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Ulrich

PIPELINE INDUSTRY

- **PIPELINE ACCIDENT CONSEQUENCES FOR NATURAL GAS AND HAZARDOUS LIQUIDS PIPELINES**
- **PIPELINE ACCIDENT CONSEQUENCES ANALYSIS USING GIS FOR NATURAL GAS AND HAZARDOUS LIQUIDS PIPELINES**

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16. Abstract

The development of a consequences database requires a description of the damages that occur in the incidents-accidents that result in fires and/or explosions. In order to determine the consequences of an incident-accident, the records of the National Transportation Safety Board (NTSB) were examined for relevant information (such as description of the damage) since that type of data does not exist in the **OPS** database. The consequences database was then used in conjunction with a sample Geographic Information System (GIS) developed by the project team. The damage area found in the consequences database was analyzed using a GIS to determine the damages that would result if an incident were to occur at various locations along the simulated pipeline in the GIS.

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PART I

ACCIDENT CONSEQUENCES FOR NATURAL GAS AND HAZARDOUS LIQUIDS PIPELINES

1.0 INTRODUCTION

This report discusses a methodology to define both safety and environmental consequences, including damage, that result from gas transmission and hazardous liquid pipeline failures.

To determine the consequences of an incident-accident, the records of the National Transportation Safety Board (NTSB) were examined for relevant information since this type of data does not exist in the **OPS** database. The development of a consequences database requires a description of the damages that occur in the incidents-accidents that caused fires and/or explosions.

The consequences database will then be used in conjunction with a sample Geographic Information System (GIS) developed by the project team. The damage area found in the consequences database will be moved through the GIS database to determine the damages that would result if an incident were to occur at various locations along the simulated pipeline in the **GJS.**

The type of damages that are of interest in forming a consequences database includes:

- The area damaged by fire during the release of transported combustible material.
- The area damaged by an explosion that results from the release of material.
- Receptors damaged by the release of hazardous material.

A summary table of major incidents-accidents studied by the NTSB is presented below. The table includes those factors deemed important in modeling the impacts of a release of pipeline transported material and the resulting fires or explosions. These factors include:

- Pipeline diameter
- Operating pressure
- Material transported
- Size of the area burned during a resulting fire
- Size of the area damaged by a resulting explosion
- Volume of material released during the incident-accident
- Material flow prior to fire and/or explosion

Not all of the information sought for this study was available from the NTSB reports. The available information is listed in the table that follows.

All of the incidents listed resulted in a fire and/or explosion. In some cases the material flowed prior to the resulting fire or explosion. In these flow situations the resulting area that burned was greater than that which would have occurred had the released material not flowed. The data represents many geometries, wind velocities, and other factors at the incident-accident site. Within these variations, an upper bound on the area effected by the incident-accident will be sought.

SUMMARY OF NTSB REPORTS ON PIPELINE INCIDENTS

NTSB #	Material	Diam (in)	Pressure (psig)	Area Burned	Burn Rad(ft)	Height of Flame (ft)	Fire	Explosion	Release Volume	Release Flowed	Blast Rad (ft)
DCA-86-009	Natura)Gas	20	675	15 Acres	300	300	Fire	Explosion			
DCA-79-006	Natural Gas	30	560		150		Fire	Explosion			
PAR 95-01	Natural Gas	36	970		300	400-500	Fire	Explosion	297 Mcf		
PAR-87-01	Natural Gas	30	990	700' x 500'	494		Fire		116,000		
PAR-87-01	Natural Gas	30	987	900' x 1000'	610		Fire				
PAR-83-02	Natural Gas	20	820	2+ Acres	330	Sev 100 ft"	Fire	Explosion	46.8 Mcf		
PAR-83-03	Natural Gas	22	260	84' x 60'	92		Fire		22.050		
PAR-77-01	Natural Gas	20	770	12 Acres	408	200	Fire				
PAR-75-02	Natural Gas	30	718	700' x 400'	350		Fire				
PAR-75-03	Natural Gas	12	490		150		Fire				
PAR-86-01	Natural Gas	30	1016	1450 x 180'	475	Sev 100 ft"	Fire				
FTW79FP-2	Natural Gas	6	900		400		Fire	Explosion			
PAR-71-01	Natural Gas	14	780		300	125	Fire	Explosion			345
PAR-81-04	Naphtha	10	650	625' x 280'	600	70	Fire			600	
FTW-81-010	Anhyd Ammon	10	550		10560		Vapor		613 Tons	5280'	
PAR-74-6	Anhyd Ammon	8	1200	8 Mi x.25 Mi	42240		Vapor	Path	2138 Barrels	42240'	
PAR-84-01	LPG	8	1075	4 Acres	300	550	Fire	Explosion	9375 Barrels		
PAR-73-04	NLG	10	525	2400 x 35'	2400	Sev 100 ft"	Fire	Explosion	6640 Barrels		
PAR-76-08	Gasoline	8	550		245		Fire	Explosion	2 Barrels		
PAR-81-03	Gasoline	Pump	72	20,000 SF	85		Fire	Explosion	3500 Barrels		
PAR-67-02	Gasoline	8	1434	730' x 50'	700		Fire	Explosion	30,000 gal	700'	
PAR-80-06	Gasoline	8	300	Flowed 2 Mi	10560		Fire	Explosion	6640 Barrels	2 mi	
PAR-86-01	Kerosene	8	430		424		Fire		1074 Barrels	424'	
PAR-81-2	Av Kerosene	32	702	To Reservoir			NO		8000 Barrels	2+ mi	
PAR-71-02	Gasol-Keros	30	120	Flowed 1700	1700	200	Fire	Explosion	718 Barrels	1700'	

SUMMARY OF NTSB REPORTS ON PIPELINE INCIDENTS

NTSB #	Material	Diam (in)	Pressure (psig)	Area Burned	Burn Rad(ft)	Height of Flame (ft)	Fire	Explosion	Release Volume	Release Flowed	Blast Rad (ft)
DCA-78-002	Propane	4	500	3 Acres +	200		Fire				
PAR-91-01	Liq-Propane	8	600	52 Acres	1700'		Fire	Explosion		3000'	
PAR-72-01	Propane	8	942		1000		Fire	Explosion	4538 Barrels		10,560
PAR-82-02	Eth-Propane	12	1100	59.46 Acres	1120		Fire	Explosion	12749 Barrels		
PAR-76-05	Eth-Propane	8	1425	Flowed 1000'	1000	200	Fire	Explosion	14,300 Barrels		
PAR-76-07	Propane	8	1100		300	500	Fire	Explosion	2389 Barrels		
PAR-73-02	Crude Oil	8	530	1800' x 600	1800	Sev 100 ft**	Fire	Explosion	7913 Barrels	1800'	
PAR-78-02	Crude Oil	Pump	235	0.5 Acres	83		Fire	Explosion	300 Barrels		
PAR-81-02	No 2 Fuel Oil	32	670	Water Intake			No		2190 Barrels	3+ mi	
FTW81FP-2	Crude oil	16	400		800		Fire		5684 Barrels	800'	
PAR-76-04	Crude Oil	26	155	20' x 8'	10		No				

- Sev-Acres --- several acres

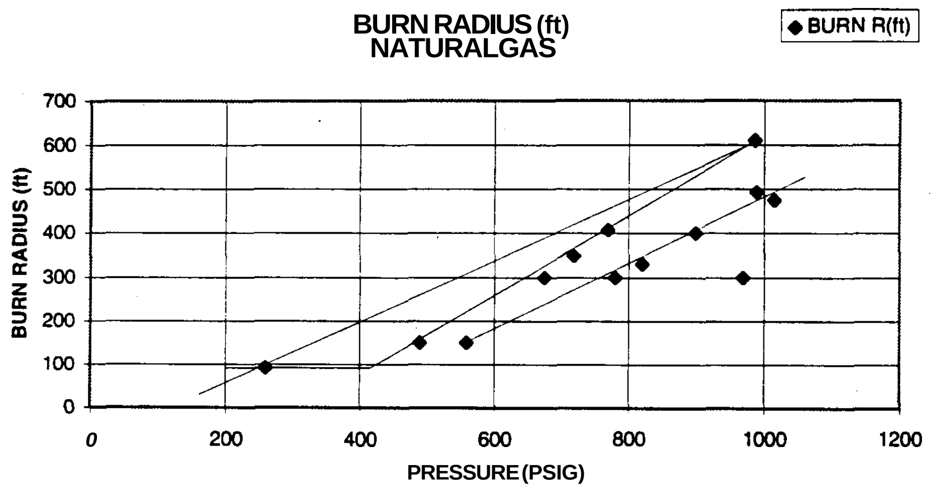
** - Sev 100 ft --- several hundred feet

2.0 ANALYSIS OF PIPELINE INCIDENTS-ACCIDENTS RESULTING IN FIRES

2.1 NATURAL GAS TRANSMISSION PIPELINES

The incident pressure and burn radius for natural gas pipeline failures resulting in fires are plotted below. A review of this plot shows a trend relating the incident operating pressure and the radius of the area burned The general.trend is for the burn radius to increase with increased operating pressure.

It is understood that there are many other factors that contribute to the area burned. These include, but are not limited to, the geometry of the surrounding terrain, the wind magnitude and direction, the depth of the pipeline that ruptured, the geometry of the rupture, the time over which material is released, the quantity of material released, the type of facilities nearby. Within these limitations, it is still possible to discern trends or upper bounds on the extent of the resulting damage area.



A line can be drawn that represents an upper bound on the burn radius (for the natural gas pipeline failures considered that resulted in fires) as a function of the incident operating pressure. This upper bound line passes through the two points:

- 260 psig 92 *ft* radius
- 987 psig 610 ft radius

The upper bound to the data is reasonably modeled by the line shown.

On the other hand, a more accurate upper bound may be drawn as the compound line shown on the plot. This line passes through four points representing incidents plus a minimum radius of **92** feet at lower pressures. These upper bounds represent conservative estimates of the area of influence of an incident resulting in a natural gas fire.

It is also of interest that all of the data, with the exception of two data points, fall on the **two** lines shown in the plot. The pertinent data is prese'nted in the table below divided between data that falls on the lower line, the upper line, and outside the two lines.

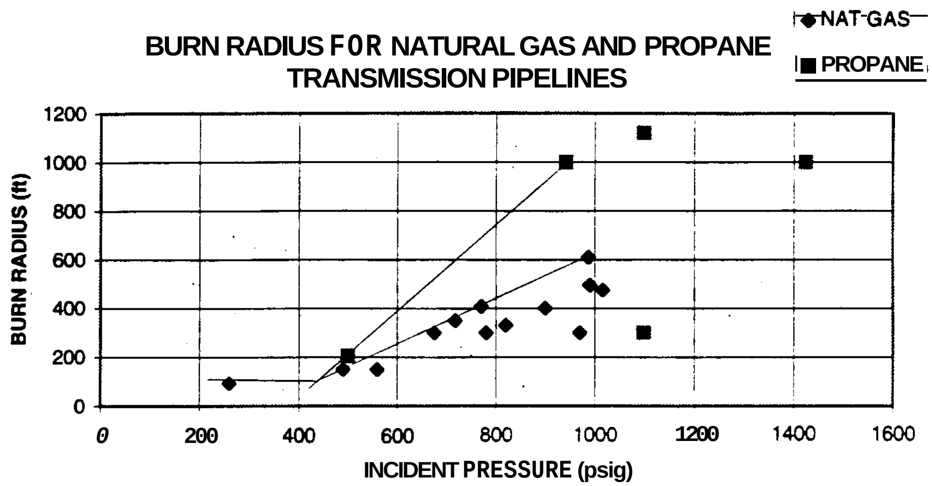
CHART LINE	DIAMETER	INCIDENT PRESSURE	BURN RADIUS	EXPLOSION
Lower	20	675	300	EXPLOSION
Lower	30	560	150	EXPLOSION
Lower	30	990	494	NO
Lower	20	820	330	EXPLOSION
Lower	30	1016	475	NO
Lower	14	780	300	EXPLOSION
Lower	6	900	400	EXPLOSION
Outside	36	970	300	EXPLOSION
Outside	22	260	92	NO
Upper	30	987	610	NO
Upper	20	770	408	NO
Upper	30	718	350	NO

An examination of the table shows that the pipe diameter does not correlate with the upper and lower line. There is, however, a close correlation with the occurrence of an explosion. It appears that the occurrence of an explosion may do damage associated with an explosion, but fire damage is a function of the radiant energy of the fire. When an explosion occurs; there is less natural gas available to burn and produce radiant energy.

In the following sections, the data for natural gas transmission will be supplemented by data for other fuels transmitted by pipeline. This will be done in a stepwise fashion, i.e., adding one product at a time. In all cases an upper bound will be sought.

2.2 NATURAL GAS AND PROPANE

The data for natural gas has been supplemented by the data for propane to see if an upper bound model still exists for the combined data. Both are gaseous fuels.



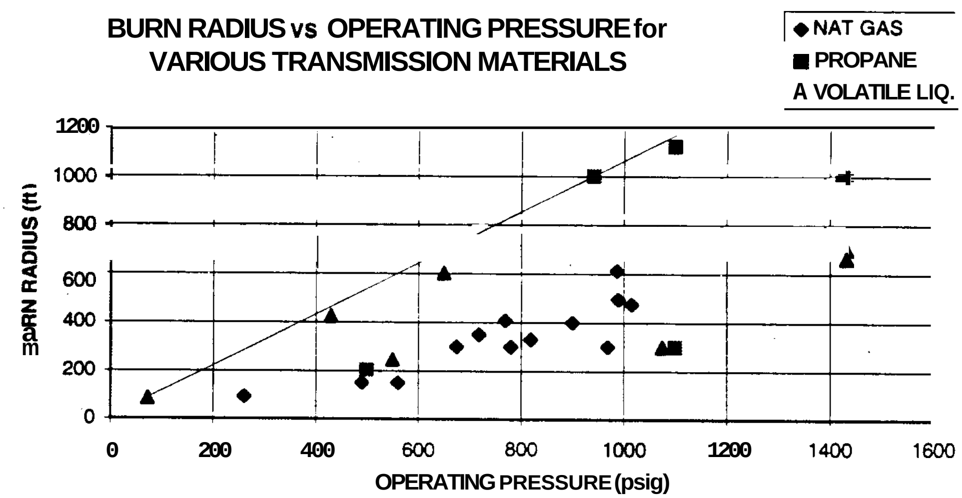
A line may be drawn that represents an upper bound on the burn radius for incidents involving propane gas. This line is significantly higher than one that represents natural gas incidents. Both upper bounds are shown. The upper bound for propane passes through the two points:

- 500 psig **204** ft radius
- **942** psig 1000 ft radius

This data is reasonably modeled by the two lines shown as upper bounds.

2.3 NATURAL GAS, PROPANE AND VOLATILE LIQUIDS

The data for natural gas and propane have been supplemented by the data for **LPG** and gasoline (volatile liquids) to determine if an upper bound model exists for the combined data or for each material individually. The data shown does not include the accidents where extensive flow occurred before ignition. These accidents are considered later in this report.



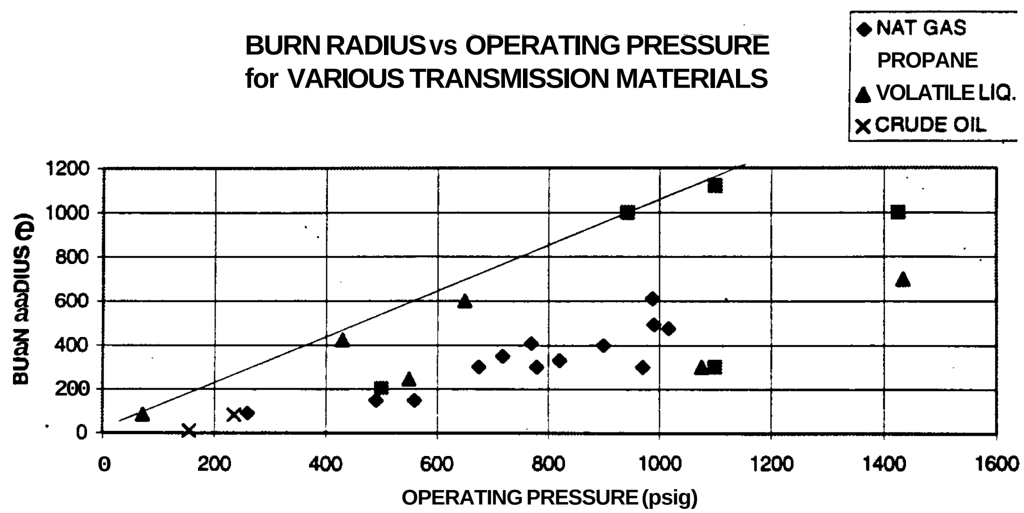
An upper bound may be drawn that contains all of the accidents. Propane and volatile liquids appear to have a similar upper bound where there has not been a major flow situation prior to ignition. The natural gas upper bound, as developed earlier, is still valid.

2.4 NATURAL GAS, PROPANE, VOLATILE LIQUIDS AND CRUDE OIL

The data for the previous case has been supplemented by the data for crude oil to determine if the two upper bound models are still valid for the combined data. The major flow accidents will be treated later in the report.

The crude oil data also introduced an anomalous data point due to major flow prior to ignition. This will be deleted from the data.

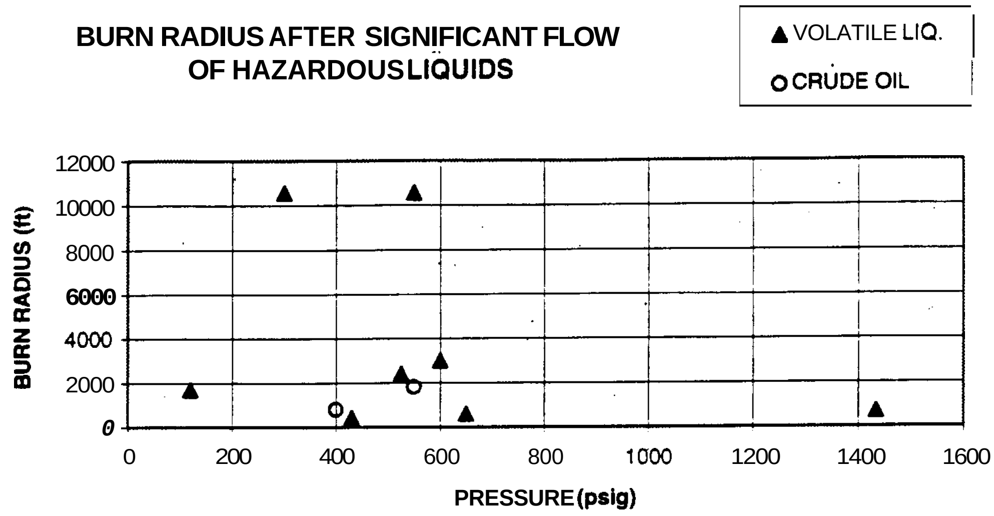
The upper bound model, however, is still valid for incidents-accidents that result in a fire at the source of the leak. An upper bound is again drawn.



2.5 HAZARDOUS LIQUIDS WITH SIGNIFICANT FLOWS PRIOR TO IGNITION OF PRODUCT RELEASED

The accident data for which there was a significant flow of released material prior to ignition are plotted in the following chart. There is no discernible pattern. Depending upon the individual situation, the length of flow will vary. It does not correlate with the incident operating pressure.

Transported liquid, when accidentally released, may flow a significant distance before it ignites and either burns or explodes. The NGL and other accidents included in this chart represent a different phenomenon than the gaseous releases considered earlier.



3.0 ANALYSIS OF PIPELINE INCIDENTS-ACCIDENTS RESULTING IN ENVIRONMENTAL DAMAGES

It is not feasible to develop a radius of influence for environmental damages resulting from a transmission pipeline leak. This is because the environmental damage that results from a leak is very site specific.

The released material will impact a sensitive environmental receptor if a receptor exists at the site of the leak. The environmental damage of a pipeline leak is a function of:

- the quantity of material released.
- the proximity of a sensitive receptor.
- local topography if the released material is liquid.
- prevailing winds if the released material is gaseous.

The possible radius of influence of a hazardous materials release is potentially quite large. In the accident represented by PAR 80-06 in the table at the beginning of this report, leaking gasoline flowed approximately two miles in a small stream before it was ignited. Released material, if topography allowed, could, in theory, flow until it reached a lake or the sea. NTSB report PAR 74-6 represented a release of anhydrous ammonia vapors that traveled eight miles after release in an accident.

The operator must be cognizant of all sensitive environmental receptors along a pipeline route and all possible routes from their pipeline to the receptor. Particular attention should be given to sources of potable water supply, both ground and surface supplies, and other important environmental receptors.

Study is needed to classify types of environmental receptors with regard to the importance of protecting,these receptors. RSPA/OPS might then consider developing a class location system, similar to that for natural gas transmission pipelines, for hazardous liquid pipelines. This process is very complex and would require the cooperation and assistance of many public agencies in identifying and classifying the importance of environmental receptors with regard to allowable risk.

PART 2

A GIS BASED PIPELINE RISK MANAGEMENT MODEL

4.0 INTRODUCTION

Encroachment of new land development on existing natural gas and hazardous liquid pipelines rights-of-way has posed a real concern related to added risk and the consequences of potential accidents. Several major accidents have occurred in the past few years resulting in loss of life, extensive property damage and water resources contamination. To reduce the probability of accident occurrence and the impact of accidents, the characteristics of the pipeline and its spatial proximity to populated and/or environmentally sensitive areas must be carefully analyzed. An illustrative GIS based strategy for analyzing the risks and consequences associated with natural gas and hazardous liquid pipelines was developed and is presented in this report.

This report presents a sample GIS that includes data requirements, data structure analytical tools, a risk management model, and an impact analysis. The GIS presented here is by no means a comprehensive and complete system. It is a modest illustration of a GIS approach that could be useful in assessing and managing risks. The information used for this study includes:

1. Spatial information on the location of the pipelines and the facilities, man-made and natural, within the potential impact area of the pipeline.

2. Attribute information on the type of facilities, their usage and the population surrounding these facilities.

Based on the above information, the risk management model and historical information, the GIS can provide a statistical assessment of the probability of a failure occurring and its impact on a given area. In the GIS that was developed here different impact buffers are presented. These buffers represent a "what if" scenario. For example, if an accident occurs at a given point and the impact radius is 750 feet from that point, the GIS will show what will be affected by the accident.

5.0 THE GIS SOLUTION

A GIS allows one to study pipeline risk processes by developing and implementing a risk management model (RMM). According to Muhlbauer ***(Pipeline*** Risk ***Management Manual,*** Gulf Publishing Co., 1992), building a risk management tool takes four steps:

1. SECTIONING. Breaking the pipeline system into sections of similar characteristics and condition.

2. ,CUSTOMIZING. Deciding on a list of risk contributors and their relative weight.

3. DATA GATHERING. Building the database by computing the risks associated with each section

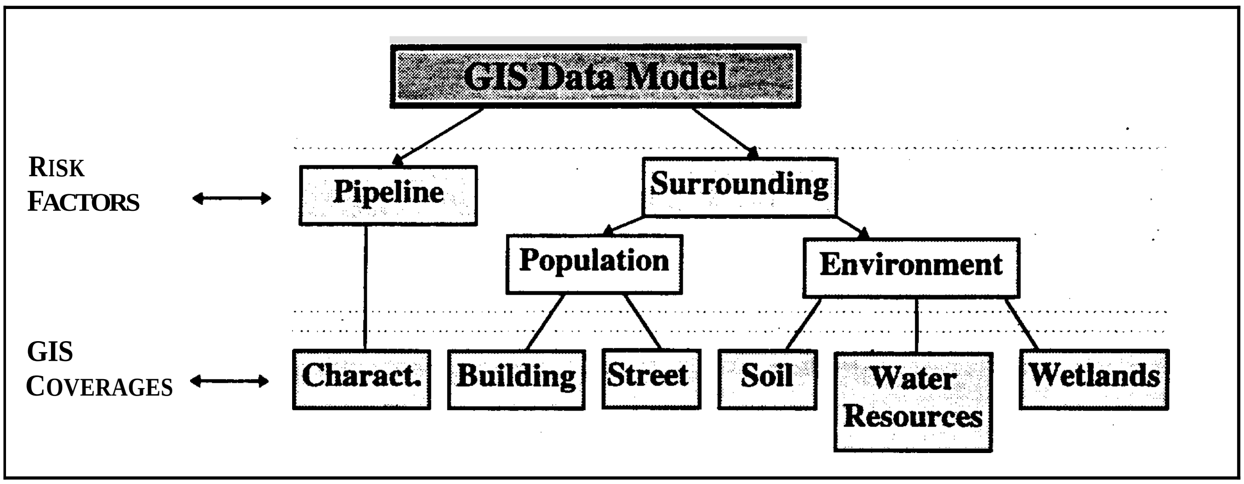
4. MAINTENANCE. Updating the database to reflect changes in pipe data and potential risks.

Building a risk management system based on GIS and these four steps is a natural match. GIS has many tools to handle both the spatial aspects and the database aspects of the Muhlbauer outline. Sectioning of the pipe and the computations of the relative risk associated with each section are classical vertical selection and analysis operations that are at the core of GIS technology.

To carry out the risk analysis it is necessary to collect pipeline surroundings environmental data.

5.1 DATA DEFINITION PIPELINE AND ITS ENVIRONMENT

An essential step in implementing a risk management model with GIS is the establishment of a data model. The data model is a conceptual plan for the type of data and the context in which it will be used. The following figure illustrates the sources of risks to the pipeline (risk factors) and some of the corresponding GIS data models (GIS coverages) that are needed for evaluating the associated risks.



For a pipeline risk management model based on a GIS there is a need to define two types of data. The first is the pipeline's characteristics and the second is the resources surrounding the pipeline. In addition, the characteristics of the specific product being transported (i.e. type of gas or liquid) have to be specified because different products present different risks. The pipeline's surroundings (proximity) data includes distribution of population, man made facilities, and environmentally sensitive areas. In terms of GIS coverages or data layers, the main surrounding factors that need to be considered are:

- POPULATION DENSITY AND PROXIMITY. Denser population in the vicinity of the pipeline presents higher risk in the event of pipeline failure. It also implies more activity, fence building, street construction, etc. Many of these activities present a higher risk to the integrity of the pipeline. Population related data are stored in the building and street coverage.

- ENVIRONMENTALLY SENSITIVE AREAS. The size, extent, and proximity of both groundwater and surface water to the pipeline and its usage determines the potential impact of an accident. If the water is used for swimming, fishing, livestock watering, irrigation, or drinking, even a relatively small spill could cause considerable damage. Stream, lake and wetland coverages are constructed to enable analysis of the risks associated with environmentally sensitive areas.

- SOIL TYPE. Soil is often an effective electrolyte, and the elements of the soil may directly or indirectly promote or enhance pipeline corrosion. The stability of the soil and its ability to resist erosion and stress are also important properties of the soil. A soil coverage is used to store the information on soil corrosivity, soil movement, soil pH, and soil permeability, among other factors.

- Other factors such as ecological, recreational and cultural resources.

Since the **GIS** presented here is an illustration of its potential as a risk management tool, only limited data was actually used by NJIT's Team.

5.2 PIPELINE ATTRIBUTE DATA REPRESENTATION

In pipeline risk management, the risk evaluator must decide on criteria to section (or divide) the pipeline into sections of similar characteristics. Each section is then labeled with a potential risk based on its characteristics. Dividing the pipeline into many short sections increases the accuracy of the assessment for each section, but may result in higher costs of data collection, handling, and maintenance. The appropriate approach to sectioning is to insert a break point wherever significant changes occur. Dynamic segmentation in **GIS** is an efficient method for performing this task. Dynamic segmentation is the ability to associate multiple sets of attributes to any segment of a linear feature without changing the description of the feature; the ability to link attributes to linear features using route-measure formats; and to store, display, query and analyze these pipeline product attributes without segmenting the pipeline itself.

The following pipeline risk related attribute data was available and was stored in a linear event table (a table that is needed for implementing the dynamic segmentation concept):

- The year in which the pipeline was installed, and the integrity testing data.
- The pipe wall thickness.
- The grade of the pipe.
- The diameter of the pipe.

- MAOP for gas pipelines or MOP for hazardous liquid pipelines.
- The pipeline station number.

A homogeneous section based on the above parameters was used in this study. Additional data could be added depending on the particular analysis and the availability of data.

5.3 PIPELINE SURROUNDINGS DATABASE

As noted above, the population and resources surrounding the pipeline are very important factors to be considered in pipeline risk management: In this study, a detailed database was built to account for some these attributes. In the database, attribute tables have been constructed for the types of facilities and the number of people occupying each one of them. The types of facilities in these tables are, for example: schools, hospitals, shopping centers, or residential buildings. Due to lack of actual data the occupancy of these facilities was assumed.

5.4 DATA ANALYSIS

The main power of a GIS is in performing spatial analysis. In this particular application of pipeline risk assessment, GIS can be used to perform the following spatial analysis:

- IDENTIFY PIPELINE SECTIONS BY AGE, DIAMETER, GRADE, PRESSURE, ETC. A color coding scheme can be developed for highlighting specific information. If a particular characteristic of a pipe is to be examined or evaluated, the appropriate sections can be extracted for analysis. For example, pipe of a certain grade and vintage that has a problem can be easily identified and located by a GIS.

- IDENTIFY THE PIPELINE'S SURROUNDINGS. As mentioned earlier, an area with higher population and active land development poses increased danger to the pipeline. A GIS could easily perform class location classification to determine the need for increasing safety measures.

- IDENTIFY THE SOIL CONDITION AROUND THE PIPELINE AREA. The type of soil could, for example, be a factor in determining the extent of the damage to the environment in the event of a spill.

- IDENTIFY THE WATER FLOW PATTERNS AND PROXIMITY TO SURFACE WATERS. Overlaying the water map and pipeline map and using query tools, one can assess the possible dispersion and the extent of the contamination.

- ANALYZE THE IMPACT ON EXPLOSION AND RELATED SAFE DISTANCE SEPARATION IN CONJUNCTION WITH POPULATION AND PROPERTY THAT EXISTS IN THE VICINITY OF THE PIPELINE. This would be useful in analyzing risk.

6.0 CASE STUDY

As a case study to demonstrate the concept, a GIS was built around a short (approximately 2 mile) pipeline section in Edison, South Plainfield, and Metuchen, New Jersey. The research area is depicted in Figure 1. This section is located in the vicinity of the gas explosion that occurred in 1994 in Edison, New Jersey. The pipeline characteristics information along this pipeline section was obtained from an operator of a hazardous liquid pipeline. The pipeline route and its relationship to the local streets is presented in Figure 2. The building and street coverage were digitized from a topographic map of the area and orthophotographs (TIGER data for this area was erroneous and outdated). The factors of pipeline surroundings included environmental factors and population density. Environmental data such as streams, lakes, and wetlands was obtained from the New Jersey Department of Environmental Protection and Energy (NJDEPE). Figures 3 through 6 show the data that was obtained from NJDEPE. Some of the data is presented for the entire county with an indication of the research area. This is to show that information was collected, but that very limited data falls inside the case study area. Some of the data elements do not even exist for the research area. For example, in Figure 4 (Lakes), there are no lakes that fell within the pipeline corridor. A Soil map was also digitized.

7.0 RISK ANALYSIS WITH GIS

The risk analyses performed in this .study involve hypothetical "what if" scenarios. Different incidents could have different areas of impact. Thus, it is prudent to analyze what would happen if a certain incident occurred at a certain point. The buffer spatial analysis tool was used to perform this analysis.

For pipeline risk management analysis, two types of buffers are useful. The first is a line buffer and the second is a point buffer. A line buffer analysis takes into consideration an impact area along a line (i.e. pipeline), while a point buffer computes the impact on a certain radius around a selected point (incident point). In this study we computed four line buffers with different widths and four point buffers with a fixed radius at different locations along the pipeline. The widths of the line buffers were 250 feet, 500 feet, 750 feet, and 1000 feet. The radius of the four point buffers was 1000 feet.

The determination of the actual width or radius for a particular incident is a function of many factors. Some of these factors are operating pressure, commodity transported, depth of burial, and weather conditions. A study on this matter was produced by NJIT and covered in Part I of this report.

8.0 ANALYSIS OF RESULTS

The results of the above analysis are presented in Figures 6 through 12. The following is the list of these figures and what they depict.

Figure 6 The location of the four point buffers which were analyzed.

Figure *7* Impact area on facilities within 250 feet of the pipeline.

Figure *8* Impact area on facilities within 500 feet of the pipeline.

Figure 9 Impact area on facilities within 750 feet of the pipeline.

Figure 10 Impact area on facilities within 1000 feet of the pipeline.

Figure 11 The affected population within the above line buffers.

Figure 12 The affected population within the above point buffers.

The findings from Figure 11 indicate that the wider the impact area, the more population is at risk. This is an expected result. What one can learn from these findings is that in certain areas, if a highly volatile commodity is being transported, a very large population could be put at risk. Safe separation distances or an equivalent increase in safety measures must be considered following a risk assessment.

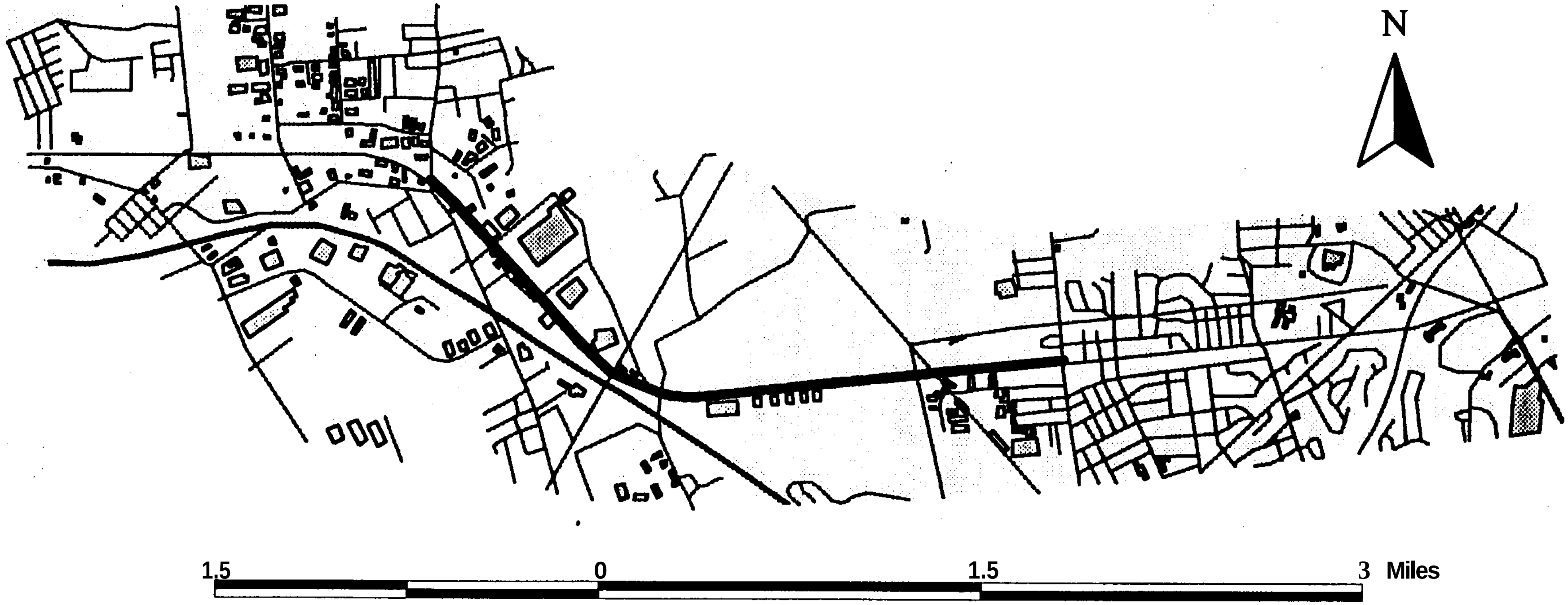
The results shown in Figure 12 are interesting as well. They show that if an incident occurred at point **4** (i.e., points shown in Figure 6) it would have no impact on the population. However, should one occur at point 3, 1100 people would be at risk. The distance between points 3 and **4** is about one mile. These results show that an appropriate risk management program must be detailed enough to accommodate and account for very large variations in very short distances. Implementing only a general risk management program is not sufficient for determining the real risk involved.

9.0 CONCLUSIONS

A brief demonstration **GIS** based risk management model was developed and a case study was presented. It attempted to show that **GIS** is an appropriate tool for implementing a risk management model and for maintaining a risk management program. It was also shown that a broad brush risk management program that does not consider detailed spatial data is insufficient in assessing the real risks associated with transmission pipelines.

APPENDIX A

Study Area and its Surroundings



Street Network
Pipeline Segment
Buildings
Study Area

Figure 1

Pipeline Route System

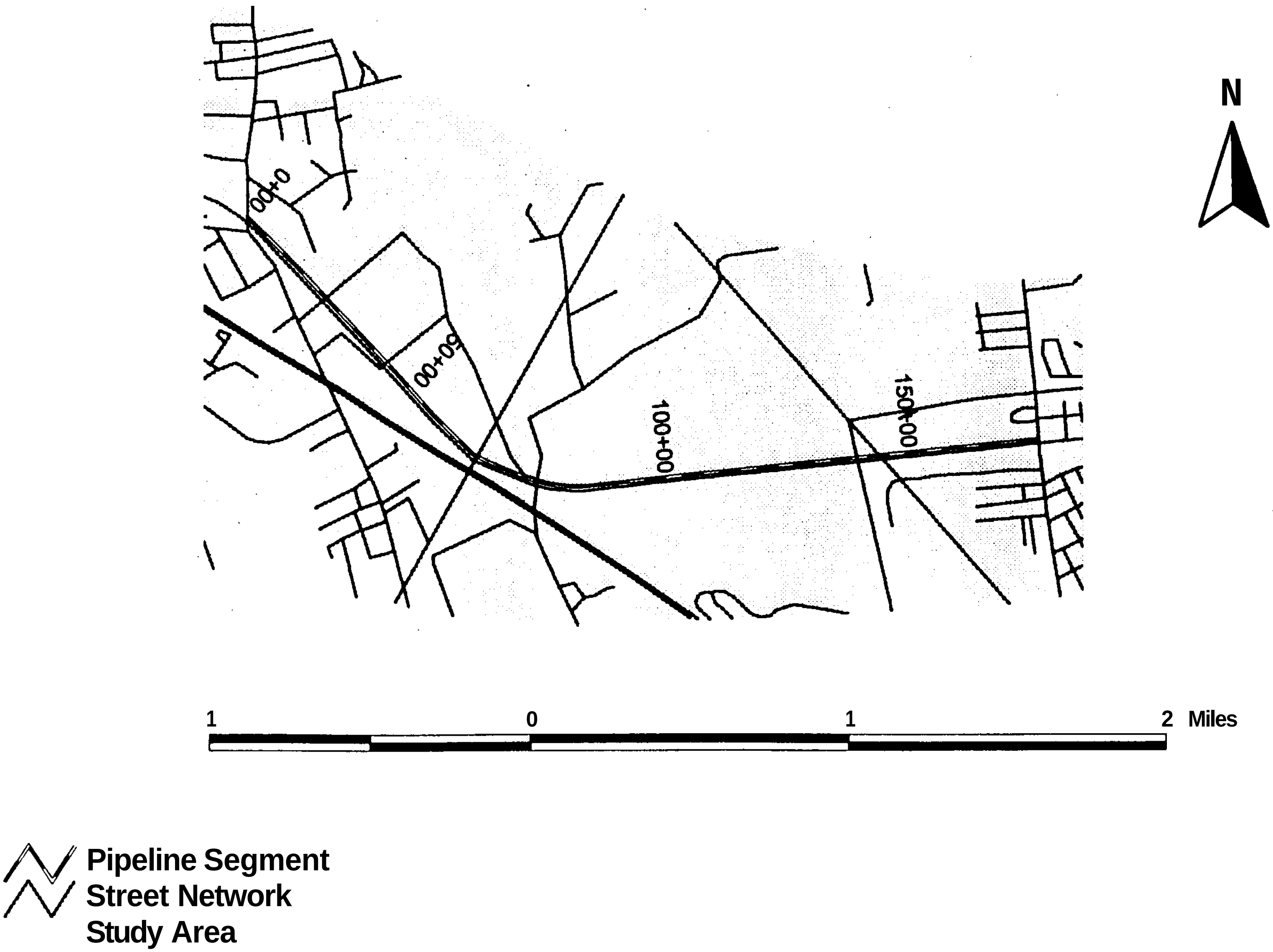


Figure 2

Wetlands

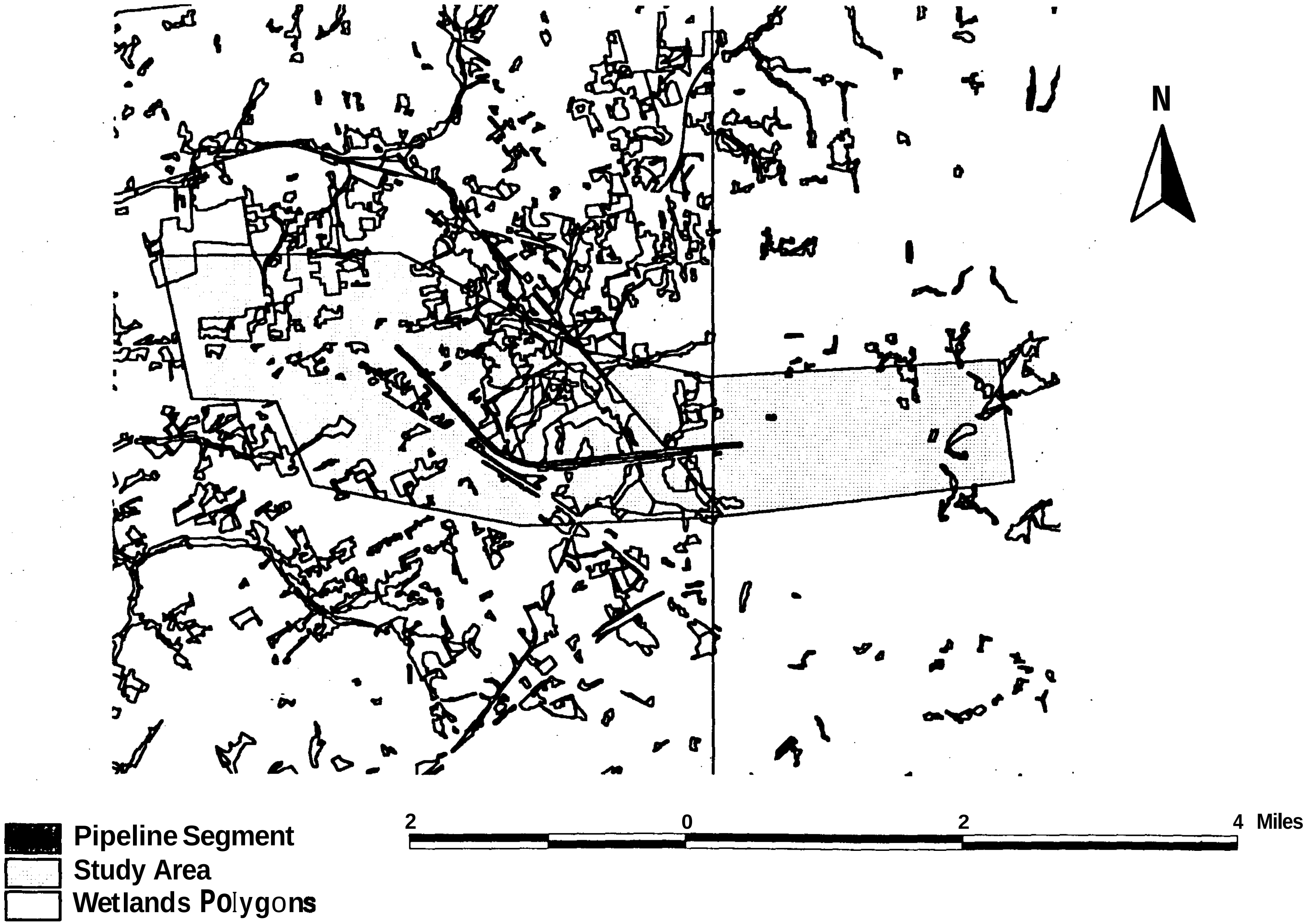


Figure 3

Lake Coverage

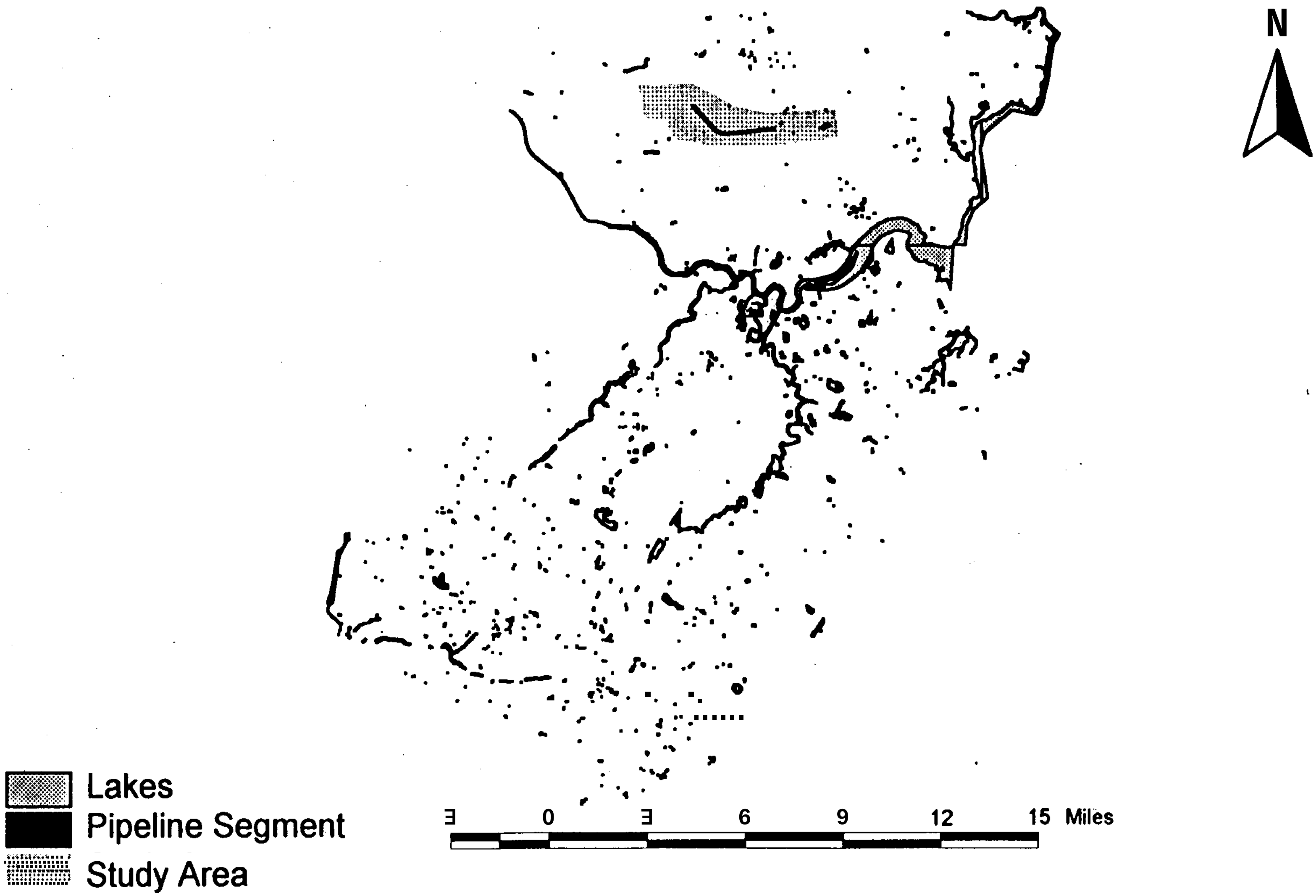
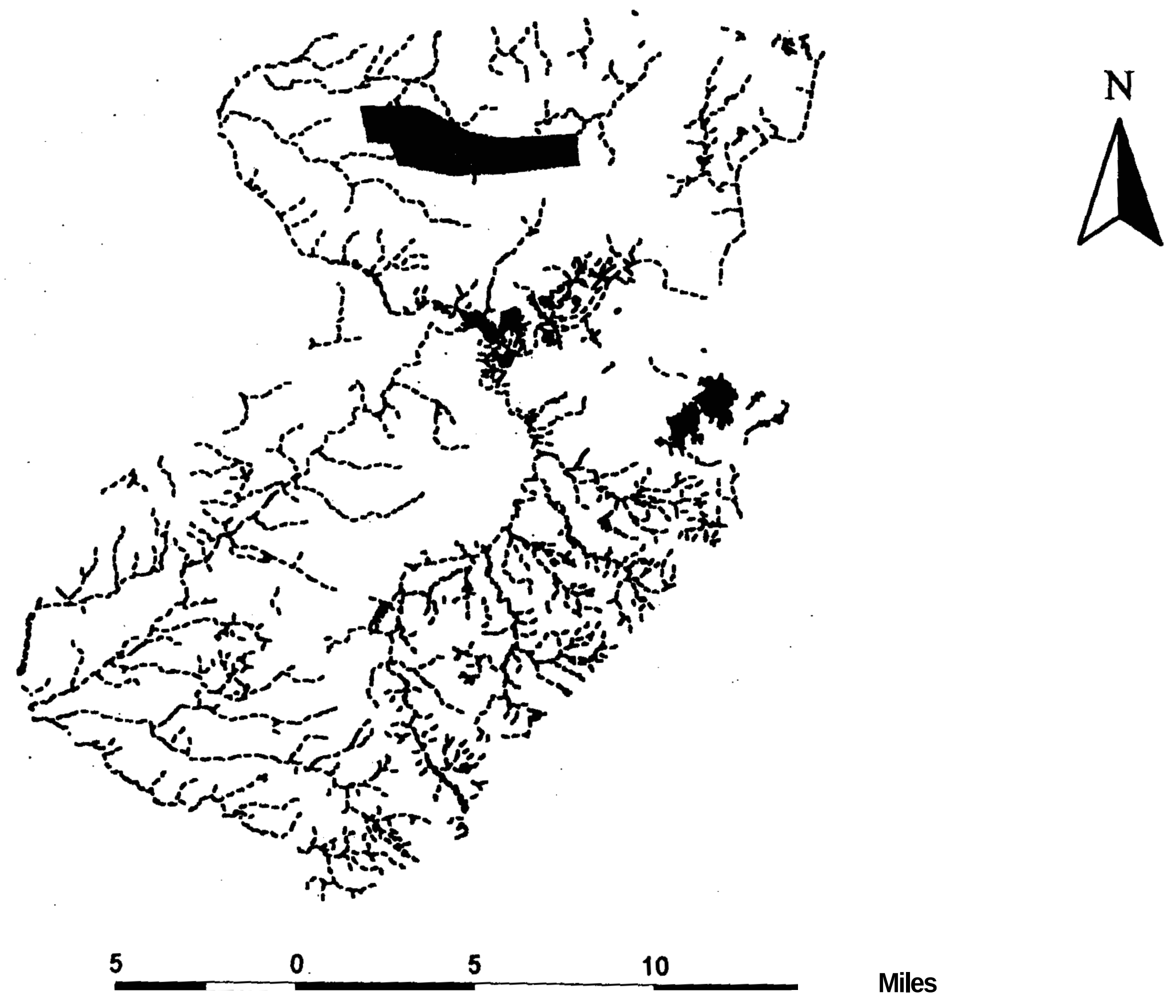


Figure 4

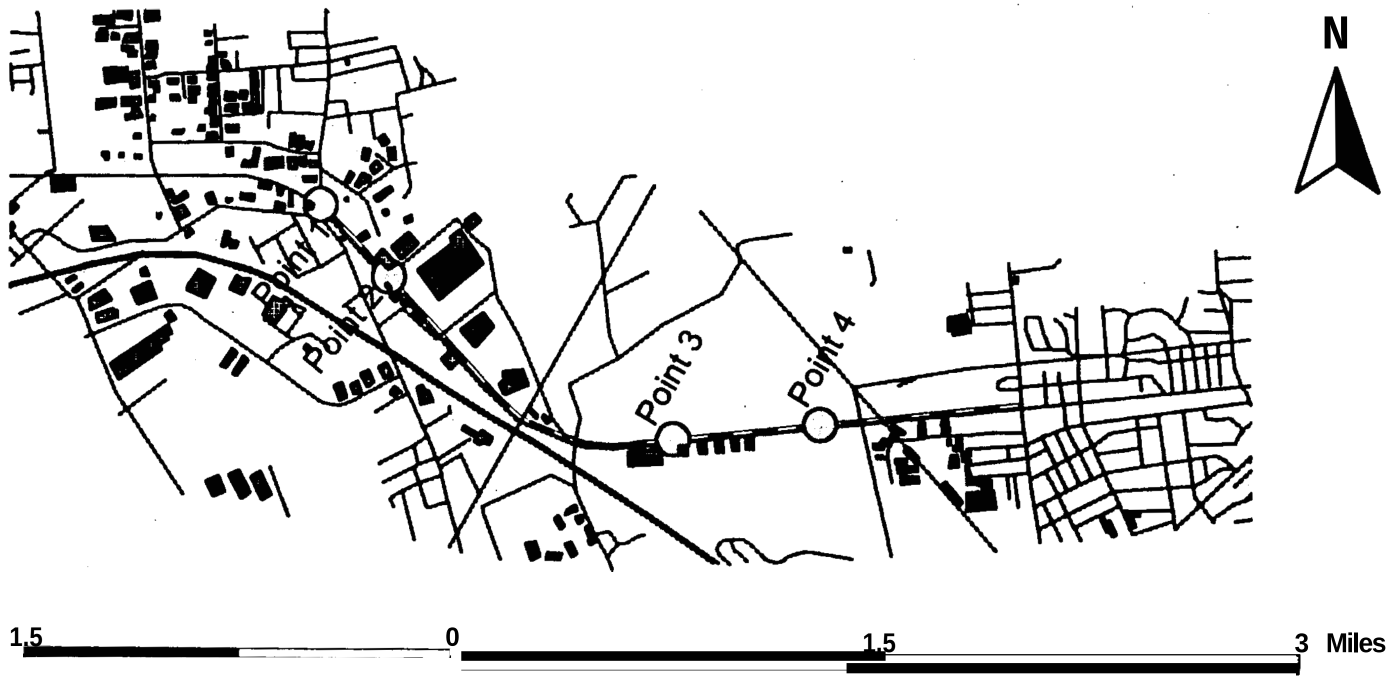
Streams Coverage



Pipeline Segment
Study Area

Figure 5

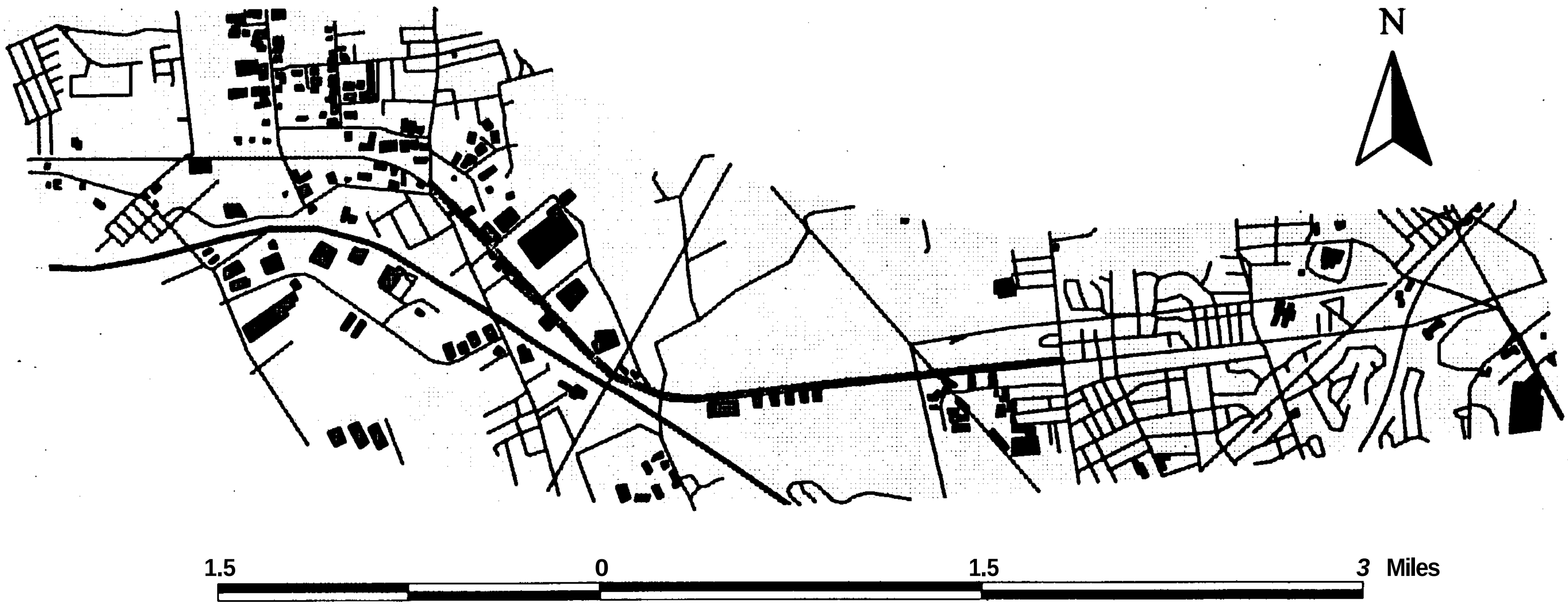
Impact of Point Incidents



Buildings
Point Buffers
Pipeline Segment
Std
Study Area

Figure 6

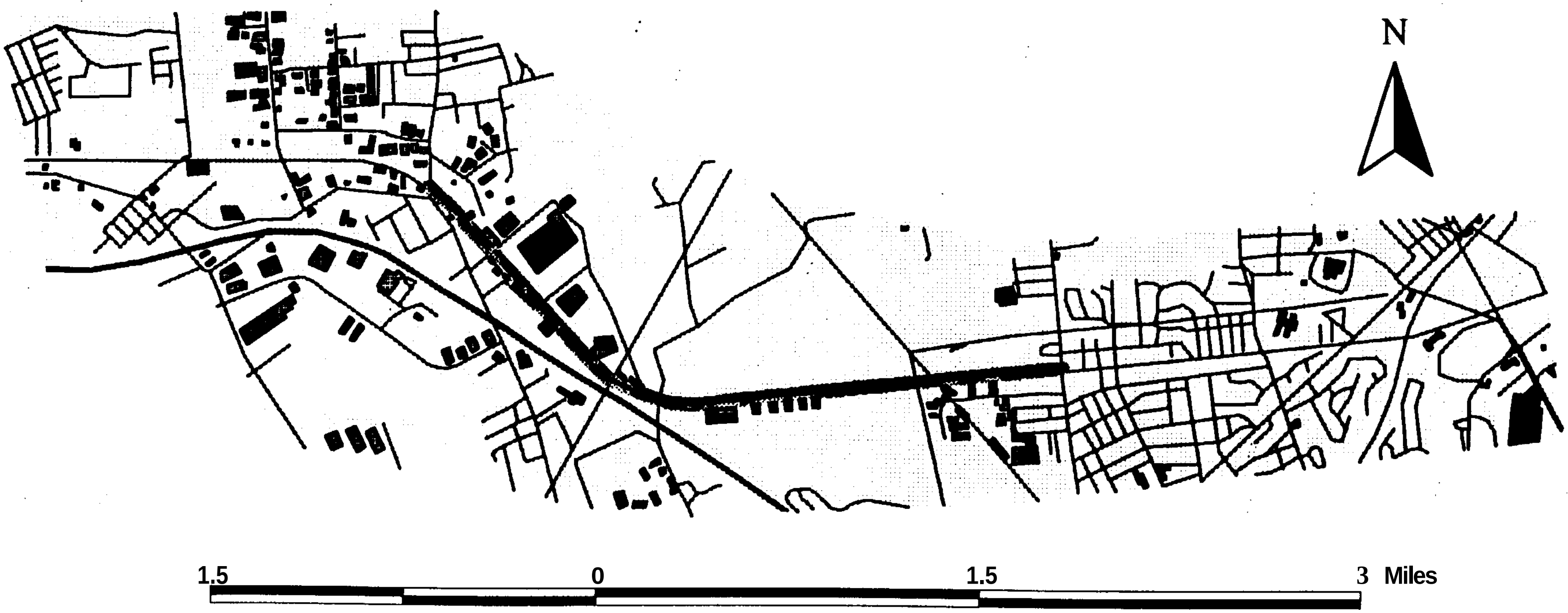
250 ft. Buffer



Pipeline Segment
Buildings
250 ft. Buffer
Streat Network
Study Area

Figure 7

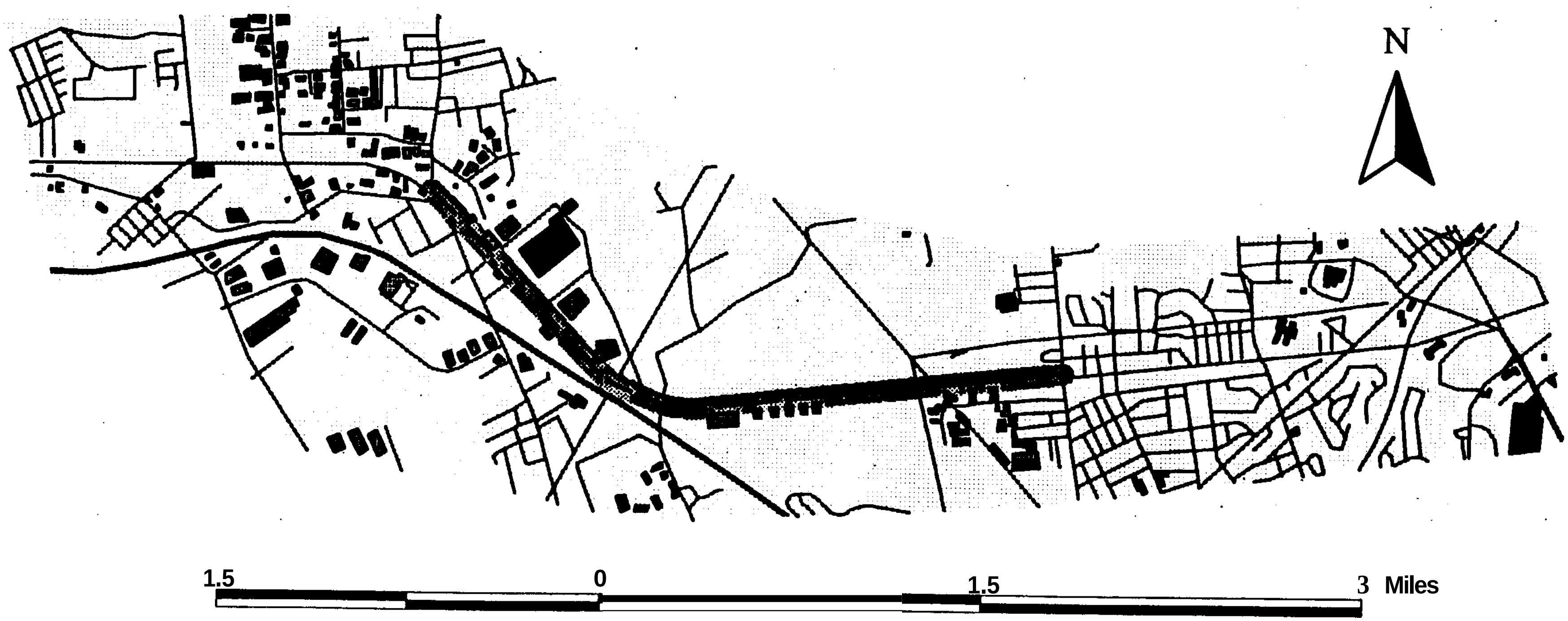
500 ft. Buffer



Pipeline Segment
Buildings
500 ft. Buffer
Streat Network
Study Area

Figure 8

750 ft. Buffer



Pipeline Segment
Buildings
750 ft. Buffer
Streat Network
Study Area

Figure 9

1000 ft. Buffer

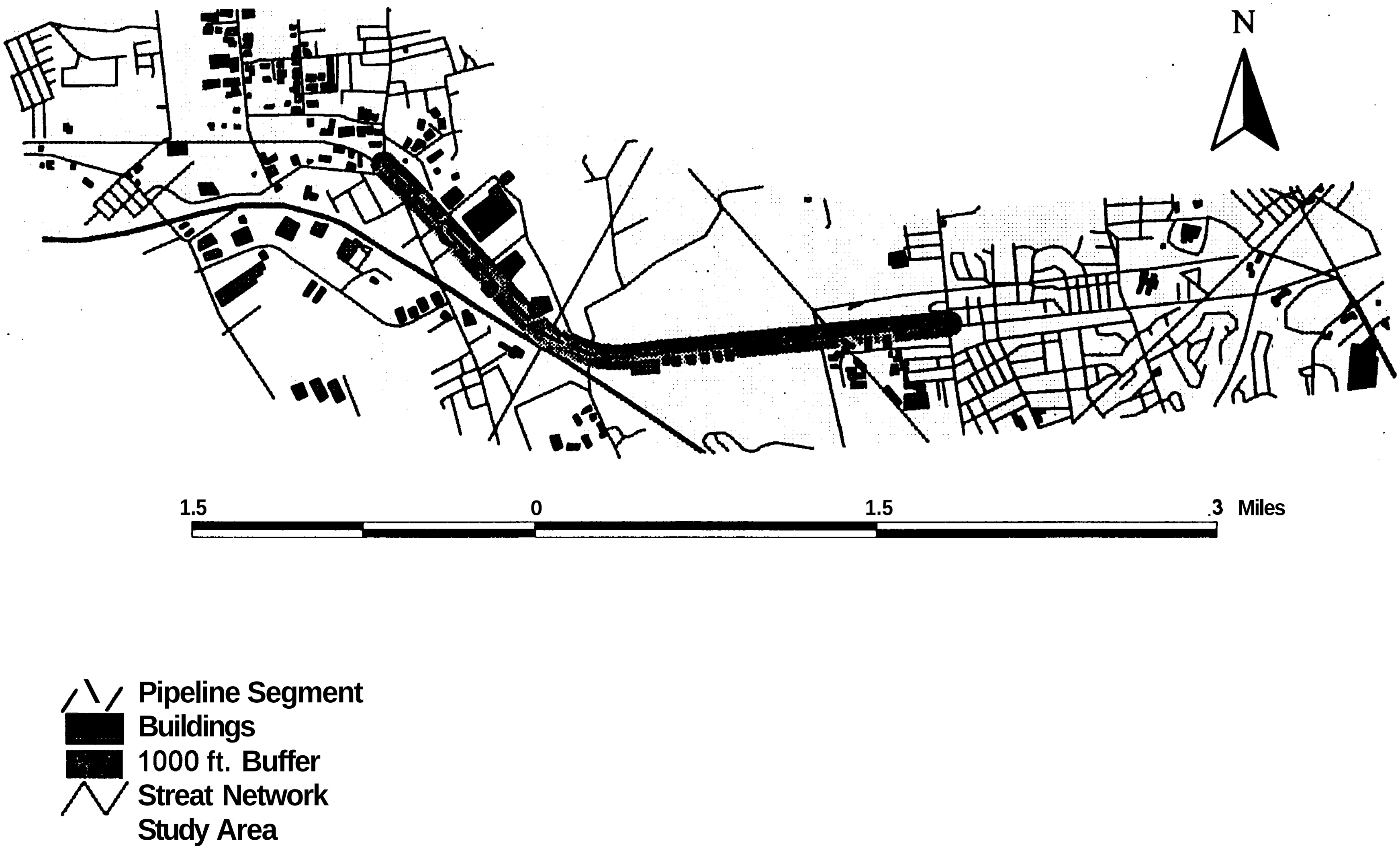


Figure 10

Line Buffer				
Buffer Distance	250	500	750	1000
Population	*660*	1810	2190	*2990*

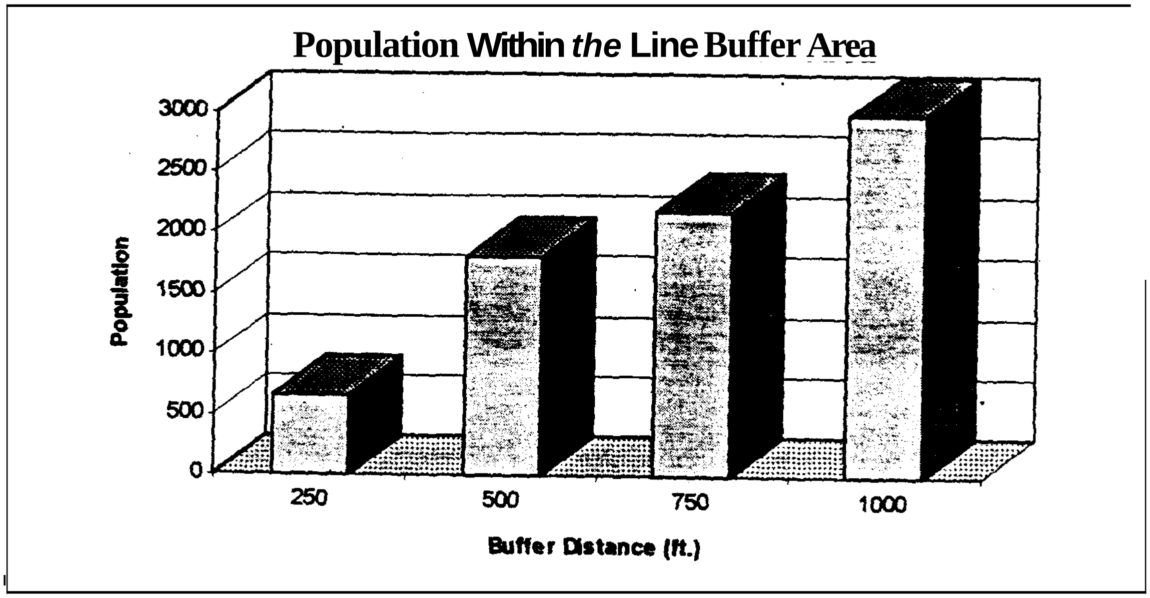


Figure 11

Point Buffer				
Location	Point 1	Point 2	Point 3	Point 4
Population	*660*	1810	2190	*2990*

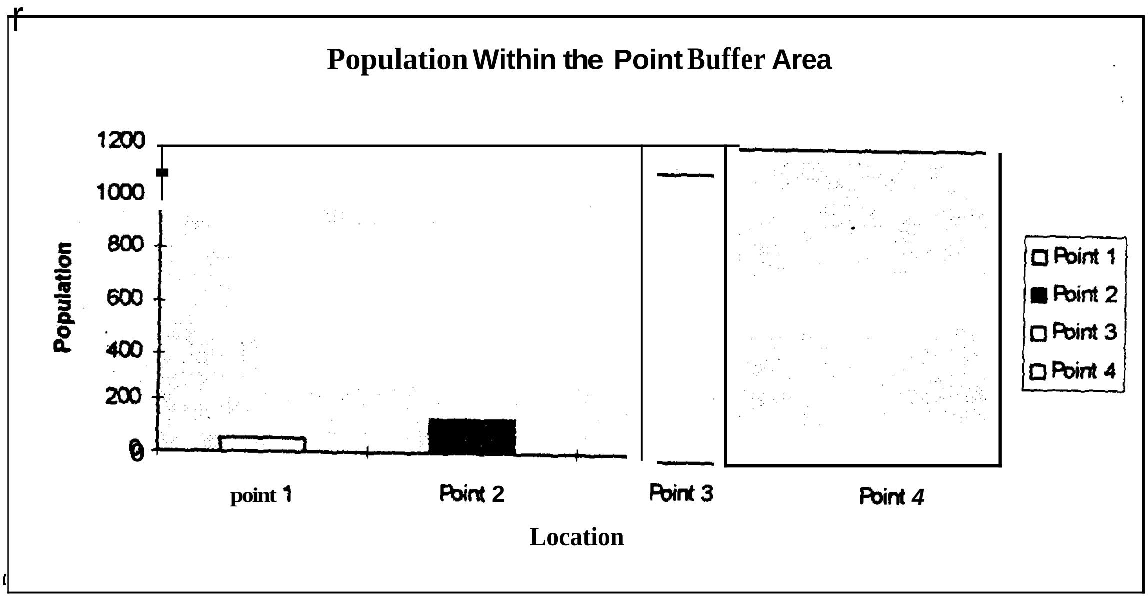


Figure 12