THE RISK VERSUS ECONOMIC BENEFITS FOR THE ALTERNATE ROUTE OF THE KEYSTONE PIPELINE IN THE NEBRASKA REGION

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by

Matthew R. Young

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DEDICATION

This master's thesis is dedicated to both my sets of grandparents who gave me a truck and money to get through my years of college.

ABSTRACT

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Keystone is a project that extends from Alberta, Canada to the Gulf Coast in Texas. It crosses an international border and is divided into two segments with the first segment extending from Alberta, Canada to Steele City, Nebraska and the second segment from Steele City, Nebraska to the Texas Gulf Coast. Lots of controversy has been raised about this project especially in the Nebraska region where it crosses endangered species, the Sandhills, and the Ogallala Aquifer. Thus, opposing sides were created involving environmentalist and "oil people" with both arguing whether or not the risk is greater than the economic benefits or vice versa. A GIS helped answer this question by using geoprocessing tools and combining several different variables for a risk assessment in order to create a map showing the overall risk using risk classes along the pipelines corridor. Percentages of the risk classes were then able to be compared to economic information involving county benefits such as taxation and spill cost. Although, with Nebraska being a Republican state the economic benefits received a higher weight in the comparison. Rankings were made for the counties but became subjective in which, risk assessments become subjective at some point. Additionally, spill cost was observed in comparison to the risk assessment and analyzed using a formula that was created specifically for finding the total economic risk of TransCanada. Other risk factors such as terrorism and pipeline diameter are mentioned in stating that the pipeline is prone to other factors.

KEY WORDS: Rankings, Subjective, Factors, GIS, Economics, Benefits, Pipeline, Nebraska, Risk

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CHAPTER I

Introduction

The Keystone XL Pipeline is a 1700 mile pipeline project proposed to stretch from Alberta, Canada to the Gulf Coast in Port Arthur, Texas. Its project plan is divided into two separate segments, a north and southern part with the southern part stretching from Cushing, Oklahoma to the Gulf Coast refineries while the northern part connects Alberta, Canada to Steele City, Nebraska across the states of Montana, South Dakota, and Nebraska. The southern leg has already been approved and was built starting in January of 2014, unlike the northern section that's created controversy among environmentalist and "oil people" in the Nebraska region over economic benefits and environmental disturbances. Environmentalists argue that the impact on the environment and people is too drastic and that the economic benefit is not worth the risk, while the "oil people" insist on a one eighty view. In which, has created a simple formula of risk versus reward, involving several differing factors that can be demonstrated spatially within a GIS. The use of the GIS encompasses a variety of methods for the establishment of a risk analysis involving the likelihood and consequence of the pipeline breaking by combining specific variables involving pipeline characteristics, environmental parameters, and human population and comparing it against the economic benefits of taxation, materials, and services at the county and state level of Nebraska. Although, subjectiveness still coordinates itself with risk versus rewards by discussing levels of "risk tolerance, which depends on subjective and personal judgments". (Kirchoff et. all, 2012) Therefore, based on readings the proposed Keystone pipeline route through Nebraska provides the region with sufficient economic rewards through taxation, materials, and services. These

benefits outweigh the different risk factors associated with crossing sensitive areas of geological and environmental significance, as well as those areas with notable human population when processed using a GIS.

Literature Review

Many controversial topics have occurred throughout the Keystone process over the years that intertwine the risk versus economic benefits. People have argued that the Keystone pipeline will be too impactful to the environment. Although, the final environmental statement provides information stating that the impact will be softened with many protocols such as relocating the American Burying Beetle that only lives a few inches below the ground. In addition, a high tech pigging system will be used to detect leaks along the pipeline according to TransCanada. The system will be the most advanced system ever created plus, an upscale protective coating will be used all around the pipelines outer side to protect it from corrosion and holes. Of course, this will not protect it forever and accidents can occur in which, most accidents that happen are excavation damage according to the FEIS (Final Environmental Impact Statement) thus; ideas like Pipeline 101 were created to report these accidents for the public. Meaning that a public citizen is allowed to call the Pipeline 101 number and report any unauthorized activity along the pipeline or to find where a pipeline might lay in the ground. There is protocol for if an accident does occur with safety crews reporting immediately to the site although, time is required to clean up a spill depending on the size and location of the spill. Thus, TransCanada did studies on worst case scenarios and calculated the probability of spills based on previous spill data and the length of the pipeline. Although, a study was also done on worst case scenario by a professor in Nebraska stating that the Environmental

Impact Statement and TransCanada's numbers were off and that the spill risk was much higher. He pointed out the weak points along a pipeline route are at pump stations, valves, and joints. These weak points deal with the direct functions of the pipeline but environmental forces can also affect the safety of the pipeline involving flood risk and scouring. Inside Climate News covered a story about the Yellowstone River causing a pipeline to break along the river bottom even after being buried underneath the river ten to twenty feet. This causes tremendous damage to an ecosystem especially to rivers such as the Yellowstone that was covered by a sheet of ice making it very difficult to clean up the mess. A mess that caused workers and the company to quit until some of the ice loosened up in order for the workers to clean up the mess. Therefore, this has worried the people of Nebraska with the pipeline crossing the sensitive Sandhills and the Ogallala Aquifer according to many news articles. They are afraid that if the pipeline was to break along any parts of this sensitive area that it would penetrate into the aquifer and contaminate the water source that is a huge part of the agriculture and community of many states especially the state of Nebraska. On the other side, with Nebraska being a Republican state according to the previous governor and presidential elections, a Gallup article states that two-thirds of Republicans choose economic benefits over the environment. Thus, Nebraska might end up favoring the benefits of the economic production than trying to save the environment even if it is a bigger risk with the pipeline being bigger than most at 36 inches.

Background

Environmentalists such as the EPA have played a tremendous part in the approval and disapproval process of the Keystone XL through the Nebraska region because of the

endangered species impact risk. The people are afraid of what might become of the Nebraska region with the possible high risk disturbance among these species. They see it as a potential habitat loss in which “habitat loss remains the main driver of extinctions” (Sodhi et al., 2009) and that “human modifications to the planet in the last few centuries, and perhaps even millennia, have greatly accelerated the rate at which extinctions occur.” (Sodhi et al., 2009) Thus, “ecological processes disrupted by extinction or species decline may also lead to cascading and catastrophic co-extinctions”. (Sodhi et. al, 2009) An example would be rainforest based figs and tiny wasps in the Southeast Asian forest in that the figs depend on the wasp for its pollination. Thus, if the wasp living quarters is small and humans disturb this area greatly, the wasp does not have the ability to move itself to a capable living environment. The consequence of this happening is that the fig will not receive its proper pollination from the wasp in the situation that the wasp becomes extinct. Similarly, environmentalists are worried about this sort of situation happening amongst the Nebraska region with the American Burying Beetle. The beetle is categorized as endangered according to the NRCS (Natural Resources Conservation Service) and has been recorded in “eighteen Nebraska counties in the last fifteen years” (Jurzenski et al., 2012) in which six of them contain the proposed Keystone route. These six counties all have differing geological soils and land use among its boundaries that provide clues for the beetles’ habitat. Evidence suggest that the “beetles have recently been found in grassland prairies, forest edges, and shrublands” (Hoback, 2016) thus, providing the necessary shelter and food for the beetle’s ability to exist among Nebraska’s ecosystem. The beetles’ main functions involve burying itself and food amongst loose sand and searching its current environment for fresh carcasses using its

antennas in order to eat and rear offspring. Pairs perform together in searching for the carcass and usually have competition after finding it in which, leads to relentless competition among the beetles and other species. If the beetles are successful in attaining the carcass the process of burial begins beginning with digging under the carcass and creating a depression in the ground. Gravity then acts upon the carcass and allows the beetles to roll it into a compacted ball. Once the carcass is buried and the beetles have taken its fur or feathers off the body the process of eating or lying of eggs begins.

Therefore, when proposing the Keystone pipeline across the habitats of the ABB it has to take into consideration the possible consequences and processes that involve construction of the pipeline in comparison to the ABB's lifestyle. The consequence might entail an oil spill of the heavy crude oil thus, trapping the beetles within the oil knowing that they live only a few inches under the surface. In which, this also impacts a viable surface for the beetle by the heavy crude contaminating the loose sand. On the other hand, the construction of the pipeline involves trenches that are several feet deep according to figure 1. Thus, the process of digging creates disruption in the areas that the American Burying Beetle is present.

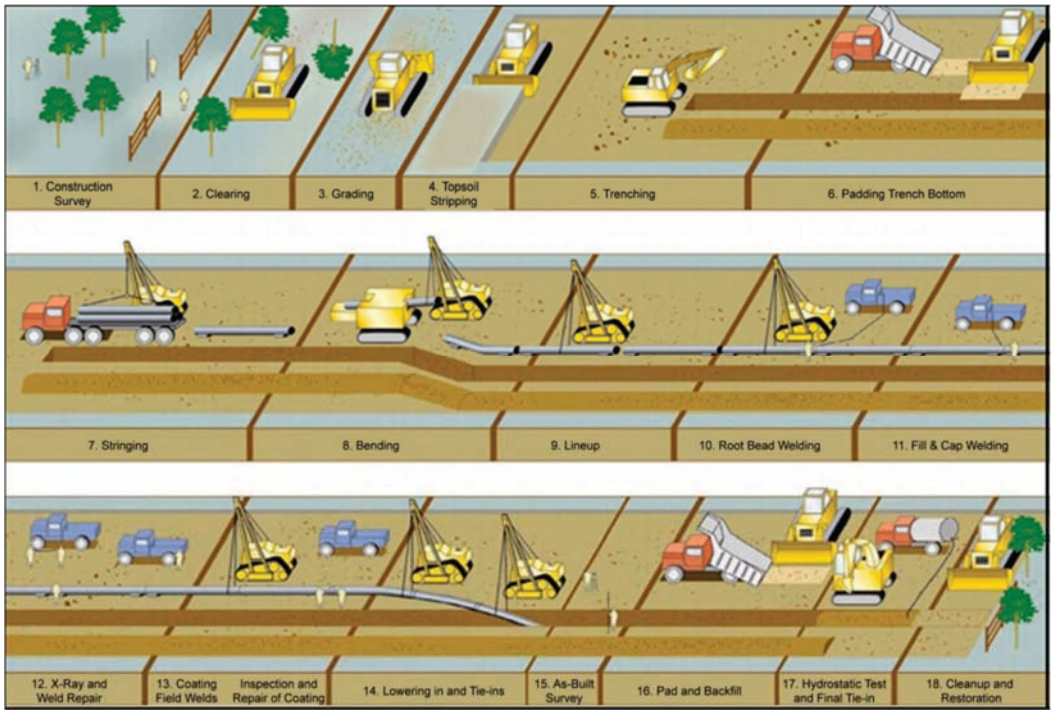

Figure 1. Pipeline Burial Process (U.S. Department of State, 2014)

The physical parameters and environment of a pipeline involve precise surveying and measuring using construction tools, GPS, and GIS mapping. Its components are usually set up at equal intervals to ensure pressures are kept at a safe level and in case of a leakage the pipeline can be shut down at any point along the route. Thus, in considering a puncture or defect in the pipeline route, its most "likely failure points are considered to be valve connections and pump stations". (Stansbury, 2011) With the automatic shut off valves being placed equally ten to twenty miles apart and the pump stations at fifty miles according to TransCanada. Both components deal with the flow of crude oil through a pipeline but have different functions for monitoring the flow. The valves monitor the flow by opening and closing a small gate while the pump stations "pressurize the flow of crude oil enough to allow continued transport through the pipeline." (TransCanada, 2014) Examples of a valve site and pump station are shown in figures 2 and 3.

Figure 2. Pump Station (Courtesy of TransCanada)

Figure 3. Valve Site (Taken by Matthew Young)

Complications arise when valves are shut down and a puncture is near the bottom of a valley because some of the previously flowing oil inside the pipeline is consequently going to flow down the hillside and into the valley where the puncture exist. Luckily the Nebraska area is relatively flat and the chances of the pipeline encountering massive hills are very unlikely. Thus, the consequence of a leak will not be as drastic as a mountainous area plus, less valve sites and pump stations will be needed for the purposes of pushing the crude oil through the pipeline. The reason for less valve sites and pump stations is

because there are not as many hills for the crude oil to overcome or as much risk involving automatic shut off valves. In saying that, Nebraska will end up needing 5 pump stations and around 16 valve sites in order to successfully push the crude oil to the southern leg. “Historically, the most significant risk associated with a crude oil pipeline is the potential for third-party excavation damage.” (U.S. Department of State, 2013)

The Sandhills (Figure 4) is a region of sand-dunes that are as high as 400 feet, as long as 20 miles, with slopes as steep as 25 percent” (Bleed et al., 1990) and is considered the biggest dune formation in the western hemisphere. “The large sand masses that were formed by blowing sand are now held in place and stabilized by vegetation that consists mainly of grasses”. (West Central Research and Extension Center, 2016) In addition, “the region supports roughly 720 species of plants and 314 species of animals” (Nahigyan, 2015) including the American Burying Beetle. The land is still “85 percent intact” (Nahigyan, 2015) because “the soil in many areas is too loose and lacking in nutrients to grow anything without significant amounts of fertilizer and irrigation.” (Nahigyan, 2015) Thus, with the sand being loose and porous it allows contaminates the chance to penetrate down into the subsurface and reach the Ogallala Aquifer.

Figure 4. Nebraska Sandhills with Alternate Route (U.S. Department of State, 2014)

The aquifer “is composed primarily of unconsolidated, poorly sorted clay, silt, sand, and gravel with groundwater filling the spaces between grains below the water table”. (Krumm, 2016) It’s considered as an unconfined aquifer (Figure 5) in that water penetrates into the ground from rainwater and snowmelt for the purposes of replenishment. The layers in the aquifer is broken down into an unsaturated zone and saturated zone with the unsaturated zone containing air and water above the water table. Although, it’s not a “source of readily available water for human consumption” (USGS, 2013) but is considered “a main factor controlling water movement from the land surface to the aquifer.” (USGS, 2013) On the other hand, the saturated zone is below the water table and contains water in all the pores and fractures.

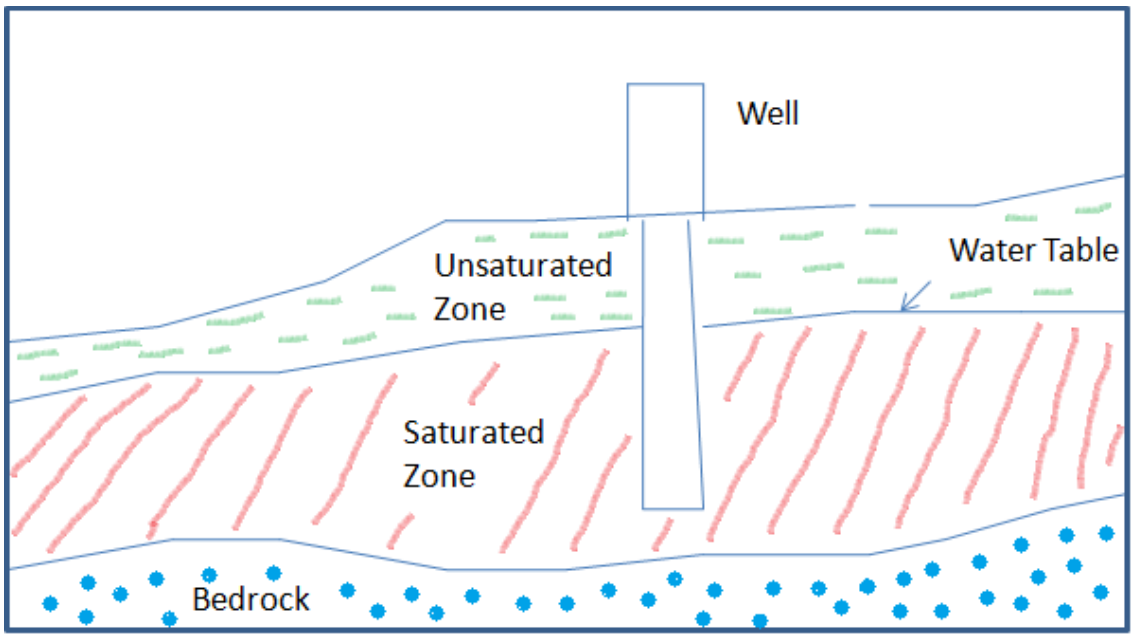

Figure 5. Unconfined Aquifer (Created by Matthew Young)

Therefore, in considering these variables together and a possibility of an oil spill along the Keystone pipeline it becomes a highly debatable topic amongst environmentalist and “oil people” over contamination and destruction of these sensitive

areas that could possibly affect humans and endangered species such as the American Burying Beetle. Both sides argue over how the pipeline could possibly affect these areas in case of an oil spill and whether or not the risk is worth the reward. “Environmentalists worry that the remote location of the pipeline increases the risk that a leak in a sensitive area could go undetected and contamination of the aquifer could occur.” (Congressional Research Service, 2014) Although, TransCanada argues that “data systems continuously monitor the pipeline system parameters, including pressures and flow rates that send information to a control center staffed twenty-four hours per day.” (TransCanada, 2016) In which, the data is then processed using “complementary” techniques such as “pressure changes that are indicative of a large leak while smaller leaks result in a mismatch of oil entering and leaving the affected portion of the system.” (TransCanada, 2016) In addition, construction with “tougher steel and epoxy pipe coating covered by cathodic protection and prevention methods involving increased depth cover, increased puncture resistance, participation in the Nebraska One-Call program and use of pipeline markers” (TransCanada, 2016) will keep the surrounding environment safe and secure from any spills.

Pipeline incidents can occur in many different ways that puncture or weaken the pipeline as shown in table 1.

Table 1

Excavation Damage Definition

Factor	Description
Excavation Damage	Excavation equipment damages to underground piping by third parties.

The most representative risk dealing with crude oil pipelines is the potential threat of third-party excavation damage. (United States Department, 2011) “Excavation damage often occurs when required One-Call notifications are not made prior to beginning excavation, digging, or plowing activities.” (United States Department of Transportation, 2014) In which, a “One Call Center is a free service to inform underground utilities or pipeline owners of any called-in excavation activities that could potentially affect their underground facilities. The facility owner, in turn, provides specific location information to the excavator and marks the underground facility with above-ground APWA (American Public Works Association) color-coded markings.” (Pipeline 101, 2016)

According to TransCanada, the valves locations will be set up in intervals ten to twenty miles while the pump stations will be at an interval of fifty miles. Major parts along a pipeline route include valve connections and pump stations that Main components involving moving parts for the sole purpose of maneuvering heavy crude oil along a pipeline route are pump stations and valves. According to a professor in Nebraska, “likely failure points include valve connections and pump stations.” (Stansbury, 2011) The valve sites are placed at equal intervals of “fifteen to twenty miles along the pipeline route” (Latimer, 2016) to stop leakage in case of a pipeline breakage. Although, the area between both valve sites is still considered a threat with the possibility of oil lying inside the pipeline and running to the pipelines current puncture. Furthermore, if the pipeline is routed through a hilly terrain then gravity becomes important when considering the oil flowing downhill and deciding whether or not a spill will be categorized as minor or extreme. Fortunately, the Nebraska area is relatively flat and the chances of the pipeline encountering massive hills are very unlikely.

With this in mind, different incidents cause different hole sizes according to a DNV Energy frequency and volume analysis. This assessment created three different categories of hole sizes and is shown in table 2.

Table 2

Spill Size Categories

Spill Size
Small(>50 gallons)
Medium(51-999 gallons)
Large(>1000 gallons)

In addition, it explains that “hole size is not the same as spill volume and that “some leaks from smaller holes could occur for a long period of time and result in a large spill volume because they would not be detected as quickly as some leaks from larger holes.” (DNV Energy, 2006) Thus, with the Nebraska area being rural along the pipeline route, a small leakage in the pipeline might not be detected for a lengthy amount of time.

Rivers have always been discussed when pipelines are being built either over or under them for the purposes of a spill happening. An example is the Exxon pipeline that is running underneath the Yellowstone River that erupted back in January of 2015 because of scouring. In which, leaked an estimated 40000 gallons of crude oil into the Yellowstone River and contaminated the drinking water of a town nearby called Glendive according to a PBS article. Figure 6 shows a picture of the crude oil in the icy Yellowstone River in Montana.

Figure 6. Oil Spill Cleanup in the Yellowstone River Photo (Courtesy of MBrown)

Thus, with the oil spill having happened underneath the river and there being ice covering the top it made it very difficult to clean up. People now worry about these types of pipeline breaks consistently especially with it being near a major river and water source. According to Northern Rockies director Scott Bosse “there are probably hundreds of pipelines across the country that is at considerable risk of rupturing under our rivers.” (Bosse et. al, 2015) Figure 7 shows an example of scouring that involved the Exxon pipeline being buried from horizontal drilling at least 20 feet underneath the river but over time the river’s bottom being eroded away thus, exposing the pipeline to flowing debris.

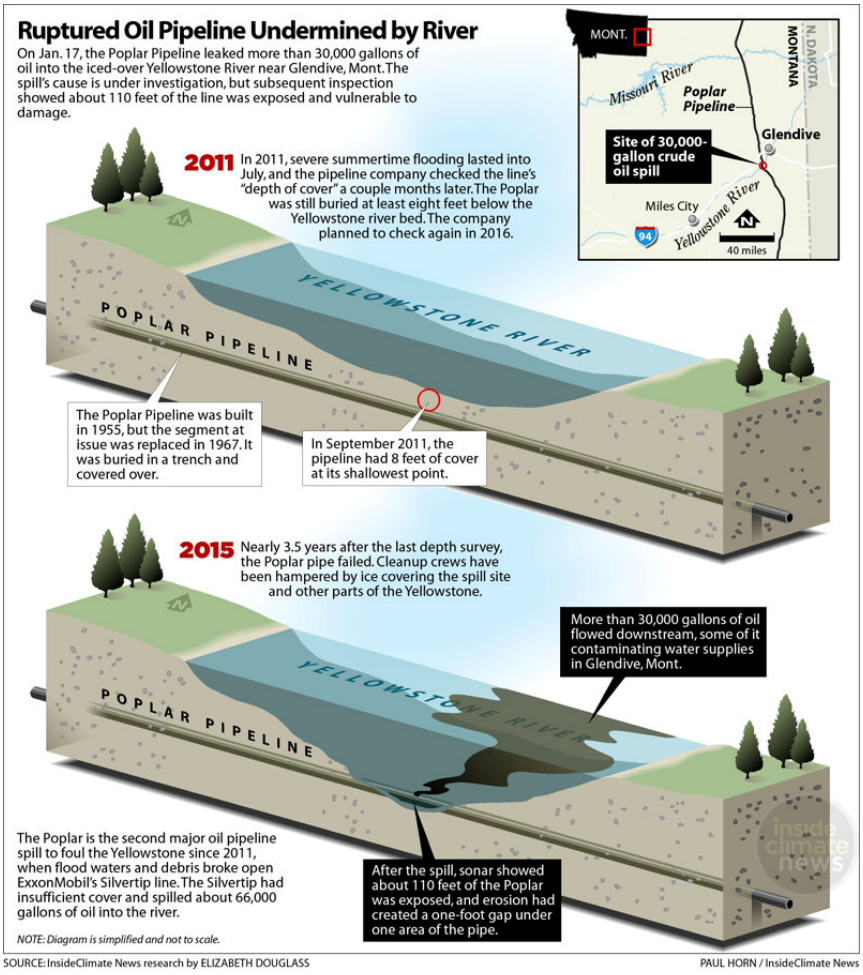

Figure 7. Scouring Example (Courtesy of Paul Horn of Inside Climate News)

Nebraska most likely will not encounter frozen rivers thus, cleanup will be easier in the case of a river spill but major rivers within the state would still be at risk to horizontally drilled pipelines. The major rivers considered similar to the Yellowstone River would be the Platte and Niobrara Rivers that travels many miles and are very wide thus, a spill occurrence within these rivers could still be costly financially, environmentally, and culturally within Nebraska. In addition, with Nebraska being a very rural state in most parts a spill could go undetected for a while even with the most advanced detection systems running through the pipeline. The spill could then impact

areas such as the sensitive Sandhills and Ogallala Aquifer in which, then might impact the drinking water that the people of Nebraska use just like the previously mentioned Exxon spill.

All the previously mentioned variables consist of a risk involving a spill along the pipeline route either categorized as likelihood asking how vulnerable the pipeline is to a spill in a certain location or considering the consequence of a future spill. Risk assessment matrixes have been made as shown in figure 8 and then displayed spatially along the route using the charts symbology. Different size matrices have been used throughout studies but a 5 x 5 matrix is the most common consisting of four classes with those classes being low, medium, high, and extreme.

The reasoning behind using one is these is not only to find the risk but compare the results to economic numbers by graphically representing a comparison and then spatially determining whether or not the risk is greater than the reward. Thus, considering that “two-thirds of Republicans favor prioritizing economic growth” (Jacobe, 2012) the people in Nebraska may side with the pipeline because Nebraska is mainly a Republican controlled state when examining the past fifteen to twenty years having Republican elected governors and the state having been turned red during previous presidential elections. Therefore, a GIS can help determine these results by using spatial analysis and geoprocessing tools by analyzing the previously mentioned components along the pipeline route. An analysis that deals with classifying and ranking of these components using the working knowledge of either where each component exist or where the components might be proposed.

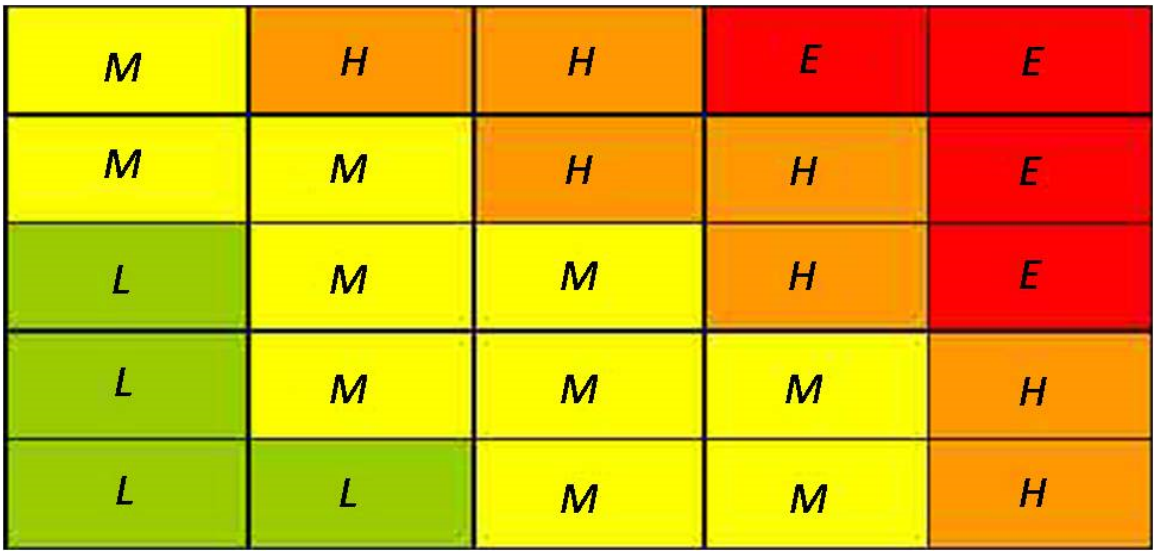

Figure 8. Matrix for Consequence and Likelihood

CHAPTER II

Methodology

There were varying methods throughout this study that involved many different aspects of GIS tools and techniques. The software used during this process was ArcGIS 10.2 at the ArcInfo level by creating feature classes and shapefiles with a Nebraska state plane projection in units of feet. They were of varying vector types from points, polylines, and polygons that were manipulated using basic processing tools in ArcMap and digitized from georeferenced images such as pump station points.

The spatial data collected and downloaded was from varying sources including TransCanada, the Nebraska Department of Natural Resources, the US Census Bureau, the University of Nebraska-Lincoln School of Natural Resources, and the United States Department of Agriculture. The lists of variables used in this study were divided into likelihood and consequence plus, the geometry type as shown in table 3. Noting, rivers and people are used in both categories because both have different aspects that relate to these categories.

Table 3

Consequence & Likelihood Variables with Geometry Type

Likelihood	**Geometry**	**Consequence**	**Geometry**
People	Polygon	American Burying Beetle	Polygon
Rivers	Line	DRASTIC	Polygon
Pump Stations	Point	People	Polygon
Valves	Line	Rivers	Line

The likelihood variables were all given a ranking of one to four with four being the highest, and one the lowest. Table 4 lists the variables and their associated rankings in the adjacent column.

Table 4

Likelihood Rankings

Likelihood	Rankings
People	4
Rivers	3
Pump Stations	2
Valves	1

These rankings were matched with every record in the attribute table by creating a new field using the field names Pop_Rank, Riv_Rank, PS_Rank, and Val_Rank. The rankings were based off of previous comments such as excavation damage being the most damaging impact to pipelines. Thus, people received the highest ranking at four involving likelihood in comparison to the other variables but received the lowest ranking of one for consequences in that people put the environment and endangered species before themselves. Although, one ranking will not cover the difference in population density along the pipelines corridor thus, four classes were made in equal intervals at four hundred people per square mile based on the variation in the data. In addition, a new field needed to be created called “Pop_Class” in order to provide the proper ranking for the data. Considering that the data was downloaded from Silvis lab at the block level and is very small and Nebraska is a rural state, a class of zero was made for blocks containing zero population. Therefore, there were a total of five classes but one of the classes is

represented as zero according to table 5. In addition, this classification scheme for people was used in both likelihood and consequence.

Table 5

Classification of Population Density

Rank	Class
0	0
1	1-400
2	401-800
3	801-1200
4	1201<

The likelihood variables throughout this study contained differing geometries of points, polylines, and polygons all of which needed to be combined into one shapefile. The resulting geometry must be of the polygon type thus, a few of the variables needed to be converted into polygon geometries. According to table 3 the rivers, pump stations and valves are the variables that needed to be converted and processed using the buffer and union geoprocessing tools. Although, there were different buffering distances for rivers and valves in comparison to the pump stations and with rivers and valves receiving a buffer of 0.5 miles while the pump stations received a buffer of 0.25 miles. The rivers received a 0.5 mile buffer because of flooding and meandering of the river causing erosion around the pipeline and rupturing the pipeline from flowing debris. Valves also received a 0.5 mile buffer but, considering that TransCanada does not know the exact placement of valves along the pipeline route and the valves are a minimum of 10 miles from a pump station at intervals of 15 to 20 miles a line shpaefile had to be created in

between the pump stations. The shapefile contained a created field called “Valve_Rank” in which, spots where valves might be placed received a number one while spots with no placement received a zero. After, breaking the line shapefile into these components, the 0.5 mile buffer was processed using this line shapefile. On the other hand, the pump stations received a 0.25 mile buffer because of the moving parts inside and around the pump stations plus, the continuous flowing of oil throughout these sections. Therefore, once buffers were made for these variables, the alternate route was also buffered by 0.5 miles in case of the pipeline route changing during the construction phase. Examples of these buffered variables are shown in figures 9-12.

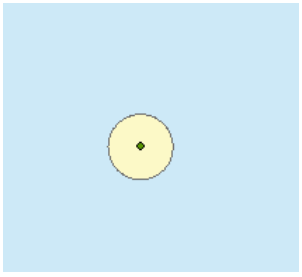

Figure 9. 0.25 Mile Buffered Pump Station

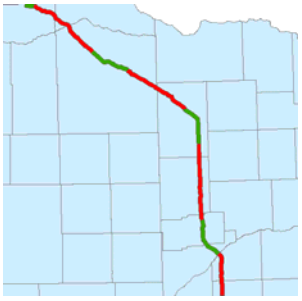

Figure 10. 0.5 Mile Buffered Valve Sites

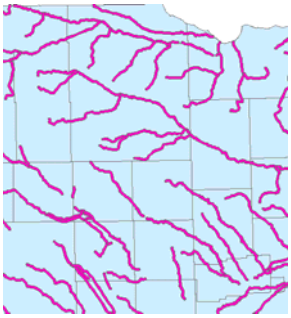

Figure 11. 0.5 Mile Buffered Rivers

Figure 12. 0.5 Mile Buffered Alternate Route

These buffered variables were then clipped to the 0.5 mile buffered alternate route individually and combined with the buffered alternate route using the union tool that combines the shapefiles into one. Thus, the previously created fields should contain a one or a zero with one record indicating that the variable does not exist in certain areas inside the polygon shapefile according to figures 13-15.

Riv_Rank
0
1
1
1
1
1
1
1
1
1
1
1
1
1

Figure 13. River Rank Field

PS_Rank
0
1
1
1

Figure 14. Pump Stations Rank Field

Valve_Fina
1
0
1
0
1
0
1
0

Figure 15. Valve Rank Field

In saying that, the creation of polygon shapefiles for rivers, pump stations, and valves allows for the intersecting of all variables contained within the likelihood category using the intersect tool for the purposes of creating a shapefile containing overlapping areas. After using the intersect tool, one shapefile was created for the likelihood category by adding the “Pop_Rank”, “Riv_Rank”, “PS_Rank”, and “Val_Rank” values together in

a newly created field called “Like_Rank”. These values then become a final likelihood rank with the possible values ranging from four to fourteen.

The consequence variables from table 3 were set up similar to the likelihood category in that each variable used was given a ranking matching table 6.

Table 6

Consequence Rankings

Consequence	Rankings
DRASTIC	4
Rivers	3
American Burying Beetle	2
People	1

These rankings were correlated with these variables by creating new fields in the shapefile and equaling those numbers to all records using the field calculator. Figures 16 through 19 shows examples of these fields.

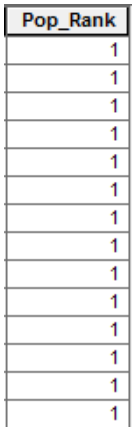

*Figure 16.*Population Rank Field

Rank_ABB
2
2
2
2
2
2
2
2
2
2
2
2
2

*Figure 17.*American Burying Beetle Rank Field

Riv_Rank2
3
3
3
3
3
3
3
3
3
3
3
3
3
3

*Figure 18.*River Rank Field

DRAS_Rank
4
4
4
4
4
4
4
4
4
4
4
4
4
4

*Figure 19.*DRASTIC Rank Field

After creating these fields with proper rankings, classes had to be made for people and DRASTIC plus, the ABB had three different components needing to be combined into one data source. The ABB pieces were collected from multiple sources that included the Nebraska NRCS, University of Nebraska-Lincoln, and USDA. The Nebraska NRCS contained information on which counties had seen the American Burying Beetle thus; a new field was created in a Nebraska state shapefile from the United States Census Bureau and called Yes_No. Counties that had seen the American Burying Beetle were given a ranking of one while the other records a ranking of zero. The University of Nebraska-Lincoln data consists of the land cover in the Nebraska area thus; a new field was created and called "Rank_LU" for land cover that most likely contains the ABB shown in table 7 was selected and given a ranking of one with the other records receiving a zero.

Table 7

Land Use Categories Used and Unused

Class Names	Used/Unused
Agricultural Fields	
Aquatic Bed Wetland	
Background	
Barren/Sand/Outcrop	
Commercial/Industrial/Transportation	
Deciduous Forest/Woodlands	*
Juniper Woodlands	*
Little Bluestem-Gramma Mixedgrass Prairie	*

(continued)

Class Names	Used/Unused
Low Intensity Residential	
Lowland Tallgrass Prairie	*
Open Water	
Ponderosa Pine Forest and Woodlands	*
Riparian Shrubland	*
Riparian Woodland	*
Sandhills Upland Prairie	*

*=Used and equals 1

The USDA data source was composed of the soil type around Nebraska thus; a new field was created called “Rank_Soil” for the soil type that most influences the occurrence of the ABB. It was selected based on previous statements shown in table 8 and given a ranking of one while the other records a ranking of zero.

Table 8

Soil Classifications Used

Class Names
Bazile-Thurman-Boelus
Brunswick-Paka-Simeon
Coly-Uly
Cozad-Hord
Dunday-Pivot
Gibbon-Gothenburg-Platte
Gibbon-Wann
Hastings-Fillmore

(continued)

Class Names
Hersh-Valentine
Hobbs-Hord
Holder-Uly-Coly
Hord-Cozad-Boel
Inavale-Boel-Barney
Jansen-O-Neill-Meadin
Labu-Bristow-Sansarc
Nora-Crofton-Moody
Thurman-Boelus-Nora
Valentine
Valentine-Elsmer-Tryon

All these variables for the ABB were then clipped individually to the previously 0.5 mile buffered alternate route and intersected together in order to find the overlap of all variables. Areas along the corridor can contain a “tri-overlap” meaning all three variables are overlapping each other while there could be areas that have no variables. The attribute table from the shapefile can display this information by creating a new field called “ES_Rank” and adding the “ranking” fields from the three separate shapefiles together using the field calculator as shown in figure 20. Therefore, areas with the number three have the most likely spots where an ABB might occur along the pipeline corridor while zero indicates the least likely. Note: areas with intersection of one or two variables can occur.

Yes_No	Rank_LU	Rank_Soil	ES_Rank
0	1	0	1
0	1	0	1
0	0	0	0
0	1	0	1
0	1	0	1
0	1	0	1
0	1	0	1
0	1	0	1
0	1	0	1
0	1	0	1
0	1	1	2
0	1	1	2
0	1	1	2
0	0	1	1

Figure 20. Variables and Rank Fields for the American Burying Beetle

DRASTIC was used and received from the Nebraska Department of Natural Resources to help explain the potential environmental damage involving the combination of the Ogallala Aquifer and Sandhills. The methodology of DRASTIC uses several factors to determine the potential impact on the surface and subsurface levels. It includes variables shown in table 9:

Table 9

DRASTIC Categories

D	Depth to Water
R	Net Recharge
A	Aquifer Media
S	Soil Media
T	Topography
I	Impact of the Vadose Zone
C	Hydraulic Conductivity

All these variables are given ranks and weights and put into the DRASTIC formula (Figure 21) in order to find the most vulnerable areas in the case of an event

happening.

$$DRASTIC\ Index = D_r\,D_w + R_rR_w + A_rA_w + S_rS_w + T_rT_w + I_rI_w + C_rC_w$$

Figure 21. DRASTIC Formula

Although, this study uses an already created final product thus, data was provided by the state of Nebraska. The data broke a vulnerability field into six categories: Very High, High, Moderately High, Moderate, Moderately Low, and Low. These categories were all given a ranking from one to four shown in table 10.

Table 10

DRASTIC Classification

Class	Rank
Low	1
Moderately Low	1
Moderate	2
Moderately High	3
High	3
Very High	4

The rivers variable used for the consequence category did not contain any rankings but only whether or not the pipeline crosses a river. Therefore, the same shapefile created in the likelihood section was used in combination with the consequence variables.

As mentioned earlier with the intersection of all variables among the likelihood category the same was done with the consequence variables. Therefore, the variables of

people, DRASTIC, ABB, and rivers were combined using the intersection tool from the final individual shapefiles created in the earlier steps. After intersecting these variables together a new field needed to be created called “Con_Rank” for the purposes of adding all the consequence variables together. These numbers come out between twelve and twenty-two in which serves as the overall consequence rankings.

The final likelihood and consequence shapefiles both contain the necessary information in order to see the overall risk involved along the Keystone pipeline corridor in the Nebraska region. In order to retrieve this information another intersection among the final created shapefiles for likelihood and consequence needed to be combined using the intersect tool. Therefore, both shapefiles were intersected and provided two fields that have records of matching spatial polygons. An example of the attribute table is shown in figure 22.

Final_Con_	Like_Final
16	5
16	5
16	5
16	5
15	5
16	5
16	5
15	5
17	8
16	8
16	8
17	8
17	8
17	8

Figure 22. Final Ranking Fields for Likelihood and Consequence

With the creation of this attribute table, the overall risk can be found using the select by attributes in ArcGIS and a 5x5 risk assessment matrix as seen in figure 23.

M	H	H	E	E
M	M	H	H	E
L	M	M	H	E
L	M	M	M	H
L	L	M	M	H

*Figure 23.*5x5 Risk Matrix

The select by attributes allows for the selection of variables in both the likelihood and consequence field at the same time by using the “AND” command. Thus, allowing every ranked combination between likelihood and consequence to be found. Table 11 shows every combination possible although, the shapefile did not contain every combination.

Table 11

All Possible Rank Combinations

Likelihood	Consequence		Likelihood	Consequence		Likelihood	Consequence
4	12		8	12		12	12
4	13		8	13		12	13
4	14		8	14		12	14
4	15		8	15		12	15
4	16		8	16		12	16
4	17		8	17		12	17
4	18		8	18		12	18
4	19		8	19		12	19
4	20		8	20		12	20
4	21		8	21		12	21
4	22		8	22		12	22
4	23		8	23		12	23
5	12		9	12		13	12
5	13		9	13		13	13
5	14		9	14		13	14
5	15		9	15		13	15
5	16		9	16		13	16

(continued)

Likelihood	Consequence		Likelihood	Consequence		Likelihood	Consequence
5	17		9	17		13	17
5	18		9	18		13	18
5	19		9	19		13	19
5	20		9	20		13	20
5	21		9	21		13	21
5	22		9	22		13	22
5	23		9	23		13	23
6	12		10	12		14	12
6	13		10	13		14	13
6	14		10	14		14	14
6	15		10	15		14	15
6	16		10	16		14	16
6	17		10	17		14	17
6	18		10	18		14	18
6	19		10	19		14	19
6	20		10	20		14	20
6	21		10	21		14	21
6	22		10	22		14	22
6	23		10	23		14	23

(continued)

Likelihood	Consequence		Likelihood	Consequence		Likelihood	Consequence
7	12		11	12			
7	13		11	13			
7	14		11	14			
7	15		11	15			
7	16		11	16			
7	17		11	17			
7	18		11	18			
7	19		11	19			
7	20		11	20			
7	21		11	21			
7	22		11	22			
7	23		11	23			

Once the combination was selected, the total number of polygons was written down for that combo. These numbers were then applied in a 3D bubble chart that specifies the percentage of combos by varying sizes in the bubbles. A 5x5 risk assessment matrix was then placed in the background that categorizes the risk into four different classes as shown in the previous figure 24. In addition, the axis were numbered based on the extent of the data meaning that the highest and lowest number the data contained was used as the high and low markers along the X and Y axis. Although, the chart displayed the markers at intervals of 0.5 in order to fully see the bubbles. A new

field was then created in the final shapefile called “Risk_Class” in order to match the combos with the proper low, medium, high, and extreme classifications. The matching involved taking every combination one by one and finding out its classification by looking at where the bubbles fell inside the risk assessment matrix. Select by attributes was then used in order to select the combination and provide the proper classification by using the field calculator for every record in that combo. An example of the attribute table is shown in figure 24.

Final_Con_	Like_Final	Risk_Class
17	8	Medium
16	8	Medium
16	8	Medium
16	5	Low
16	8	Medium
17	5	Medium
17	8	Medium
17	8	Medium
16	5	Low
16	8	Medium
16	5	Low
16	8	Medium
16	8	Medium
17	8	Medium

*Figure 24.*Likelihood and Consequence Rank Fields with the Risk Classification

After matching every record to its proper classification, the symbolization of the shapefile was matched to the color of the chart in that low equals green, medium equals yellow, orange equals high, and red equals extreme. Therefore, after going through all the buffering, intersecting, and creation of new fields, the final map shows a final overall spatial assessment risk shown in figure 25. In addition, the 5x5 matrix with the 3D bubbles are in figure 26.

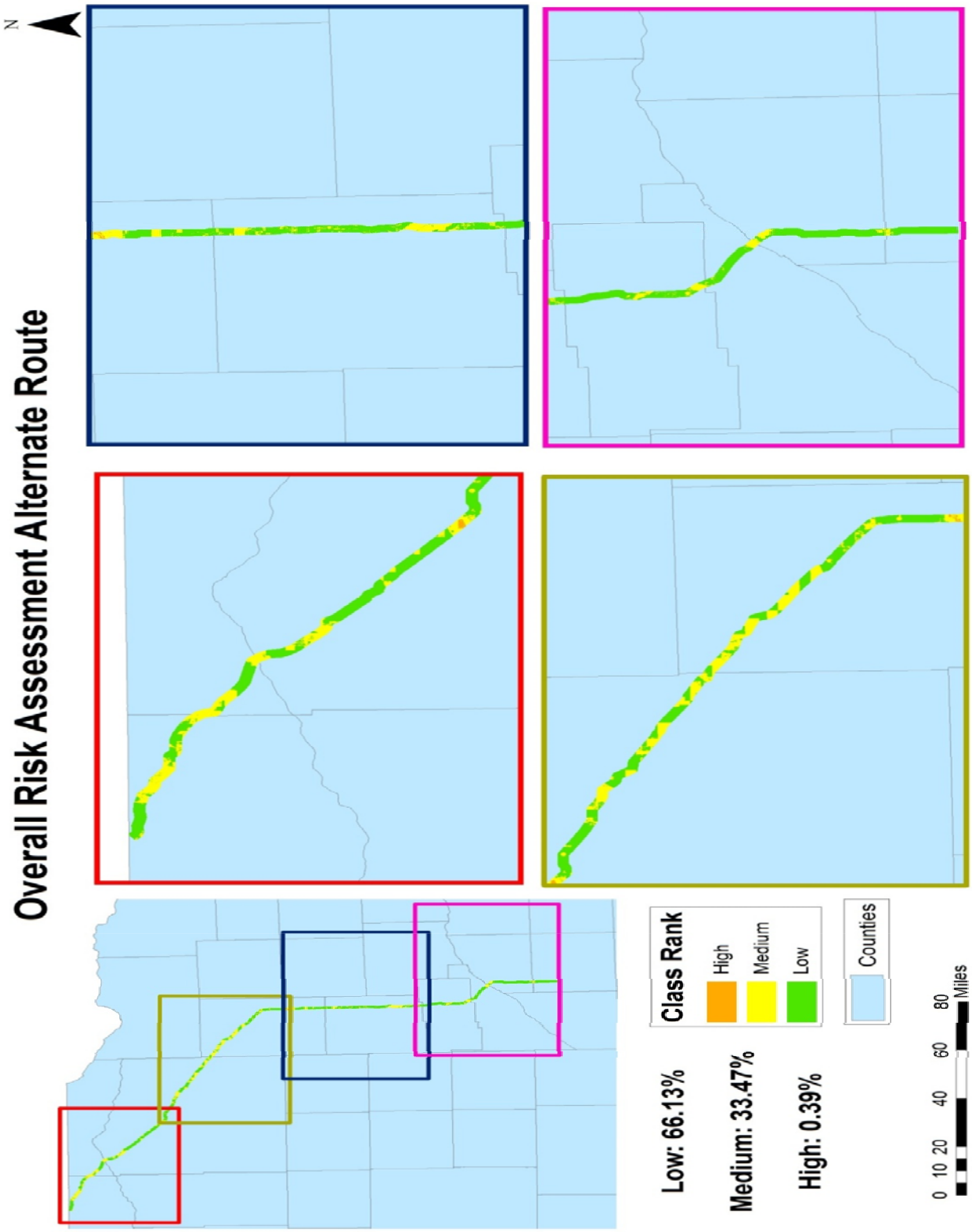

*Figure 25.*Overall Risk Assessment Map

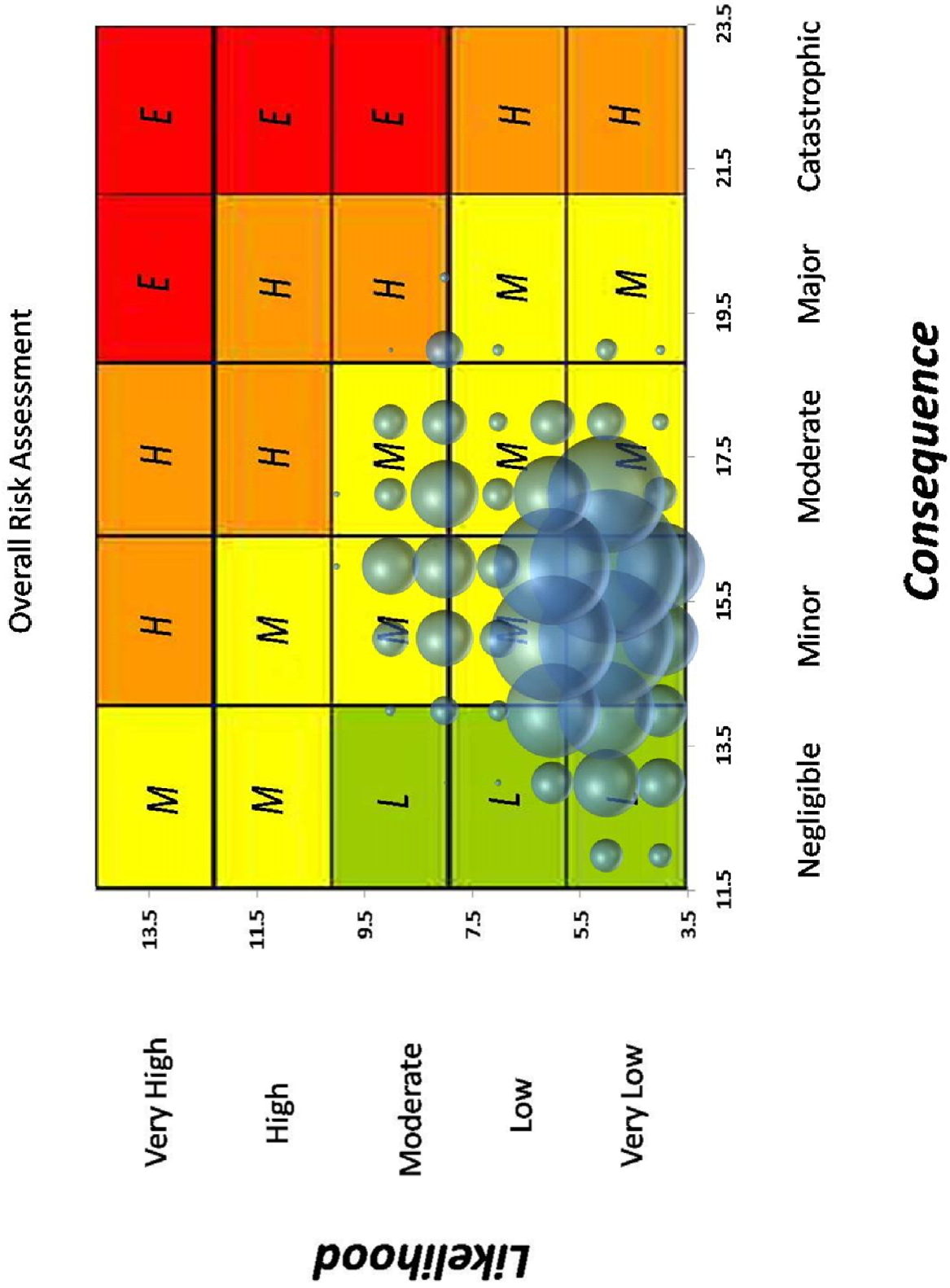

*Figure 26.*Overall Risk 5x5 Matrix

Although, in order to tell a cost difference between low, medium, high, and extreme classification areas a ranking system of one to four had to made with low being one and high being four. Lastly, using the select by attributes function the low, medium, high, and extreme were all selected one by one in order to find the total amount of area that the corridor consist for each individual class. All these different components were then placed inside figure 27 for each class in which equals the total economic risk that TransCanada would be taking on for the whole corridor in the Nebraska region.

$$Risk = \left(Total\ Class\ Area \left(Class\ Rank \left(\frac{\frac{Total\ Cost}{\#\ of\ Incidents}}{Total\ Square\ Miles\ of\ Corridor} \right) \right) \right)$$

Total Cost= total spill cost

# of Incidents= amount of spill occurrences

Total Square Miles of Corridor= calculated square miles of the pipelines corridor

Class Rank= rank of risk class

Total Class Area= percentage of class rank along the corridor

Figure 27. Risk Cost Equation

CHAPTER III

Results

Discussion

As stated previously, the state of Nebraska has mainly been a republican state based on the presidential elections and elected governors. In which, the Republican Party has mainly chosen economic benefits over environmental risk when it comes to choosing between these two factors. In considering this concept, the analysis done in comparing risk versus reward gave the economic benefits a slighter edge over the risk because of Nebraska being controlled by a Republican mindset. Thus, using figures 28-30 for each county a comparative analysis was used for risk versus economic benefits with each county receiving a ranking in comparison to the other counties using data from Goss Institute for Economic Research processed by Ernie Goss and previously calculated risk percentages from each county.

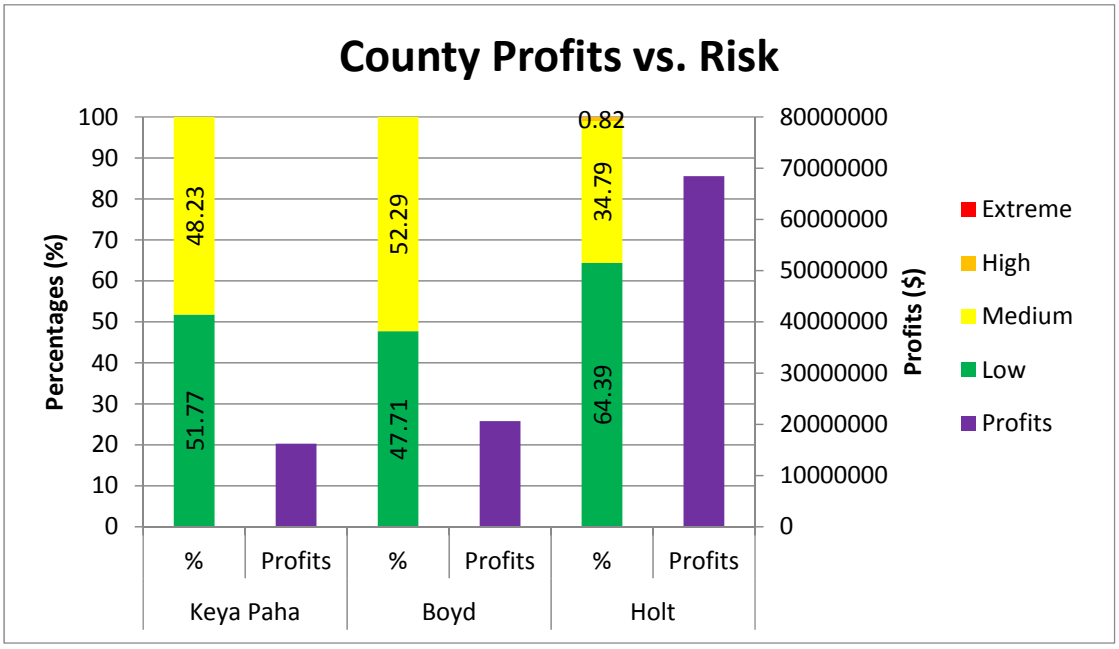

Figure 28. County Benefits vs. Risk Three Counties

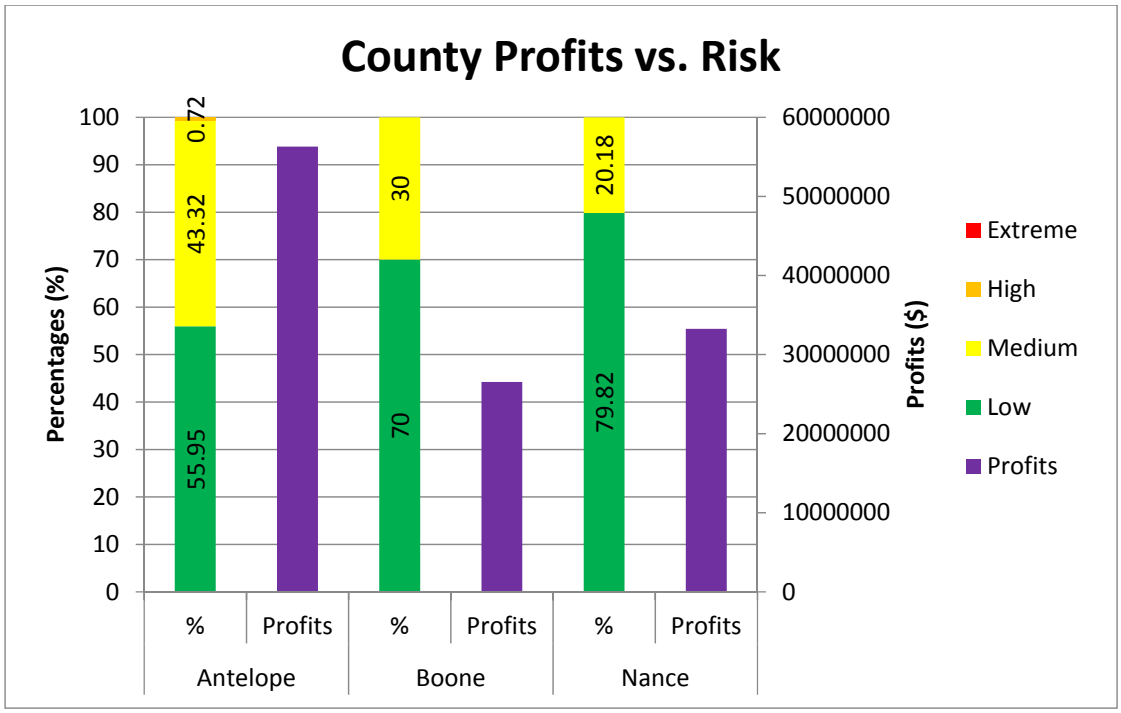

Figure 29. County Benefits vs. Risk Three Counties

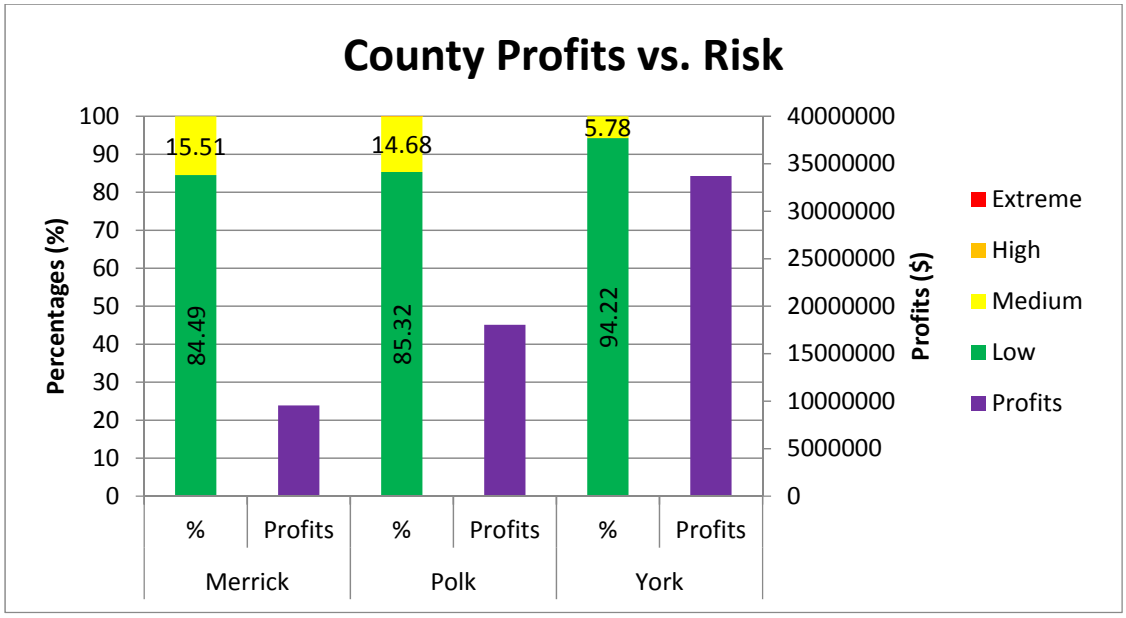

Figure 30. County Benefits vs. Risk Three Counties

The ranking used numbers one through nine with the most efficient county receiving a one and the worst a nine. These counties with correlated rankings are shown in table 12 and are explained in the following explanation by breaking down every county into its proper components and comparing it to the other counties.

In saying that, Boyd County contains the highest risk in that it contains 52.29 percent of medium risk and 47.71 percent of low risk. Although, Holt County could be considered as the higher risk because of it containing 0.82 percent of a high risk but it only has 34.79 percent medium risk. In which, Boyd County has 17.5 percent higher medium risk than Holt County thus, a 0.82 high risk percent does not justify Holt County having a higher risk than Boyd County. Although, Holt County provides the most economic benefits out of all counties at $69,745,618 and exceeds Boyd County by $45,826,578. Therefore, Holt County outweighs its higher risk factors with a high economic benefit while Boyd County, with the lower economic benefits, has difficulty maintaining a balance of risk versus reward and ranks second to last at number eight. On the other hand, York County has the lowest risk by having 94.22 percent low risk and only 5.78 percent medium risk with an economic benefit of $35,782,768 in which is among the top four economic benefits. Thus, York County could be considered as the most efficient county in that it contains very low risk and would have a descent economic return. Although, both Merrick and Polk Counties run a close second behind York County in terms of risk because, 84.49 and 85.32 percent constitute low risk areas in these counties. The downfall of these counties though involves low economic returns being at $10,182,158 and $19,495,010 in which, downgrades these counties at five and six in efficiency ranking. All the other counties risk and economic benefits vary in

between these two extremes but Antelope County tends to lean towards the same range of percentages and benefits of Holt County. The differences between these two counties risk percentages are 8.53 percent for medium risk and 8.44 percent low risk with Holt having the lower medium risk and higher low risk. Additionally, Holt County has a $12,698,047 economic advantage thus; Holt County observes less risk and more benefit. These statistics then allow for Holt County to be ranked right above Antelope County at number two. Next, Boone and Nance counties both have about the same amount of risk at 30 and 20.18 percent for medium risk with Nance County having the lower percentage. Plus, Nance County has a higher economic benefit at $34,571,814 versus $26,918,831in Boone County. Consequently, Nance County receives a higher ranking at four based on having a lower risk and higher benefits in comparison to Boone. The ranking of four puts Nance County above Polk and Merrick also because of the economic benefit being considerably less in Polk and Merrick counties. Lastly, Keya Paha Counties 48.23 medium and 51.77 low risk percentages are close to Boyd County thus, it’s among the higher risked counties and its economic benefits are extremely low at $16,563,502 in comparison to the other counties. Therefore, the county receives the lowest rank out of all counties because of the high risk and very low economic benefit.

Table 12

Economic Benefits vs. Risk Rankings

Counties	Efficiency Rank
York	1
Holt	2
Antelope	3
Nance	4
Polk	5
Merrick	6
Boone	7
Boyd	8
Keya Paha	9

After examining these components and seeing the rankings between all crossing counties there is no distinct spatial correlation. Although, one could subjectively argue over the placement of rankings throughout table 12 because of risk acceptability in which, could change the rankings completely and cause spatial patterns to appear throughout the data. An example might be taking weight off of the economics and placing more emphasis on the risk thus, placing higher rankings on counties such as Merrick and Polk above Holt, Antelope, and Nance because of the two counties having a lot lower risk. Furthermore, in observing the overall risk of the route the risk only contains a tiny fraction of high risk while the rest of the route is within the medium and low classes. This shows that the whole pipeline corridor actually is not very risky considering the news surrounding the Keystone pipeline. Especially that the projected benefits reach into the hundreds of millions of dollars for the state of Nebraska when adding all the counties totals together. Again, the whole idea of risk versus economic benefits involves human judgment thus; people could see this in many different manners.

The state of Nebraska needs to know the benefits and risk associated with the pipeline in order to make a proper judgment surrounding the idea of a multi-million dollar project but so does TransCanada. They need to know what it might cost them if a spill does occur anywhere along the pipeline since they will be the ones absorbing the cost after an accident. Information needed for TransCanada would be spill size and cost of cleanup based on the spill size and risk. This information is shown in figures 31 and 32 using data from the PHSMA database.

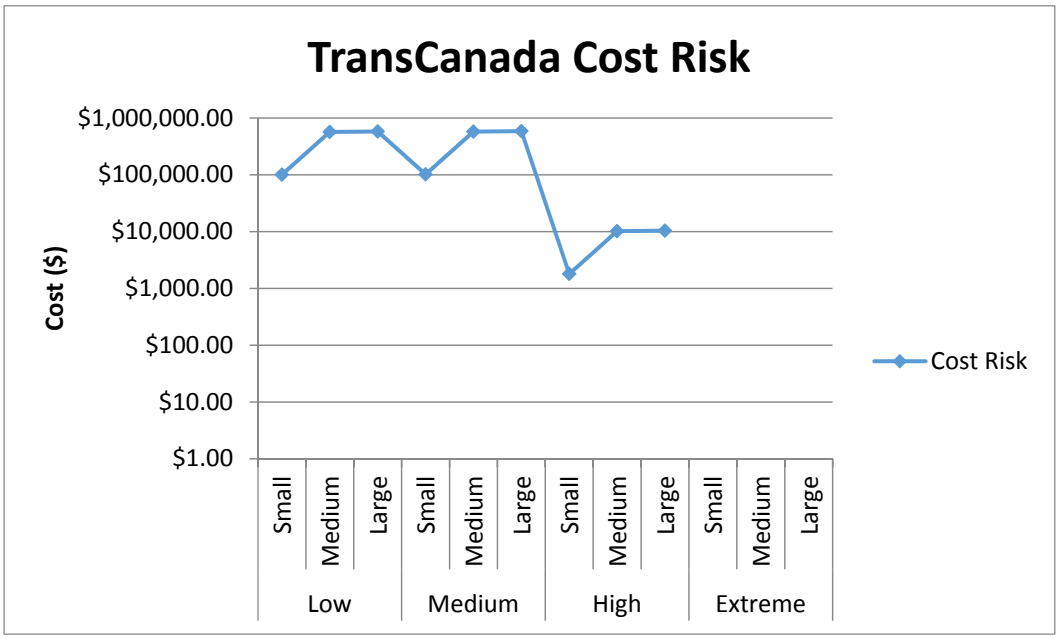

Figure 31. TransCanada Cost Risk by Spill Size

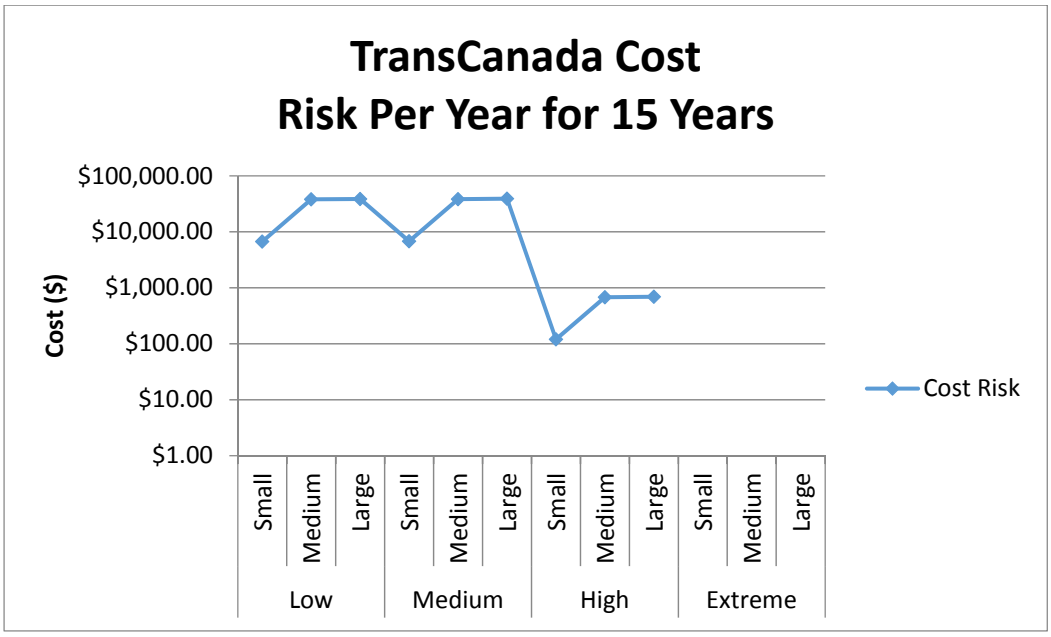

Figure 32. TransCanada Risk Cost by Spill Size per Year Over 15 Years

After using chart 4 the results show that medium risk is TransCanada's highest potential risk cost at around $1,000,000 for a medium and large spill over the whole corridor while the lowest potential risk cost is a small spill in a high risk area. Although, the high percentage of low risk areas causes the cost to rise close in proximity to the medium risk cost at around $1,000,000 also. Lastly, these costs were divided by 15 in order to come up with the cost per year over 15 years in which the largest and smallest potential cost would not have changed. In saying this, TransCanada's risk is in a more favorable situation because the cost may seem high in the low and medium risk areas but that is with around 98 percent of the pipeline being low and medium risk. Unlike the high risk areas where it is about 2 percent of the pipeline and adds up to around $10,000 in which, if the high risk areas had a higher percentage than the potential cost would be dramatically more than the 98 percentile of the low medium risk categories.

Most pipelines in America are around 18 inches in diameter but the Keystone pipeline is a 36 inch diameter pipeline thus, higher risk must be accounted for along the corridor. Therefore, a low risk area along the Keystone route is considered a higher risk than one with half the diameter because more oil is carried through the Keystone and there are more chances of a hole or damage with more material present. With more oil running inside the pipeline the more oil spillage that can occur especially if the leak is very small and is not detected with a pigging system out in a rural area. The consequences of this undetected leak could be very costly to both the environment and TransCanada. Therefore, when examining the cost for TransCanada, the company must take in consideration the higher potential cost with owning a higher diameter pipeline.

Lastly, leaks can occur through defections in the material, weather, and excavation damage but “terrorism” can be a real ordeal involving pipelines. Opponents of the pipeline have considered this option in “launching a campaign to classify it as a national threat”. (Foran, 2014) They say that “Keystone’s national exposure could increase its chance of becoming a target” (Foran, 2014). Of course, the opposition counters this argument by saying “terrorist attacks on energy infrastructure may be on the rise around the world but, terrorist strikes on U.S. soil have declined dramatically in recent decade.” (Foran, 2014) Data from the National Consortium provides proof of this idea in that “attacks fell from 468 in 1970 to just 13 in 2012”. (Foran, 2014) This study does not include any risk assessment of terrorism but terrorism to pipelines is a very real issue around the world thus, mentioning the potential risk is essential. The implications of a disaster would not only be a danger to local or regional risk but it would be put at a national level. National security of all pipelines would be placed at the highest level in

which, would up the level of risk and most likely decrease support among economic benefits.

Conclusion

In conclusion, the Keystone pipeline has many different aspects to consider involving the associated risk and economic benefits. It's seen by environmentalists as harmful towards the environment and non-beneficial towards the Nebraska economy. On the other hand, "oil people" see this as an opportunity to boast the Nebraska economy and that the risk surrounding the pipeline does not outweigh its economic benefits. In order to asses this comparison between risk versus reward, variables involving likelihood and consequence needed to be spatially examined using a GIS. Tools inside the GIS such as buffer, intersect, and union allowed for the creation of an overall risk map in which, was used for a comparison to the economic benefits of each county and spill cost for TransCanada. A ranking for each county was given based on the risk versus economic benefits with the economics receiving a higher weight because of Nebraska being a Republican controlled state over the years. Although, varying points of view cause the rankings to be subjective throughout the study. Thus, with the pipeline corridor mainly being medium and low risk only a smidge of high risk. The economic benefits outweigh its risk by having a descent return to the passing counties of Nebraska plus, TransCanada's cost risk is minimal.

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APPENDIX

Brown, Matthew <MBrown@ap.org>
To Matthew Young

This message contains blocked images. Show Images Change this setting

Greetings Matthew Young-
If it's for your thesis only and not any commercial purpose that's fine.
Thanks for checking.
Matt Brown

Matthew Brown
Associated Press Correspondent
PO Box 36300
Billings, MT 59107
mbrown@ap.org
phone-406 896 1528
mobile-406 696 4213
fax-406 896 8117

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image001.png

Matthew Young [redacted] Sep 14 at 4:21 PM
To cooljerk@cooljerk.com

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My name is Matthew Young and I doing a risk assessment over the Keystone pipeline in the Nebraska area for my thesis at Sam Houston State University and I am wanting to use a graphic that was created by you at Inside Climate News. I was wandering if I could have permission to use this graphic? The graphic is below.

Thank you, Matthew Young

Reply Reply to All Forward More

Paul Horn <cooljerk@cooljerk.com> Sep 14 at 10:55 PM
To Matthew Young

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Sure-- just give proper credit to "Paul Horn / InsideClimate News"

Best, PH

- - - - - - - -

At 9:21 PM +0000 9/14/16, Matthew Young wrote:

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Carla Whamond <carla_whamond@transcanada.com> Today at 12:15 PM
To Matthew Young

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Hi Matthew, you have our permission to use this photo for your original requested purpose of including it in "a risk assessment thesis over the proposed Keystone pipeline in the Nebraska area for Sam Houston State University."

Thanks.

Carla

Carla Whamond
Senior Brand & Visual Identity Specialist,
Public Affairs & Communications
carla_whamond@transcanada.com

VITA

Matthew R. Young

Academics:

Sam Houston State University
Graduation Date: December 2016
Master of Science: GIS
Thesis: *Keystone Pipeline Route Risk Assessment*

University of Houston (Main Campus)
Graduation Date: Summer 2014
Bachelors of Science: Major: Geology, Minor: Geophysics

Projects:

Aerial Mapping Projects *(Fall 2015 present)*
Analyzing/processing orthoimagery for aerial mapping projects

Pipeline Surveying Project *(Fall 2015)*
Creating plats for owner properties based off of centerlines

LiDAR Project (*Summer 2015)*
Using LP360 ext., Global Mapper, & Microstation for LIDAR data in order to extract features

GPS and LIDAR Project *(Spring 2013)*
Using OPUS and AUSPUS to compare and plot data

Remote Sensing Project *(Fall 2013)*
Finding oil seeps in Venezuela using ENVI

Demographics GIS Project (*Fall 2014)*
Analyzing possibility on professional sports team in Little Rock, Arkansas using ArcGIS 10.2

Work Experience:

SAM (Surveying and Mapping): August 2015-Present
Survey/Geospatial Technician

SAM (Surveying and Mapping): June 2015-August 2015
-GIS Intern

Greentree Services: September 2013-2015
Janitor for churches

Mckenzies Barbeque: January 2009-June2013
Cashier/Meat Cutter

Computer Experience:

Microsoft Products
ENVI, ERDAS
ArcGIS 10.2(ArcInfo)
AutoCAD
Global Mapper
Microstation

GIS Skills:

Cartographic techniques
Projections/Coordinates Systems
GIS Principles/Techniques
Spatial Analysis

Community Service:

West Conroe Baptist Church Bethlehem City
December 2014, 2013, 2009, 2008
Analysis