Administrative and Political Implications of GIS Implementation within the Fire Service A Case Study of Norfolk, VA

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(Abstract)

The advent of faster, cheaper, and more powerful computer hardware has led to the widespread integration of GIS technologies into decision making processes within local governments. Most GIS literature has focused on the models and benefits that the technology can produce and not on the impacts that GIS has on the organization. This research explores the political and administrative implications of utilizing a GIS to address a resource allocation problem within the Fire Service Administration of the City of Norfolk, VA. A network model is employed to allocate rescue resources throughout the city in various configurations. The goal of NFPS (Norfolk Fire and Paramedical Services) is to be able to cover the entire City of Norfolk within five minutes of travel time. City and NFPS administrators evaluate various models based upon a provided questionnaire that focuses on the administrative and political viability of each of the models produced.

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Chapter 1: Introduction to Research

Hypothesis:
Desktop Geographic Information Systems (GIS) can be utilized by *fire service professionals* to produce models that increase the efficiency, effectiveness, and equity of the distribution of fire fighting resources. However, actual allocations of resources are determined in a political environment that may or may not implement the model derived. Proficient administrators must build a case based upon the political benefits of the model produced by a GIS in order for it to be implemented. Potential gains in resource allocation will go unrealized unless the political leaders within a polity can be convinced that there are political gains to be had by the implementation of the model. If an administrator does not plan for the political environment within which the GIS must operate, it is quite likely that the analysis produced will be ignored in favor of an argument that has been framed with the political framework in mind. According to Deborah Stone in her book Policy Paradox (1997), politicians always have at least two goals. The first concerns the approval, defeat, or implementation of a particular policy concern. The second is the preservation of enough political power to complete future policy projects. Savvy administrators realize the objectives of their superiors and utilize the incredible graphical and data handling capabilities to GIS to frame their arguments accordingly. GIS must operate like everything else in a political environment: it must prove its worth to those who make the decisions within an organization. For their part, policy makers (both elected and appointed) will now be presented with powerful arguments that are reinforced by vivid graphic representations of the environment. To avoid being overwhelmed by these arguments, policy makers need to understand, now more than ever, the inner workings of the organizations that they oversee and the basics of any decision support technology (like GIS) that they choose to implement. The consequences of being overwhelmed by the technology are poor decisions, which may undermine future implementations of this potentially powerful technology.

What is GIS?
Geographic Information Systems are computer-based systems that are designed to operate specifically on geographic information. Since its development in the early 1970’s GIS technology has been used to store and manipulate geographic data for planning purposes. “The technology has developed so rapidly over the past two decades that it is now considered an essential tool for the effective use of geographic data (Arnoff, 1993).” A GIS is specifically used to collect, store, and perform analysis on geographic objects and phenomena. A GIS database consists of geographic location, attribute information (speed limit, road type, etc.), and topologic data (the spatial interrelations of the various features with one another).

The power of this technology becomes apparent when modeling situations with hundreds or even thousands of factors associated with each data set. Large volumes of data are too costly and time consuming to manipulate manually. However, data that have been entered into a GIS can be manipulated and easily incorporated into a planning model or updated for future use.

The analytical potential of GIS technology is immense; however, it cannot exist without problems to address and people to support it. GIS exists for the sole purpose of serving the analytical and data maintenance needs of an organization. Organizations are not vacuums, but value-laden entities that are socially constructed to achieve goals. GIS differs from automated mapping and CAD applications in that it is used to produce new information for the user or client. The information processed and produced by a GIS system is laden with the values of the agency utilizing the technology. For this reason no two GIS systems are identical. Differences in data content, construction, and presentation arise from the values and objectives of utilizing agent.

Study Area Specifics:

The research was conducted for the Fire Department of the City of Norfolk. Norfolk is a city with approximately 300,000 citizens in the southeastern corner of the state of Virginia. Located just north of Virginia Beach, Norfolk has one of the largest ports in the world and is the home of the largest naval base to service the US armed forces. From 1992 to 1995 Norfolk Fire and Paramedical Services (NFPS) responded to 112,643 (an average of 28,160.75 per year) paramedical emergencies (Table 1.1). With the present configuration of resources, 82.15% of all fire demand points (fire demand zone points are a geographical means used by the city to track responses within their database) are within a 5-minute radius of at least one of the 10 fire stations equipped with ambulances. 83 of 87 paramedical response zones are reached within five minutes as well (a paramedical response zone has been defined by the city of Norfolk as a census tract).

Five-minute coverage is important because after five minutes of blood or air loss the brain suffers permanent trauma. Present coverage of the city is good (Map 1.1), but it should be noted that the coverage is extraordinarily egalitarian as well. Census tracts from the 1990 census were divided by the percentage of families classified as poor and overlaid by the 5-minute area of coverage layer for the city's paramedical services (Map 1.2). Note the extremities of the city tended to fall outside this range, the heart of the city is covered completely. Of the areas uncovered, none of them had an average family poverty rate greater than 50% (the lowest rating), only one area fell within the 35.7%-50% range, and the majority of the areas had ratings ranging between 0%-20.9%.

Introduction to Research:

In general, the fire-fighting environment is a dynamic one that involves a plethora of political, technological, and environmental factors. Presently, fire departments often have to rely on outside sources for the resources to address many of their planning needs. Some of this is due to the labor-intensive nature of fire fighting. Fire departments are responsible not only for putting out active fires, but for the maintenance of their equipment, and all the activities that go into the prevention of fires. These duties within the present political environment of more for less often leave the average fire department with little time for the creation of complex planning models. These agencies often rely on outside sources that do not have a full understanding of the fire-fighting milieu. The models produced are often technically sound, but lack the "perspective" that a first hand analysis might have. This study seeks to define the applicability of desktop GIS to planning in the fire service.

Desktop networking applications may provide fire service administrators the analytical tools they need to model within the time critical environment of the fire service. GIS is capable of producing time-based analysis for fire departments in an automated and timely manner. With the advent of Arc/View GIS one no longer has to be a GIS specialist to produce high quality planning products. GIS could potentially provide fire departments with the tools they need to do most of their own planning without a large time or personnel commitment.

This study tests the relevance of GIS produced time-based models within the *political environs* of the fire service administration of the City of Norfolk. The NFPS does not operate in a political vacuum. It is one facet of the City of Norfolk's governing administration. Decisions made by the NFPS are influenced and influence other aspects of this overarching organization. This research seeks to explore not only how GIS technology can be utilized in fire service administration, but also how the models produced by this technology are utilized in this dynamic environment. The question of utilization is what sets this research apart from existing GIS literature. Administrators and elected officials within the organization need to be aware that the utilization of GIS has democratic as well as administrative implications.

On the administrative side, a wealth of new information becomes available as decision support models are produced by lower level officials within an organization (Arnoff, 1992). Civic leaders, elected officials, and high level managers now need to be more aware of the how their organizations operate on a day to day basis because they will now be inundated with claims for resources based upon the models produced with GIS technology. Advanced knowledge of how their organizations operate, and how GIS works will be indispensable for responsible leaders sifting through the deluge of new information.

Authors such as Pickles (1995), Masser (1996), Campbell (1996), and Craglia (1996) argue that widespread adoption of GIS by governmental organizations has broad implications for a democratic society. As organizations convert to digital data formats there is the possibility that data may become inaccessible to those without access to the computer hardware necessary to utilize it. Many have argued that the computer revolution will usher in an unprecedented era of democratic governance. Spurred on by new technologies the citizenry will have more access to information, agencies, and decision-makers. This type of scenario is plausible, but not automatic. One does not simply employ a new technology like GIS and then stand back to watch the democratic magic unfold. Geographic information systems, and information technologies in general, are most likely to enhance the democratic process when they are employed in agencies that embrace the core values of democracy, equity and liberty.

Democratic Implementations of GIS:
If democratic institutions (and the instruments used by them such as GIS) are to foster democracy they must embrace democratic values such as equity and liberty, but organizations differ in how they define equity and liberty. Organizations are often deemed more equitable if they treat everyone equally. But is this always the most "equitable" course of action? Circumstances differ and some citizens may require more of some services than others. Environmental circumstances surrounding various cases differ. Is it fair to those who belong to society's most disadvantaged groups to be treated "just like everyone else?" Under these circumstances, would those who needed the help of government institutions get it? The answer to these questions is no. Government action is based upon the reality that some citizens need to be treated differently than others in certain situations (Stone, 1997). How and why they are treated differently is a matter that has been taken up by Stone and should be taken up in other works. Here, however, I will postulate that a GIS can promote equity in an institution by broadening access to the information that pertains to the citizenry. The mapping capabilities of GIS can be used to provide information to citizens and civic groups so that they can decide if they need to address a specific issue with a responsible institution. As with any information, access to it does not ensure good decision making. Only citizenry educated in the nature of the data and GIS will be able to utilize it for analysis.

Liberty, often associated with freedom, is an ambiguous concept that, just as with equity, means different things to different members of society. Is there a way in which GIS can embrace such an ambiguous concept? GIS can promote liberty if the capabilities of the GIS are utilized to provide individual members of the polity the information they need to decide for themselves if the institution is infringing upon their *perception* of liberty. The polity as a whole may decide what liberty is defined as, but the key to keeping a society free is the ability of each individual to decide if his liberties have been infringed upon and to challenge those he believes responsible.

The common denominator of both the above arguments is the issue of access. GIS or any other information technology can be utilized to embrace democratic principles if the institutions that utilize their capacities to increase the polity's access to information. Institutions that embrace democratic values are self-critical (Dryzek, 1990). Critical of how they can improve access to their services, improve the delivery of those services, and how the discourse surrounding their milieu can be open to informed public debate. Often times, the above values work at cross-purposes. Increasing the access the public has to an institution may mean that services are no longer delivered as efficiently as they once were. Public debate invariably brings with it scandal and criticism. The resources used to open institutions to public forums could be used to deliver services. Institutions are exposed (open to scrutiny) and vulnerable (open to criticism) in this setting, but an exposed system is the only way foster the democratic values that we as a polity embrace.

The State of the Literature:
GIS literature is replete with works that elaborate on the technical aspects of an application while ignoring *how the results are utilized.* Authors such as Ian Masser and John Pickles lament the stagnation that has occurred in the literature. GIS literature is

dominated by technical journals that describe the great success of GIS technology within an organization. As Pickles points out:

"GIS authors have generally grounded their analysis in terms of value neutral models of observation, science as the mirror of reality, and theory as the product of data collection and testing and have not chosen to engage in the disciplinary and social theoretic debates of the past two decades that address the intellectual, social, political impacts of this form of instrumentalization (Pickles, 1995 p.17)."

“The development and application of GIS have rarely been treated as having serious political and social implications. Moreover, for the most part, GIS users themselves have failed to address the wider context of practice and meaning within which their own activities are located (Pickles, 1995 p.5).”

Furthermore GIS literature, like most technologically based literature has what Masser terms a "pro innovation bias". Pro innovation bias is the tendency to view the replacement of older methodologies with newer more advanced methods as a beneficial way of doing things because of perceived gains in efficiency (Masser, 1996 p. 9). Both Masser and Pickles argue that because the present criteria for judging GIS within the literature is so technical that many of the social and political externalities have not been explored. Most GIS literature is based upon the assumption that the adoption of this technology is beneficial. Yet, experience has shown that often once a technology becomes fully integrated into society it displays what Masser terms a "dark side". As an example Masser points to the farming industry and notes all the problems that have been associated with the "green revolution". When the technology was first being established the focus was on the increased yields and reduced growing times that the innovation produced. However, now we are dealing with the increased erosion, water pollution, and rural unemployment that are the byproducts of advanced farming methods (Masser, 1996).

This research seeks to fill a void within the present literature by analyzing the impact of an application upon the political environment and vice versa. The questions that are to be addressed by this research are:

- How will the Norfolk Fire and Paramedical Service utilize the models produced by the network GIS applications?
- What are the administrative ramifications of using this tool?
- What are the political factors that influence how this tool is used?
- Does this tool produce any externalities, which may impede the democratic process?
- Does a network GIS significantly increase the analytic capabilities of the NFPS?

There are two reasons that the City of Norfolk is a good study area to explore these issues. First, the city government of Norfolk has been working with the NFPS for many years to integrate GIS technology into its administration. Digital data pertaining to Norfolk's delivery of rescue resources dates back to 1992 (and in many instances 1991), allowing the researcher to integrate more than one aspect of the problem at hand into the analysis. Secondly, NFPS is confronted with a politically charged problem that GIS was ideally suited to address. At the present time NFPS is only able to respond to approximately 50 percent of the rescue calls it receives in less than five minutes (Tables 1.1 - 1.4). NFPS would like to reduce its response time because of the brain damage that is incurred after five minutes of blood and air depravation. NFPS leaders hoped that the analytic models produced by GIS will enlighten administrators as to why the average rescue response times are so high and what actions might be taken by the city to reduce those times.

Chapter Two: Literature Review

Computer Applications within the Fire Service:

The mission of the fire service has traditionally been to prevent fires and to respond to those that do occur and to put them out. Although most fire departments are the primary providers of preventative fire protection, all fire departments are organized to react promptly to crisis situations (Drake, 1972). The milieu within which the fire service operates is complex, with financial, technical, managerial, legal, and political factors affecting department operations (Massan, 1981). The fire service is unique, in that to be effective, other agencies within the political unit must be relentless in the completion of its duties. Building inspectors, teachers, police officers, and the fire service all play a vital roles in fire safety education, building inspection, and fire prevention. If any one of those duties is not performed adequately, the fire service may be unable to complete its duties in a satisfactory manner. Within local governments, adequate and timely fire protection depends on the formulation and administration of effective housing policies and building codes, architects and building contractors, fire insurance companies, telephone companies, and equipment manufacture (Drake, 1972).

Traditionally fire departments have been reluctant to embrace new methods of administration, because the potentially high price of failure is often overwhelming. As a line-operating agency the fire service has traditionally been ill equipped in planning skills and organization to undertake significant change. However, increasing public demand for public services coupled with a decrease in the willingness to pay for those services has pushed fire service administrators to look for tools to enable them to allocate scarce resources more effectively. Fire departments have turned to Geographic Information Systems (GIS) to improve their in-house planning capabilities. Prior to the infusion of computer technology into the fire service, administrators typically had to rely on outside agencies and consultants to complete the majority of their planning activities (Hoetmer, 1996). The human capital simply was not available to perform these duties within the departments themselves.

Computer technology has enabled fire departments to analyze data in a sophisticated manner without a monumental investment in time. This has reduced the reliance fire departments traditionally have had upon outside departments and consultants. This is advantageous because the demands of fire fighting are so rigorous that it is difficult for an outsider to model them all accurately when devising a plan for resource allocation. The advent of desktop GIS has quickened the pace of the movement of fire departments utilizing this technology. Increased hardware performance and easier to use software has made GIS an invaluable tool in fire resource planning. Fire station location or relocation studies are good examples of how GIS can support the decision making process of fire service administrators. Using GIS generated alternatives administrators can review a range of possibilities for a selected level of coverage and review those possibilities on a map. As a result of these developments GIS based computer analysis is the type of analysis most frequently discussed by departments undertaking a master plan (Hoetmer, 1996).

The issue of allocating resources is the most basic issue that a fire department will have to address in its planning process. Various models and factors need to be taken into account by fire service officials when allocating resources. Cities differ widely in their properties and in the demands they place on their emergency services. Clearly, it is impractical to rely on a specific allocation policy for all locales. Traditionally, fire service administrators allocated their resources based upon distance models. This was so for two reasons. The first reason was that the insurance industry established placement of fire fighting resources as a key-underwriting criterion in rate development and changes. Secondly, analysis based upon distance was relatively easy to follow and complete. However, distance is not necessarily directly related to time, and when providing a service in which time is the critical factor, distance often proves to be an inadequate indicator of potential performance.

In fact “optimal” is relative in a system with ill-defined objectives and hidden constraints. However, the fire service administration literature points to a number of factors that should be considered when developing any allocation model (Drake, 1972):

1) The nature of the geographic area being served. Are there any major impediments to traveling from one region to the next, such as bodies of water, natural geologic formations, or man made obstructions (including traffic congestion)?
2) The population density of the area in question.
3) The land-use patterns of the locality.
4) The distribution of calls for service within the locality.
5) The maximum travel speed responding units can expect to maintain in different parts of the region.

These are factors that should be taken into account when designing an allocation model for the administration of fire services. The above are not the only factors that can be modeled, each locality must decide for itself what factors to consider. There are also certain operational aspects of an emergency service system, which are not part of the allocation policy, but have a major influence on the quality of fire protection provided. Some of these are:

1) Support functions such as: maintenance, supply, training, and administration.
2) The protocols followed at the scene of an incident.
3) The suitability of an individual for a particular assignment.

These are all impractical to model with a GIS, but have a huge impact on the efficient and effective delivery of emergency fire services. Managers need to be aware that GIS is not an answer in itself. But, if used appropriately it can provide data to uncover an appropriate course of action.

Government and Network Modeling

“Decisions are the very heart of government. Good decisions help us achieve more effective government and get a better return on our investment (Iimavirta, 1995)." The efficient and effective allocation of scarce resources is the key to a successful and well-perceived government operation. More and more government entities are turning to GIS, more specifically, networking applications of GIS, to help them serve their constituents in the most efficient manner possible. Due to the fact that network modeling is so computationally intensive, it was not until recently that advances in hardware and software allowed any but the most financially well endowed governments and industries to tackle problems in route selection, the allocation of resources, and facility location with GIS technology (Hart, 1996).

The largest hurdle to overcome now in the creation of a network model is the generation of the impedance coverage. Even with recent advances, data generation makes up roughly 70% of the cost of implementing GIS network applications (Korte, 1995). However, it should be noted that due to the number of agencies and firms selling data it is possible to cut the time it takes to build functioning network coverages.

Because more and more planners have access to networking applications at lower cost, the technology is poised to have a long term impact on the planning field (Lewis, 1990). GIS gives the transportation analysts and urban planners ready access to the other's data. This exchange gives the modeler greater flexibility in choosing which variables to model in a particular application. One no longer has to be a transportation engineer to model networked variables for a land use analysis project.

Methods of solving network problems

Techniques for solving network problems are all characterized by the tremendous number of complex mathematical calculations needed to model the problem. Until recently the computing power to manage these calculations was limited to high-end workstations to which very few people had access. With the increase in computing power that recent advancements have brought us, desktop GIS's are now able to tackle complex networking with little trouble (Hart, 1996).

Various techniques exist for modeling networks; however, Dijkstra’s algorithm is one of the most common found in GIS software. It is the algorithm of choice for ESRI’s Arc/Info (ESRI, 1992) and Arc/View software packages, the most widely used GIS software packages today. Dijkstra’s algorithm is a tree searching method that generates a total cost for a path by examining the link cost and predecessor node for each branch of the route. Total costs are compared and the path of least resistance is chosen. Another popular method for solving network problems is known as matrix multiplication (Nordbeck, 1969). This method calculates the distance between all of the nodes in a network at the same time. As network coverages get larger the number of calculations that have to be completed grows. Large models can take millions of calculations to complete.

Why use network models?

Network models allow one to analyze real world transportation systems. Modeling allows the user to depict the interaction of the variables that are specific to the inquiry at hand. Transportation networks contain various road types. The roads that make up a coverage are likely have varying speeds, lanes, direction, etc. However, only some of these attributes are pertinent to the study at hand. The generalization of real world features within a model allows the user to perform analyses faster and easier than they could without the model to guide them. In this research, the road network of Norfolk was generalized to include only the following attributes: speed limits, one-way streets, over and underpasses, direction, mandatory turns, and closed roads.

Significant benefits have been achieved using network analysis in municipal and corporate planning (Grupe, 1992). Grupe's (1992) examination of vehicle tracking and route selection he found a number of advantages to using GIS as a management tool for allocating vehicular resources.

1. Time critical operations can be handled quickly and efficiently by reducing driver time, reducing driver confusion, reducing response time, and allowing for immediate vehicle to dispatcher communications.
2. The most appropriate vehicle can be directed to an emergency location because the dispatcher will know the responsibility (territory) and status of each vehicle.
3. Management control is improved by collecting computer-generated data that can be manipulated using decision support software.
4. Fleet deficient areas become apparent, so that investments can be directed to overcome them.
5. Landmark features such as closed roads and detours can be incorporated into future analysis.
6. Service objectives such as the number of fires responded to can be tracked and analyzed.

In "Time Critical GIS" Blair (1992) contends that GIS could be used as a command and control coordinator to manage mobile assets such as traffic police and emergency resources, while allocating fixed resources in the most efficient manner possible. He argued that the inability of manual maps to store updated information effectively, and their inability to display updates in a timely fashion limits their usefulness in time critical management situations. GIS can provide updated graphical representations of a particular situation in a matter of minutes. The analytical capabilities of GIS are unmatched by analog mapping systems. The ability to model a situation means that planners can reroute resources to the areas that need it. From a citizen's standpoint, more efficient use of fire and paramedical resources can reduce the potential loss of life, serious injury, or property loss in service areas and neighborhoods.

Case Studies

<u>Fire Station Siting</u>

A 1993 article by Timothy Foresman detailed the tactical uses of network GIS in the Marine Corps effort to preserve the natural resources at Camp Lejune, a 111,000 acre military reservation used for training purposes. Environmental laws of the 1970's forced the Marine Corps to reevaluate how it managed it natural resources. The threat of base closings loomed in the wake of endangered species protection and other environmental regulations. In reaction to this turn of events those in charge of the base initiated a research study known as the Land Use Management System (LUMS). LUMS was an automated system that utilized GIS technologies. The design of the applications in LUMS focused on the primary needs of the base. First, a system was needed to manage training and range operations. The second application was to build a comprehensive natural resource inventory and mapping database. By 1986 the development team had the inventory and mapping applications running. The data consisted of 50 layers based on USGS 7.5-minute quadrangles.

The fire department on the base used LUMS to aid in the siting of a new fire station. The leadership of the base determined that the camp's French Creek section was inadequately protected by the base's fire fighting resources. It became apparent early on that there was only enough funding to build the station- no funds were available for any of the fire fighting infrastructure that resides inside the station (trucks, ladders, etc.). The base command built a network model of the road network and determined the range of each existing fire station based upon a fire minute response time scenario. Using this model a gap in response time was apparent for the French Creek region. It was determined using a GIS network model that if the Burger King fire station was moved to French Creek the fire department would be able to guarantee a five minute response time for the entire base.

Current applications of GIS at Camp Lejune are focused on integrating the software into the everyday running of the base. Recognizing that people and politics remain major obstacles to continued success, automated data coordinators have been established to address interdepartmental communications. A data base dictionary is being established and a committee is addressing standards for information exchange throughout the base.

Yellow Freight

Yellow Freight System is a trucking transport company that has hundreds of terminals throughout the United States. Good facilities and real estate planning are crucial parts of its business strategy. In 1990 the company made the decision to convert their analog map decision support system to a digital GIS framework (Peck, 1992). Using the networking abilities of Arc/Info, Yellow Freight uses GIS to locate new facilities, map facility capabilities, create more efficient trucking routes, analyze service areas, and facilitate capital planning.

Yellow Freight has 640 terminal facilities, each serving a specific area. In many metropolitan areas the company uses up to seven terminals, each identified with a particular geographic area delimited by zip codes. Prior to converting to a GIS system service area maps were updated infrequently, at most every two to three years using hand-colored delivery codes. This manual system was time consuming and cumbersome. Frequent use of out of date maps led to mishaps that severely hurt performance. With the digital system in place much of the manual infrastructure required to produce area maps has been reduced. The GIS can produce the maps in a quicker and more sophisticated way that relies on computing power not manual labor. As a result Yellow Freight can give its customers a more accurate time assessment of likely delivery times.

Getting the most out of a facility is an important part of any enterprise. Prior to the application of network GIS technology, Yellow Freight was experiencing significant trouble maximizing the use of its terminal service areas. When a delivery lies outside the service area for a region the cargo must be transferred to a competitor who serves the region. These transfers reduce profits and thus need to be avoided at all costs. With the use of GIS technology, management can instantly analyze the traffic that is being routed through each terminal, as well as analyzing the terminal coverages for the entire network. Armed with this information, management can now uncover gaps in terminal coverage and make any necessary decisions regarding the placement and removal of terminals.

Significant benefits have accrued to Yellow Freight as a result of their use of GIS. Planning is now more accurate and takes less time to complete. The graphics that are produced are sharper and more accurate than their analog counterparts resulting in a more efficient allocation of resources.

Bus Routing in North Carolina

In the mid 1980’s Johnston County NC implemented a network model (TIMS - Transportation Information Modeling System) at the local school district level to improve the “efficiency and cost effectiveness” of route scheduling for school buses (Graham, 1993). As of 1992 the TIMS program had led to a reduction of the bus fleet by 10% while mileage had decreased by 20%. The success of the program caught the eye of the state, which mandated that after 1992 all local districts use TIMS to manage their bus routes and schedules.

The TIMS system is based upon two databases that together model the most efficient transportation routes for the buses to use. The entire system is built around a geo-coded digital street network. All key transportation data such as, student residences, address ranges, direction of travel, speed, bus stops, and road names and conditions are referenced to this data. A second database consisting of student information such as location, grade, ethnicity, and gender is used to assign students to the nearest bus stop. The TIMS optimization model addresses the following objectives:

- Minimize the total travel *time* for all the buses.
- Minimize the total number of buses used by local educational agencies.
- Minimize the total number of stops.
- Assure that buses arrive at school within a certain time frame.
- Assure that buses do not exceed a specific payload of students.
- Students outside of a specific threshold cannot walk to school.

Once the model has been generated, a professional, with local knowledge, assess it to uncover inconsistencies and implausible routes. The TIMS street network was, as of 1993, the most complete statewide data set of street addresses in North Carolina. Due to software limitations each county had to be scaled individually. Efforts are now underway to standardize the data to U.S. Census TIGER files. Recent data support the assertion that GIS has increased the efficiency of North Carolina’s student busing programs (Figure 2.1).

Chapter Three: Methodology

Identification of the problem.
The purpose of this research is to develop a network GIS application for the city of Norfolk's Fire and Paramedical Services for the purpose of analyzing the political and administrative implications of utilizing GIS technologies within local government. The application will be able to determine the service areas based upon time or distance for any of the 15 fire stations and it will be able to determine which fire station should respond to an emergency call using the network as an accumulated surface.

How will data from different sources be handled?
All data will be obtained from the City of Norfolk as Arc/Info coverages, which will be converted to shape files in Arc/View. They will be converted to shape files because Arc/View is unable to do network modeling on Arc/Info Coverage's. Arc/View can display coverages but it cannot operate on them.

What data structure or model will be used to develop the data (why)?
Arc/View utilizes a relational data structure and the vector data model to organize and operate on the data. The data has been collected and formatted by the city to work with ESRI products (Arc/Info and Arc/View). The primary data type used will be shape-files.

What steps will be taken to maintain the integrity of the database?
A master data set has been developed by the City of Norfolk and is kept on a separate server. No analysis is directly performed on this data. Agencies get copies of the data they need and perform any analysis on a copy of the master data. The network data coverage was derived from the street center line coverage that the Bureau of GIS (City of Norfolk Department of Information Systems) created in 1993. A copy of this data has been modified to meet the requirements for network analysis in Arc/View. The coverage was converted to a shape-file and the necessary modifications accomplish this task are detailed below. Once this application is completed it will be stored and accessed separately from the master data set. Because developing a network application in Arc/View requires many modifications, the data that are used to develop network applications will be kept separately from the master data set and will not be used in any way to update the master files. Updates to the master data sets are performed incrementally by the GIS Bureau.

How will data consistency and compatibility be ensured?
All data collected for the City of Norfolk are in State Plane Coordinates, which are referenced to NAD 83 and part of the Virginia South Zone. Coordinates are in feet and distance units are most often set to miles. All data attribute information collected is referenced to geographic data created and maintained by the City's GIS Bureau. The centrality of this structure ensures that data formats are consistent and compatible. When data conversion needs to be done it is undertaken by the Bureau for the above mentioned reasons. The Bureau formats all data for use with Arc/Info because all departments utilizing GIS run various ESRI products (primarily Arc/View 3.0a). The GIS Bureau is a small department so each department is responsible for updating its own data (this is done

when management feels a need for it), and the GIS Bureau is responsible for integrating these updates into the master database. This process can be lengthy, but the integrity of the data is much easier to maintain in this manner. Accountability is also fairly easy to establish in the case of a question.

Network Modeling

Network applications of GIS are based upon the geography of movement (Mitchell, 1995). Geographic Information Systems model movement with a frictional surface, which will be referred to in this research as an impedance coverage. This coverage is made up of arcs and nodes that are attributed with values that restrict the movement of an entity from one portion of the surface to another. For example most network coverages set a maximum speed (a time impedance coverage) which a given entity can travel across an arc. This prevents instantaneous shifts in location on the coverage. Other impedances are overpasses, underpasses, one-way streets, detours, and roadblocks. Cost is another means of impeding movement in a transportation model. For instance, a plane will very rarely travel the shortest possible distance to arrive at its destination. In most cases it will be routed to follow the atmospheric currents that will either aid or provide the least resistance to its travel. This will cut down on flight costs because fuel consumption will be lower. For my study for the City of Norfolk's Fire Department I will use a model based upon time and speed. Norfolk's Fire Department needs to have its equipment situated in such a way that the entire city is covered within 5 minutes (1 minute to prepare and 4 minutes of travel time), thus the only appropriate way to model the network is by using a frictional surface based upon time.

Elements of a Network Coverage

The *node* is the most basic element of a network model (Mitchell, 1995). As the designation of the origin and destination of all arcs, nodes are an integral part of the topology of a coverage. Nodes represent points of change and intersections within a coverage. *Arcs* are linear features made up of two or more nodes (from and to) that represent features such as roads, streams, and railroads. Attributes of various nodes and arcs reside in tables, which are *related* to them by a logical join of the databases (Figure 3.1). GIS models rely on a relational data model to organize data (Arnoff, 1995). Spatial and attribute data are stored as a collection of values in the form of simple records (tuples) aggregated together into two-dimensional tables. A relation is established between a network element and its attribute via a key field, such as the unique identification number that is established for every element in the network by the GIS software package. Using the relational model a GIS is able to perform searches on any table using one or more attribute fields. "There are no restrictions on the types of queries that can be done, so long as there are the necessary common data fields. (Arnoff, 1995). The third element of a network model is the route. A route is a channel along which interaction between any two nodes occurs (Lowe, 1975). Fixed routes such as roads, rivers, canals, and railways are spatially constant. They are inflexible and do not move within the context of the model. Plane and shipping routes are based upon atmospheric and oceanic currents that change on a consistent basis. Thus, they are termed flexible routes to note their nature. Regardless of whether it is fixed or flexible, routing applications seek to minimize distance or cost.

What process or functions are needed to calculate a solution?

The Arc/View Network Analyst is used in conjunction with the Arc/View 3.0a desktop GIS package to model spatial networks. ESRI defines a network as any system of interconnected linear features, such as roads, railways, rivers, and telephone lines through which transportation takes place (ESRI, 1996). The Network Analyst operates under the premise that "everyone tries to use networks as efficiently as possible." That is, we try to take the quickest route between any two points whenever possible. The Arc/View network model consists of a line theme (which is made up of arcs and nodes), point theme(s), and rules of the road (Figure 3.1a).

The line theme can come from any number of sources. In the case of this thesis it is an Arc/Info coverage that was converted to an Arc/View shape file (Figure 3.1). All Arc/Info Network coverages are compatible with the Network Analyst however, Arc/View shape files are not supported by Arc/Info. The line theme must have attributes, which describe how objects move through them (rules of the road). For example, street networks are made up of one and two way streets, intersections that may have restricted turns, streets with designated speed limits, and overpasses and underpasses (Figure 3.5). These features are all stored within various tables related to the line theme (Figure 3.4).

Network attribute information is derived from the traffic code which dates back to 1953. Many of the roads listed in the code have changed. Updates are not always made apparent in the code. For this reason it is imperative to work with someone who is intimately familiar with the city and its road network. These individuals can point out areas that may need updating. Field confirmation of these updates is an essential element of building an accurate and complete road network.

The Networking Algorithm

"Arc/View Network Analyst is a subset of the Arc Network package, integrated with Arc/View GIS version 3.0 and packaged as an optimal extension with an easy to use graphics user interface. (ESRI White Paper Series, November 1996)" There is little literature on the nature of the algorithm used in the Network Analyst. The above statement was found after extensive exploration of the ESRI web site (www.ESRI.com), and is the best clue as to the nature of the algorithm. From this statement it may be inferred that the algorithms used in the Network Analyst and the Arc Network package are very similar. Due to these circumstances, research on the networking algorithm was obtained from the Arc Network manual released in 1992.

Arc/View's network analysis extension is based upon Dijkistra's optimal routing algorithm (ESRI, 1992). What follows here is a brief description of this algorithm. Dijkistra's algorithm is a recursive algorithm which assumes that the shortest route between any two points will be no greater than 1.25 * the Euclidean distance between the two points. The algorithm uses this criterion as a means of general elimination as it automatically eliminates all routes which do not meet this measure. The process starts when the user identifies the start and end positions of the route. The computer then scans all the nodes that are adjacent to the start position and calculates the impedences to all of them. These scanned nodes are placed in a table that keeps track of the cumulative impedances. As the algorithm scans for routes, it eliminates all those that are greater than 1.25 * the Euclidean distance, until it reaches the destination. Once a route is established between the two points it is considered the solution until a shorter route is uncovered by future iterations of the algorithm (Daskins, 1995).

Setting Travel Costs

For the purposes of this research each street segment was assigned a speed limit based upon the traffic code of the City of Norfolk. To add this data to the line theme the numeric field "speed_limi" was added (Figure 3.4). Because the data already had a distance field detailing the length of each segment in feet it was possible to calculate the time it took to traverse each line segment. The formula: time = distance/rate was used to calculate the "minutes" field. In this calculation, distance is converted to miles by dividing by 5280 feet and rate is converted to miles per minute by dividing by 60 minutes. The "minutes" field is the cost field used by the network analyst to determine the service areas for each of the fire stations examined in this analysis.

Restricting Turns at an Intersection

In a network coverage, wherever two arcs intersect a turn is possible unless specified otherwise by the user. To specify which turns are restricted a turntable (Figure 3.2) is created. Turntables must contain a *node field* that stores the identification number of the node in the line theme where the turn occurs. For shape-files such as the one used in this analysis, this field is related to the "fjunction" and "tjunction" fields stored in NODES.DBF located in the network index directory and created the first time the network coverage is run through the Network Analyst. The name of this field in the turntable ("OTHERTURNTABLE.DBF") created for this thesis is specified as "NODE_." Turntables must also contain *from and to line fields* (Figure 3.2). These fields store the record numbers of the lines in the network theme that the turn is made between. A turn is made from the line in first field to the line in the second field. These fields are designated as "F-EDGE" and "T-EDGE" in the turntable. Finally, a cost field is established in the turntable to specify each turn in the turntable as prohibited. Any negative value in this cost field renders the turn prohibited. This field must have the same name as the cost field in the line theme. For this analysis, the cost field in the turntable is designated "minutes" and all of the values of the prohibited turns are set to -1. Turntables must be declared by running the script located in the online help under the "turntables". Please refer to figure 3.3 for the text of this script.

Setting One-way Streets

It is possible to represent one-way streets in the line theme feature table (Figure 3.4) by adding a string field designated "ONEWAY". Note that this field must be included in the line theme feature table and not a joined table. Because Arc/View stores the digitized directions of the line theme it is necessary to designate in which direction the streets run. Using the "FT" or "TF" designation in the "ONEWAY" field does this. A value of "FT" specifies that travel is permitted from the start to the end of the line segment, which is the same as the digitized direction. A "TF" designation implies that travel is permitted from the end of the line to the start, which is opposite the digitized direction. Setting the cost field equal to "N" closes the line segment to traffic.

Setting Overpasses and Underpasses

Line themes contain many locations where one line theme feature crosses another. Many of these intersections are overpasses and underpasses that must be modeled in a specific way by the Network Analyst to mimic real world conditions. To represent over and underpasses in Arc/View it is necessary to add two elevation fields to the line theme. The "from" and "to" elevation fields should be populated by examining the lines in the network theme that are part of an overpass or underpass. The same value should fill the elevation fields to identify the ends of lines that are connected. The values used do not have to be actual elevation values; relative values do nicely. For example, if the ends of four lines meet where there is an overpass, the ends of the two lines forming the overpass could be given an elevation value of 1, while the ends of the two lines not part of the overpass could be given an elevation value of zero (Figure 3.5). If the ends of the lines meet where there is not an overpass or underpass they should be given the same elevation value. Travel is prohibited between arcs that do not have the same elevation value at the adjoining node.

What are the products of the functions or processes?

The above functions produced three separate network models that will be used in further analysis by the City of Norfolk's fire service. Three different street coverages were used, all with the same attributes, except that the first had its speed limits set according to the traffic code of the City of Norfolk. The next coverage had its speed limit restricted to a maximum value of 25 miles and hour. The final coverage had its speed limit set to a maximum of 35 miles per hour. Research done by NFPS shows that the average speed of travel for an engine company is 25 miles an hour and 35 miles an hour for an ambulance within the city of Norfolk. One should note that with speed limits ranging from 15 to 55 miles per hour, the coverage based upon the city's traffic code models a 4 minute travel range that is deemed unrealistic by Norfolk Fire Service administrators (Figure 3.6). This is primarily due to the extended range offered by the high-speed interstates near some of the stations. When these pathways are normalized at 25 and 35 miles an hour for engine companies (Figure 3.7) and rescue units (Figure 3.8) respectively, the models produced delimit an area of coverage that is much smaller (Figure 3.9).

How will the political environment be evaluated?

Insight on how GIS works within the political environment of the City of Norfolk's fire and paramedical service administration will be based upon the set of questions detailed below, interviews with GIS technicians and administrators, NFPS personnel and administrators, City of Norfolk budgeting officers, and personal experience.

To more fully understand the environment within which GIS operates I felt it necessary to become a participant in the process of developing a GIS model with the Fire Service. The GIS modeling was done on site at NFPS headquarters. I spent 12 weeks working with the GIS Bureau and 3 weeks working at NFPS headquarters developing the models used in this research. By working within the system as opposed to outside of it I was able to establish a high level of familiarity with numerous members of the GIS bureau and NFPS administration. Daily contact with NFPS decision-makers allowed me to make observations that would have been overlooked had I relied on surveys alone.

Following the presentation of the model to Norfolk's Fire and Paramedical Services Administration the following survey was administered to four members of the NFPS administration, the head of Norfolk's GIS Bureau, and a management analyst assigned to the City Manager's Office. The information derived from the answers to these questions will be integrated into the analysis and conclusion sections of chapter five.

I GENERAL BACKGROUND

1) What position do you hold with the City of Norfolk?

2) Please elaborate on your association with the NFPS?

II MODEL SPECIFIC QUESTIONS

1) Mr. Bloom presented three possible options for increasing Norfolk's rescue unit coverage, of the three which one would you favor?

2) Please elaborate on why you would make that particular choice.

3) What are the strengths of Mr. Bloom's analysis?

4) What are the weaknesses?

5) What concerns did the model presented raise for you or your organization?

6) What factors would you like to see integrated in future network analysis?

7) How do you see your organization utilizing the results of this analysis?

III Integrating GIS into a Public Organization

1) Please elaborate on any political constraints that may impede the use of GIS technology within the City of Norfolk?

2) How might these factors be addressed by the "line agencies" utilizing GIS technology?

3) What impact (if any) has GIS had on your organization?

4) How has GIS altered the "structure of information flow" within your organization?

5) What concerns do you have about integrating GIS into your organization?

6) Has GIS increased the public's access to your organization? Why or why not?

7) Has GIS “opened up” the democratic process to the citizenry of Norfolk? Why or why not?

Chapter Four: Results

Introduction:

The purpose of this chapter is to describe to the reader how the network model was integrated with demographic and rescue response time data to develop decision support models for the allocation of rescue resources. Details will be provided on how the three options constructed were derived and what the resource implications are for each model.

Constructing the Models:

In Drake's 1972 work Analysis of Public Systems he forwards the notion that the allocation of fire fighting resources must address the following factors:

1) The nature of the geographical area being served. Are there any major impediments to traveling from one region to the next, such as bodies of water, natural geologic formations, or man made obstructions?
2) The population density of the region.
3) The land-use patterns of the locality.
4) The distribution of calls for service within the locality.
5) The maximum travel speed response units can expect to maintain in different parts of the region.

This research was focused on the allocation of rescue units not fire fighting resources per se. Therefore, the focus within the analysis will be on factors 1, 2, 4, 5, the demographics of the City of Norfolk, and the response statistics for the various rescue units.

The three models produced by myself and members of the NFPS drew upon demographic data generated from the 1990 census, the 1992-1995 response data for each rescue unit, and the network model. Because the NFPS indicated that the majority of their responses were areas of high population (map 4.1), low income (map 4.2), and elderly populations (map 4.3), the following data sets were taken from the 1990 census and mapped by census tract: percent family poverty, population, and population over the age of 65. For the rescue units the following data was integrated: average response time (Table 1.2), total number of calls (Table 1.1), average number of calls (Table 1.1), number of calls over five minutes (Table 1.1), and the percentage of calls over five minutes (Table 1.1). Regression analysis points to a high correlation between the average response time and the percentage of calls that were responded to in over five minutes (Multiple R +0.9882, Correlation statistic of +0.985857), which strongly suggests that reducing the number of calls responded to in over five minutes will help the NFPS reach their goal of city wide five minute coverage.

The network data was then overlaid upon census and rescue response data to identify areas of incomplete coverage and weak performance by the rescue units. In general the positioning of the rescue units is good (map 4.4). Most of the major population centers are covered and there does not seem to be any overt discrimination (economic status) with regards to unit placement.

Present Gaps in Coverage:
Presently stations 4, 7, 12, and 15 are without rescue units, consequently the areas near these stations do not fall within the projected five minute travel times for any of the rescue units (map 4.4). It should be noted that station 12 lies just south of the world's largest naval installation (map 4.4). Thus, much of this area does not fall under the jurisdiction of NFPS therefore the gap in coverage near station 12 is not of great concern. Station 7 is positioned in the north west corner of the city's downtown area (map 4.4). Dominated by port facilities, this area is sparsely populated with only one area of intense poverty (map 4.2 and map 4.6) and one area with a moderate population over the age of 65 (map 4.3 and map 4.7). Positioned near the southwestern border of the city, the area surrounding station 4 is characterized by low poverty rates (map 4.2 and map 4.6), moderate levels of population (map 4.1 and map 4.5), and an exceptional concentration of citizens over the age of 65 (map 4.3 and map 4.7). Station 15 is located between stations 13 and 16 along the northern coast of the city (map 4.4). Centrally located, this station is in a prime position to cover the area left uncovered by the stations on either side of it. Moderate to high levels of population (map 4.1 and map 4.5) and citizens over the age of 65 (map 4.3 and map 4.7) characterize this area. The poverty rates in this area tended to be moderate to low (map 4.2 and map 4.6).

Station 12:
Because the naval base (which is responsible for its own paramedical services) dominates the uncovered area near this station, this area was excluded from consideration for new or relocated rescue resources.

Proximity and the Downtown Area:
The greatest concentration of paramedical calls occur in the downtown area, which is the responsibility of units one, two, and six (unit three is a hazardous materials unit). From 1992 to 1995 units two and six responded to more calls than any other station (Table 1.1). In 1992 unit two had an average response time of 5.66 minutes and unit six had an average response time of 5.39 minutes (Table 1.2). In 1993 rescue units were added to stations one and eleven and there was a marked improvement in the performance of units six and two (Table 1.2). In 1993 unit two's average response time fell to under 5.3 minutes and unit six's average response time fell to 5.11 minutes (Table 1.2). From 1993 to 1995 units one, two, and six were the only units even to approach the 5-minute response time that the NFPS has set as its goal (figure 1.1). The remarkable response times for these units have been attributed to two factors: the overlap of the response zones of all three units and the compactness of the downtown area (map 4.8). Because of the outstanding response times in this area none of these units were relocated any of these to station seven to cover the gap in coverage near that station. While modeled five minute coverage may have been extended, the minimal population in that area did not warrant the relocation of a unit (from stations 1, 2, or 6) or the addition of a unit (map 4.1).

Unit 11:
Unit 11 is located near the center of the city, just north of the downtown area. Most of the area that it responds to falls within the outskirts of the response zones to units 2, 10,

14, and 9. However, these units do not have direct access to the station as the Lafayette River (maps 4.4 and 4.8) separates units 2 and 9 from station 11. The proximity of these stations in comparison to the proximity of the downtown stations is much less. Station 11 exists on the outskirts of five-minute ranges of all the aforementioned stations. Thus it does not enjoy the significant benefits of proximity that the downtown stations do. With the notable exception of unit 2, the average response times of these units (1993-1995) range from 5.752 minutes to 6.07 minutes (figures 1.1 and 1.4). (Please note these statistics on unit 11 because relocating unit 11 to station four is an integral part of proposed options 1 and 2.)

Option 1 (maps 4.9, 4.10, and 4.11):
This option consists of moving the rescue unit present at station 11 to station four. This option would cover the extensive elderly (maps 4.7 and 4.11) and affluent populations (maps 4.6 and 4.10) that are presently uncovered in the southeastern portion of the city. This option only increases the coverage for the southeastern portion of the city. The gaps near stations 15, 7, and 12 would not be addressed by merely moving a unit to station 4. Although substantial increases in performance look promising for this region of the city, under this option, the present performance of station 11 taken in conjunction with the 1990 census data points to a different conclusion. The area surrounding station 11 constitutes a major population center that is comprised of one of the largest concentrations of elderly citizens in the city.

The population composition certainly plays a role in rescue 11's 5.75 minute average response time (50.13% of its calls were responded to in over five minutes). Although the uncovered area surrounding station 4 is large it does not have the population that the area around unit 11 has (maps 4.1 and 4.9). What makes this option so attractive is that no new units would be required to increase the city's coverage. With new units costing nearly $140,000 to equip and purchase, a means of efficiently allocating all present resources is of prime concern to NFPS. However, the statistics lead many within NFPS to believe that it would be inappropriate to move unit 11 at this time.

Option 2 (maps 4.12, 4.13, and 4.14):
This option entails moving rescue 11 to station 4 and adding rescue units to stations 7 and 15. This more vigorous approach would eliminate the gaps in coverage north and east of station 7, the gap along the coast and extending southward between stations 13 and 16, and the gap in the southeast portion of the city near station 4. The arguments for and against moving a rescue unit to station 4 are the same as for option 1; what needs to be addressed is the addition of units to stations 7 and 15.

The area to the north and east of station 7 falls outside of the five-minute projected coverage for the city. Station 7 serves an area that is mixed in character. Poor, affluent (maps 4.6 and 4.13), and aged populations (maps 4.7 and 4.14) comprise the census tracts lying to the north. However, the area to the south of the station is largely unpopulated due to the large number of shipping transactions that take place in this area. Because this area lies along the Elizabeth and Lafayette Rivers, only station 7 has the access needed to serve it. Some argue that it is unnecessary to provide a new unit for station seven when there is a "surplus" of units in the downtown area. Why not reposition a unit from the downtown area to station 7 to serve this population? One should refer to the arguments made earlier in this chapter about proximity and the downtown area. The rescue units in the downtown area respond to the greatest number of calls with the best response times in the city. By repositioning a unit from the downtown area to station 7 you risk impairing the effectiveness of a system that provides the most care in the quickest time to the most people.

The purpose of placing a new rescue unit in station 15 is to serve the populace that resides in the area falling outside the five-minute ranges of stations 13 and 16. The gap near station 15 is comprised of a sizable population (maps 4.5 and 4.12) that is affluent (maps 4.6 and 4.13) and aged (maps 4.7 and 4.14). The five-minute response area for this unit would enable it to cover most of the area falling outside present five-minute coverage as well as provide significant overlap with the coverage areas of units13, 16, 14 and 9. Because the response statistics for these units are well above the five-minute goal that NFPS has set, it is believed that the addition of this unit would serve to alleviate much of the demand for this region of the city. Thus, reducing response times for all the units in the vicinity, much as the addition of unit 1 in 1993 did for the downtown area (figures 1.1 and 1.4). All stations in this region of the city with the exception of station 15 have rescue units, so there were no relocation options brought to light by the network model.

Option 3 (Maps 4.15, 4.16, and 4.17):
This option proposes placing new units at stations 4, 7, and 15 without relocating any existing units. This proposal is attractive because it addresses issues related to coverage and workload. Many within NFPS argued that merely relocating units does little to relieve the workload issues brought to light by the performance statistics for the rescue units. Adding units in strategic areas where gaps are present may alleviate coverage and workload difficulties. This argument is especially strong considering the weak response statistics of units 11 (the unit that would be moved in options one and 2), 9, and 14 (figures 1.1 and 1.4).

Chapter Five: Analysis-Conclusion

Introduction:

The purpose of this chapter is to integrate interview and survey results, as well any observations made while working with the City of Norfolk into the analysis of the GIS research results. The following issues will be addressed in this chapter:

- Which option was chosen (why)?
- Has this application proven itself to be of use to the City of Norfolk?
- How will this model be used by NFPS (What are the policy implications)?
- Has GIS integration into the fire service enhanced or hindered the democratic process for the citizens of Norfolk?
- Concluding remarks.

Which option was chosen (why)?

The majority of NFPS administrators involved in this research favored option two over options three and one. A minority of NFPS and city administration officials favored option three, while option one received no support from NFPS or the city administration officials taking part in this research. NFPS officials argued that the workload data strongly supported option three, but that the fiscal and political environment of the city of Norfolk would not support a plan requiring the level of new resources called for by option three. The following points were made by Norfolk Fire and Paramedical Services officials when assessing the viability of option two:

- Option two is the most cost-effective solution that we could propose at this time.
- Option two could be expanded to match option three in the future.
- Due to the City of Norfolk's current fiscal position option two is most likely to be approved by Norfolk's governing body.
- With the cost of purchasing, manning, and equipping a new paramedical unit at nearly $140,000 there are significant fiscal impacts to implementing option three.

Despite the above arguments, many administrators within NFPS and within Norfolk's administrative apparatus felt that the data and the political environment support option three. The following points were made in support of option three:

- In light of the workload data the relocation of existing units would only provide a cosmetic solution to the problem of lowering the average paramedical response time to below five minutes.
- *There are severe political implications involved in relocating a unit from one station to another. The citizens being served by the unit being moved are likely to mobilize in political opposition to such a proposal.

*Members of Norfolk's administrative staff not NFPS raised this concern.

Demographic data gleaned from the 1990 census factored into the construction of the models, but not the selection of which model would be supported.

Has this application proven itself to be of use to the City of Norfolk?
Desktop GIS has proven itself to be a valuable analytic tool for the positioning of resources by NFPS. The ability to display geographic data in a spatial manner adds a powerful graphic dimension to the analysis produced by NFPS. Those surveyed within the city and NFPS believe that the ability to model geographically and display data are the greatest strengths of GIS. The point to be made here is that within the environment of a local government, often it is not what one knows about a particular problem, but what one can convey to others that is important.

This point is especially salient in terms of the research conducted for NFPS. The NFPS administration is composed of men who have served the city for over twenty years. Even the most junior fire service officials have an intimate knowledge of the city. It became apparent (through interviews with NFPS administrators) during the course of this research that the NFPS was aware of the gaps in the paramedical five-minute service areas of the city. The network application developed for this research did not uncover anything that the NFPS did not already know, but it served to justify the decision to request funds for new rescue units. The graphic images produced by the GIS not only reinforce the arguments made by NFPS, but provide a medium in which these arguments can be made more clearly and succinctly.

The GIS analysis performed for this research had three sources of data: NFPS rescue unit data, the City of Norfolk Road network, and 1990 census data. It took nearly six years of continual data collection for the data incorporated in this analysis to be collected. Because data is the most important part of any GIS application other agencies working at a similar scale, seeking to perform equivalent analysis should expect to work within a comparable time frame.

The Arc View 3.0a software package performed the analysis admirably. Its ease of use and low training time make this package ideal for NFPS to use in future analyses of this nature. This is an important point because this research was conducted on site with the full cooperation of NFPS. The models produced combined the GIS expertise of a specialist with the intimate knowledge that NFPS had of Norfolk and rescue services. Because Arc View is so easy to learn and use, future analyses of this nature can now be performed by fire service officials, on site, with little or no input necessary from GIS specialists.

The implication of this finding is that GIS analysis will be performed more and more by people who are fire service officials first and GIS specialists second. As the technology becomes more fully integrated into the organization there will be more of a need for all members of NFPS and city management to be familiar with how the technology works at a basic level.

How will this model be used by NFPS and what are the policy implications?
NFPS plans to present the results of this analysis to the budget committee to justify the allocation of additional resources (funding and personnel) for departmental operations and programs. NFPS officials interviewed believed that the visual power of this analysis will crystallize the arguments that the department wishes to make for more resources. Because the visual images presented are so vivid, and it is human nature to give credence to visual analysis, managers and administrators who implement this technology within their organizations need to have some basic understanding of how it works. Furthermore, organizations that implement GIS will inundate high-level decision-makers with very convincing graphic products (most likely maps) designed to persuade organizational decision-makers. Thus, to avoid being overwhelmed by these arguments, policy makers need to be intellectually comfortable with the inner workings of the organizations they oversee and the basics of the GIS technology that is integral to the analysis presented to them. This is especially important in light of the results of the survey in which became obvious that NFPS administrators were most likely to back the GIS results that they thought would sustain political support within the given environment.

GIS integration also has significant implications for the role of the analyst. This research has shown that GIS reflects the values of the organization that implements it. In the case of the models constructed for the NFPS those values were efficiency, effectiveness, and equity. Data was collected, models were constructed, and analysis was produced with those concepts permeating every facet of the GIS. The question then arises: Is GIS analysis or policy analysis in general relegated to a role of advocacy? Under extreme circumstances, in which the GIS system is used to confirm expert analysis (i.e. NFPS), I would argue that GIS is relegated primarily to an advocacy role.

In a democratic society where public officials make decisions, these realities impose additional responsibilities upon the GIS analyst. Public officials, administrators, and citizens need to be educated as to what values are represented in the GIS models presented to them. What trade-offs do these values imply? What are the policy ramifications of utilizing the proposed models? The trade-off made in this research by NFPS was between cost effectiveness and an additional rescue unit to serve the city. The analyst has a responsibility in a democratic society to ensure that all the actors in the policy process are informed of these issues. If decision-makers are not made aware of the intricacies and trade-offs of the analysis, GIS could make the policy environment less open, more susceptible to poor decisions and a danger to democratic society.

Implications for the Democratic Process
GIS integration into the fire service has had some impact on the democratic process for the citizenry of Norfolk. This is primarily due to the character of what the NFPS does, the character of the data used in analysis, and the level of GIS integration in society.

Geographic information systems, like any other tool, are used in a manner that reflects the values that the organization holds to be central to fulfilling its mandate. In the case of NFPS its mandate is clear: To prevent the loss of life and property due to fire and medical emergencies. Lives and property can be lost in a matter of minutes in the environment in which the NFPS works. This agency is judged, for the most part, on how efficient and effective it is in performing its duties. Certainly there are issues of equity to be addressed, but those issues are usually framed by community leaders and city administrators within the criteria of efficiency and effectiveness.

In the case of this research the primary question that was addressed was "Does everyone have access to rescue services within five minutes of travel time?" The GIS was implemented to address this issue, and by doing so the technology was used to address issues of equity framed by the values of efficiency and effectiveness. Did this application enhance or hinder the democratic process for the citizens of Norfolk? The GIS model presented options that took into account issues of efficiency (the time based network model), effectiveness (the response time data), and equity (the census data) in an effort to locate gaps in the city's coverage and to correct those gaps. Detractors may point to the census data and argue that the variables chosen (population, population over 65, and percentage of family poverty) pointed to areas of high risk for medical emergencies; those statistics were chosen with efficiency and effectiveness in mind.

In response to that argument I forward the notion that the elderly and poor tend to be the some of the most disadvantaged groups within society, and that, by framing the GIS analysis with these groups in mind, NFPS embraced a very egalitarian notion of efficiency and effectiveness. These groups often do not have the resources to pay for the services they receive from NFPS. The analysis could have been framed with an ability to pay criteria (are all the rich served within five minutes), but it was not. The primary concern was serving those individuals who are most at risk, regardless of socio-economic class. The equitable treatment of citizens promotes trust in the institutions that govern the citizenry. NFPS, by including equity in their model of efficient and effective rescue resource delivery, in some small way promotes trust in all of the institutions that make up the government of the City of Norfolk. Citizens that trust their institutions of government are more likely to cooperate with those institutions and are more likely to participate in the democratic process that legitimate those institutions. It is in this manner that GIS can be used within the fire service to promote democracy.

This research also shows that while GIS integration into fire service resource decision making can potentially promote the democratic process it does not increase access to these institutions. There are two reasons for this. The first is that the data used by the NFPS and the fire service in general consists of confidential medical or property information that is used in GIS analysis but cannot be released to the public. This data is most often collected at the scene of an emergency (medical or fire) and is necessary for the fire service to evaluate itself and perform analyses like those in this research. However, most of this information is highly personal, and most citizens would consider it a gross invasion of privacy if this information were to be released to the general public. Secondly, even if NFPS made some of its GIS data available, most citizens are not familiar enough with the technology to be able to utilize it and/or they do not possess the software to view the data. Most administrators involved in this research felt that the telephone, email, and the fax were likely to have more of an impact than is GIS in providing citizen access to the institutions that comprise the government of the city of

Norfolk in the near future. The potential of digital data is recognized, but at the present time the technology is not integrated sufficiently to provide access for most citizens.

Concluding Remarks:

This research hypothesized that desktop Geographic Information Systems could be utilized by the fire service to produce models that would increase the efficiency, effectiveness, and equity of the distribution fire fighting resources. However, it was shown that a GIS system does not automatically produce models that embrace these values. GIS systems are built by human beings within an organizational context, thus the geographic decision support systems built reflect the values of the organizations that design them.

Organizations work within the constraints of a political environment and this research has shown that it is impossible for GIS to divorce itself from this environment. Administrators who implement this technology are aware of the constraints of their environment and seek to tailor their analysis accordingly. The ability of GIS to model various scenarios proves to be especially useful in this context. Potential gains in resource allocation that may become apparent in a GIS model may be unrealized unless the political leaders within the organization can be convinced of the political gains to be had by the implementation of any model. Deborah Stone's research on this subject is particularly helpful here. As stated in chapter one, politicians have at least two goals. The first concerns the approval, defeat, or implementation of a particular policy concern. The second is the preservation of enough political power to complete future policy projects (Policy Paradox, 1997). Successful administrators will utilize the capabilities of GIS to frame their arguments accordingly. In the case of this research, option three was the optimal model that NFPS wanted to implement, but they realized that the fiscal implications of that particular model were highly prohibitive to the implementation of that plan of action. Thus, option two was supported because it was the most viable under the constraints present in the City of Norfolk.

This research has shown that one of the primary strengths of GIS is its ability to provide vivid graphic representations of the environment (and potential changes to the environment). Organizations that incorporate GIS into their operations will present policy makers with powerful arguments that are reinforced with powerful geographic models. To avoid being overwhelmed by these arguments policy makers need to understand the operational demands of the organizations that they oversee and the basics of any decision support technology such as GIS that they choose to implement.

This research aimed to dispel the notion that GIS is a "value neutral" analytic tool because, in reality GIS laden with the values of the organizations that implement it. As a result GIS implementation has very serious administrative and political implications. The case studies in chapter two highlighted the vast analytic power of network GIS and served as a technical guide for applying the technology in this research. However, this literature is typical in that if failed to address the implications of utilizing GIS for the utilizing organizations. Technical specifics were addressed, but the context within which these systems operated were given cursory descriptions. This research has shown that the context within which a GIS is utilized is as important to the successful operation of the technology, if not more so, than the information technology that comprises the system. This deficiency is exposed and addressed by this research.

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Appendix Chapter 1

Table 1.1

Ambulance Reponses by Station (1992-1995)

Station #	1992	1993	1994	1995	Average ('92-'95)	Average ('93-'95)
1	0	1430	2523	2889		**2280.667**
2	3969	3945	4000	3871	3946.25	**3938.667**
3	296	18	23	7	86.00	**16.00**
6	4177	3857	3826	3656	3879.00	**3779.667**
8	2319	1972	1721	1770	1945.500	**1821.00**
9	3180	3105	3297	3275	3214.250	**3225.667**
10	3516	3269	3117	3133	3258.750	**3173.00**
11	0	2137	2534	2111		**2260.667**
13	2777	2719	2664	2867	2756.75	**2750.00**
14	3330	3015	3078	3223	3161.5	**3105.333**
16	2699	2485	2376	2467	2506.75	**2442.667**
Totals	26263	27952	29159	29269	**28160.75**	**28793.33**

Station #	# of Responses Average ('93-'95)	Time Average ('93-'95	Percent over 5 min Average ('93-'95)
1	**2280.666667**	5.055	38.73%
2	**3938.666667**	5.214	39.82%
6	**3779.666667**	4.939	34.62%
8	**1821**	5.210	37.07%
9	**3225.666667**	6.070	56.19%
10	**3173**	5.786	53.39%
11	**2260.666667**	5.752	50.13%
13	**2750**	5.750	50.50%
14	**3105.333333**	6.035	55.01%
16	**2442.666667**	5.976	55.64%
		5.643	47.26%

Table 1.2

Average Response Time by Station (1992-1995)

Station #	1992	1993	1994	1995	Average ('92-95)	Average ('93-'95)
1	0.00	5.06	4.98	5.12	5.05	5.05
2	5.66	5.28	5.09	5.27	5.32	5.21
3	6.33	6.34	6.67	5.84	6.29	6.28
6	5.39	5.11	4.74	4.97	5.05	4.94
8	5.78	5.50	5.09	5.04	5.35	5.21
9	6.57	6.10	6.01	6.11	6.19	6.07
10	6.50	5.89	5.55	5.91	5.96	5.79
11	0.00	5.65	5.75	5.85	5.75	5.75
13	6.18	5.97	5.54	5.74	5.86	5.75
14	6.68	6.30	5.98	5.83	6.20	6.04
16	6.46	5.94	5.75	6.24	6.10	5.98
Averages	6.17	5.74	5.56	5.63	**5.78**	**5.64**

Table 1.3

Average Response Time to Medical Emergencies- Engine Responses.

Station #	1992	1993	1994	1995	Station Average (92-95)
1	3.37	3.24	3.16	3.24	3.25
2	2.99	3.09	3.16	3.09	3.08
3	3.13	2.97	3.02	2.97	3.02
4	3.88	3.89	2.94	3.89	3.65
6	3.02	3.27	3.02	3.27	3.14
7	3.42	3.24	3.38	3.24	3.32
8	3.17	3.35	3.26	3.35	3.28
9	3.92	3.82	4.05	3.82	3.90
10	4.29	4.39	4.33	4.39	4.35
11	3.42	3.56	3.66	3.56	3.55
12	3.68	3.49	3.56	3.49	3.55
13	3.62	3.60	3.67	3.60	3.62
14	4.04	4.06	4.05	4.06	4.05
15	4.17	4.04	4.07	4.04	4.08
16	3.81	3.88	3.93	3.88	3.87
Yearly Average	3.53	3.54	3.48	3.54	3.58

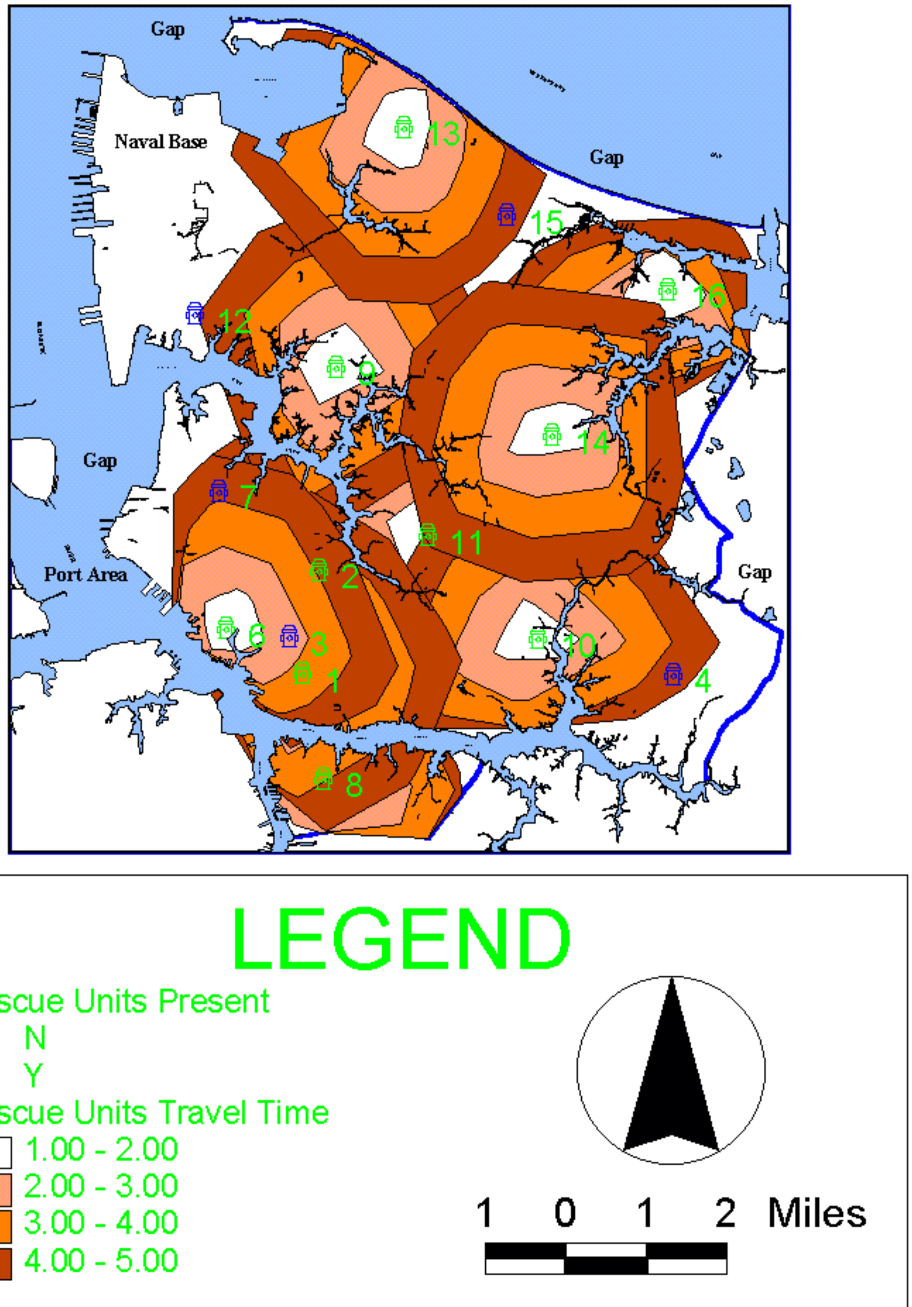
Table 1.4

Engine Responses to Medical Calls.

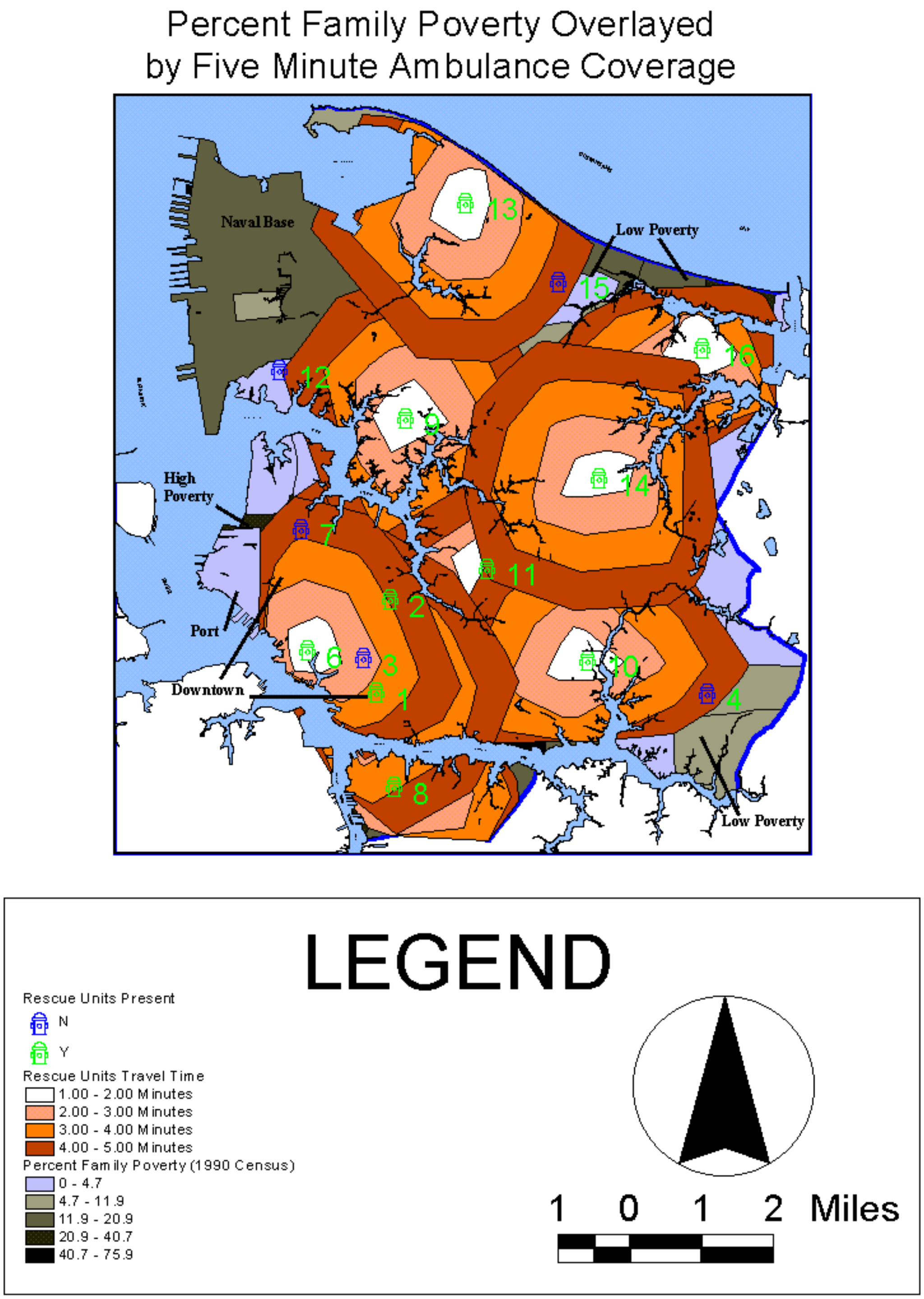
Station #	MC '92	MC '93	MC '94	MC '95	Totals '92-'95
1	871	894	924	740	3429
2	971	1080	1155	938	4144
3	253	220	245	186	904
4	580	530	654	680	2444
6	1002	1068	1094	929	4093
7	553	514	633	567	2267
8	618	534	691	625	2468
9	789	752	919	829	3289
10	855	799	804	775	3233
11	652	650	749	698	2749
12	381	364	415	407	1567
13	724	691	867	692	2974
14	1025	1055	1112	1105	4297
15	859	872	820	737	3288
16	754	760	732	705	2951
TOTALS	10887	10783	11814	10613	44097

Map 1.1

Present Five Minute Ambulance Coverage
City of Norfolk NFPS



Map 1.2



Percent Family Poverty Overlayed
by Five Minute Ambulance Coverage
Naval Base
13
Low Poverty
15
16
12
9
14
High Poverty
7
11
2
Port
6
3
10
Downtown
1
4
8
Low Poverty
LEGEND
Rescue Units Present
N
Y
Rescue Units Travel Time
1.00 - 2.00 Minutes
2.00 - 3.00 Minutes
3.00 - 4.00 Minutes
4.00 - 5.00 Minutes
Percent Family Poverty (1990 Census)
0 - 4.7
4.7 - 11.9
11.9 - 20.9
20.9 - 40.7
40.7 - 75.9
1 0 1 2 Miles

Appendix Chapter 2

Figure 2.1 - Bus Routing in North Carolina

Year	Number of Buses	Annual Mileage	Fuel Consumption (Gallons)
1989-1990	13,231	126,353,582	20,732,383
1991-1992	12,759	123,704,678	19,463,030
Percent change.	-3.6%	-2.1%	-6.1%

Appendix Chapter 3

Figure 3.1 - The Elements of a Network Coverage.

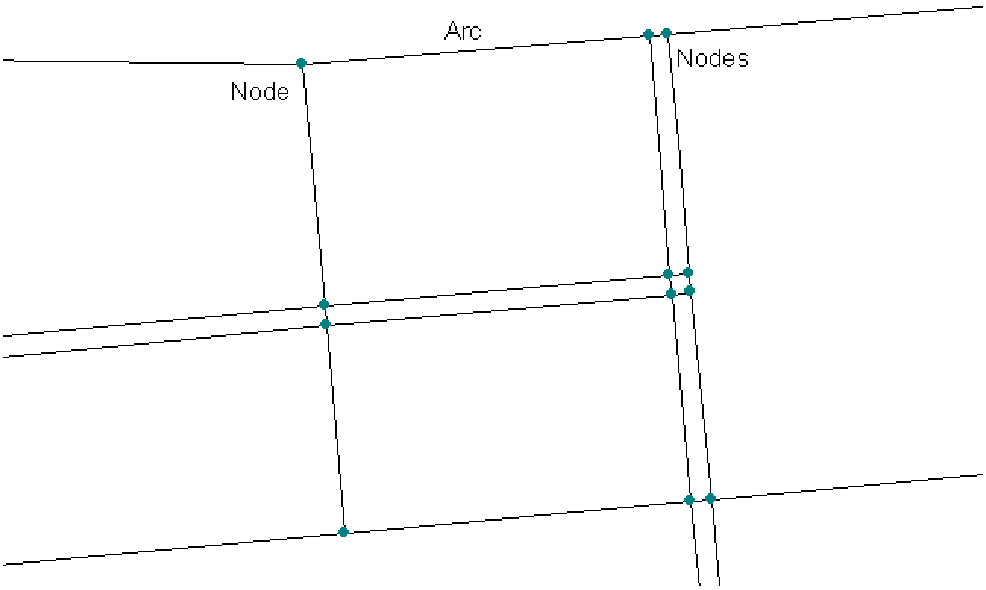


Figure 3.1a - A Routing Solution.

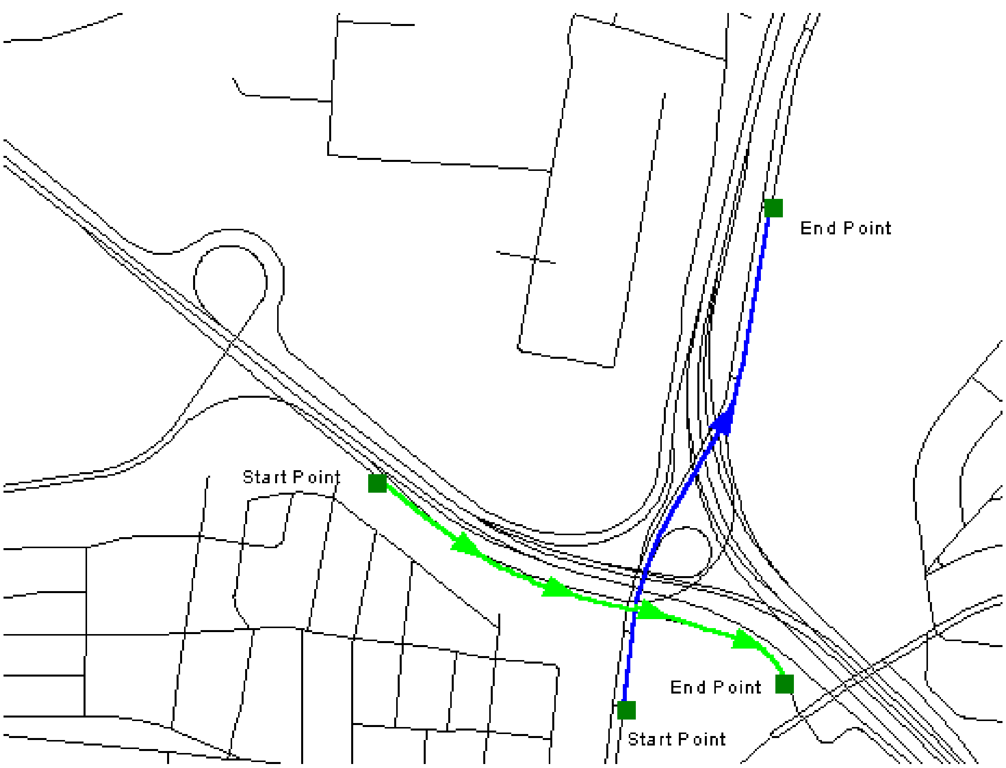


Figure 3.2 - Excerpts of Otherturntable.dbf and Nodes.dbf

NODE_	ARC1_	ARC2_	MINUTES
640	12817	13849	-1
1835	11865	1883	-1
1835	11865	1872	-1
2038	11857	11861	-1
2038	9071	11853	-1
2038	11861	9071	-1
2038	11853	11857	-1
2069	7220	3483	-1
1989	11936	9152	-1
2523	13523	3791	-1
8252	11794	14356	-1
2491	11435	2655	-1

Note that the restricted turn is referenced by the intersected node in the NODE_ field, and is restricted from ARC1_ to ARC2_ by the -1 in the MINUTES field. The node field is related to the FJUNCTION and TJUNCTION fields stored in the Nodes.dbf file.

FJUNCTION	TJUNCTION
2540	2557
2564	2574
2530	2540
2515	2530
8648	8640
8640	8638
8545	8640
8640	8644
9974	9972
2355	2425
2683	2591
2591	2425

Figure 3.3 - System Script Used to Declare Turntables.

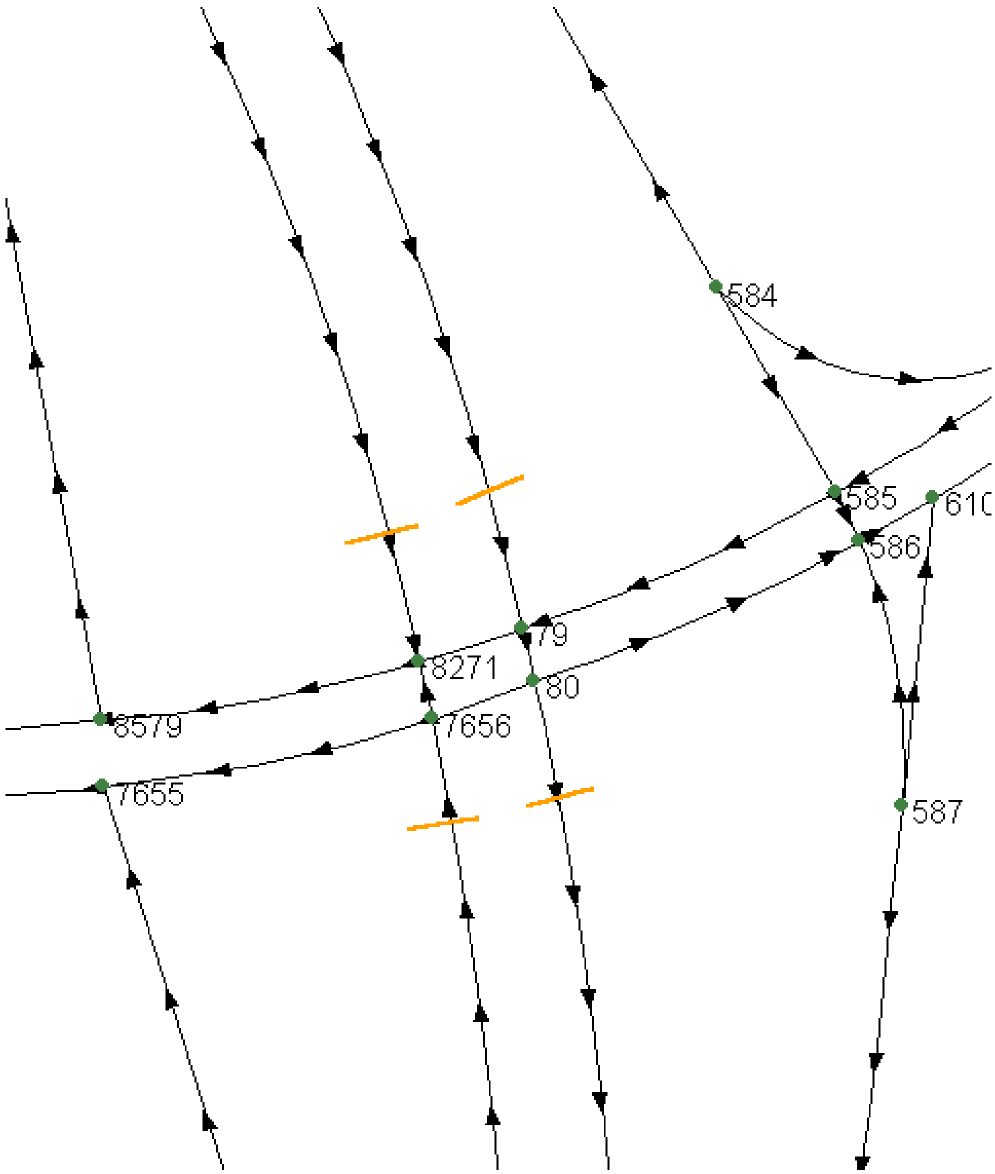
```
' This script declares a turntable. Before running this script, you must have a project open
with a turntable and a view open with a network theme.
' Get the view and the network theme. Substitute aViewName with the name of your view
and aThemeName with the name of your network theme.

aView = av.GetProject.FindDoc("view1")
aNetworkTheme = aView.FindTheme("streetcl.shp")

' Make the network definition object
aNetwork = av.Run("Network.GetNetwork",{aNetworkTheme})
aNetDef = aNetwork.GetNetDef

' Get the turntable and declare it. Substitute aTurntableName with the name of your
turntable.

aVTab = av.GetProject.FindDoc("aTurntableName").GetVTab
aDeclaredTurntable = aNetDef.SetTurnVTab(aVTab)

' Make sure the turntable has been properly declared

if (aDeclaredTurntable) then
  MsgBox.Info("Your turntable has been declared","Turntable status")
else
  MsgBox.Info("Unable to declare turntable","Turntable status")

end
```

Figure 3.4 - Excerpt from Streetcl.dbf.

FNODE_	TNODE_	LENGTH	STREETCL_	SPEED_LIMI	ONEWAY	STREET_NAM	MINUTES	F_ELEV	T_ELEV
28	61	1856.57757	44	55	TF	I-64 Highway	0.38359	0	0
81	117	1933.90220	45	55	TF	I-64 Highway	0.39957	1	1
117	119	34.17685	46	55	TF	I-64 Highway	0.00706	1	1
119	223	1714.82055	47	55	TF	I-64 Highway	0.35430	1	0
657	450	1263.46732	48	55	TF	I-64 Highway	0.26105	1	1
444	661	1331.87872	49	55	TF	I-64 Highway	0.27518	1	1
663	657	26.35413	50	55	TF	I-64 Highway	0.00545	1	1
661	666	31.00383	51	55	TF	I-64 Highway	0.00641	1	1
663	670	47.15927	52	55	FT	I-64 Highway	0.00974	1	1
666	679	49.08689	53	55	TF	I-64 Highway	0.01014	1	1
677	681	11.17750	54	55	TF	I-64 Highway	0.00231	1	1
689	681	32.20522	55	55	FT	I-64 Highway	0.00665	1	1
690	677	29.93603	56	25		I-64 Highway	0.01361	0	0
654	690	730.10283	57	55	FT	I-64 Highway	0.15085	0	1
691	681	30.02499	58	25		I-64 Highway	0.01365	0	0
690	691	7.70685	59	55	FT	I-64 Highway	0.00159	1	1
690	695	25.67554	60	25		I-64 Highway	0.01167	0	0
695	654	721.66995	61	55	TF	I-64 Highway	0.14911	1	0
689	696	29.96075	62	25		I-64 Highway	0.01362	0	0
691	696	34.40674	63	55	FT	I-64 Highway	0.00711	1	1
697	691	25.66819	64	25		I-64 Highway	0.01167	0	0
697	695	4.26966	65	55		I-64 Highway	0.00088	1	1
696	704	26.16471	66	25		I-64 Highway	0.01189	0	0
704	697	36.80941	67	55	TF	I-64 Highway	0.00761	0	1
705	697	27.61790	68	25		I-64 Highway	0.01255	0	0
695	705	27.98911	69	25		I-64 Highway	0.01272	0	0
679	769	443.63206	70	55	TF	I-64 Highway	0.09166	1	0
883	689	1401.26921	71	55	FT	I-64 Highway	0.28952	0	1
696	887	1391.63768	72	55	FT	I-64 Highway	0.28753	1	0
705	887	1493.31408	73	25	FT	I-64 Highway	0.67878	0	0
670	908	1499.53291	74	55	FT	I-64 Highway	0.30982	1	0
887	1801	8274.72051	75	55	FT	I-64 Highway	1.70965	0	0

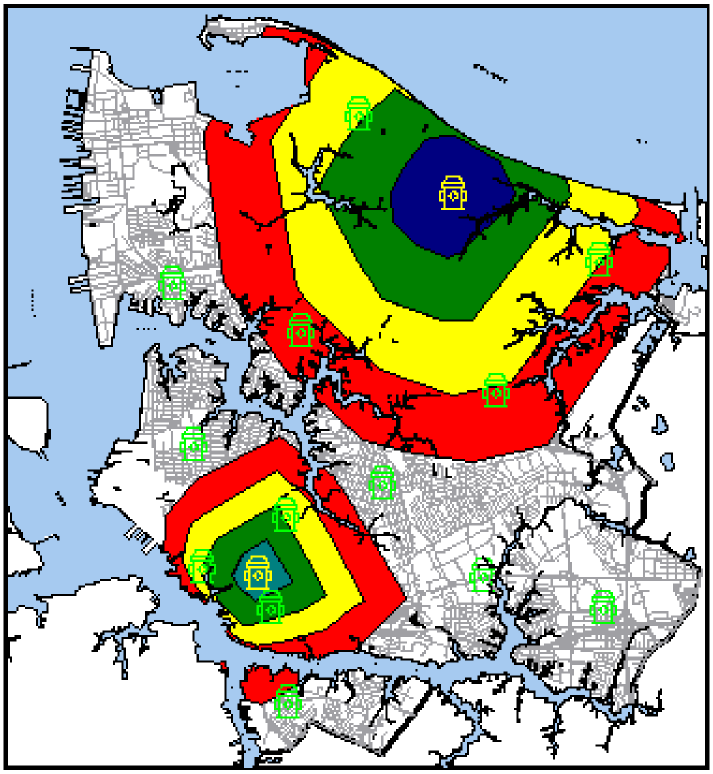
Note the 'TF" and "FT" designations in the "ONEWAY" field to denote the direction of one-way streets within the street centerline coverage. One should also observe the elevation values present within the "F_ELEV" and "T_ELEV" that are used to denote over and underpasses within the database.

Figure 3.5 - Overpasses and Underpasses.



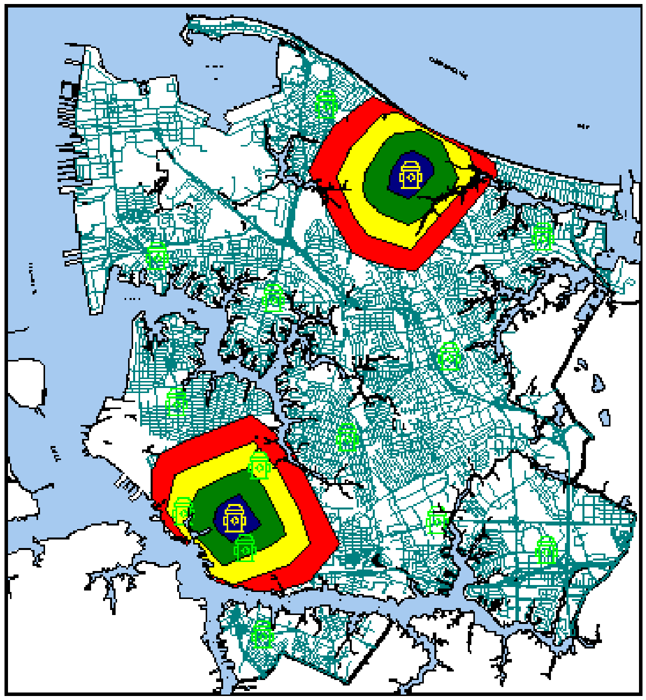
FNODE_	TNODE_	F_ELEV	T_ELEV
585	79	0	0
79	8721	0	0
8721	8579	0	0
80	586	0	0
80	7656	0	0
7656	7655	0	0
79	80	1	1
7656	8721	1	1

Figure 3.6 `- <u>A Service Area Model Based Upon the City of Norfolk's Traffic Code.</u>



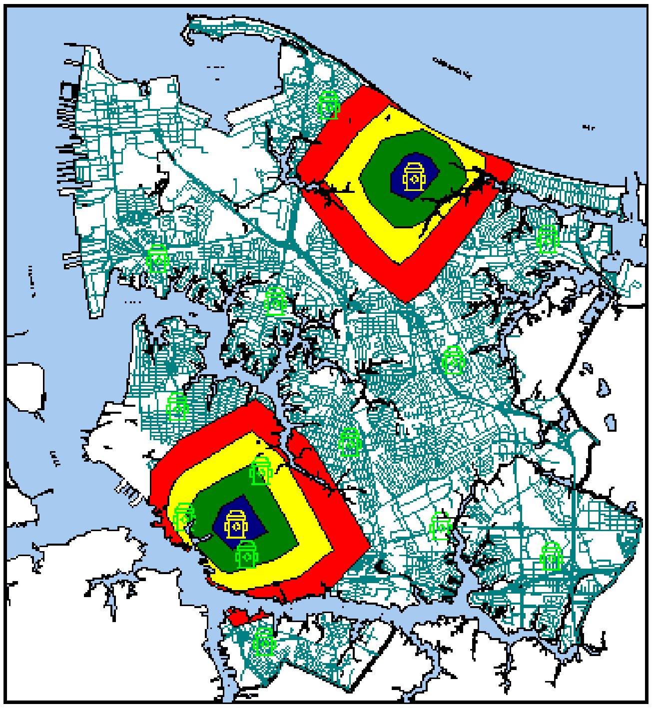
Notice how large the service area is for the station in the northern portion of the map. This particular station has been allocated a large service area because it is near roads with higher than average speed limits such as the interstates (i.e. 44, 264, and 664) . The station in the lower portion of the image is located in the downtown section of the city. Speed limits tend to gravitate towards the 15 to 25 miles per hour range in this region; thus the area covered within five minutes of travel from the station is less than its northern counterpart.

Figure 3.7 - Service Area Model For Engine Companies (25 mph).



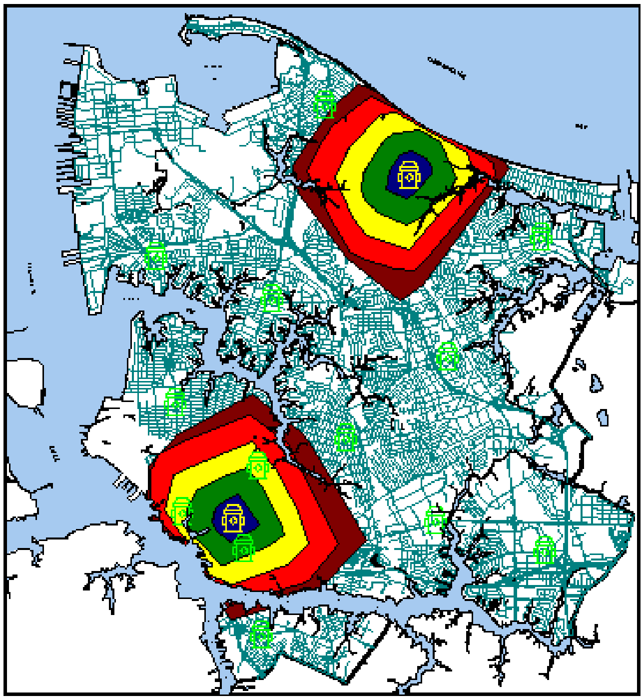
Now that speed limits have been equalized the service areas are almost identical in size. Notice that the downtown region of the city has three fire stations within 5 minutes of the highlighted station (for a total of 4 station down town), while the station located in the northern more rural portion of the city has no additional stations within the five minute service area of the selected fire station.

Figure 3.8 - Service Area Model For Ambulances (35 mph).



With an average maximum speed of 35 miles per hour ambulances have a slightly greater range than the fire engines do.

Figure 3.9 - Service Area Models Compared. 25 vs. 35 mph.

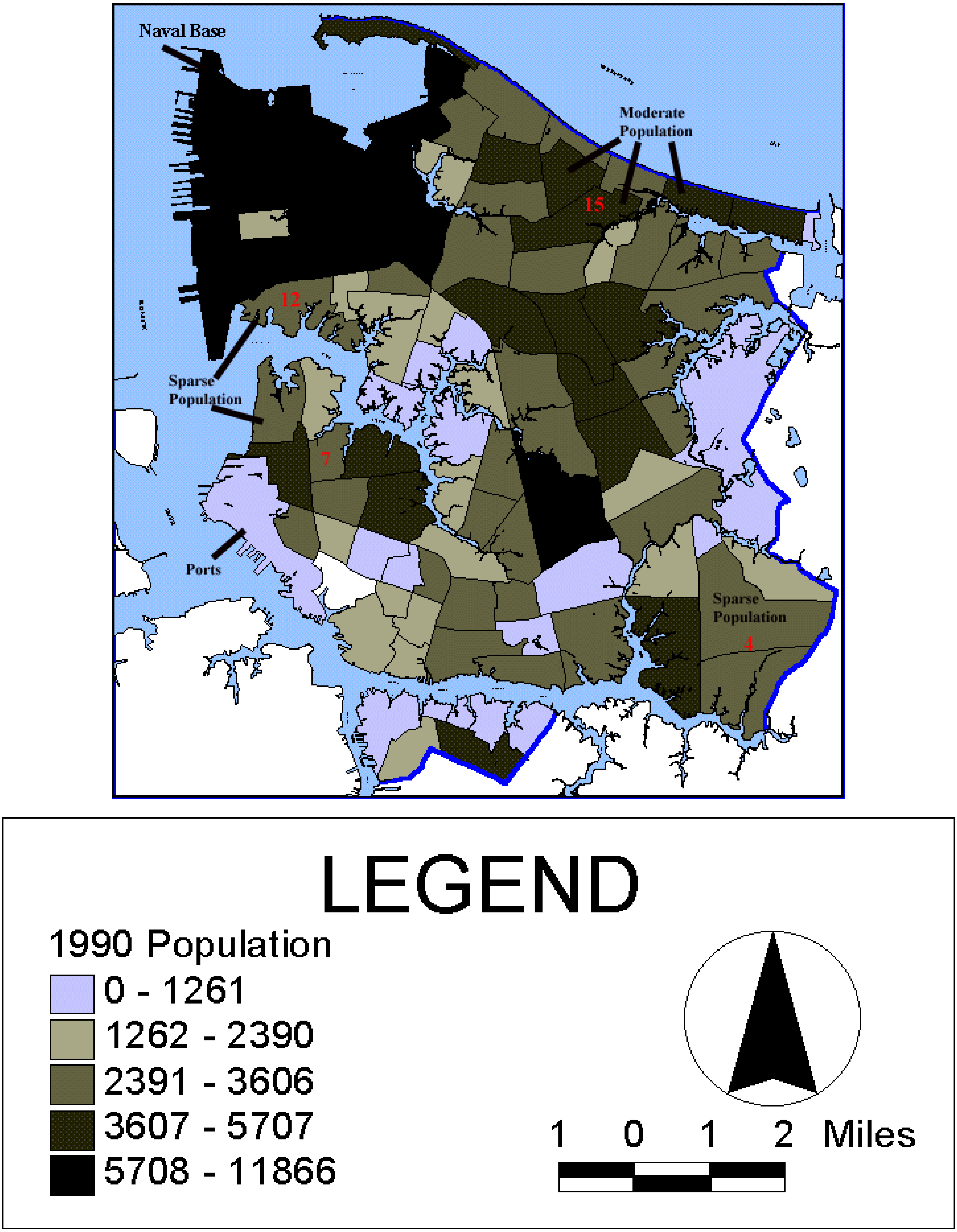


The maroon area is the additional area covered by the ambulances due to the different speed limits used in the street centerline coverages (25 for fire engines and 35 for ambulances).

Appendix Chapter 4

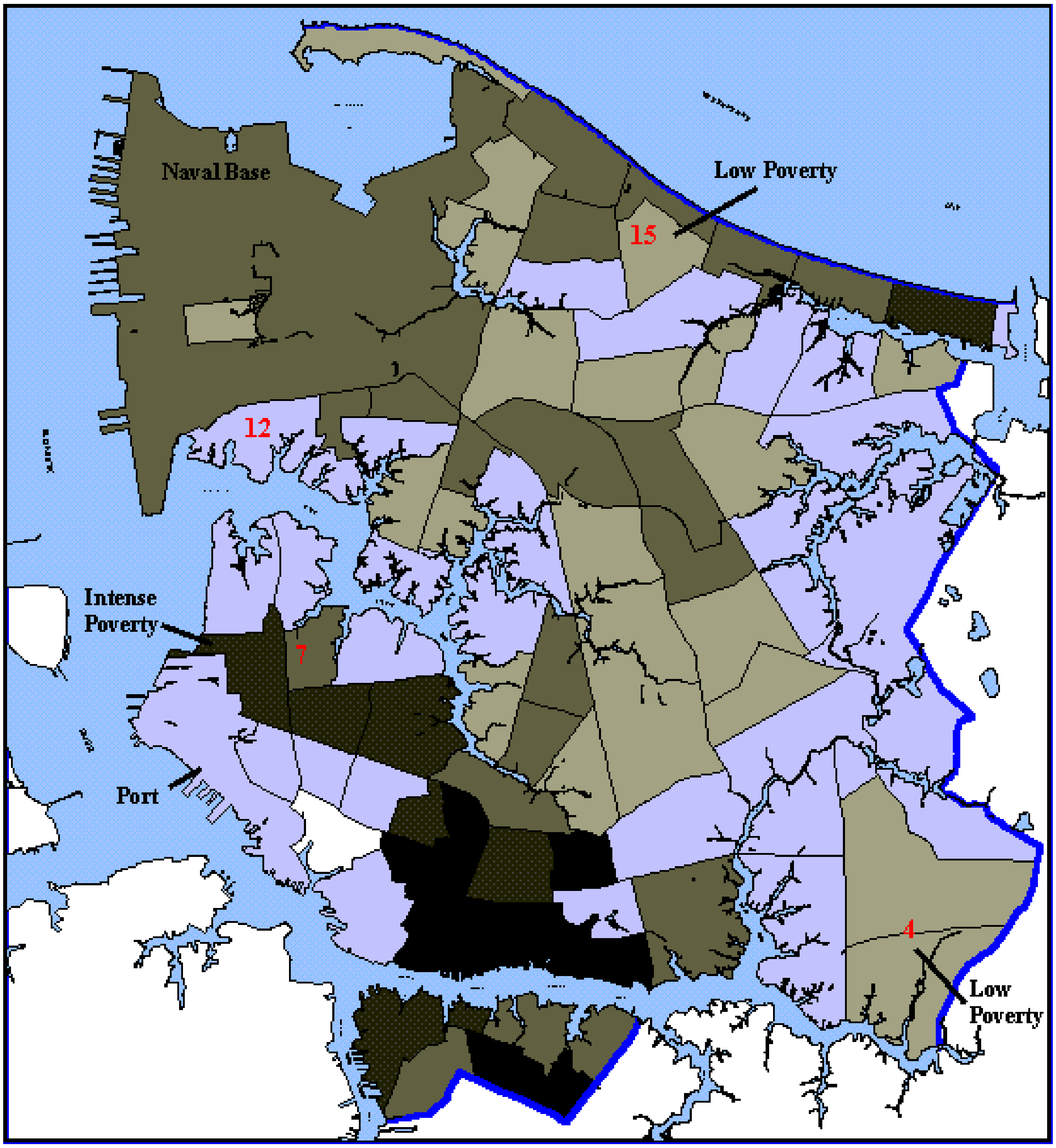
Map 4.1

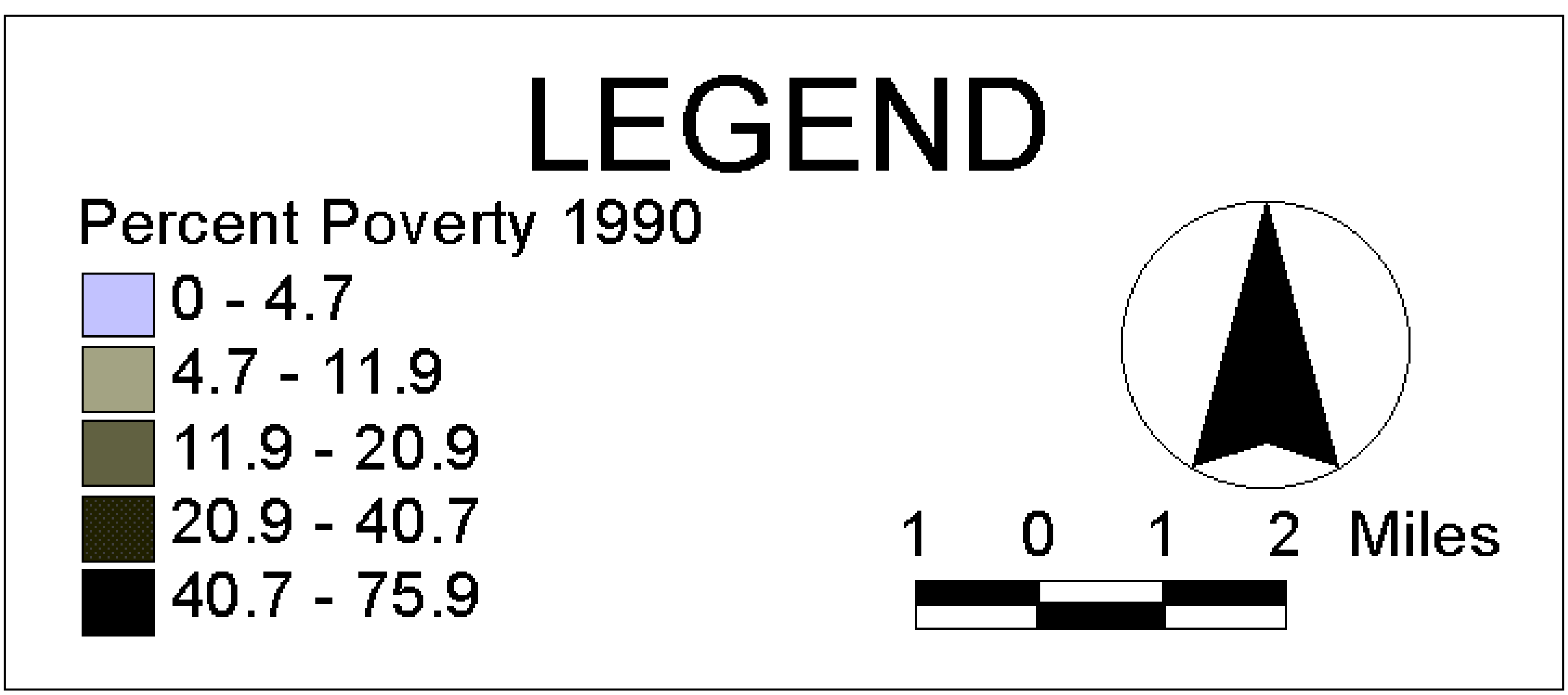
Population by Census Tract 1990
City of Norfolk



Map 4.2

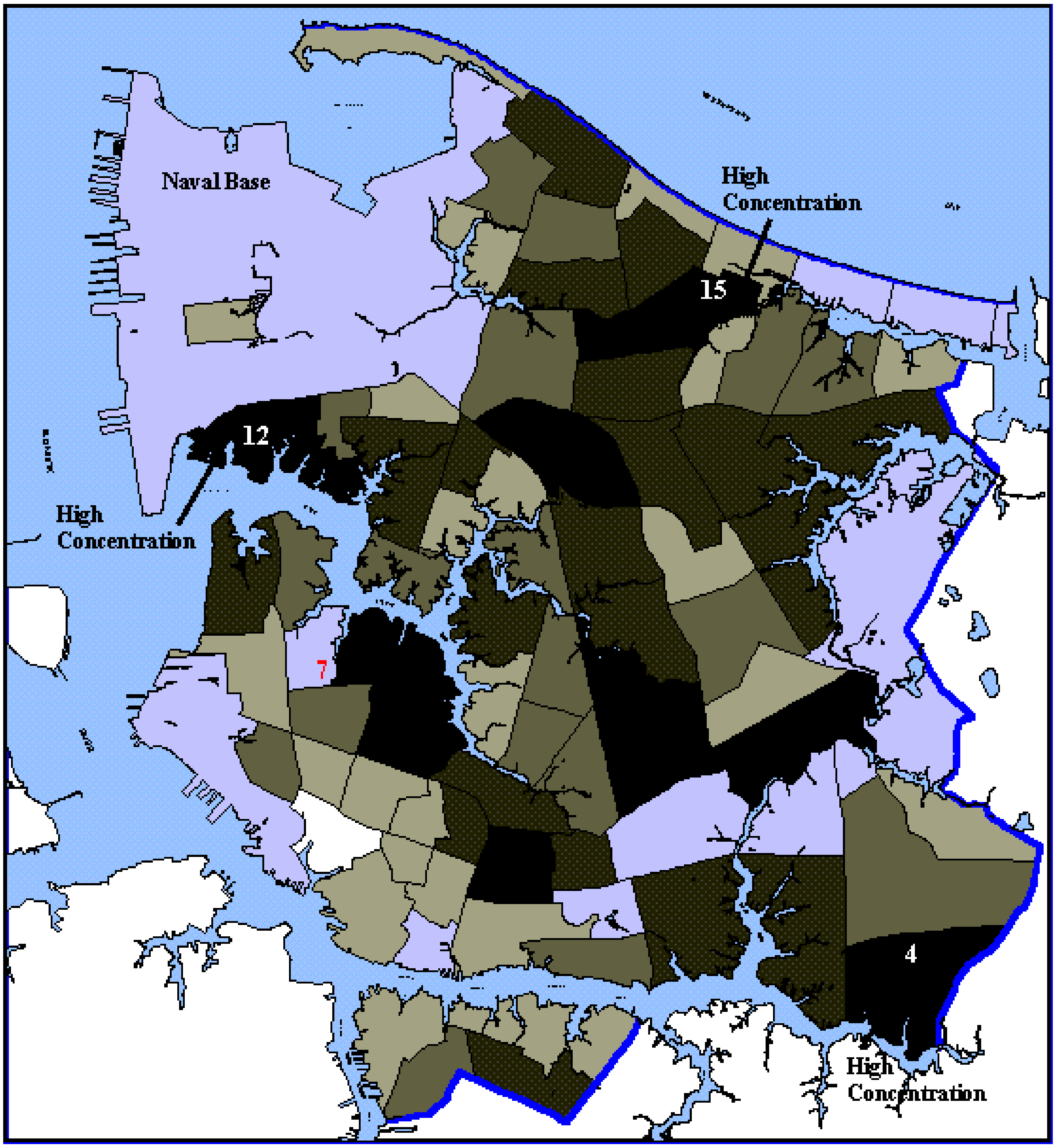
Family Poverty by Census Tract 1990
City of Norfolk

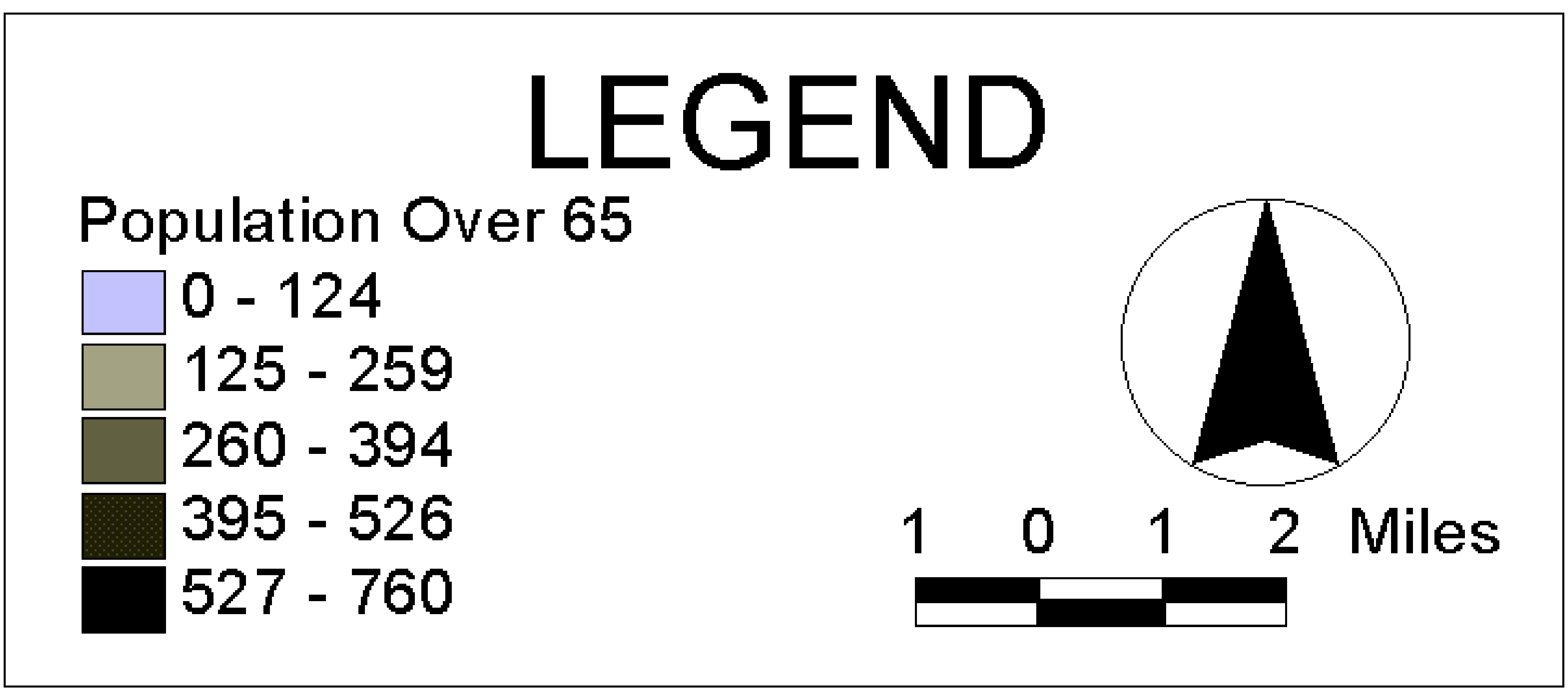




Map 4.3

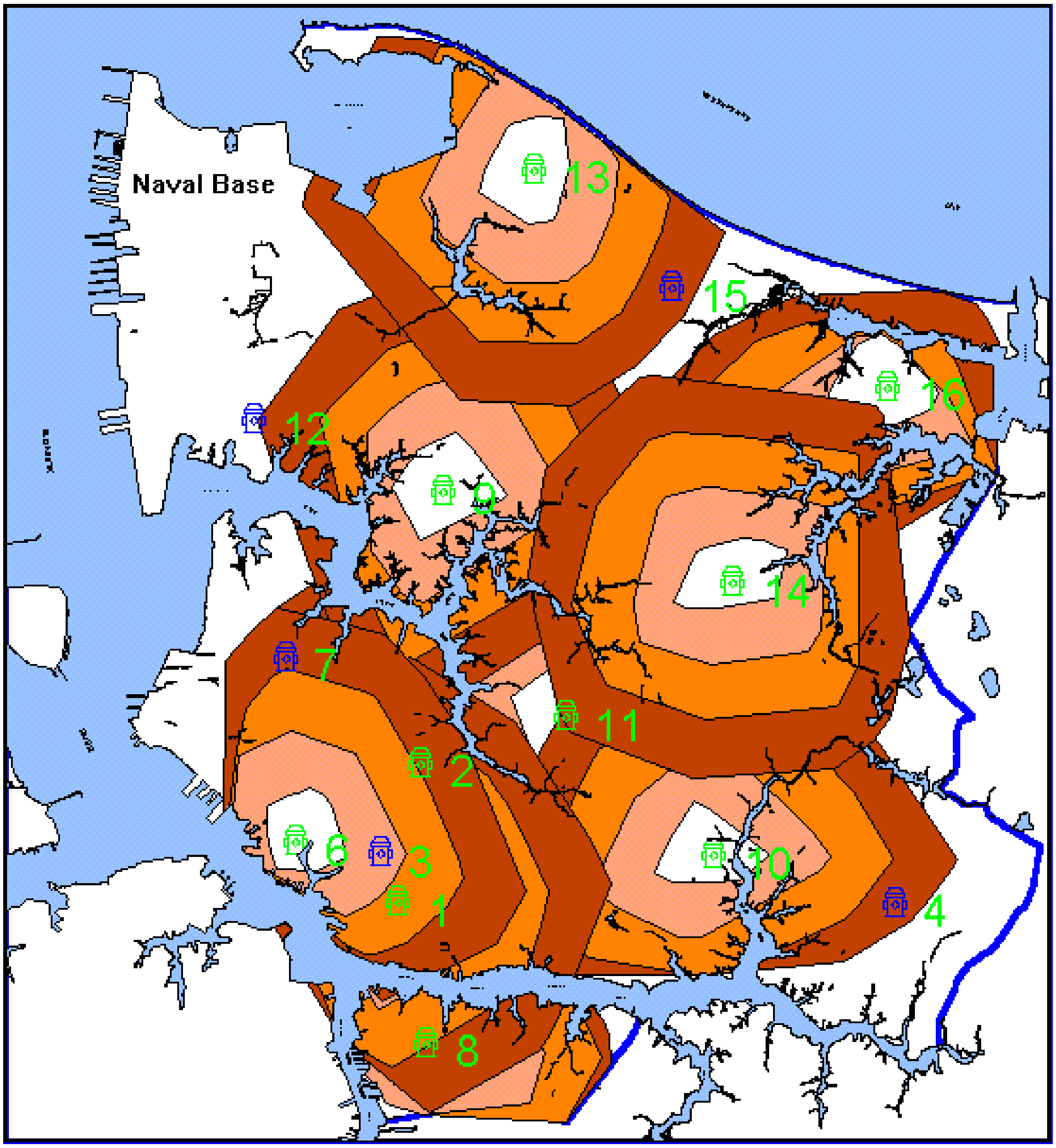
1990 Population Over 65 by Census Tract
City of Norfolk

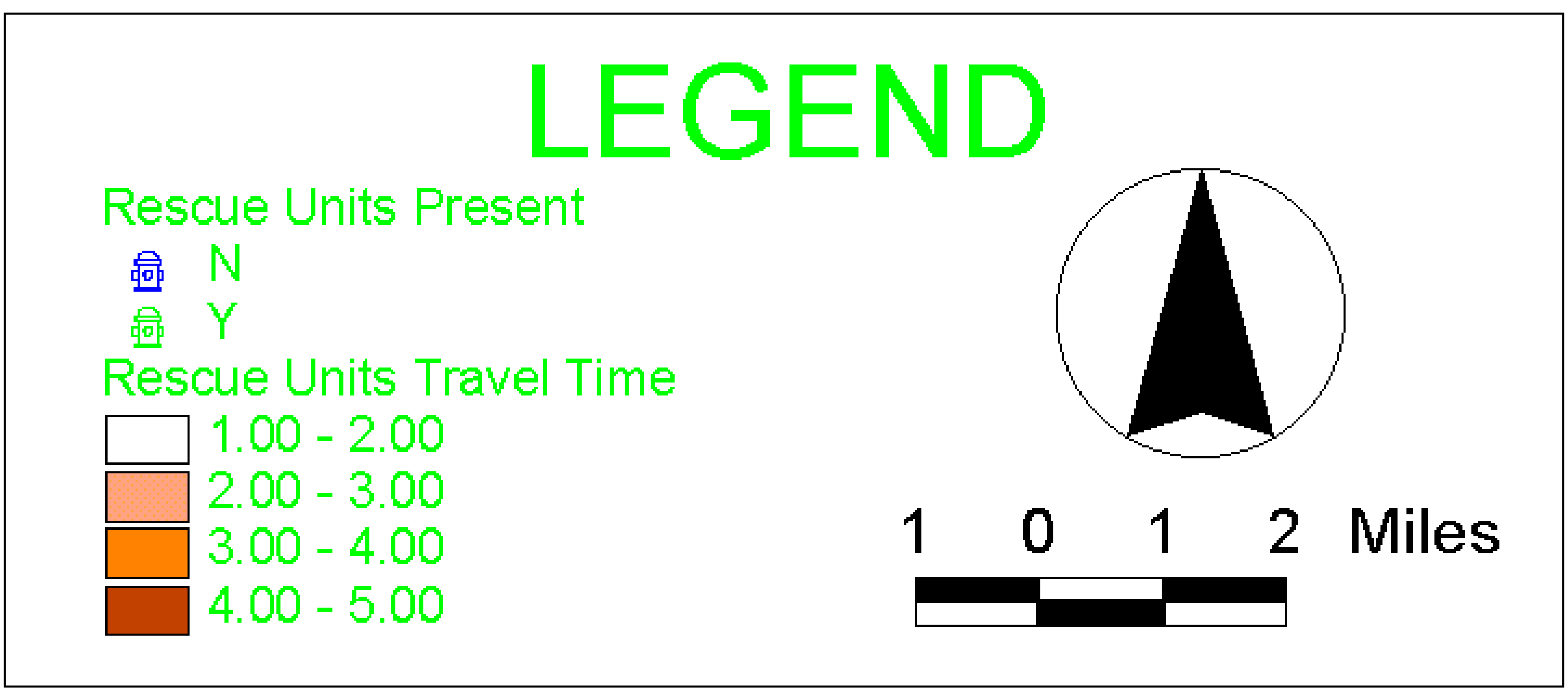




Map 4.4

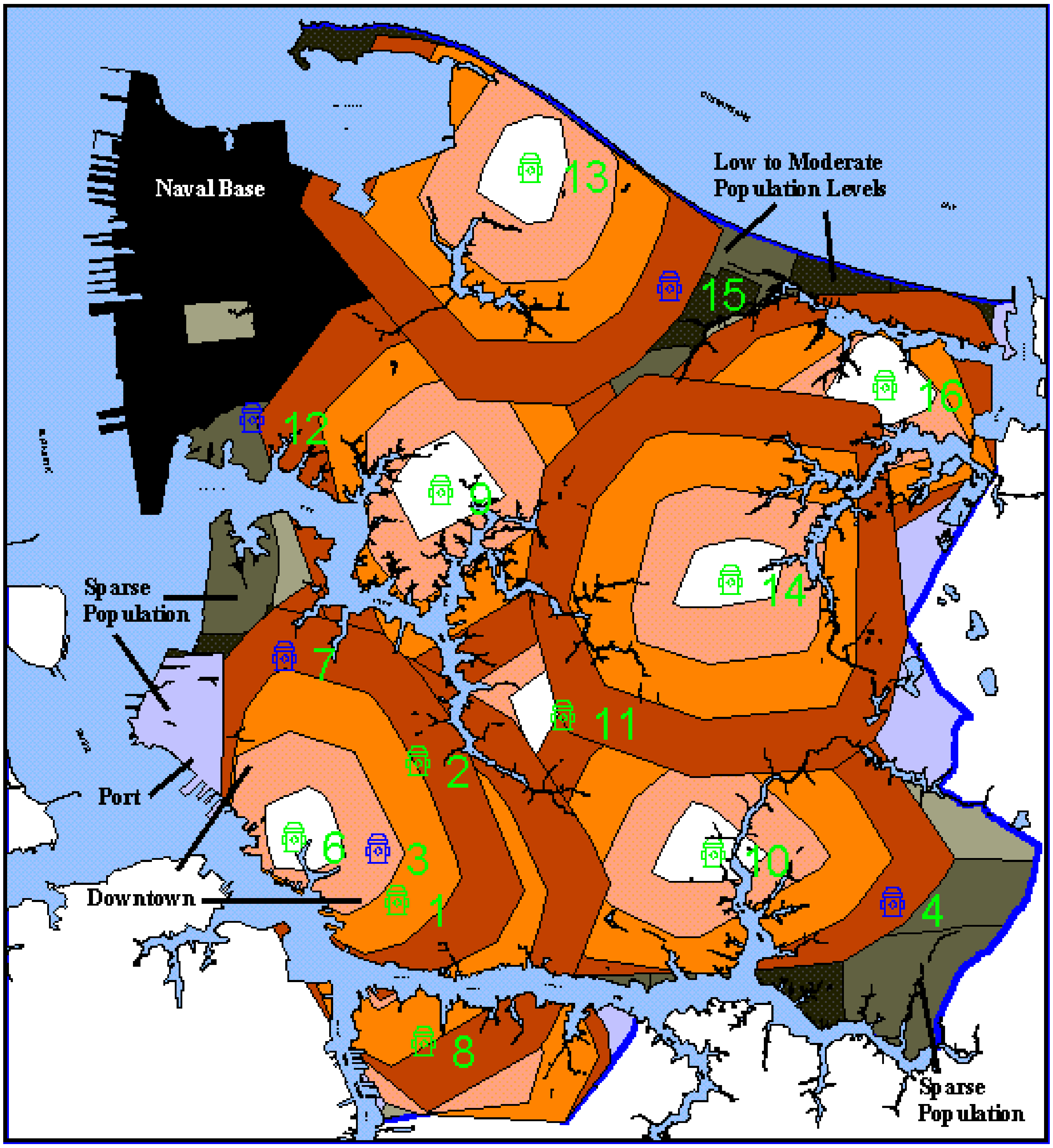
Present Five Minute Ambulance Coverage
City of Norfolk NFPS

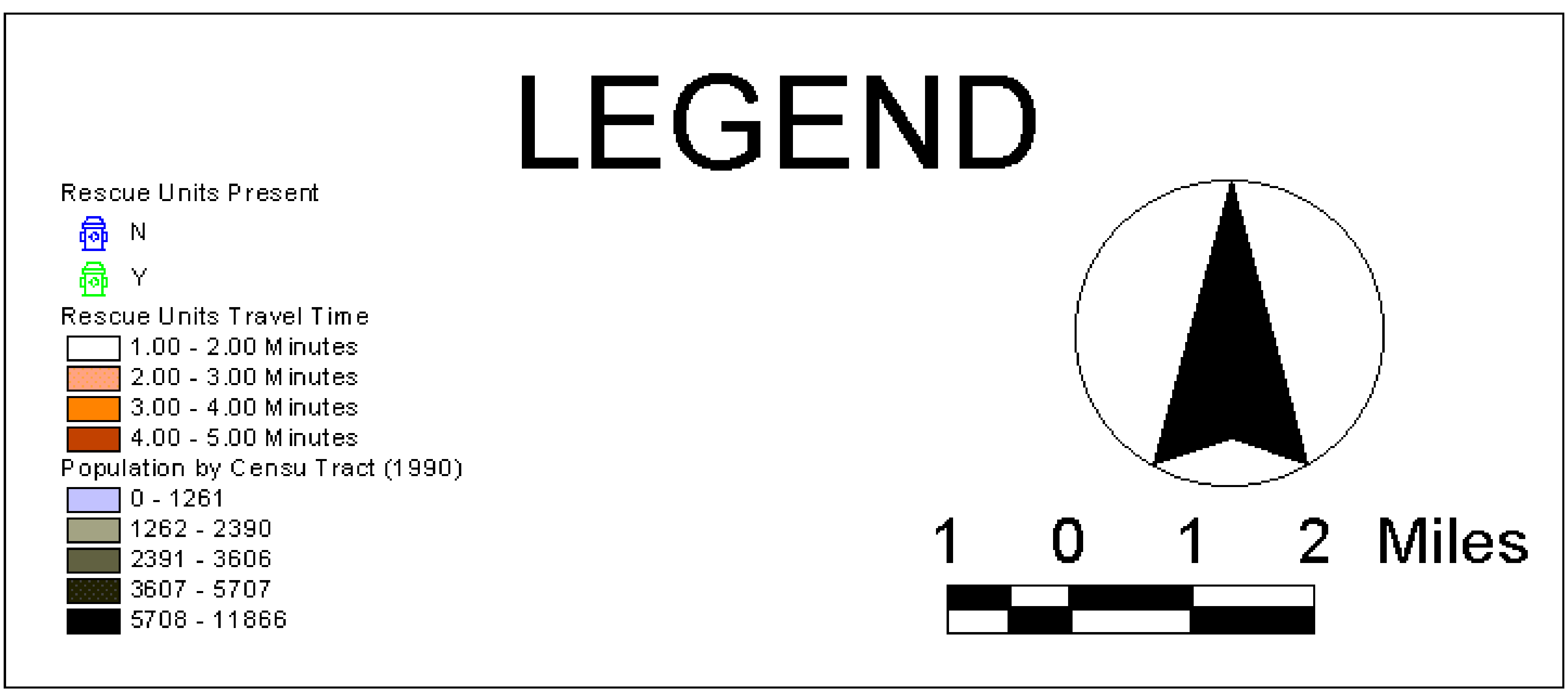




Map 4.5

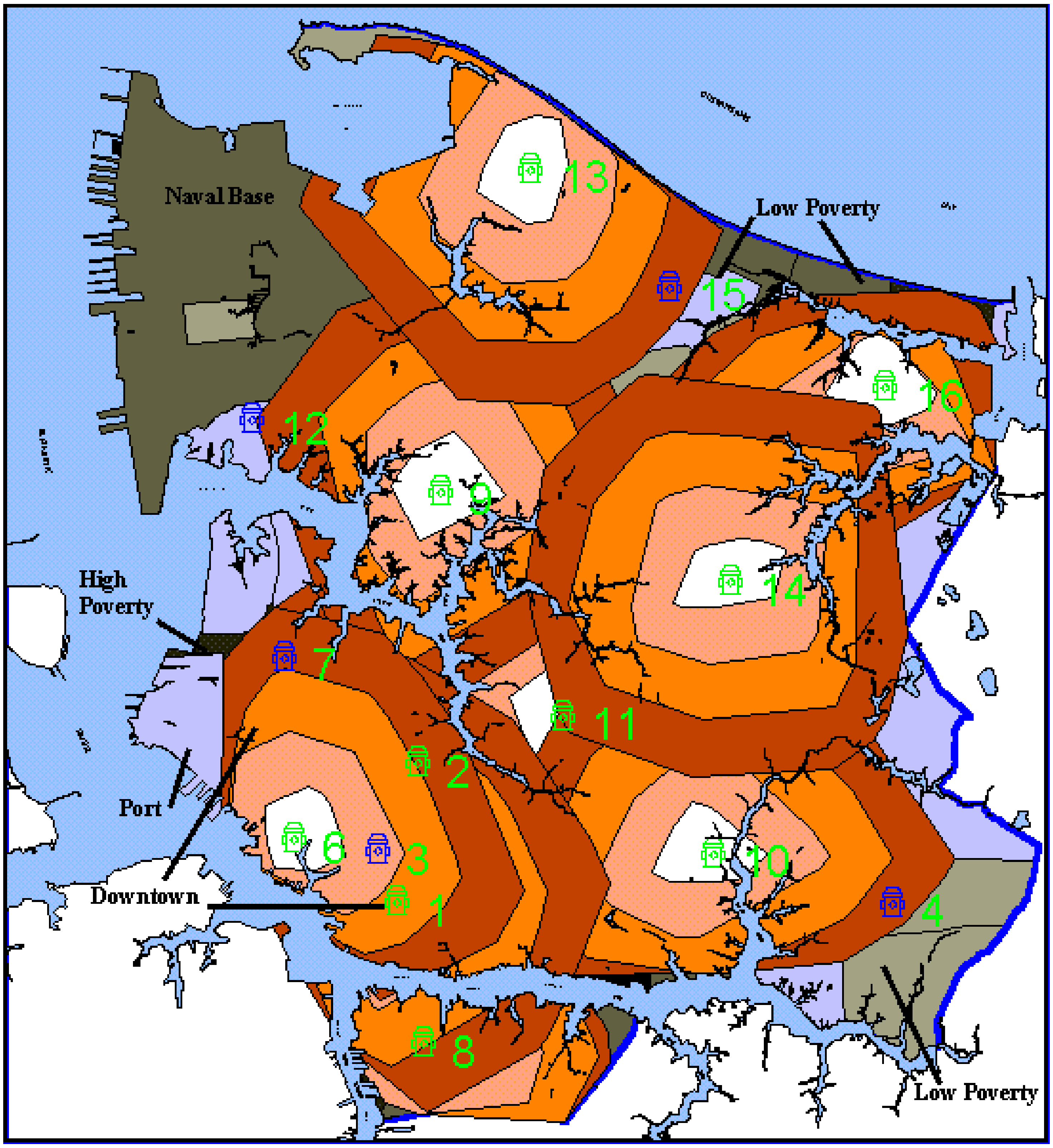
Population by Census Tract Overlayed by Five Minute Ambulance Coverage

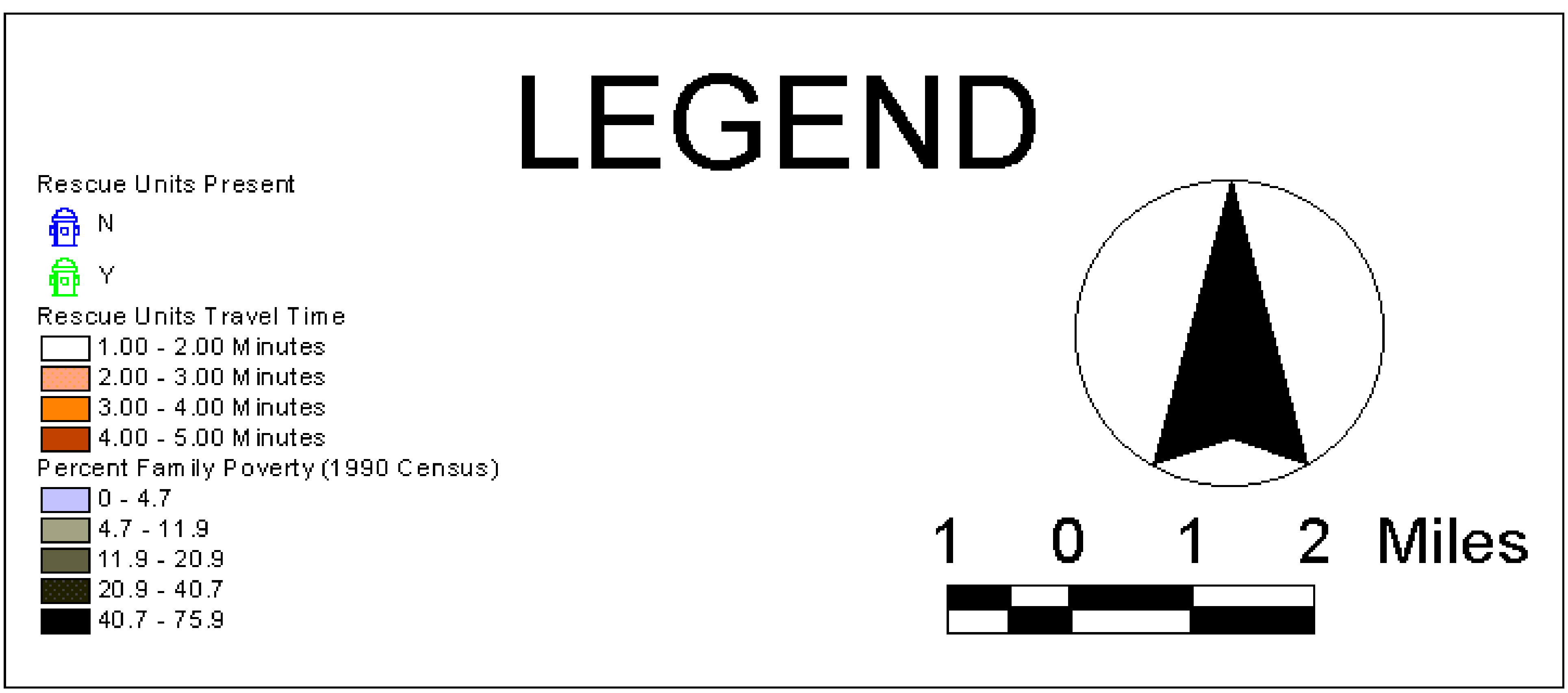




Map 4.6

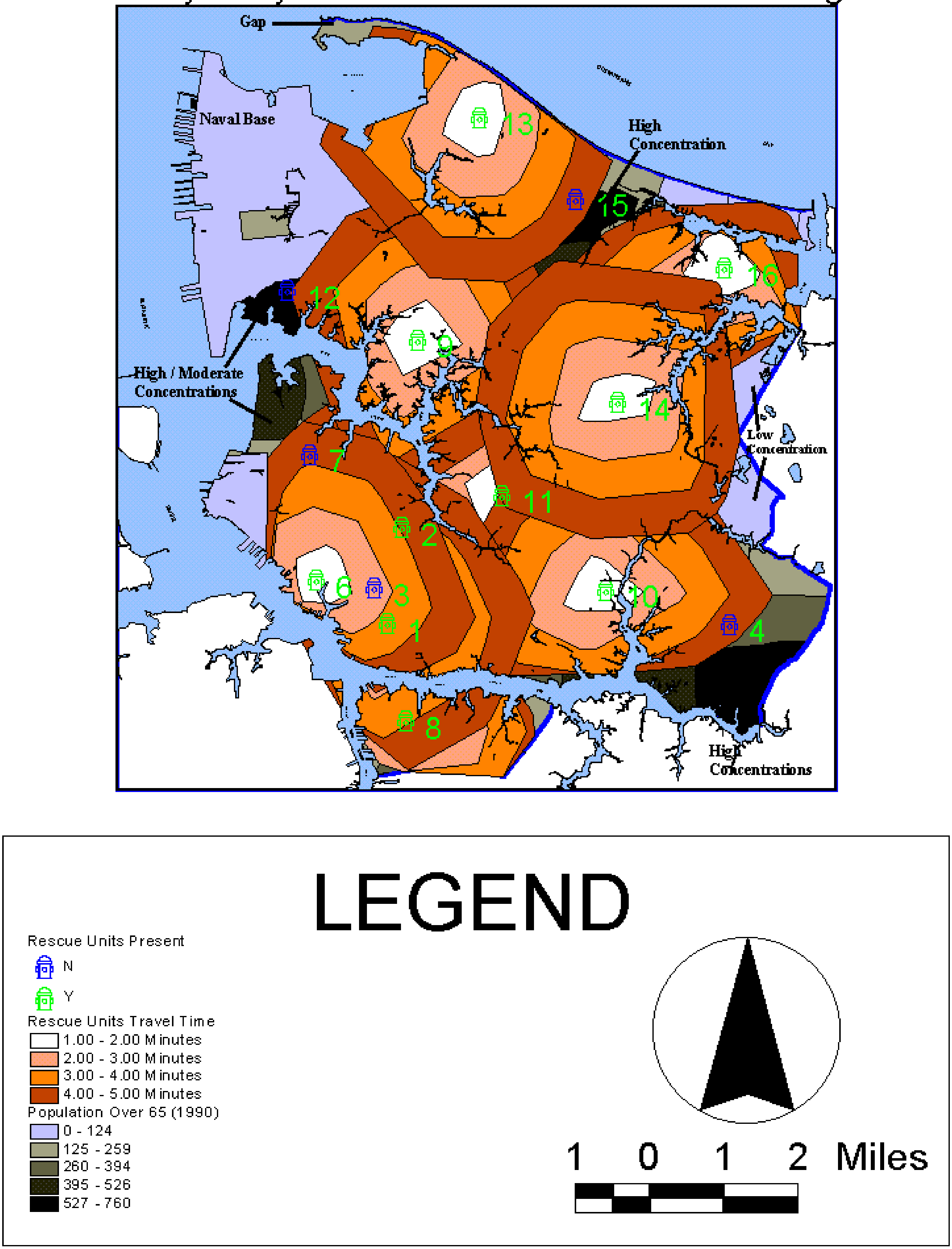
Percent Family Poverty Overlayed by Five Minute Ambulance Coverage





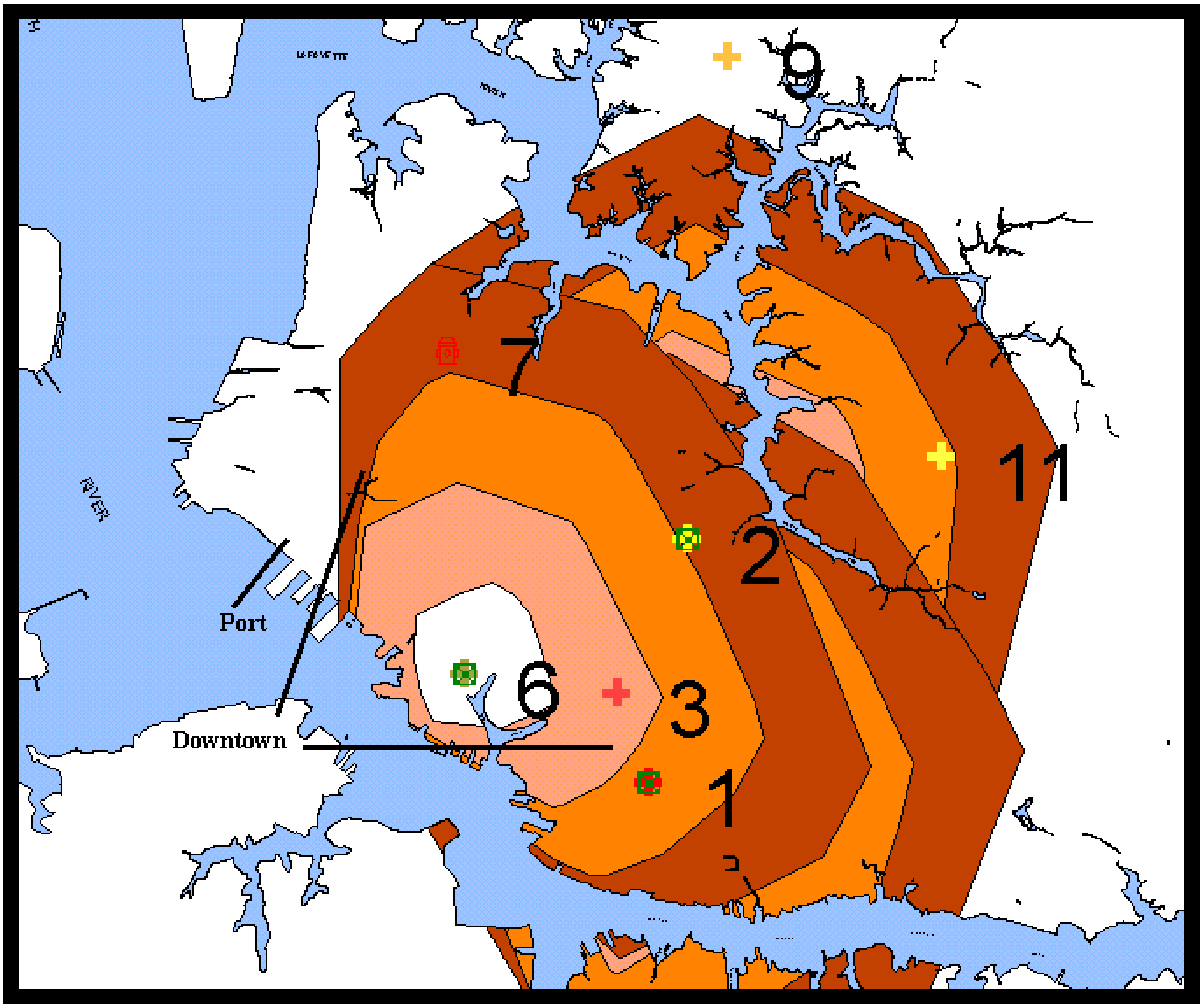
Map 4.7

Population Over 65 by Census Tract (1990) Overlayed by Five Minute Ambulance Coverage



Map 4.8

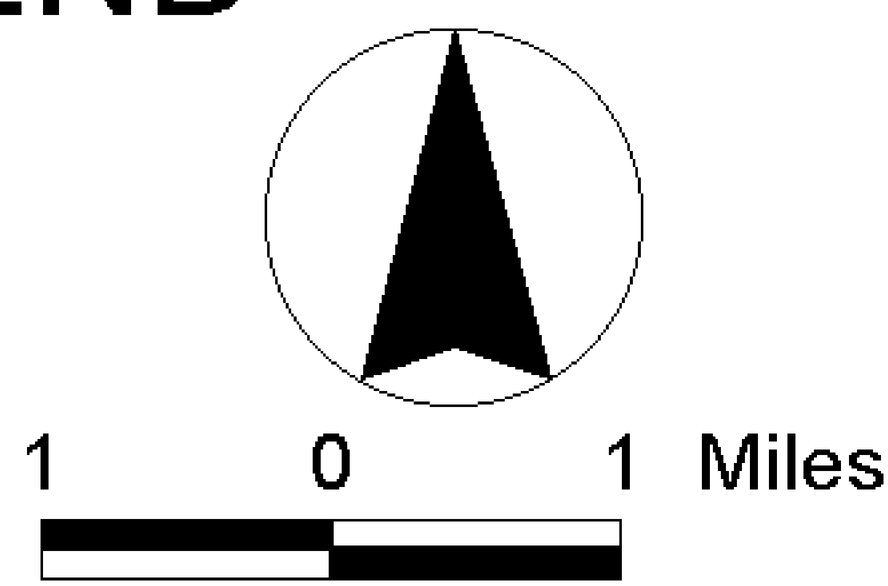
Proximity-High Workload + Good Performance
Downtown Norfolk '92-'95



LEGEND

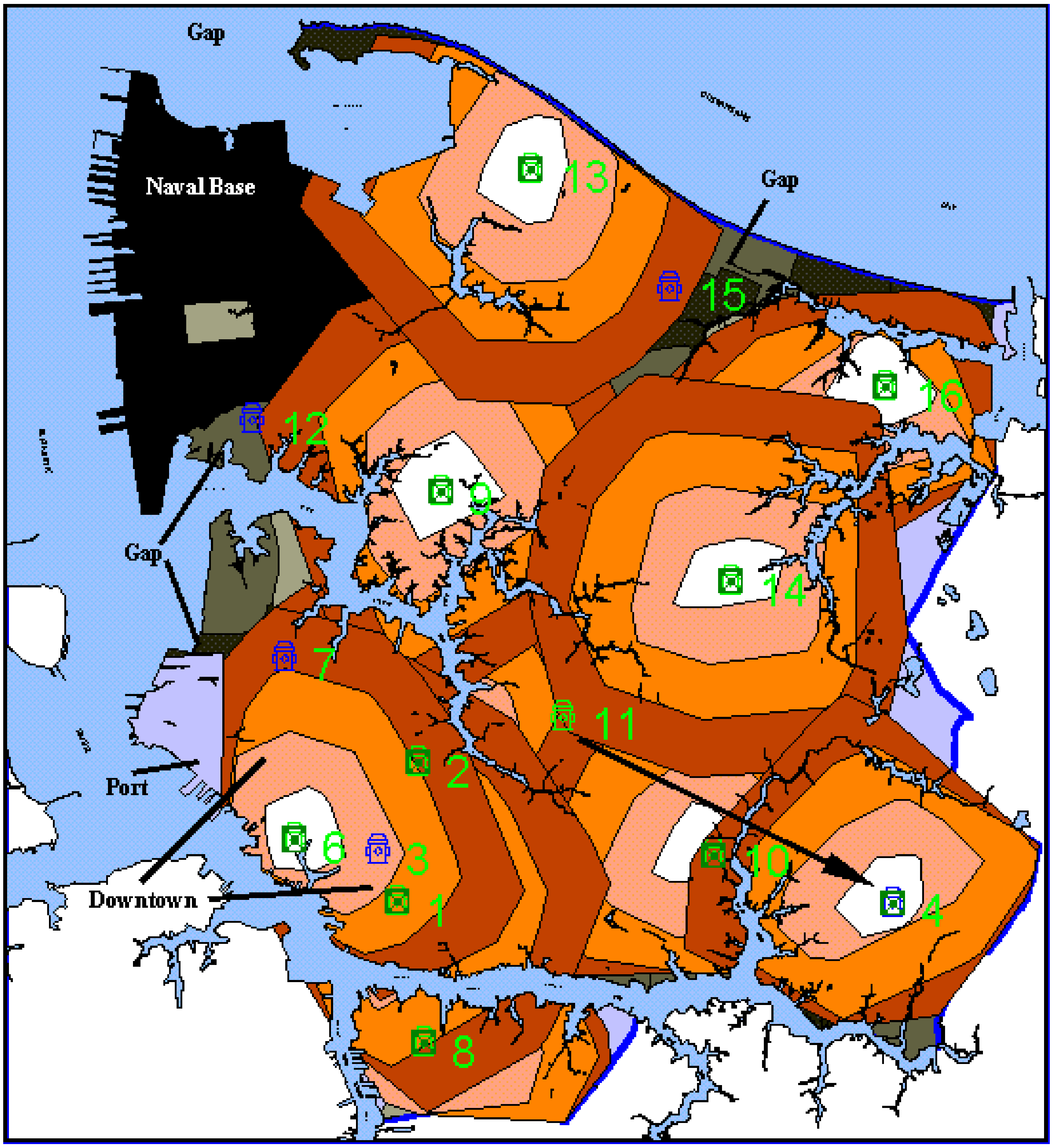
Totals '92-'95 (Number of Responses)

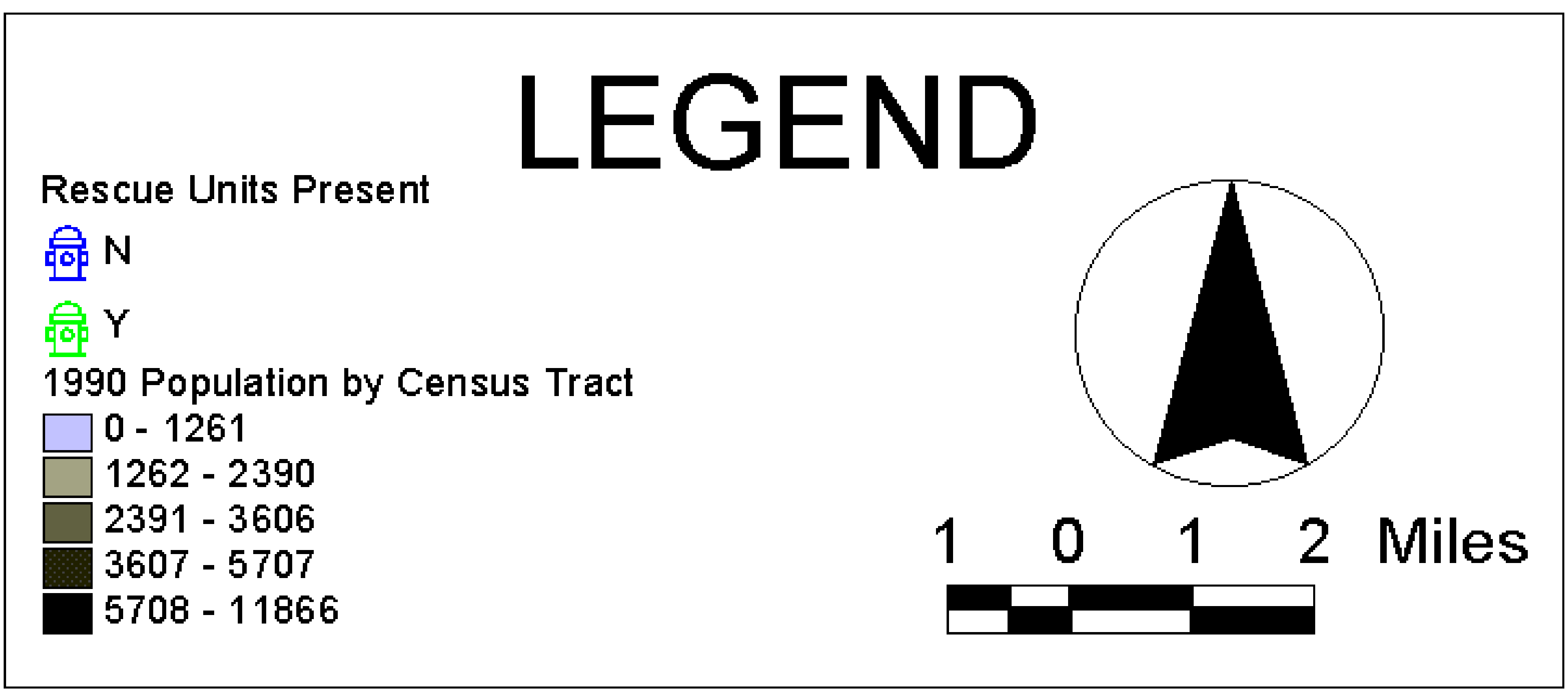
(fire hydrant symbol)	0	
(cross symbol)	344	Unit 3
(cross symbol)	6842	Unit 1
(cross symbol)	15516	Unit 6
(cross symbol)	15785	Unit 2



Map 4.9

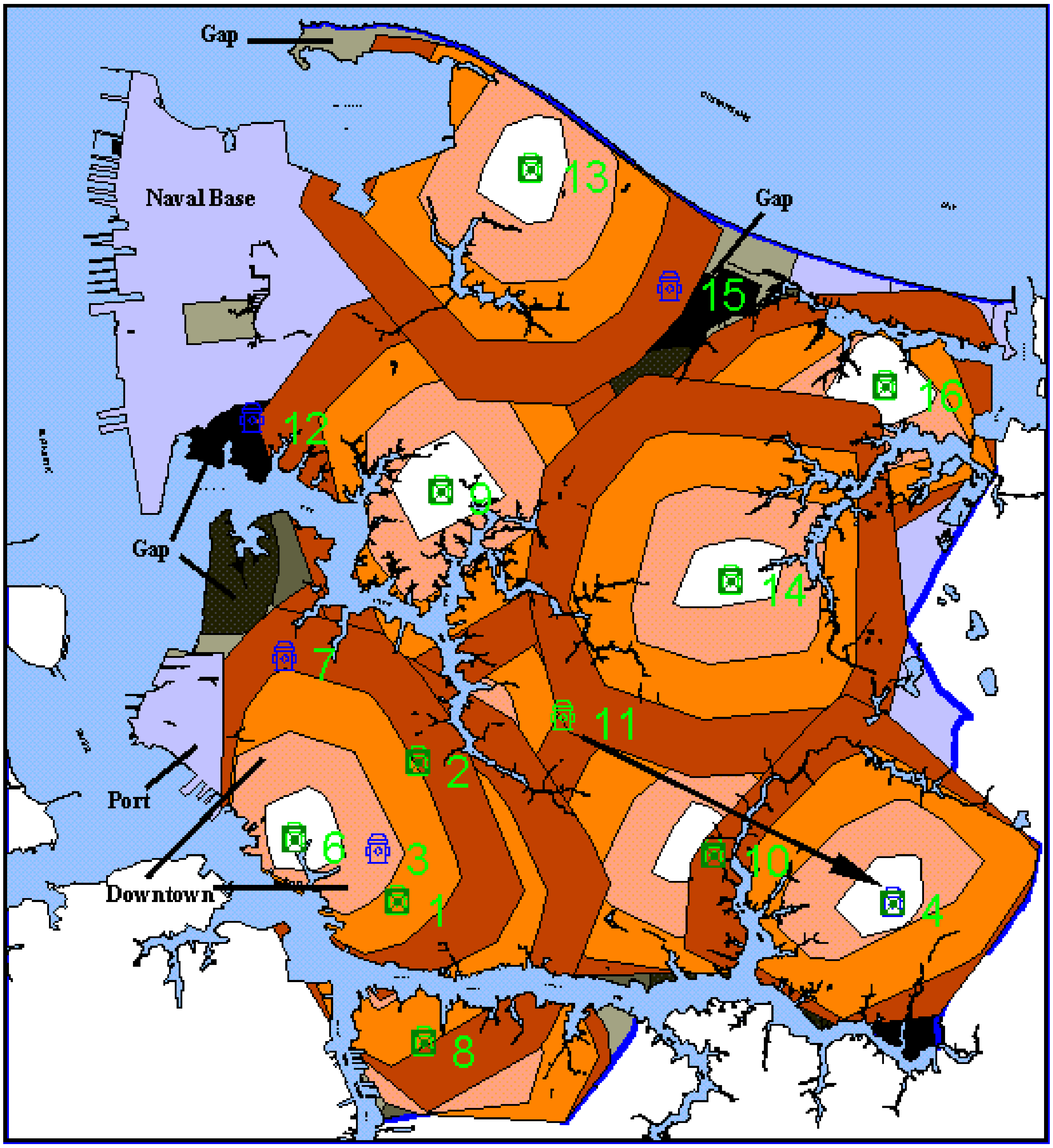
Option 1 - Move Rescue 11 to Station 4
Overlayed onto 1990 Population

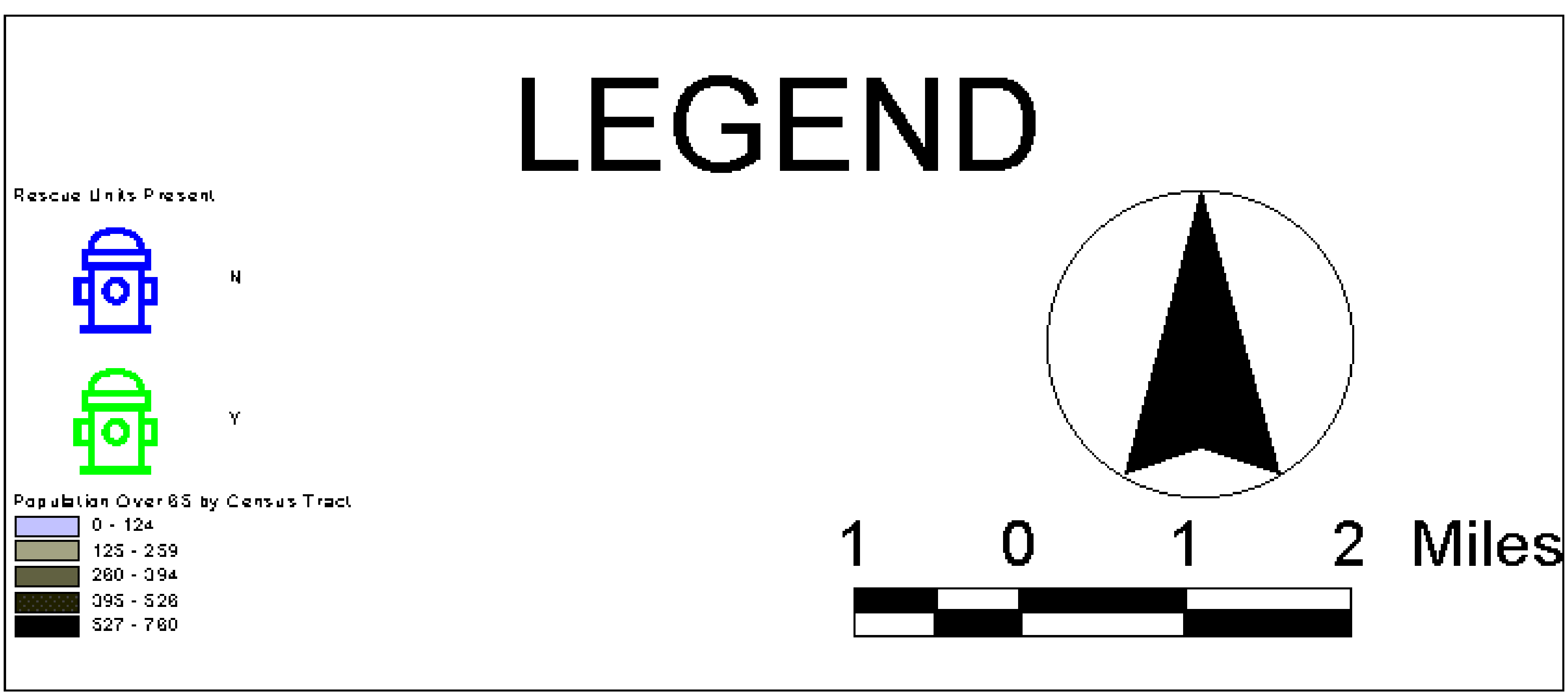




Map 4.10

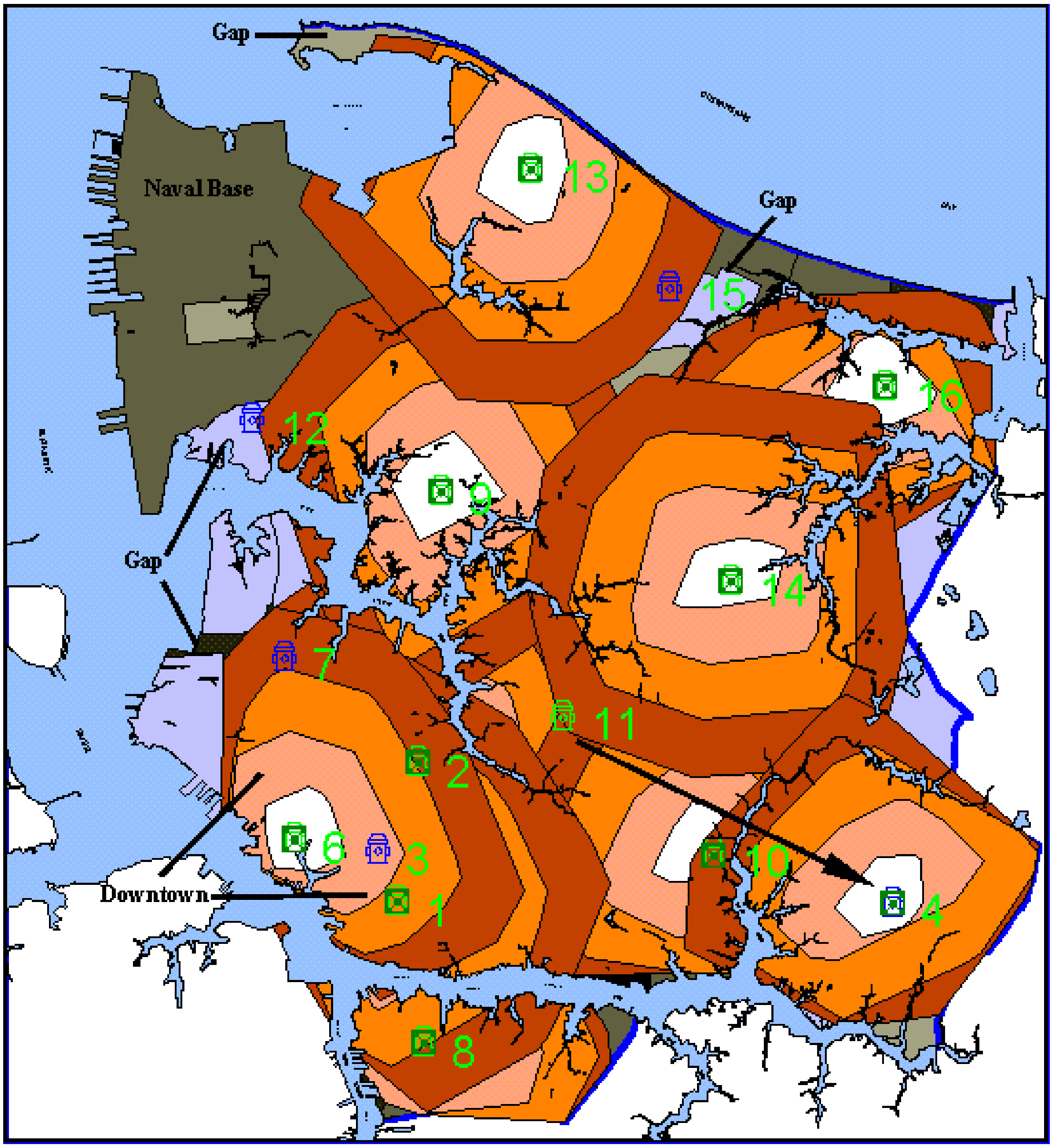
Option 1 - Move Rescue 11 to Station 4
Overlayed onto Population Over 65 (1990)

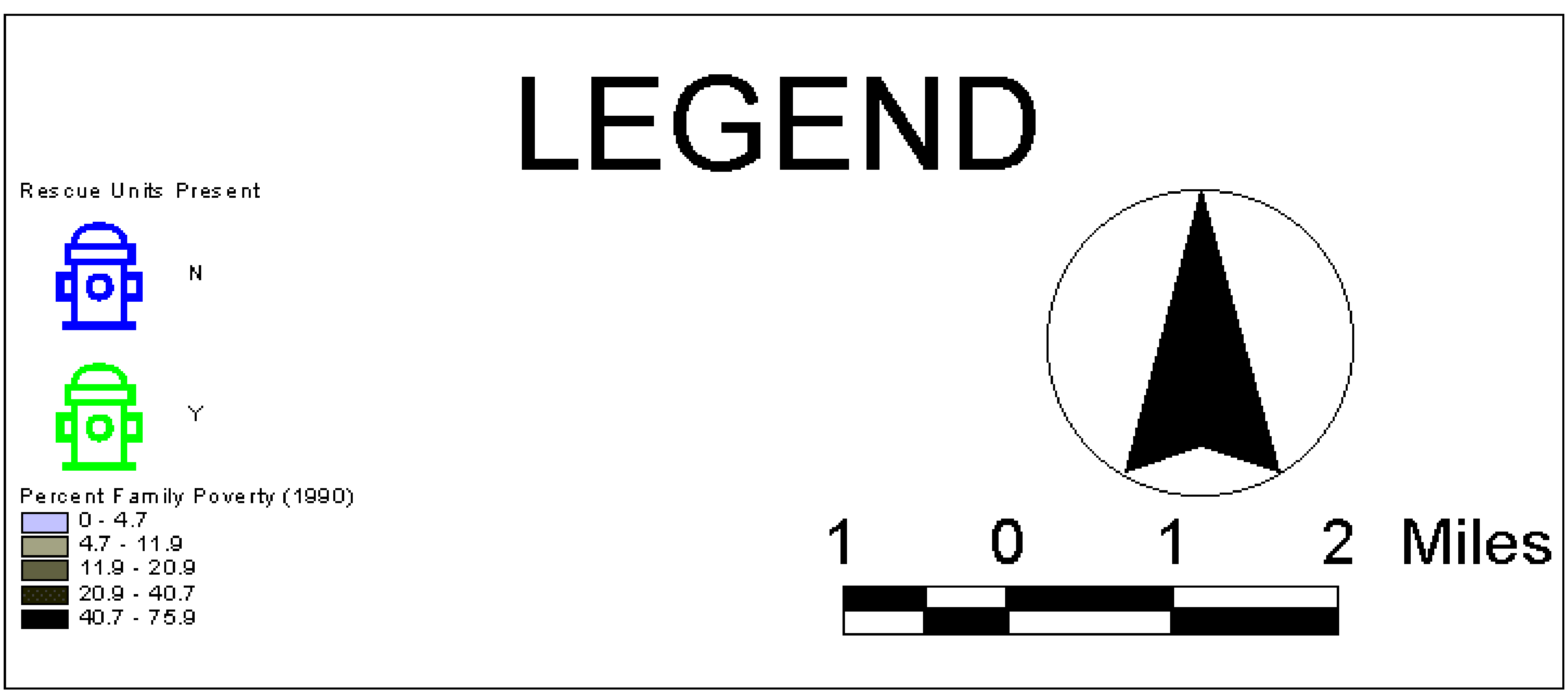




Map 4.11

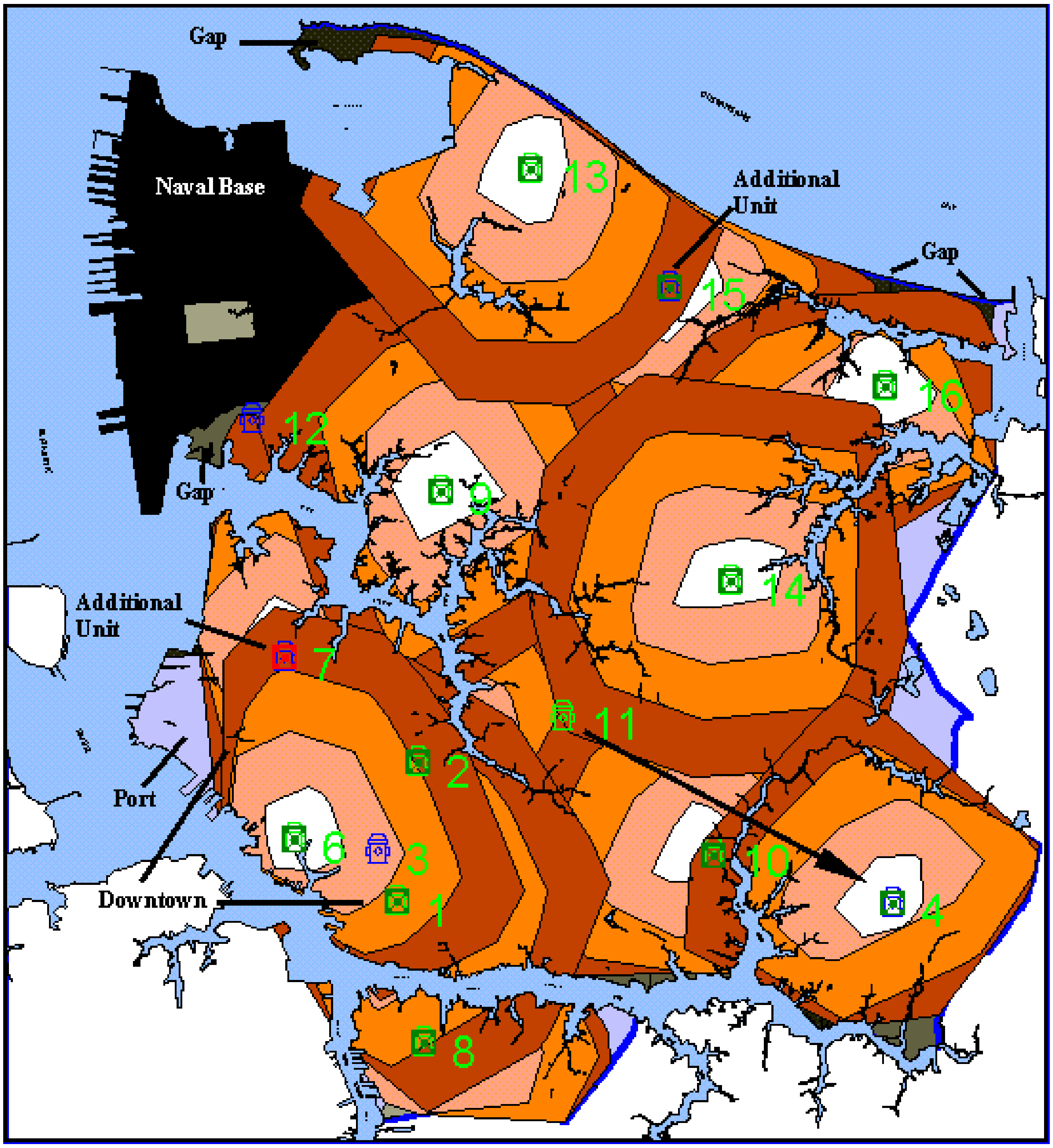
Option 1 - Move Rescue 11 to Station 4
Overlayed onto Percent Family Poverty (1990)

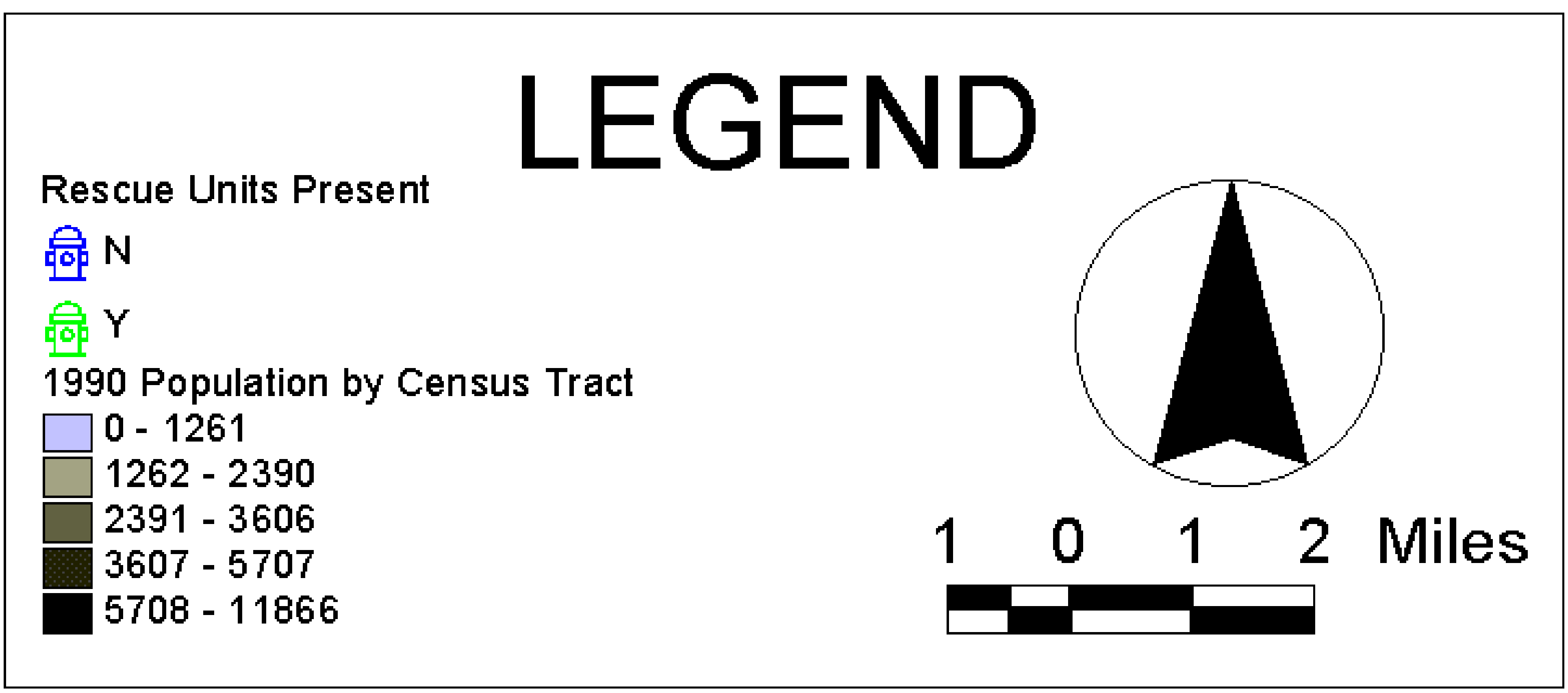




Map 4.12

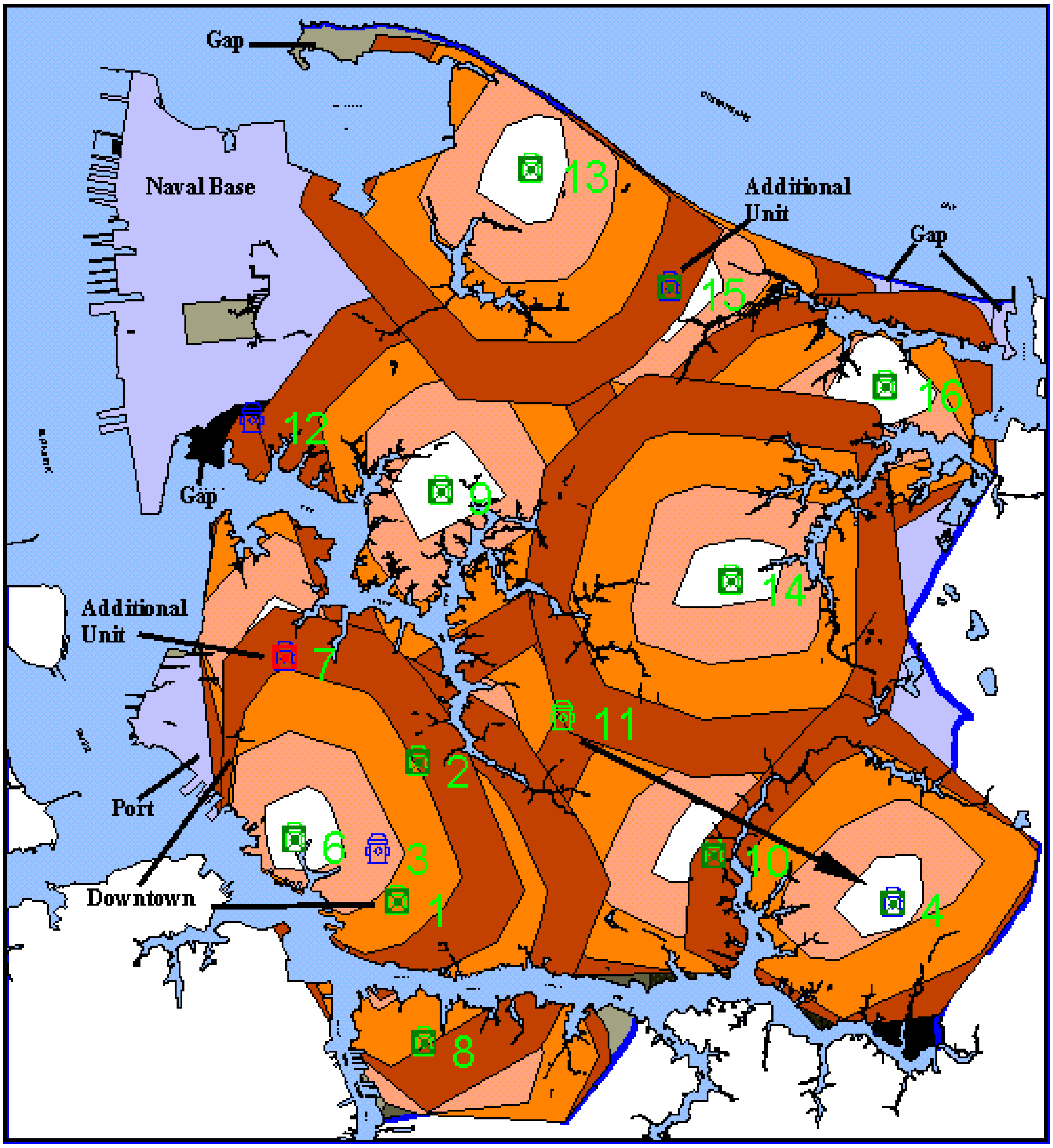
Option 2 - Move Rescue 11 to Station 4 and Add Rescue Units to Station 7 and Station 15

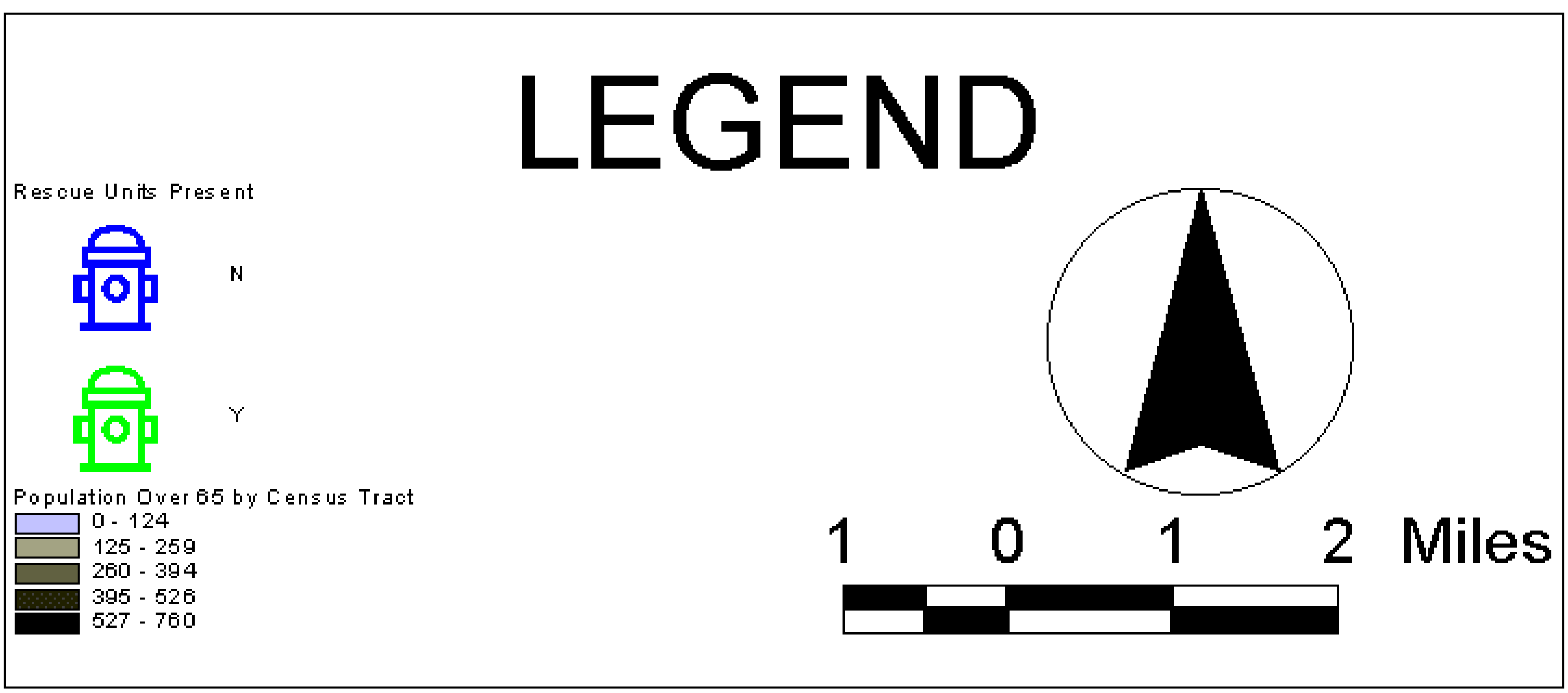




Map 4.13

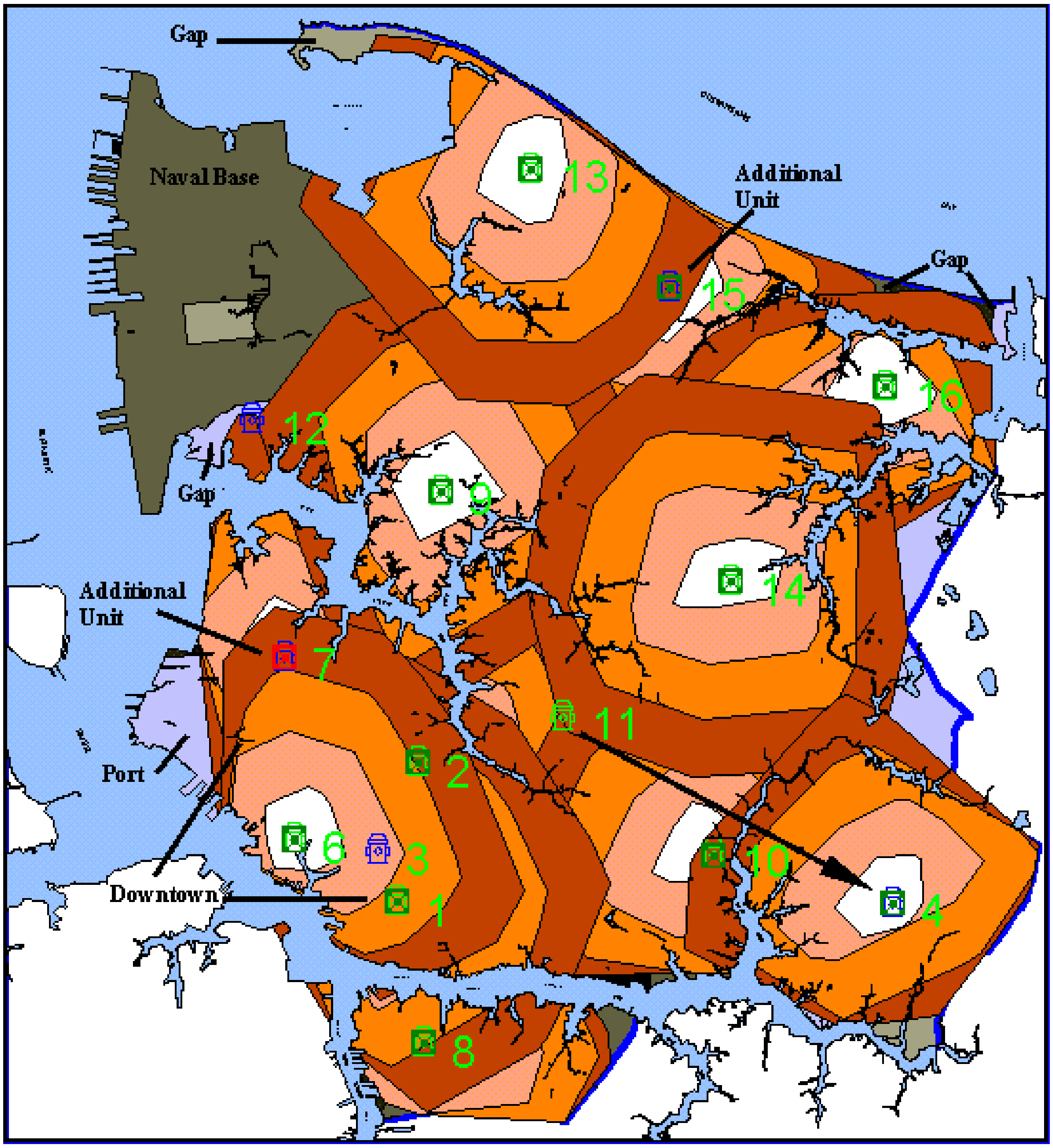
Option 2 - Move Rescue 11 to Station 4 and Add Rescue Units to Station 7 and Station 15

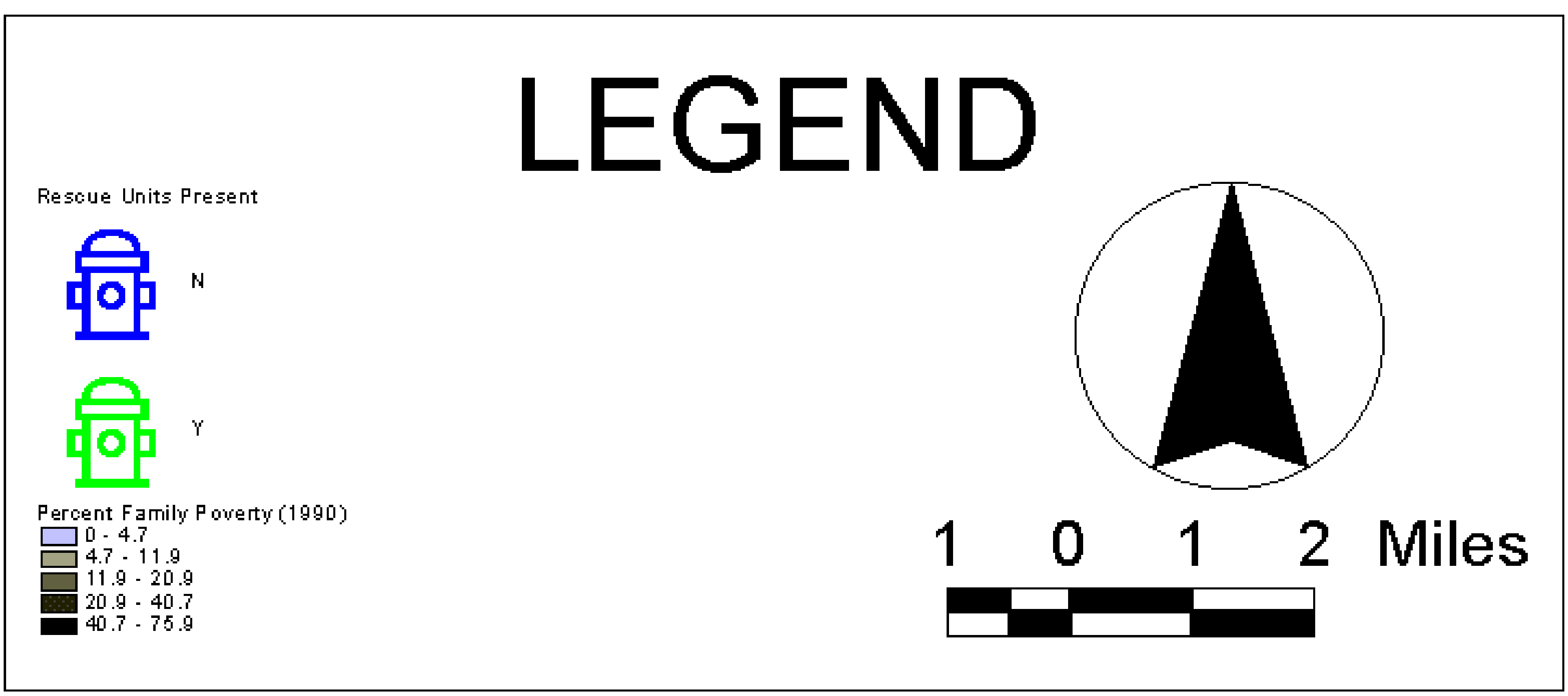




Map 4.14

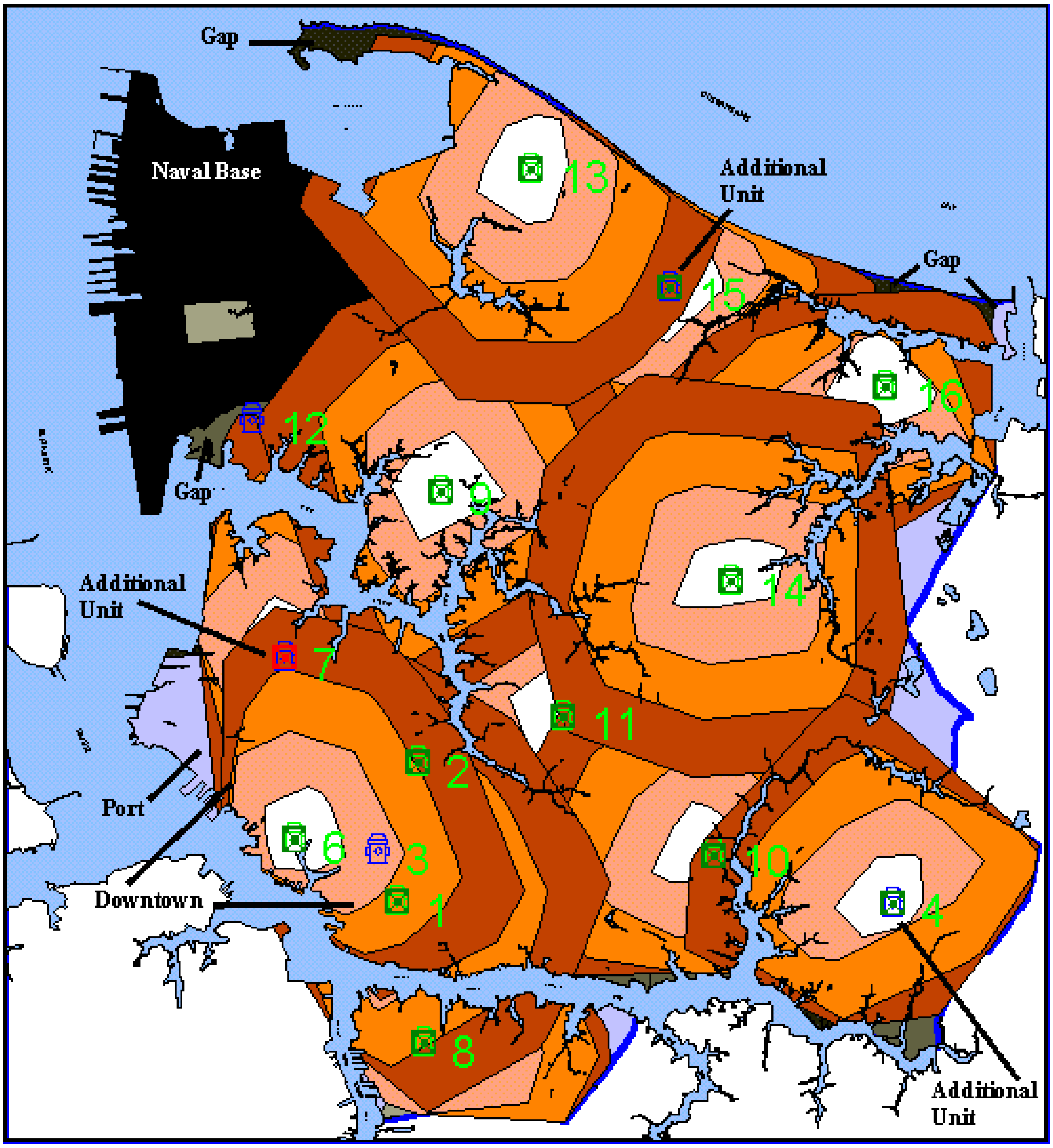
Option 2 - Move Rescue 11 to Station 4 and Add Rescue Units to Station 7 and Station 15





Map 4.15

Option 3 - Add Rescue Units to Stations 7,15, and 4



LEGEND

Rescue Units Present

N

Y

1990 Population by Census Tract

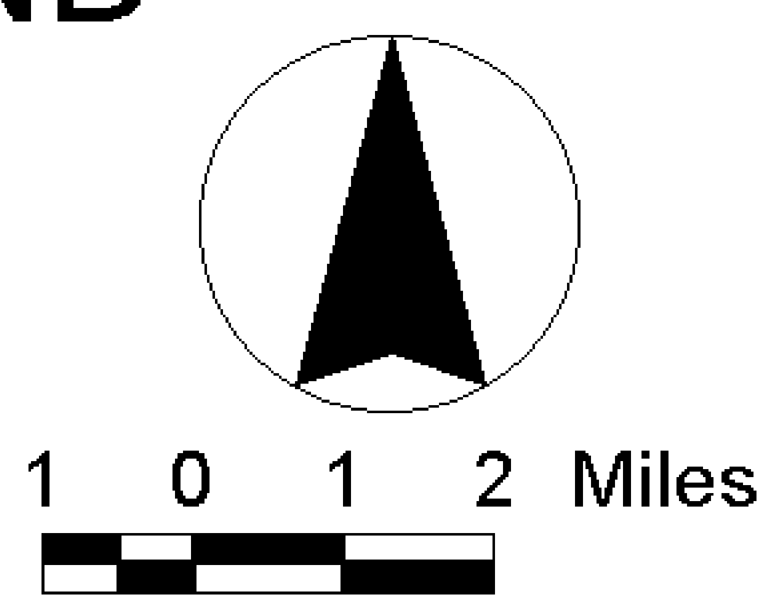
0 - 1261

1262 - 2390

2391 - 3606

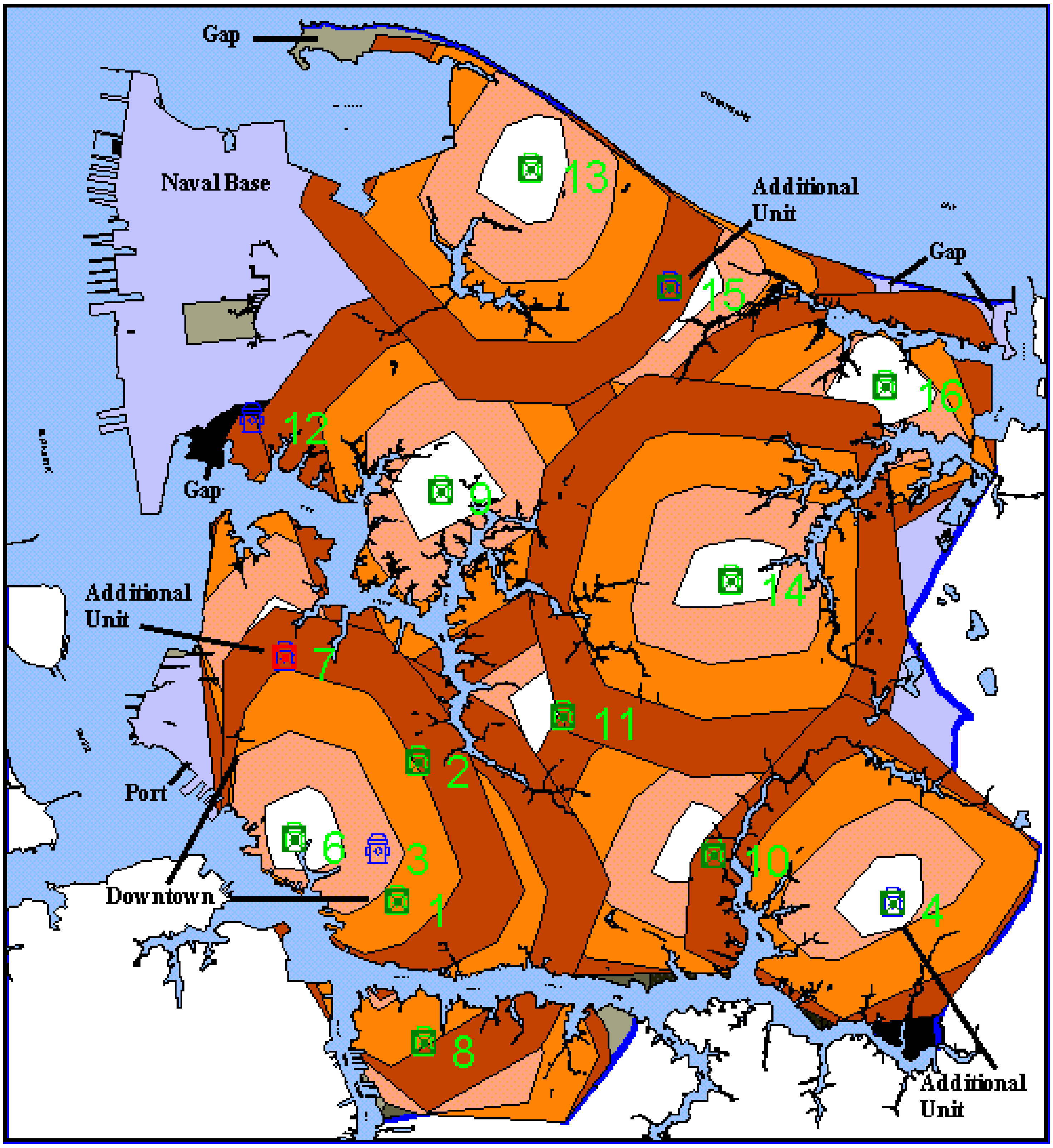
3607 - 5707

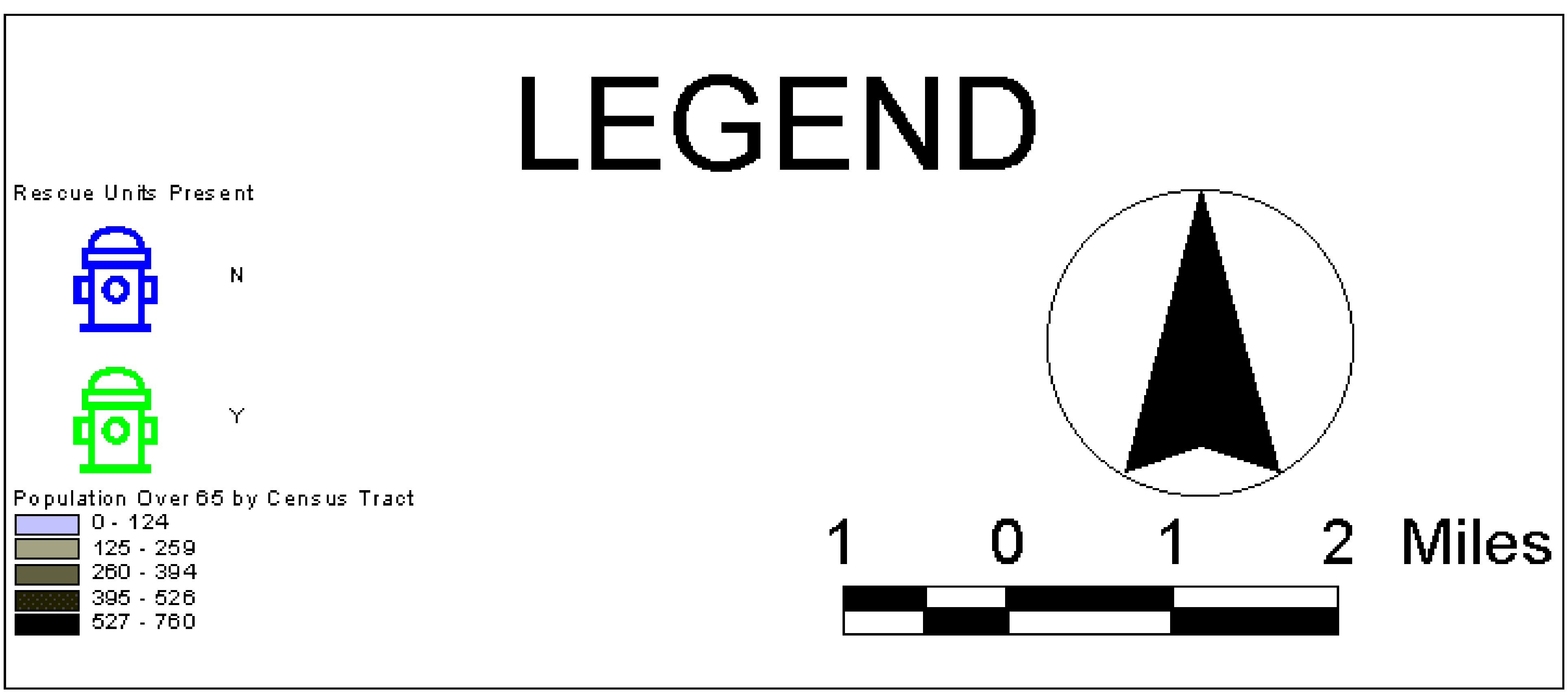
5708 - 11866



Map 4.16

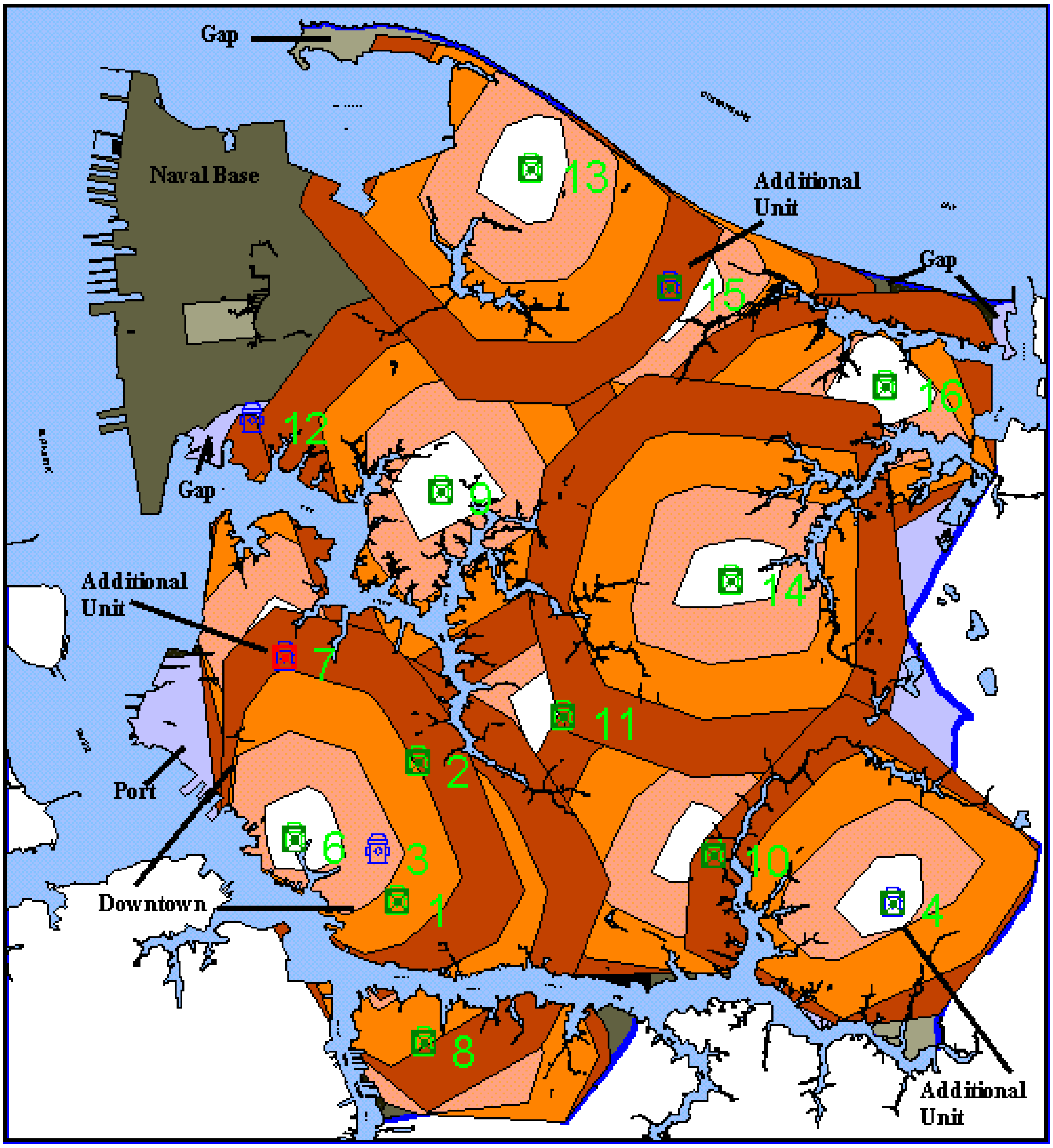
Option 3 - Add Rescue Units to Stations 7, 15 and 4

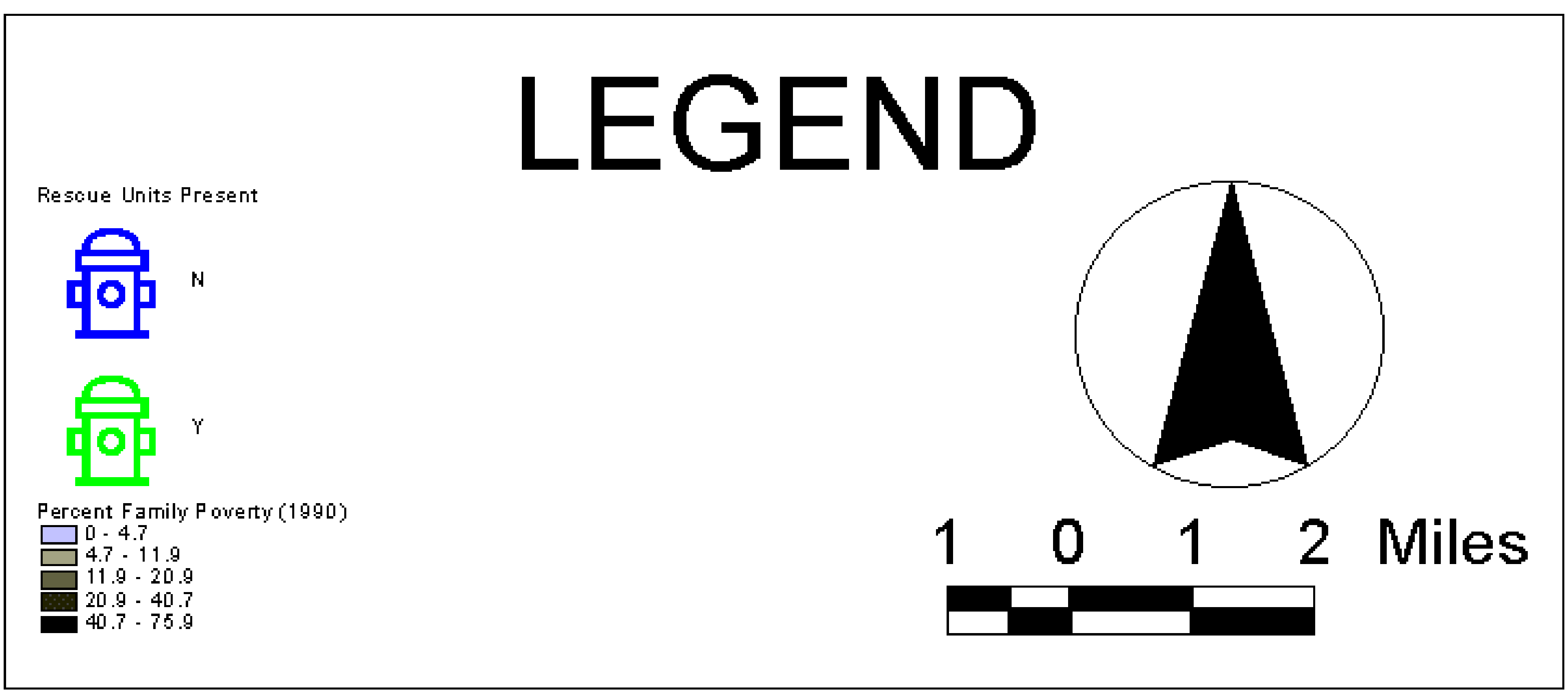




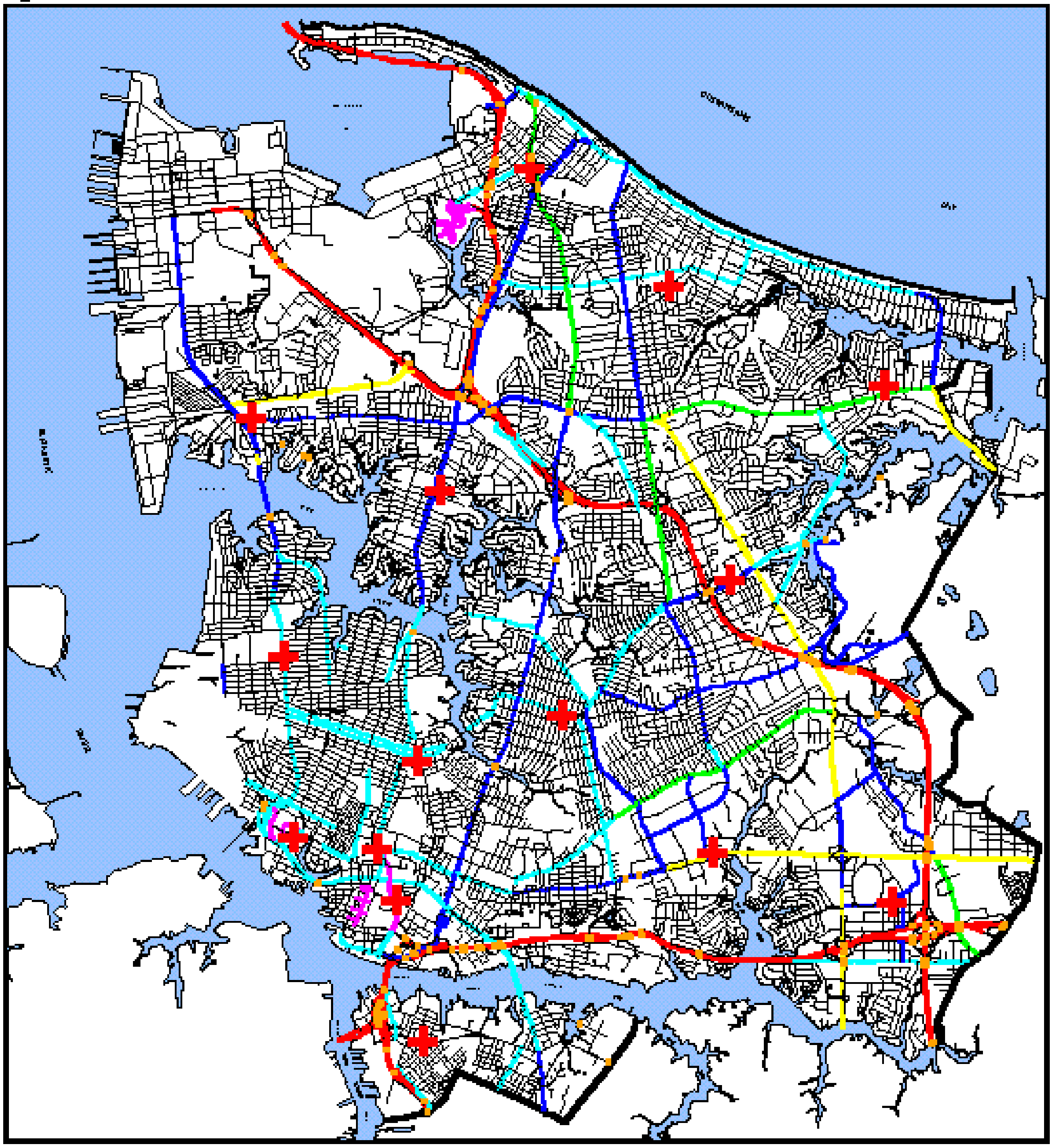
Map 4.17

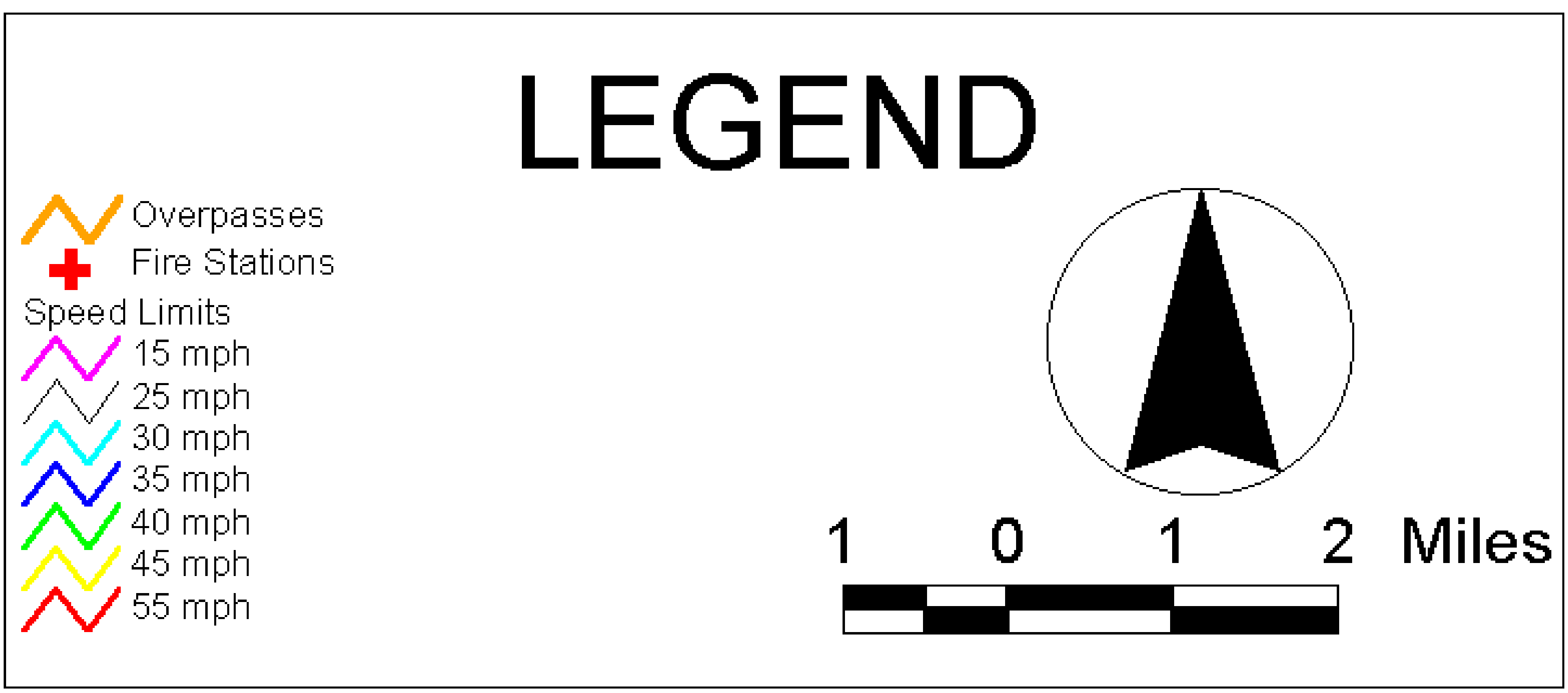
Option 3 - Add Rescue Units to Stations 7,15, and 4





City of Norfolk Network Coverage





VITA

Paul Sean Bloom was born on August 22, 1974. Paul graduated from Floyd E. Kellam high school in 1992 and enrolled at Virginia Polytechnic Institute and State University the following fall. At Virginia Tech Paul completed his B.S. in Public Administration while earning minors in Urban Affairs and Geography in May of 1996. While at Virginia Tech Paul was on the Dean's List eight times, a member of the Golden Key National Honor Society, and involved with the Hillel Jewish student organization. Paul began his graduate program in Geography in the fall of 1996. He graduated in May of 1998 with his M.S. in Geography.