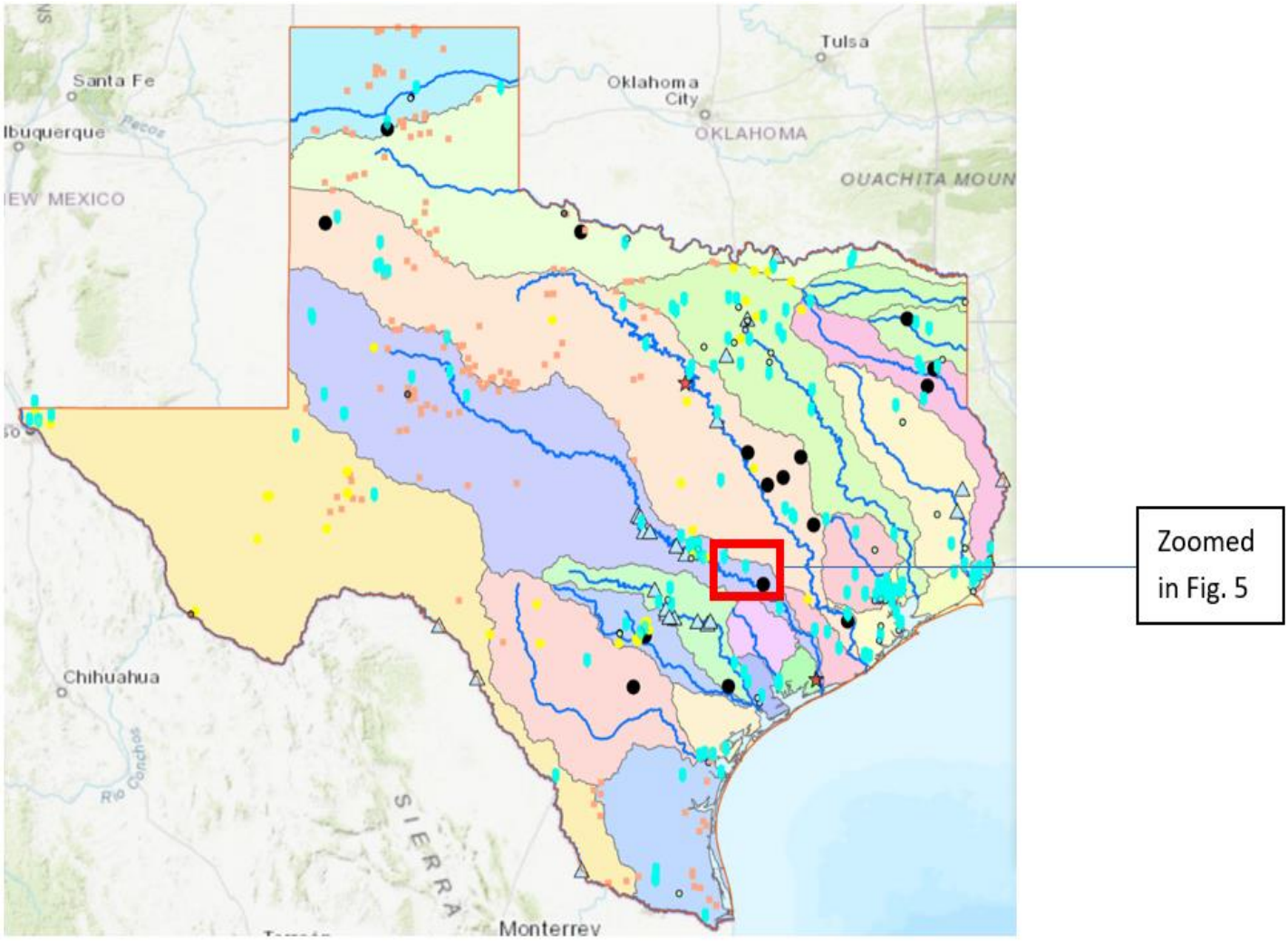

Fig. 4: Map showing the power plants, major rivers & major river basins of Texas to observe the pattern of the locations of the power plants.

Afterwards, it was decided to zoom in into the map to look for finer details. Shown below is a snapshot of the map in Fig. 4 where a red colored box is marked which is zoomed after rotating the map by 45 degrees to make clearly visible the locations of power plants near the Colorado river (depicted in blue color below). In fact, all the power plants in this case, happen to be either natural gas or coal as shown in Fig. 5 below:

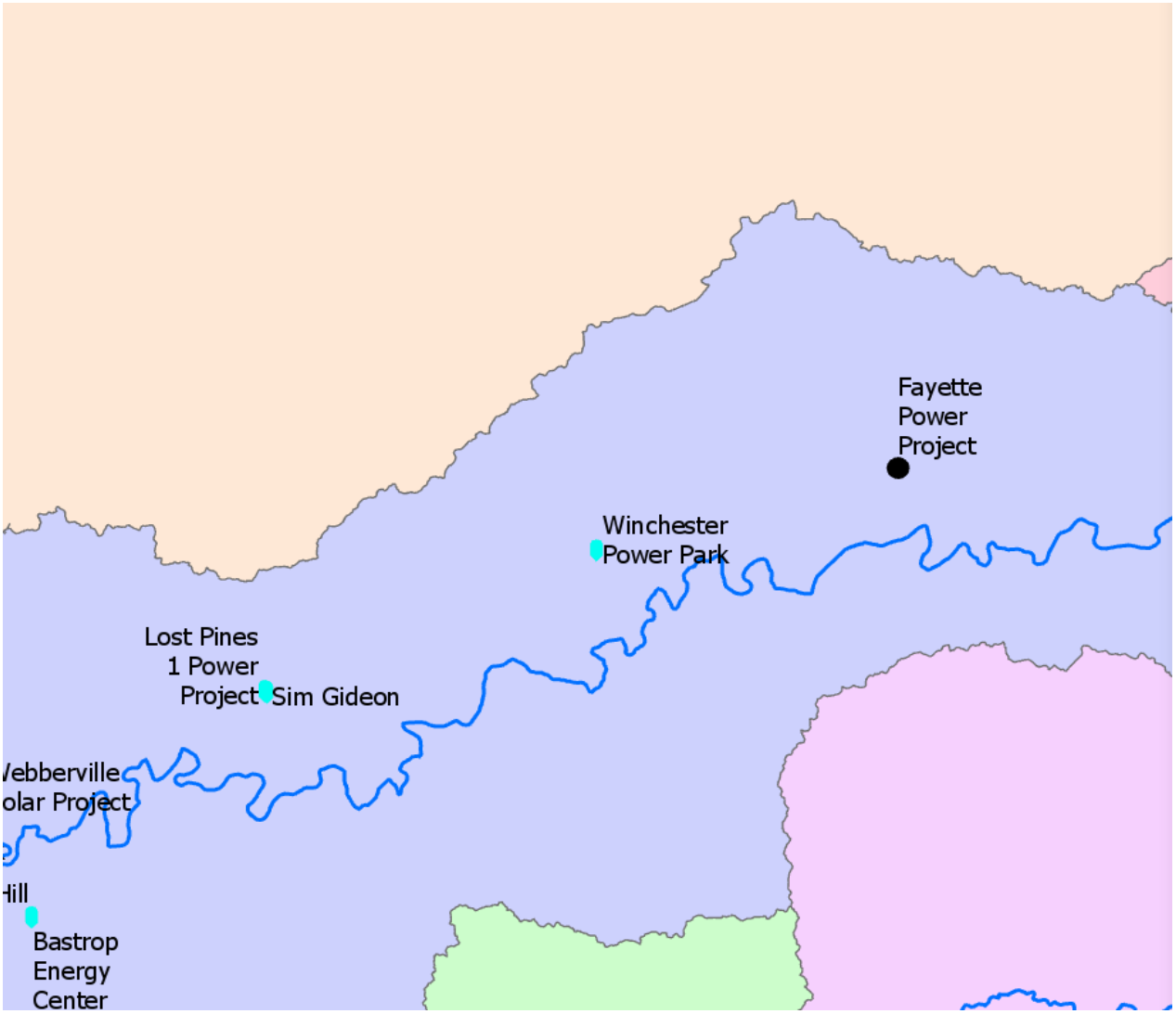

Fig. 5: Image showing the spatial locations of power plants near the banks of Colorado river. (Blue dots: Natural Gas, Black dots: Coal)

Analysis:

Having plotted the rivers, river basins & power plants in ArcGIS & making certain inferences from the plot, then, the next step i.e. the analysis part required data pertaining to change in water consumption during the period of study (2008-09). The research work of Pacsi, A. P. et al. 2014 and Pacsi, A. P. et al. 2013, was consulted and the requisite data for further analysis was derived from that study. Among the various fuel types, those that require water to an extent to exert a considerable effect on the water availability in the river basins, are natural gas, coal, nuclear & petroleum. So, focusing on the power plants based on these energy sources, let us see how the water consumption changes in the Texas river basins over a defined time interval. The data used here has been taken from the study conducted from Aug 2008 through Dec 2009, also published in the form of a scientific research paper (Pacsi, A. P. et al. 2014). The following map (Fig. 6) shows that there is a maximum increase in water consumption (> 3.0 billion gallons) in the Trinity river basin (Red colour). This is easily understandable because of the presenece of the large number of natural gas power plants in that basin. On the other hand, Brazos river basin, though does contain a few natural gas power plants, but shows the maximum decrease (> 3.0 billion gallons) in water consumption. This is because of the presence of 7 major coal power plants, with large nameplate capacities, in that basin, which are the major guzzlers of water in that basin & thus offset the effect of the presence of a few natural gas plants.

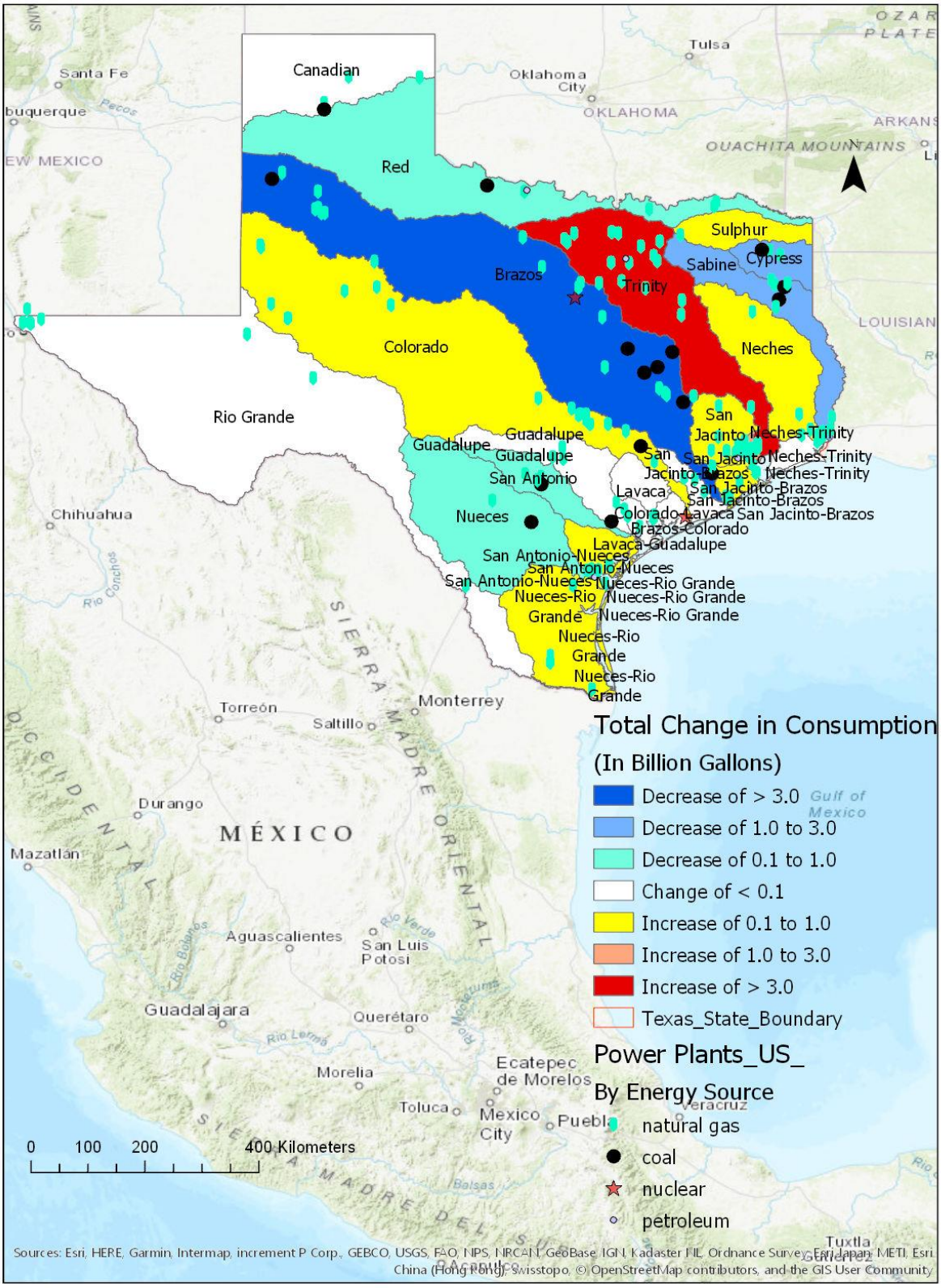

Fig. 6: Map showing the change in the water consumption of the river basins during the period of study, 2008-09. (Pacsi, A. P. et al. 2014)

Discussion and Conclusion:

It is to be noted here that, over the period of past 10-15 years, the U.S. fuel economy has been greatly influenced by the rapid increase in the usage of natural gas to generate electricity due to advances in hydraulic fracturing technique. Thus, even small changes in the prices of natural gas (or the natural gas price volatility) can have a measurable effect on the water consumption changes of the river basins.

This way, these changes in the water consumption of the Texas river basins are proposed to be mapped every year from 2008 onwards. Then suitable inferences shall be drawn from the pattern that would emerge. These inferences shall be used to develop a scientific & economically viable water management policy such that it will outline the guidelines regarding the relative operationality of power plants such that those areas with poor water availability must face least water stress. Thus, this ArcGIS project shall act the fulcrum of the author's broader research work which is currently in the phase of collecting the requisite data pertaining to changes in water consumption of the Texas river basins, for the years onwards 2009, on the lines of the scientific study conducted & published in the form of research papers referenced below. (Pacsi, A. P. et al. 2013) (Pacsi, A. P. et al. 2014).

References:

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2. Power Plants Layer Info, US Energy Information Administration (https://www.eia.gov/maps/layer_info-m.php)
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5. Pacsi, A. P. et al. Changing the spatial location of electricity generation to increase water availability in areas with drought: A feasibility study and quantification of air quality impacts in Texas. Environ. Res. Lett. 2013, 8, 035029.
6. Pacsi, A. P. et al. Spatial and Temporal Impacts on Water Consumption in Texas from Shale Gas Development and Use. ACS Sustainable Chem. Eng. 2014, 2, 2028−2035.