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GIS as a Tool for Route Location and Highway Alignment

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Dedication

I present this work to who gives every thing and doesn’t wait any thing. To the candle that is burnt to light my way…………… My Mother.

Acknowledgement

First of all, I thank my God for all the blessings, he bestowed on me and continues to bestow on me.

It is with sincere gratitude and pleasure that I express my profound acknowledgement to my supervisor: Prof. Sameer Abu Eisheh, An-Najah N. University, who has been most gracious, diligent, and resourceful in his efforts to accomplish this study and write up this thesis.

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Abstract

Selecting best route location and highway alignment process is a complicated one, due to the many variables that must be taken into consideration for achieving the best results. Geographic Information Systems (GIS) can easily model such variables, including topography, environment, built-up areas, and geology variables. This study took advantages of GIS capabilities that offer the ability to overlay maps, merge them, and perform spatial analysis on various layers of information in either two or three dimensions.

In this study, a GIS model for route location and highway alignment was developed and used to generate alternate highway route applications. After these alternatives were preliminarily designed using CADD software (Softdesk 8.0), the model was used to analyze, evaluate, and then select the alternative with least impacts on environmental, economical, and political aspects.

In this study, the GIS model was tested on an application that aims to select the best alternative of three suggested highway alignments. This selected highway is supposed to connect two major cities in the north of the West Bank (Nablus and Jenin). In this application, the advantages of the developed model was clear in the preliminary stage of alternatives

generation where it was possible to avoid impacting of the different sensitive areas. In addition, a lot of information can be concluded once the user identifies a suggested route because the profile can be developed and drawn immediately. In final stages of analysis and evaluation, the model showed high capabilities in analyzing the impacts of each alternative, using buffering and spatial relations between the different features and the suggested alternatives, and then evaluating these impacts.

The results of this study clearly showed the applicability and potential of using GIS as a tool in route location and highway alignment with least potential impacts.

CHAPTER ONE

INTRODUCTION

Chapter One

INTRODUCTION

1.1 Background

Geographic Information Systems (GIS) are increasingly used in civil engineering applications. Transportation and highway engineering is one field which has been affected by developments in GIS aspects, as spatial variables, including environmental, topography, built-up areas, and geology related variables, can be easily modeled. Such criteria are taken into consideration in the selection of route location and the design of highway alignment processes that are usually perceived as rather complicated. Therefore, this complexity motivates highway engineers to give more attention to GIS applications in route location and highway alignment, due to their ability to consider many spatial variables simultaneously.

1.2 Objectives

The task of selecting the optimal route alignment for highways is an application of transportation engineering that can benefit from GIS technology. The main objective of this study is to take advantage of this technology that offers an opportunity to overlay maps, merge them, and perform two and three-dimensional spatial analysis on various layers of information. Therefore, the procedure will be established to perform the analysis of the preliminary location of highway routes, this will be applied to a real world case study for a new route between Nablus and Jenin in the northern part of West Bank.

1.3 Importance of the Study

The importance of this study comes from the use of a developed GIS model in highway alignment preliminary selection, analysis, evaluation, and final selection. The developed GIS model and its different extensions, especially 3D Analyst, have many of advantages in highway alignment selection field. The following points show these advantages:

1. In the preliminary stage of route selection, it is possible to avoid impacting the different sensitive environmental areas such as valuable agricultural and biodiversity areas, forests, and water resources, such as wells and springs. Such option remains possible because all layers can be shown simultaneously.

2. A lot of variable details can be reached once the user identifies a suggested route because the profile can be developed and drawn immediately. GIS provides preliminary dynamic evaluation of the suggested route:

- It is easier to select the preliminary centerline when there is a 3D topography for the study area, which makes it possible to avoid any steep slope.

- Using 3D model of the study area, the user can take a clear enough impression about the suggested center line by producing an immediate profile for the different segments of the center line. On the other hand, the length of each route is shown.

3. In final stages of analysis and evaluation, GIS has high capabilities in analyzing the impacts of the suggested highway, using buffering

and spatial relations between the different features and the highway, and then evaluating the proposed road depending on its impacts.

4. Finally, the user can visually certain the chosen alignment as well as he/she can see the final designed highway in three dimensions and can simulate driving through the highway.

1.4 Study Area

The study area is located in the northern part of West Bank. The area is part of two main districts, Nablus and Jenin, as shown in Figure (1). There are two main reasons behind selecting this area for the application of this study. First is the variety of land use and topography of the study area that extends from Nablus in the south to Jenin in the North as shown in Figure (2). Such variety shows the capabilities of GIS in spatial analysis in two or three dimensions. Second is the availability of environmental and socioeconomic information necessary for the analysis and evaluation phases of the intended model.

1.5 Study Outline

This study is composed of five chapters. Chapter One includes the background of using GIS in transportation and highway alignment, study area, aims and objectives, the importance of the study, and the study outline. Chapter Two presents a review of the developments in the application of GIS in the transportation sector, especially in highway alignment selection. Chapter Three explains the data collection and its examination, it has also the description of the developed GIS model. Chapter Four deals with the application of the developed GIS model. Finally, Chapter Five presents the conclusions and recommendations.

Figure (1) Location of the Study Area in the Northern part of West Bank

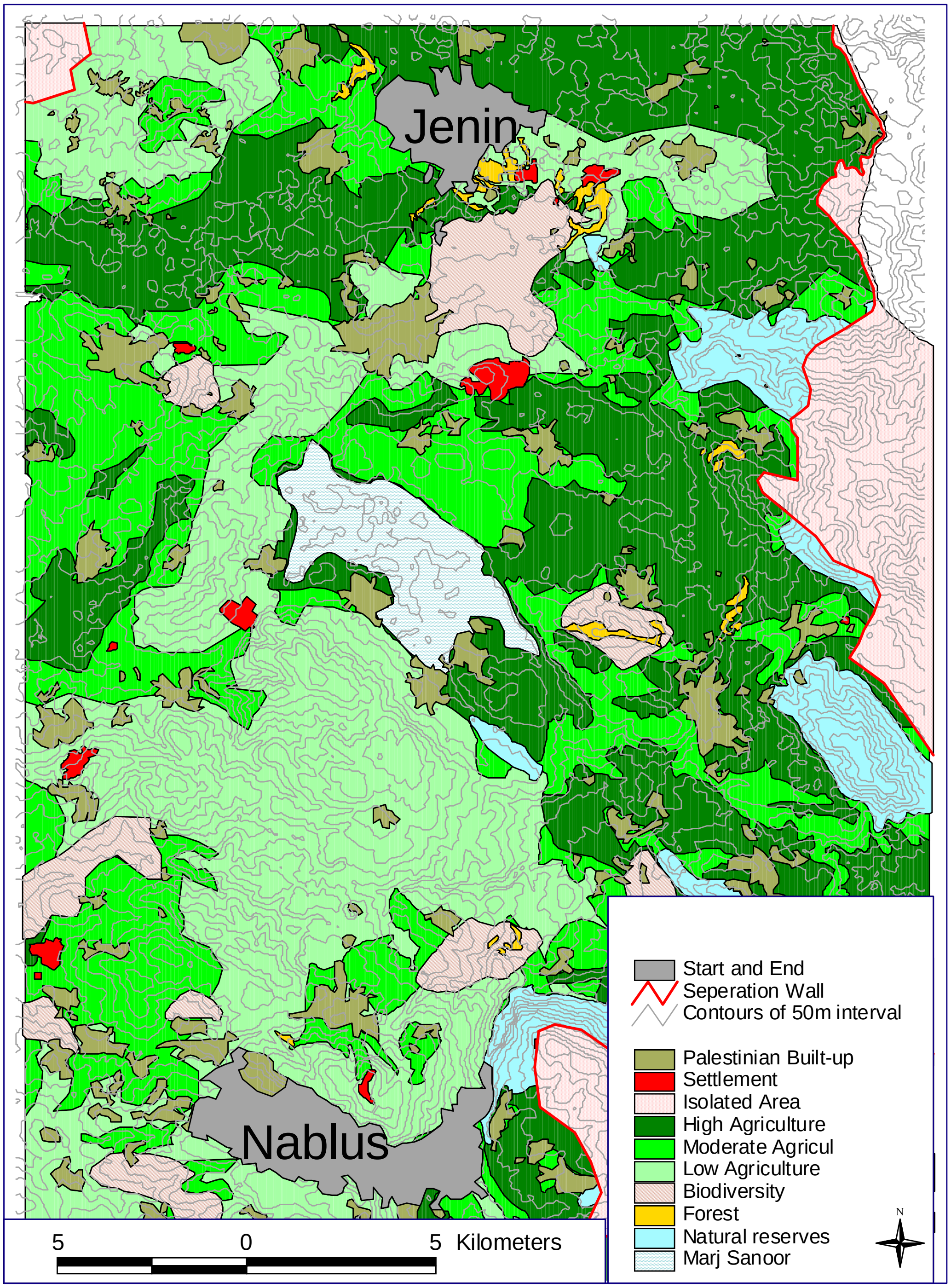


Figure (2) Detailed Study Area

CHAPTER TWO

Literature Review

Chapter Two

LITERATURE REVIEW

2.1 GIS Applications in Transportation Planning

2.1.1 Introduction

GIS can have a significant role in transportation planning because GIS can help capture, store, analyze, and display geographical information based on its location character and link it with transportation planning variables. The use of GIS is particularly useful in transportation since it is an effective way to integrate the information needed to support many criteria for transportation planning, evaluation, and analysis.

GIS play a main role in transportation application planning. It is useful to address complex tasks in policymaking, planning, analysis, evaluation, design, construction, and maintenance of different types of transportation facilities. In addition, it provides database management for extending human memory, spatial analysis for rigorous computation, and map display for visualization of large amounts of information about transportation networks.

2.1.2 Worldwide GIS Application in Transportation Planning

A large number of studies regarding use of GIS in transportation planning were prepared around the world. One of these studies was titled ‘A Methodology Using Geographic Information Systems to Evaluate Socioeconomic Data Concerning Impacts of Highway Bypasses in Oklahoma’ was prepared by Jonathan, Allen, and Amanda (2000). This study focused on developing a methodology for selecting and aggregating socioeconomic data that will be useful in assessing the impacts of highway bypasses on towns in Oklahoma. GIS technology was used in this study to develop a comprehensive modeling framework that will allow the users to assess quantitatively the potential economic impacts bypasses may cause. Within this framework, bypass alternatives were selected and evaluated via five primary factors: total cost, ability to serve traffic, number of residential and commercial displacements, effect on the local businesses, and environmental considerations along the route.

Alternative routes could be easily derived and compared to find the best one, including the possibility of not constructing a new bypass but widening and improving the existing route instead. This aspect of the project set it apart from other studies of highway impacts analyses.

As part of this study an automatically updated GIS database for Oklahoma highway network was constructed to keep the planners and engineers well informed to the activities and needs of communities throughout Oklahoma. By properly developing and maintaining the GIS database and using the developed model, users would be able to identify a proposed new bypass route graphically on a map, identify the bypassed highway section, and quickly calculate estimates of affected businesses and other economic activities within a specified distance of these routes. This identification, combined with the impact models developed by using past bypass experiences in Oklahoma, provides the users with a reasonable estimate of changes that could be expected for the proposed bypass route and replaced highway section.

The methodology for determining the impacted area of a bypassed city involves several steps. First, the path for either an older, already-bypassed route or a proposed new route was selected. Using the predefined functions developed for this project, the user “traces” over the old or proposed route with the cursor, and ArcView created an impact buffer around the selected street or proposed highway at a distance defined by the user. In the second stage of buffering, ArcView selected all impacted streets and side street segments intersected by the initial buffer and created a second buffer around all these segments.

During the third and final phase of the buffering and selection process, ArcView chose all block groups that intersect the buffer from the second stage. After completing this process for both the old and new routes, ArcView passed the tabular data relating to the selected block groups for the outlined routes to an analytical model for impacts analysis or for direct computation of summary measures along the routes. By identifying impacted zones in this manner, the user can select and analyze the potentially impacted areas and the data relating to these areas more accurately. When the analyses of the impacts of past bypasses are complete, determining the impacts of such bypasses on any highway will be a relatively rapid process, compared to such analyses made without GIS.

Another study related to the improvement of highway planning with the help of GIS was prepared by West (1999). A major highway planning project took place over a period of years and involves a wide range of engineering and technical specialties.

The study aimed to compare between the traditional methods of doing highway planning with the method of using GIS. Traditional methods of performing highway planning dealt primarily with analyzing spreadsheets, using planimeters to calculate areas, and using hardcopy maps with overlays. Non-intelligent CAD data was also used to display and overlay specific data to the environmental planner. GIS technology gave the planner powerful tools to perform spatial analyses, such as the tools to identity, merge, clip, buffer, and joining of tabular data.

Some common benefits of using a GIS on highway planning processes were mentioned in the study, like:

- Improved access to data, which means earlier project completion
- Better access allows more sophisticated analyses
- Heightened system performance encourages users to better utilize data
- Cost effective due to time saving processes

The study finally discussed the limitations and the capabilities of different GIS software like ArcInfo and ArcView in highway planning. ArcInfo tools were used to perform specific tasks that ArcView could not handle due to software limitations. Importing data could be performed in ArcView or ArcInfo, while reprojecting data seemed to work better with ArcInfo. Building topology for each dataset was very important to do because polygons need to be created for wetlands, new alignments, and property owners. Stationing is also done in ArcInfo, but it can also be done in the CAD environment. This step was necessary to identify each wetland. Positioning of the data was critical when producing map sheets. Because of ArcView's limitations, the data was rotated in ArcInfo and then taken into ArcView for plotting.

2.1.3 Local GIS Applications in Transportation Planning and Traffic

There is a limited number of studies regarding use of GIS in transportation planning in Palestine. Transportation planning was part of study that was prepared by Abu Gharbiyyeh (2001). One objective of this study was to describe the capabilities of GIS in transportation planning, and on the other hand to study the role of GIS and how it could play a role in Palestine by developing this system.

The study introduced a general background of the planning situation in Palestine. The reasons for introducing GIS at Palestine were described, as well as the obstacles that face the application of GIS in regional planning in Palestine. The need of a GIS system for Palestinian Planning was described and the current situation of the Palestinian information system was discussed.

The study also contained a practical application of GIS by viewing techniques that could be used to upgrade the master plan of Bethlehem City. History and the predominant situation in Bethlehem were outlined. The use of GIS in the maps production process was presented by discussing how GIS could be used to upgrade the exiting land use road networks of Bethlehem.

Finally, the study provided a proposal to develop GIS in Palestine by outlining a framework for the establishment of Mapping Authority of Palestine (MAP).The requirement to fulfill the functions of MAP and Implementation Strategy and program were given to assure the effective use of GIS in Palestine.

An other study titled ‘The Use of Traffic Assessment Modeling Technique in Evaluating and Testing Transportation Policies and Projects Nablus City: Case Study’ was prepared by Douleh (2000). Since the scientific methods are the tools for proper planning, the estimation of origin-destination trip matrix and traffic assignment were the basic methods that were studied, discussed and. utilized in this study. Stochastic User Equilibrium assignment was the method used for traffic assignment processes, while the multiple path matrix estimation was used for the estimation of origin-destination trip matrix. These methods gave acceptable simulation for the travel behavior and travel patterns, where an equilibrium condition in the traffic flow pattern over the street network was observed. GIS based computer software, TransCAD, was used in this study. TransCAD is a powerful tool for transportation planners in terms of GIS support for planning and modeling. Traffic assignment and origin-destination trip matrix estimation were parts of the transportation planning demand module in TransCAD.

In this study, the physical and operational characteristics of the links and nodes of the transportation network were defined, and the origin-destination trip matrix was estimated, the simulation for the existing traffic conditions was made also.

GIS had been used in traffic issues on the local level, such as in the analysis of data accidents, studying and understanding why accidents occur, identifying accident prone-location, and aiding in the choice of proper safety programs or countermeasures. In this direction, a study that was prepared by Kobari (2000). In this study, a GIS-oriented database using TransCAD software was developed as a tool in improving quantitative accidents data analysis. The database was applied for a two-year study period (1997-1998) for Nablus City. This database was of great use in road safety improvements and management. This study included a number of phases: establishment of detailed database with information on accidents, traffic characteristics and physical road data; integration of these databases into a GIS; and definition and development of GIS-based applications to road safety and management.

The general aim of Kobari's study was to develop a safety management tool by establishing an accident database for the City of Nablus using Geographic information System (GIS). This database had the ability to deal with systematic statistical analysis of accidents, safety management, and the evaluation of safety improvements. An integrated spatial database of accidents was established that included information of road-physical and traffic flow characteristics. The developed system was applied to the analysis of a number of specific road safety issues such as pedestrian accidents, children accidents near schools, and area-wide analysis in a certain neighborhood. Finally the hazardous locations in the study area were identified. The results of this study clearly showed the applicability and potential of using GIS as a tool in road safety management and improvement.

2.2 GIS Studies in Route Location and Highway Alignment

Route location and highway alignment presents a highly complex decision environment in which a variety of social, environmental, and economic factors must be defined, analyzed, and evaluated. There are several studies that benefit from the GIS for this purpose; one of these studies was prepared by Bailey (2003).

The design and development a GIS-based corridor route planning methodology called Analytic Minimum Impedance Surface (AMIS) was described in this paper. This methodology facilitated choice of a route corridor for a section of a proposed interstate highway connector in the southeastern U.S. Also it would both provide comparative information about pre-selected corridors and/or aid in the selection of corridors based on user-defined path inputs or endpoint location specifications.

The area of this study was located in a complex karst landscape possessing a variety of landforms and geologic characteristics. Much of the study area was dissected by a dense network of streams and steep gradients and cliffs were common. Although this area was mainly rural, containing large sections of a National Forest, several pockets of development were found in the study area.

Five classes of data were defined in this study

- Environmental: Unique habitat, archaeological feature and streams
- Man-made public Features: Hospital, water tank, school and airport
- Dirt and rock: Oil and gas wells, mine, quarry and 15-25% Slope
- Socioeconomic: Land value, poverty rate and Population growth rate
- Picnic area: Picnic area, national properties register, state park

The study discussed how the various data inputs; including the classes above; elicited and aggregated into a decision support model. AMIS combined system priorities, such as economic development and connectivity improvement, with varied but specific features, such as wetlands, schools, median incomes or areas where endangered species were located. Both the system priorities and features could be user-specified.

Input was in both written and electronic data format, while the output was displayed on standard GIS software. AMIS was therefore built using iterative process that incorporated input from engineers, planners and environmental specialists.

GIS database for AMIS was constructed to the same resolution as the underlying terrain data; 30 meter digital elevation models (DEMs). All of the vector data was converted to raster grids within ArcInfo. The integer value of each grid cell was taken directly from the calculated values for that data layer. Once all the raster layers were completed, ArcInfo then added the values of all cells in the corridor study area. The result was an impedance surface, representing the sum of all the calculated costs on a per-cell basis. Using Avenue scripts within ArcView, the routing function was invoked with a button which then allows the user to specify where the route should terminate. Finally ArcView determines the least cost route to that cell and drew it onscreen as a graphic element.

Another study related to use of GIS in route location was prepared by Sadek, Kaysi and Bedran (1998). In this study, an integrated GIS framework was developed as a decision-aid tool for a multi-criteria evaluation of route alignments. The framework integrated specialized slope stability and roadway design packages within the ArcView user friendly environment. The objective was to allow for multi-criteria analysis and evaluation of route alignments based on the integration of: topographic, geometric design, geologic and geotechnical slope stability analyses, environmental impact, and community disruption evaluation. The developed layout assessment approach worked within an integrated GIS platform. It had three basic elements: a digital model of the study area, an integrated computer-based module, and an assessment framework.

Different types of data layers were required to create a geographically referenced database or model for a given region, depending on the type of analyses and anticipated applications. The GIS model could be thought of as a geographically referenced base consisting of data layers of various types. The required layers of information relate to the application being implemented. The more the data layers, the more complete the model is; however, for developed application, the following layers were needed; Political and administrative, existing roads, existing structures, land-cover, land-use, topography, rivers/streams, geology, soil, and depth to water table.

The proposed framework provided the decision-maker with a set of evaluation criteria associated with any given route layout. The development of the integrated approach was a complex and tedious task given the numerous and varied possible assessment criteria. The computer-based approach is built using the ArcView GIS package and it integrates the AutoCIVIL specialized roadway design package. The system engine and the interface environment was ArcView. Customized ArcView menu-driven interface was specifically developed by the authors to provide a user-friendly analysis system. The user interfaces with the evaluation tool through ArcView using customized pull down menus. The system itself was a mix of PC ARCINFO and ArcView scripts in Avenue languages, CAD scripts, and LISP functions. The resulting computer-based approach could be broken down into several distinct steps. The user only needs to define the road alignment on the GIS model of the study area (by defining a series of points, interactively, using the mouse or by assigning particular coordinates). The rest of the analysis was automatically run: the developed tool would call upon and use the various platforms and customized scripts and computer codes, moving sequentially through all the steps without intervention by the user. A report characterizing the specified route alignment based on the assessment criteria is automatically generated

The assessment framework builds on the results of the analyses conducted in the step by step procedure. The final report that the engineer can use to evaluate a given alignment includes factual information resulting from the analyses. Possible alignments are evaluated based on two sets of criteria. First, traditional evaluation criteria focusing on geometric design factors and impact on man-made features are considered. Second, the developed assessment framework builds on the GIS platform to generate specific environmental and geotechnical criteria for route layout evaluation.

CHAPTER THREE

MEHTODOLOGY

Chapter Three

METHODOLOGY

3.1 Introduction

This chapter explains how decisions to select a new highway alignment are made and highlights the major elements of the process. The process for highway alignment selection is a rational one that intends, among other aims, to furnish unbiased information about the effects that the proposed highway will have on the highway environment. The traditional highway selection process is modified here to reflect using GIS in an integrated model. The process therefore comprises five basic phases, which are interrelated. The information acquired in one phase of the process will be helpful in the later phases. These phases are:

- Data Collection and Variables Identifications
- Software Selection
- Input of Existing Data
- Defining Alternatives
- The Evaluation of Alternatives and Final Selection

These phases are described and illustrated in Figure (3), and each one of these phases is explained in the following sections.

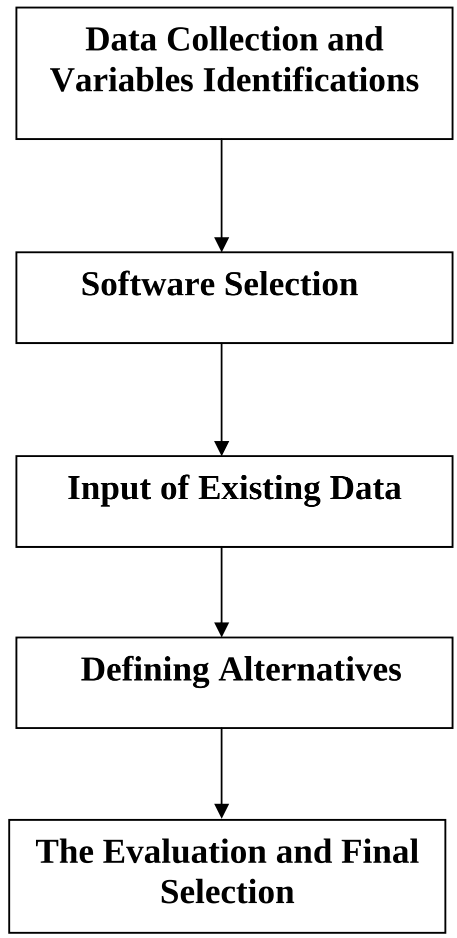


Figure (3) Phases of Highway Alignment Selection Process

3.2 Data Collection and Variables Identifications

The Data Collection stage of the study involves the assembly of all relevant information to undertake the highway alignment selection. Highway alignment selection should be built on a comprehensive body of information. This information should be prepared in digital format, as a base model for the region of interest. The data collection process is a critical and time intensive stage. At the beginning of any project, the database requirements should be set as part of the objectives. These objectives include the required data layers, the features required in each layer, the attribute data needed for each feature type, and how to code and organize these attributes. For highway construction projects, all types of data about the suggested highway alignment should be collected. This data depends on the study area characteristics and the priorities of the designer. In general, the following data categories should be collected:

1. **Topographic Data**: Usually contour maps are prepared for the study area which is very useful to avoid rough topography. Using GIS, three-dimensional model of the study area can be built. This model is very useful in selecting a primary center line of the suggested highway because the user can see the topography of the study area as it is in reality and to show the final highway in three dimensions. On the other hand, it is very important from economic point of view to estimate the earthwork; cut and fill volumes and to reduce the operational cost of the suggested highway by reducing the grades of designated highway.

2. **Environment Data**: Environmental data is necessary to specify the impacts of the suggested highway on the surrounding environment where the highway will be laid down. This data is to be divided into several classes and each class of them is to be represented in a separate layer. Collected environmental data contains the following data:

    - Agriculture Lands: Constructing new highway will result in the direct and indirect loss of agricultural lands. This loss ranges from lost income from land and crop damage to yield reductions on fields adjacent to construction. The government in this case compensates farmers for the removed lands from agricultural production.

      Therefore, it is necessary to classify these areas according to their agricultural value.

- Natural Reserves, Biodiversity areas, and Forests: Data about these lands is very important due to their environmental role and due to its recreational role as well.

- Water Resources: It is very important to collect data about water resources either ground or surface resources. These resources should be avoided by any highway project, because any serious source of pollution in the road will affect the water resources in the project area. Polluting these resources will, on one hand, destroy a main domestic water resource. On the other hand, it will destroy a major agricultural supply of water in the region. Therefore, the highway should be laid down without causing any significant harm to the exist water resources.

3. **Built-up Areas and Existing Infrastructures Data**: To avoid demolishing of built up areas and available infrastructures. Also constructing a new highway could cause residential and commercial relocations and significantly disrupts traffic during the construction. In addition, distribution built-up areas' population is necessary, in highway location, to determine the population served by it.

4. **Geopolitical Data**: Geopolitical aspects play a main role in all infrastructures development, especially in highways development. For any proposed highway project, data about all political obstacles should be collected and these obstacles should be defined and classified. These obstacles could be special regulation on the study area or it could be found on the ground such as settlements, military areas, and the Separation Wall.

5. **Data of Cultural Sites**: Collecting of this data depends on the historical importance of the study area. Historical and cultural sites must be defined for any new highway project. This is necessary to avoid demolishing these sites and affecting its touristic role as well.

3.3 Software Selection

In this study, GIS is used as the main software to build the intended model. Also Computer Assisted Drafting and Design (CADD) package is used to do some specific processes, such design the horizontal and vertical alignments, to avoid the limitations of the GIS software.

3.3.1 GIS Software

ArcView 3.2 and its extensions were selected to be the main software. It is a GIS software with the ability of capturing, storing, updating, manipulating, analyzing, and referencing the information which describes the ground surface. In addition, ArcView deals with the graphical display and analysis of spatial feature data as presented in Figure (4).

Each one of these layers has its attributes that contain the information about each feature in the layer. GIS connect the features with its attributes so it is very useful in highway alignment selection, especially in the analysis and evaluation phases. Further information about ArcView and the used extensions is available in Appendix A.

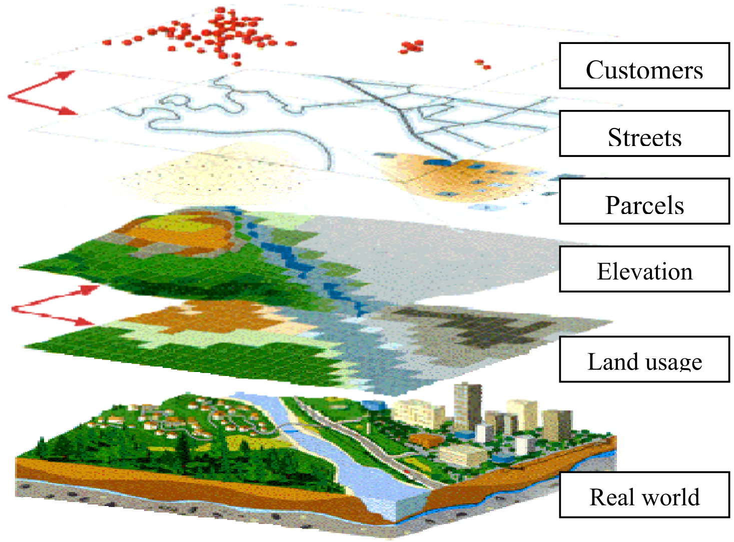


Figure (4) Layers of Different Features as Represented in ArcView

Source (Townsend, 2004)

3.3.2 CADD Software Used

The CADD software was selected to be used in this study because the GIS software is very limited in the geometric design. The geometric design is a main part of highway alignment selection. It is necessary in both the analysis and the evaluation phase.

Softdesk 8.0 Civil-Survey (SDSK) software package was selected to be the CADD software. This software is a convenient way to handle data capture, drafting, and design for a large number of projects involving surveying, land-use planning, transportation, and infrastructure design.

The main objective of using Softdesk in this study is to design the horizontal alignments and the vertical alignments. The profile for a given highway centerline can be easily produced. This profile will be useful to generate the design surface that contains the elevation points (Design points) of the final design surface of the highway. The elevation of these points will be obtained from the profile. Figure (5) shows an example of expected output from Softdesk 8.0.

3.4 GIS Model Building

The disruption of different environmental areas, such as agricultural, forest, biodiversity areas, and water resources, caused by the suggested highway should be minimized. Environmental impact studies are therefore required before the final selection of a highway alignment. In this study, the suggestion and the selection of highway alignment process is done using the GIS model. In this model, several phases are followed to generate alternatives of highway and then to select the best one of these alternatives. These phases are shown in Figure (6) and are explained in the following sections.

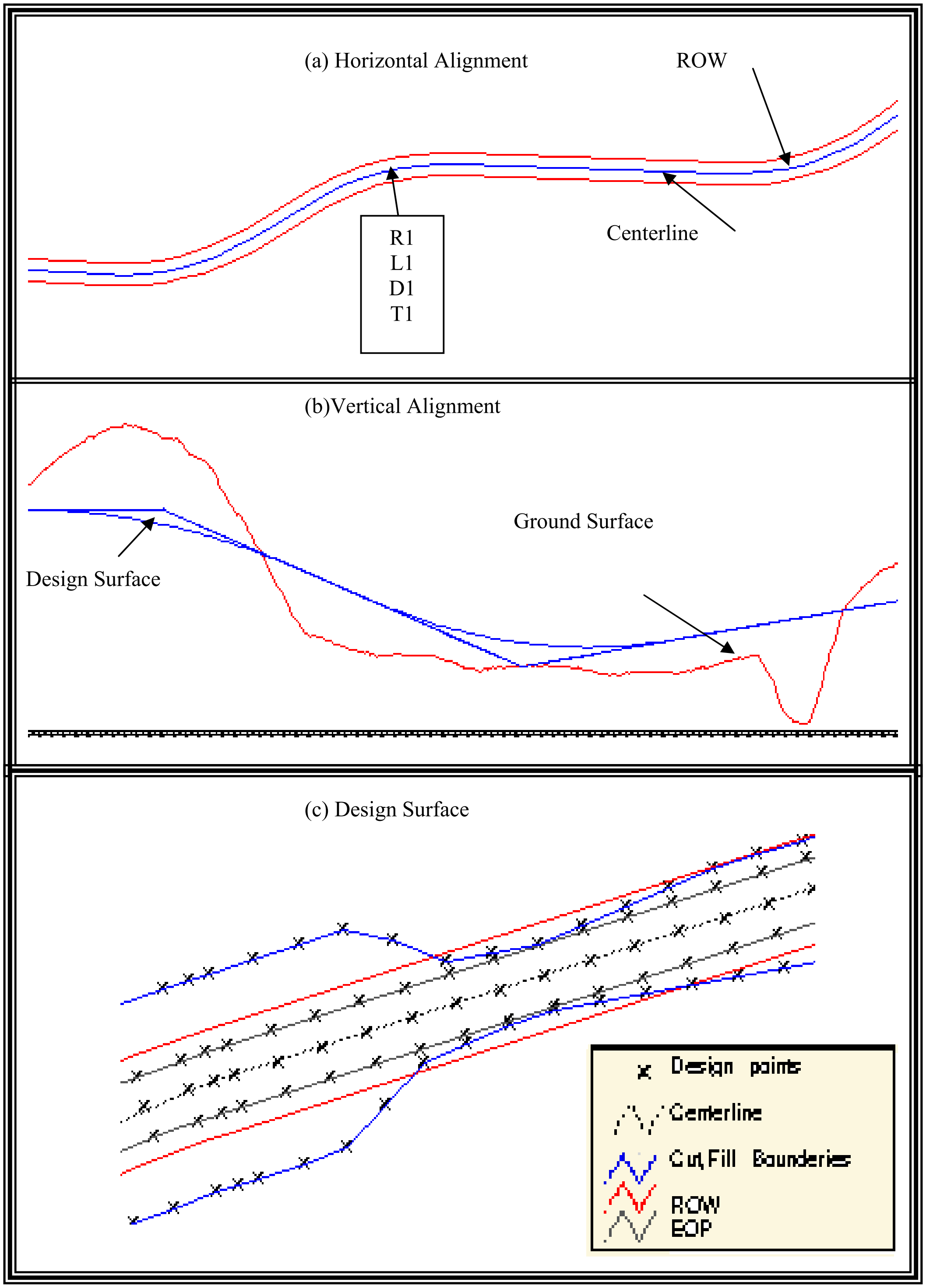


Figure (5) Sample of SDSK Output

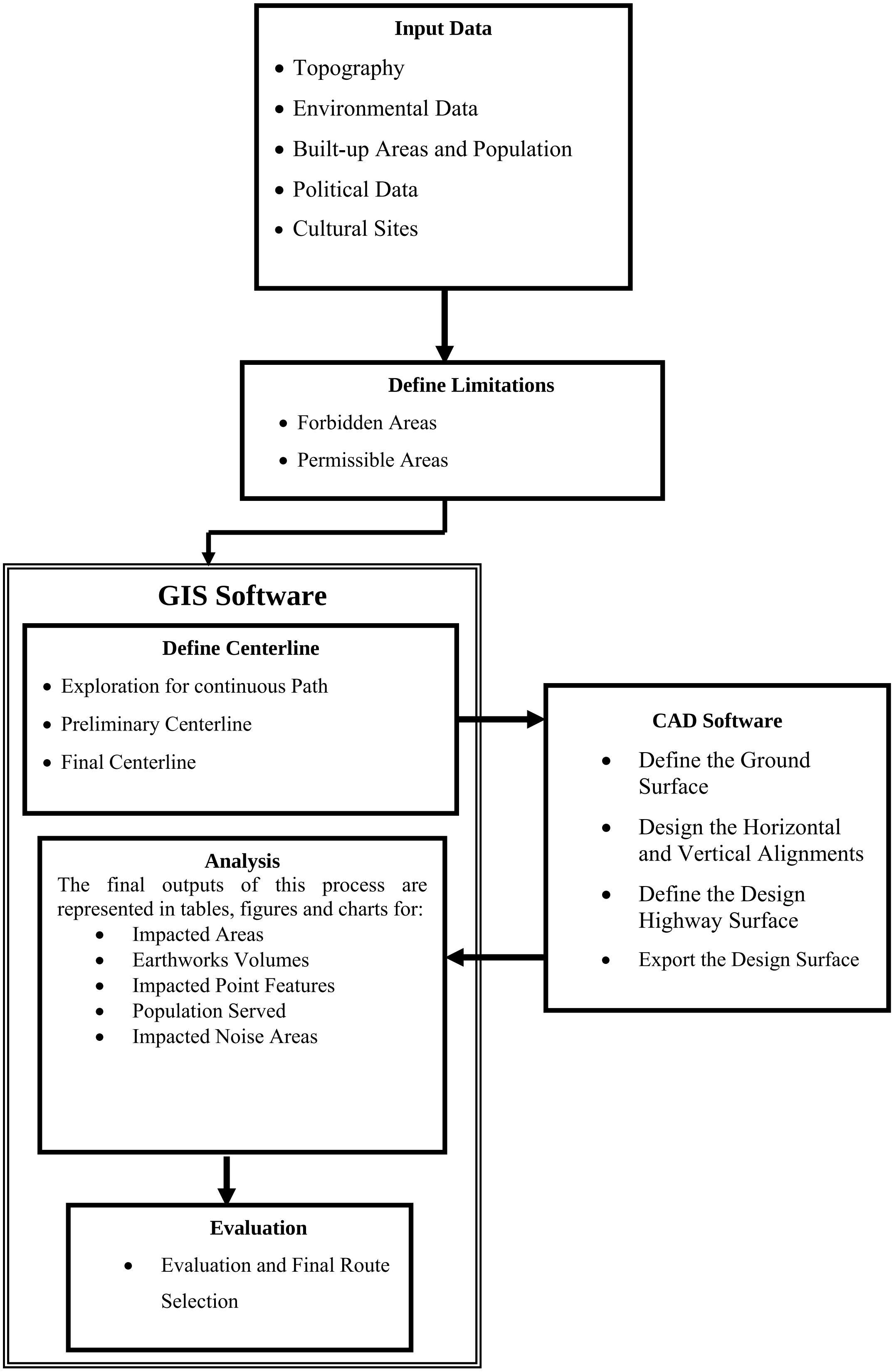


Figure (6) Flowchart of the Developed GIS Model

3.4.1 Input Data Phase

In this study, the GIS model for alignment selection is built on a comprehensive body of information. This information was prepared to be used as a base map for the study area. This data contains:

1. The study area boundaries

2. The data layers and the features of each layer.

- Environmental Data which contains:

    1. Agricultural Areas

    2. Forests

    3. Biodiversity Areas

    4. Natural Reserves

    5. Water Resources: Surface water resources, Wells and Springs

- Built up Areas and Population

- Topographic Data

- Political Areas: Settlements and Isolation Wall

- Geological Maps

- Cultural Sites

3. The attributes data needed for each feature that contain the data about each feature. These data represent the sensitivity of the features.

The developed GIS model connects the features with their related data which make the analysis and evaluation processes easier.

3.4.2 Define Alternatives Phase

The most difficult phase of any highway project is selecting its centerline. In this phase of the developed GIS model, several centerlines will be suggested depending on different limitations to be analyzed and evaluated in the next phases. These centerlines are generated through these steps:

1. **Exploration**:

In this step, exploratory trials are done to find out a continuous path, between the origin and the destination of the intended highway that avoids the predefined sensitive areas. This exploration can be done using one of two methods Red and Green Method (RGM) and Graduate Color Method (GCM):

- Red and Green Method:

In this method, the study area is divided into two types of area, Forbidden and Permissible areas. Forbidden areas are the areas where the intended highway is completely prohibited to pass through, while the Permissible areas are the areas where the highway is allowed to pass. In this method, there is no graduation neither in the prohibition nor in the permission. Therefore, all Forbidden areas have the same degree of prohibition and the Permissible areas have the same degree of permission as well. Figure (7) shows the flowchart of this method.

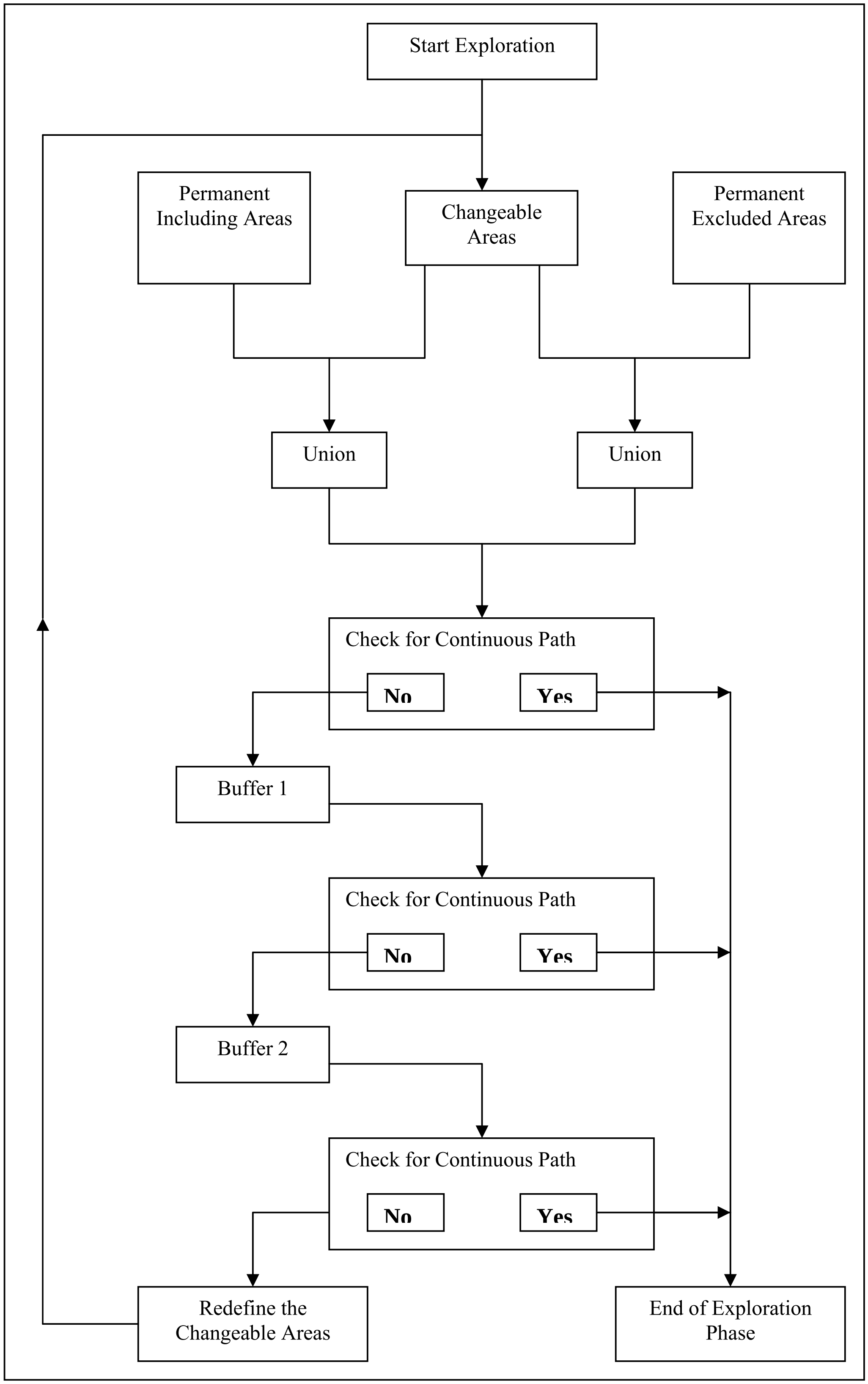
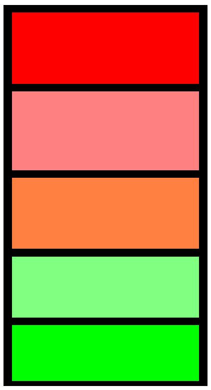


Figure (7) Flowchart of Red and Green Method

- Graduated Color Method

According to this method, the study area is divided into five different classes according to its sensitivity. The classes are colored red, orange and green to indicate the degree of restriction:



Dark Red: completely restricted areas

Light Red: restricted areas

Orange: in between area

Light Green: recommended areas

Dark Green: the strongly recommended area

The user of this method has to use his judgment to decide which path will have more advantages, trying all the way to avoid red colored areas.

In general, there are no limitations or special conditions to use one of these two methods. In this study, both methods RGM and GCM will be used to generate three highway alternatives.

2. Define Preliminary Centerline

In this step, a new line theme is added to the view that contains the continuous path, which has been generated in the previous step, to draw a line within the boundaries of the continuous path. This line represents the preliminary centerline of the suggested highway. The preliminary centerline is drawn with the help of a 3D model of the included areas and with help of PE extension as well. This assures that the sensitive areas and the steep slopes are avoided.

3. Define Final Centerline

Depending on the preliminary centerline, a new line is drawn in this step with the help of contour map of the study area; this line represents the final centerline of the highway. This centerline overlaps the preliminary centerline in most of its parts with limited modifications.

3.4.3 Design Phase

The final centerline, which has been created in the previous phase, will be imported to the Softdesk 8.0 to generate a new surface that represents the design surface of the suggested route shown in Figure(5) in the previous section. This surface will be created after the horizontal and vertical curves are designed. Horizontal alignment is straight sections of the road are connected by horizontal curves. These curves are usually segments of circles, which have radii that provide for smooth flow of traffic along the curve. The vertical alignment of a highway consists of straight sections of the highway known as grades, or tangents, connected by vertical curves. These tangents and curves are drawn on the profile of the center line. Vertical curves are used to provide a gradual change from one tangent grade to another, so that vehicles may run smoothly as they traverse the highway. The designated centerline and surface will be exported to the GIS software as dxf file.

3.4.4 Analysis Phase

In this phase, all calculations related to the new designated highway will be done such as the impaction of environment and cultural sites, earthwork calculations, population served by the designated highway and other calculations. The final outputs of this process are tables, charts and maps. The results of this phase will be the input of the next and final phase of the

GIS model; the Evaluation and Final Selection phase. Briefly, all calculations are described in the following points:

- Impacts of Environment

All areas of different agriculture, forests, biodiversity, natural reserves will be calculated and presenting in maps, charts and tables. Impacted water resources that are located within the right of way for each alternative will be determined also.

- Earthwork calculations

The design surface, generated in the CADD software, will be imported to the ArcView to calculate the cut and fill volumes. Using the 3D spatial analyst extension a Triangulated Irregular Network (TIN) will be built for the study area using the available contour map. This TIN represents the ground surface topography. Other TIN will be built for the design surface using the design points. The difference between these two surfaces represents the volumes of cut and fill.

- Population Served within Five Kilometers

Number of served people within five kilometer from the centerline of the alternate highways will be estimated. This number will be one of the most important criteria in the evaluation process

- Impacted Areas by Traffic Noise

The level of highway traffic noise depends in general on three things: (1) the volume of the traffic, (2) the speed of the traffic, and (3) the number of trucks in the flow of the traffic. In addition, traffic noise levels are reduced by distance, terrain, vegetation, and natural and manmade obstacles. In this study, the only factor of noise that was taken into the consideration was the distance between the highway and built-up areas. According to the 'Highway Traffic Analysis and Abatement Policy and Guidance' study that was prepared by US Department of Transportation, traffic noise is not usually a serious problem for people who live more than 150 meters from heavily traveled freeways or more than 30 to 60 meters from lightly traveled roads (USDOT, 1995). Therefore, the built-up areas within 150m were determined and analyzed in this study.

- Other Calculations

The number of impacted cultural sites, the length of each alternate highway, and the number of geological faults that are crossed by the alternatives will be determined.

3.4.5 Evaluation and Final Selection Phase

The evaluation process depends on the results of the analysis conducted in the step by step procedure described above.

The final selection depends on the results in the evaluation process the optimum alternative will be selected depending on a weighting system. This system is detailed in the next section.

3.5 Weighting System

The user can evaluate a given alignment using information resulted from the analyses process. The evaluation process is intended to provide the decision makers with a comparison of the impacts of each alternative in order to allow them to make an informed decision about the final selection. The alternative highway alignments are evaluated based on an Environmental Assessment (EA) that was performed between October

2000 and January 2001 for proposed Nablus-Jenin highway (Wilbur Smith Associates and Universal Group for Engineering and Consulting, 2000).

3.5.1 Environmental Assessment (EA)

This EA was performed for Nablus-Jenin proposed highway to address, in detail, the reasonably foreseeable significant effects, both beneficial and adverse, that the proposed project is expected to have on social, economic, and ecological environment. The EA is intended to provide the decision makers with a comparison of the significant environmental effects of the project in order to allow them to make an informed decision. The assessment includes decisions of efforts to avoid or minimize the adverse effects and methods to maximize the positive effects.

In this EA, an examination and ranking of the potential impacts was conducted. This ranking was based upon concerns expressed by the Ministry of Environmental affairs (MEnA) and the Ministry of Planning and International Corporation (MOPIC), and during interviews with relevant Palestinian governmental agencies and on information obtained during two public scoping meetings, interviews with important groups who did not attend the scoping meetings, and the social survey. A ranked listing, from most important to least important, of the various categories of impacts, from the public and involved government agencies, is listed in Table (1). A weighting system was developed in this EA and listed in Table (2). This system aimed to evaluate each alternative based on a combination of information listed in Table (1); in addition to information obtained by individual expert's surveys. The weighting mechanism was supported during a panel meeting of the experts who participated in the preparation of the EA.

Table (1) Important Considerations from the Public and Involved Government Agencies

<table>
<tr><th>Scoping Meetings (Sept 4 and 6, 2000) and Interviews (Sept, 2000)</th><th>Social Survey (Oct 25 - Nov 20, 2000)</th><th>MEnA From the Emergency Natural Resources Protection Plan</th><th>MOPIC From Regional Plan</th></tr>
<tr><td>Agricultural Lands</td><td>Agricultural Lands</td><td rowspan="3">Water Resources/ Water Quality/ Land Degradation</td><td>Agricultural Lands</td></tr>
<tr><td>Water Resources</td><td>Relocations</td><td>Water Resources/ Recharge Areas</td></tr>
<tr><td>Safety</td><td>Water Resources</td><td>Mineral Resources</td></tr>
<tr><td>Compensate for Property Lost</td><td>Landscape / Vistas</td><td rowspan="3">Air and Noise Pollution/ Natural Resources/ Biodiversity Areas</td><td>Ecologically Sensitive Areas / Forests</td></tr>
<tr><td>Access to Travel</td><td>Access to Travel</td><td>Significant or Exceptional Landscape</td></tr>
<tr><td>Wildlife Habitat</td><td>Biodiversity Areas</td><td>Cultural Heritage</td></tr>
<tr><td>Environmental Pollution</td><td>Mineral Resources</td><td rowspan="3">Landscape/ Vistas Archaeology Sites</td><td rowspan="3">Minimizing Air, Water, Noise, and Land Pollution</td></tr>
<tr><td>Archaeology Sites</td><td>Archaeology Sites</td></tr>
<tr><td>Future Land-Use</td><td>Forests/Open Space</td></tr>
</table>

Source: WSA and UG, 2000

In Table (2), it should be noticed that the adverse effects, such impacted agricultural areas, unavoidable cultural sites…etc, take positive number of points. On the other hand, the beneficial effects, such the number of served people by the highway, take negative number of points. Therefore, the best alternative will be the alternative collects the least number of points.

Table (2) Impact Weighting System Source

Impact Category	**Value**	**Points**
Structures Relocated	Number	25
Unavoidable Cultural Resources	Number	25
population Served within 2km	thousands	15
Water Resources Impacted	Number	10
Ecologically Significant Areas	10 dunums	9
Impacts to Forest Areas	10 dunums	9
Impacts to Exceptional Areas	10 dunums	7
Safety Issues	Relative	7
Air / Noise Pollution	Relative	5
Total Impacts to Soil Class 1	10 dunums	6
Total Impacts to Soil Class 2	10 dunums	5
Total Impacts to Soil Class 3	10 dunums	4
Total Impacts to Soil Class 4	10 dunums	3
Total Impacts to Soil Class 5	10 dunums	2
Total Impacts to Soil Class 6	10 dunums	1
Total Impacts to Soil Class 7	10 dunums	0
Total Impacts to Soil Class 8	10 dunums	0
Total Cost to Construct	$US million	3
Combined Utilities Crossed	Number	2

Source: WSA and UG, 2000

3.5.2 Modified Weighting and Ranking System

This system was modified to be used in the evaluation process of the suggested alternatives in this study as illustrated in Table (3).

The modifications and the reason behind such modifications, are discussed in the following points:

1. The agricultural areas' classes were reduced from eight to three. This is because the soil was classified in eight classes depends on American System in EA. But in this study the available lands are divided depending on MOPIC Regional Plan to three classes, High,

Moderate, and Low agricultural value (MOPIC, 1996). High agricultural value, in the modified system, correspond soil Class 1, Class 2, and Class 3, in the EA weighting system. Moderate agricultural value lands correspond Class 4, Class 5, and Class 6. Finally, Low agricultural value correspond Class 7 and Class 8. Therefore, in the modified weighting system, High value is given 15 points, Moderate value is given 6 points, and Low value is given no points.

Table (3) Modified Impact Weighting System

Impact Category	**Unit**	**Points**
High Agriculture	10 dunum	15
Moderate Agriculture	10 dunum	6
Forest Areas	10 dunum	9
Biodiversity Areas	10 dunum	9
Natural Reserves Areas	10 dunum	9
Total Areas	10 dunum	1
Water Resources	number	10
Cultural Sites	number	25
Length of Highway	km	6
Cut and Fill	Millions of m^3	10
Population served within 5 km for each side of the centerline	Thousand	6

2. In the EA for the proposed Nablus-Jenin highway, $1million of constructions' cost was given 3 points. In this study there are no constructions' cost calculations but the cost is evaluated in terms of length of the suggested highway. If the cost of 1Km is $2million, so 6 points are given for each 1km of the length of the suggested highway.

3. If \$1 million is given 3 points and the cost of $1m^3$ of cut or fill is ranged from \$3 to \$4, so one point is given for 100,000 m^3 of cut or fill

4. Total impacted areas are evaluated in this modified system and given one point, for these reasons:

    - It is necessary to distinguish between the different alternative depending on the total impacted areas especially because Low agricultural value land are given no points

    - Length of highway does not evaluate total impacted lands because it evaluates the constructional and operational costs

5. EA concluded the number of people served within two kilometers. This approach is not sufficient to give a reasonable impression about the actual people served. In this study, the population within five kilometers will be estimated, a more reasonable approach. The number of people served within five kilometers is much larger than the ones served within two kilometers. As a result, the number of

    points belonging to the served population was reduced from 15 for two kilometers to six for five kilometer to indicate the ratio between the number of kilometers and the number of points. This creates a more reasonable balance in weight between the various criteria in the modified weighting system.

CHAPTER FOUR

APPLICATION

Chapter Four

APPLICATION

4.1 Introduction

The developed GIS model is used in an application that aims to select the best alternative of three suggested highway alignments. This selected highway is supposed to connect Nablus and Jenin, the two major cities in the north of West Bank. Therefore, all data about the area between these two cites was collected and prepared to be the input of the developed model. In this chapter, all layers of the collected data were overlapped and the three alternatives were generated and designed. The impacts of each alternative were determined through the evaluated process and then evaluated before the final selection was made depending on the evaluation results.

4.2 Existing Roads Conditions

Terrain and historic use have led to the development and use of two main roads that can be traveled between Nablus and Jenin. The western road that passes through the mountainous areas in the west of the study area which is about 38.5 km. The second road is that road in the eastern part of the study areas and 39.0 km as shown in Figure (8).

In order to travel from Nablus to Jenin, one must first skirt the peak of Mount Ebal. Whether one chooses either the east route or the west route, the next obstacle is the Marj Sanoor. This closed drainage basin is impassable during the heavy rainy season. During wet years, it may accumulate and hold water through late summer.

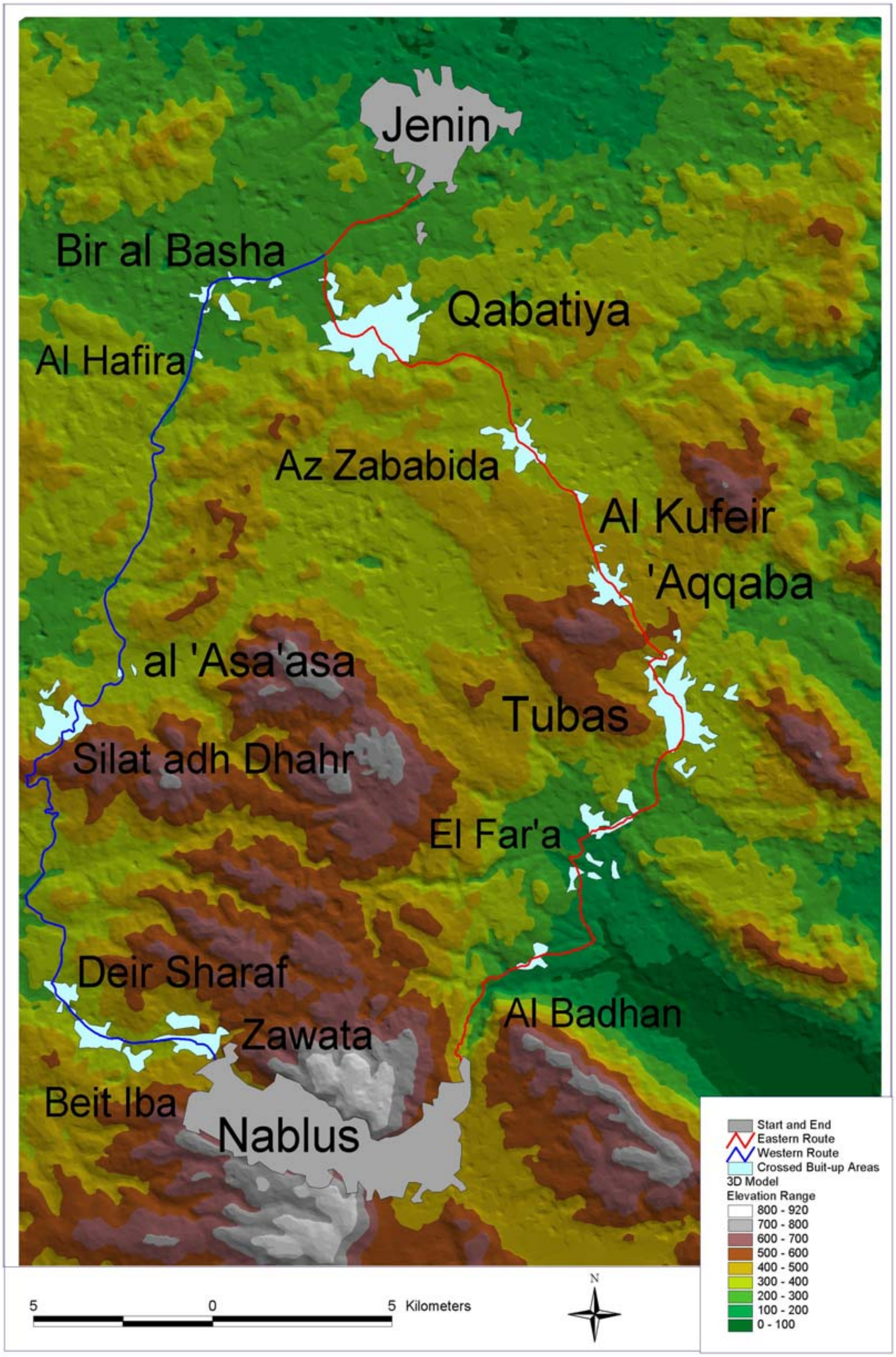


Figure (8) Existing Roads Connecting Nablus and Jenin

On the other hand, these two routes have many geometric deficiencies so that the majority of both roads lack basic safety features. The poor conditions of existing roads contributes to increased travel times, increased vehicle maintenance costs, increased congestion, and increased pollution emissions from vehicles.

Some of these deficiencies are listed in the following points:

1. The current road is paved with asphalt surface approximately six meters in width that was overlaid on the original packed earth trails. The widest areas occur on curves in mountainous terrain.

2. There was limited cut and fill to improve horizontal or vertical sight distances or minimize grades. The grades and horizontal curvature followed natural terrain and in some areas, sight distance is not sufficient.

3. Intersections with other roads occur at whatever angle without any effort to make a safe right angle intersection.

4.3 Data Collection

Most of collected data was obtained from national agencies or institutions in two ways: direct from the agencies either in softcopy or in hardcopy, or obtaining data from the agencies websites. The data was obtained in two forms: maps and tables.

1. **Maps**: these maps covered the different parts of the study area, which were represented in GIS shape file (layers). Layers data were overlaid in high accuracy because they had the same scale and

projection. These layers were classified according to their features into three types of layers:

- Polygon Layers: contain polygon features such different areas of agriculture, biodiversity, forest … etc.
- Line Layers: these layers contain the line feature such roads and geologic faults.
- Point Layers: contain the point features such the cultural sites, springs, wells…..etc.

2. **Tables**: data about each layer was contained in tables. These tables were either attached with related layer, such the attributes of agricultural, biodiversity, wells, spring….etc, or obtained separately without being attached with other layers such population of Palestinian built-up areas.

All collected data are detailed in the following sections.

4.3.1. Topography

The topography of the study area can be divided into three parts: The eastern slopes, mountain crests, and western slopes. The eastern slopes are located between the Jordan Valley, which is located between Jordan River in the east of the study area, and the mountains. They are characterized by steep slopes, which contribute to forming young wadi such wadi El Badan. Mountain crests form the watershed line and separate the eastern and western slopes. Elevation ranges on average between 750 and 800 meters above sea level. Western slopes are located in the western part of the study area. They are characterized by gentle slopes. A contour map with 10m interval was obtained in GIS shape file format from Palestinian Geographic Information Center (PIGC). This map covers all parts of the West Bank as shown in Figure (1) in Appendix B.

4.3.2 Agricultural Lands

Data about agricultural lands was obtained in one layer from MOPIC. In this layer, the study area was classified into three classes according to the MOPIC Regional Plan depending on their agricultural value as shown in Figure (9). These classes are:

- **High value class**

  These lands should be protected from all development other than agriculture as much as possible. Theses lands represent 33.2% of all agriculture lands in the study area, most of them are concentrated in the eastern part of the study area.

- **Moderate value**

  Theses lands contribute 32.5% of all agriculture lands. These lands can be used for other developments besides the agriculture.

- **Low value**

  These lands have very low agricultural value and present 34.3% of agricultural lands. Most of these lands are concentrated in the eastern part of the study area.

4.3.3 Natural Reserves, Forests and Biodiversity Areas

Currently, nine nature reserves in the study area that occupy a total area of approximately 53.6km^2 which is about 5.4% of study area. In addition, there are ten forests in the study area, with a total area of about 4.1 km^2,which is not more than 0.4% of total study area.

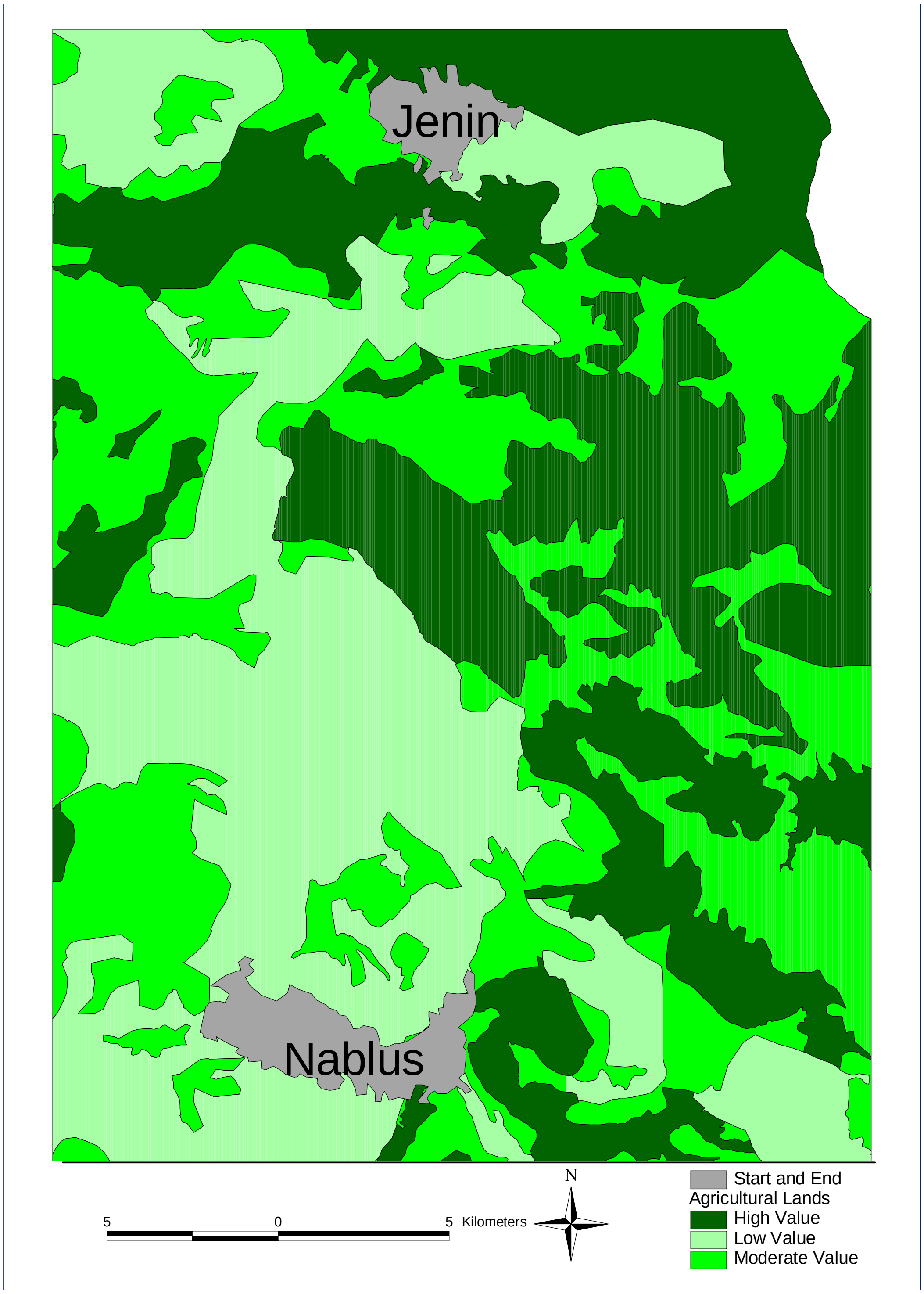


Figure (9) Study Area Divided According to its Agricultural Value

Biodiversity areas occupy a total area of approximately 47.2 km^2 which contribute about 4.7% of all study area. Each one of these areas was obtained in different layer from MOPIC as shown in Figure (10).

4.3.4 Palestinian Built-up Areas and Population

There are 86 Palestinian built-up areas in the study area with projected population of 365,140 people in 2005 (PCBS, 1999). Table (1) in Appendix B summarizes the projected populations in the study area. These built-up areas occupy about 84 k m^2 that represents about 8.4% of the study area as shown in Figure (11).

4.3.5 Water Resources

Data about several water resources in the study area was collected. These data was collected in two layer types; point layer and polygon layer as shown in Figure (12) and detailed bellow:

- **Point Layers (Springs and Wells)**

  In the study area, there are about 44 springs and seeps and 13 wells. People of the study area utilize these springs and wells for different purposes such as domestic agricultural and recreation. These data was obtained in two separated layers from Palestinian Geographic Information Center as point layers.

- **Polygon Layer (Marj Sanoor)**

  Marj Sanoor is a closed drainage basin that occupies about 17.1 km^2 and exists approximately in the middle of the study area. During wet years, it may accumulate and hold water through late summer that gives it a high agricultural value. This polygon layer was obtained from MOPIC.

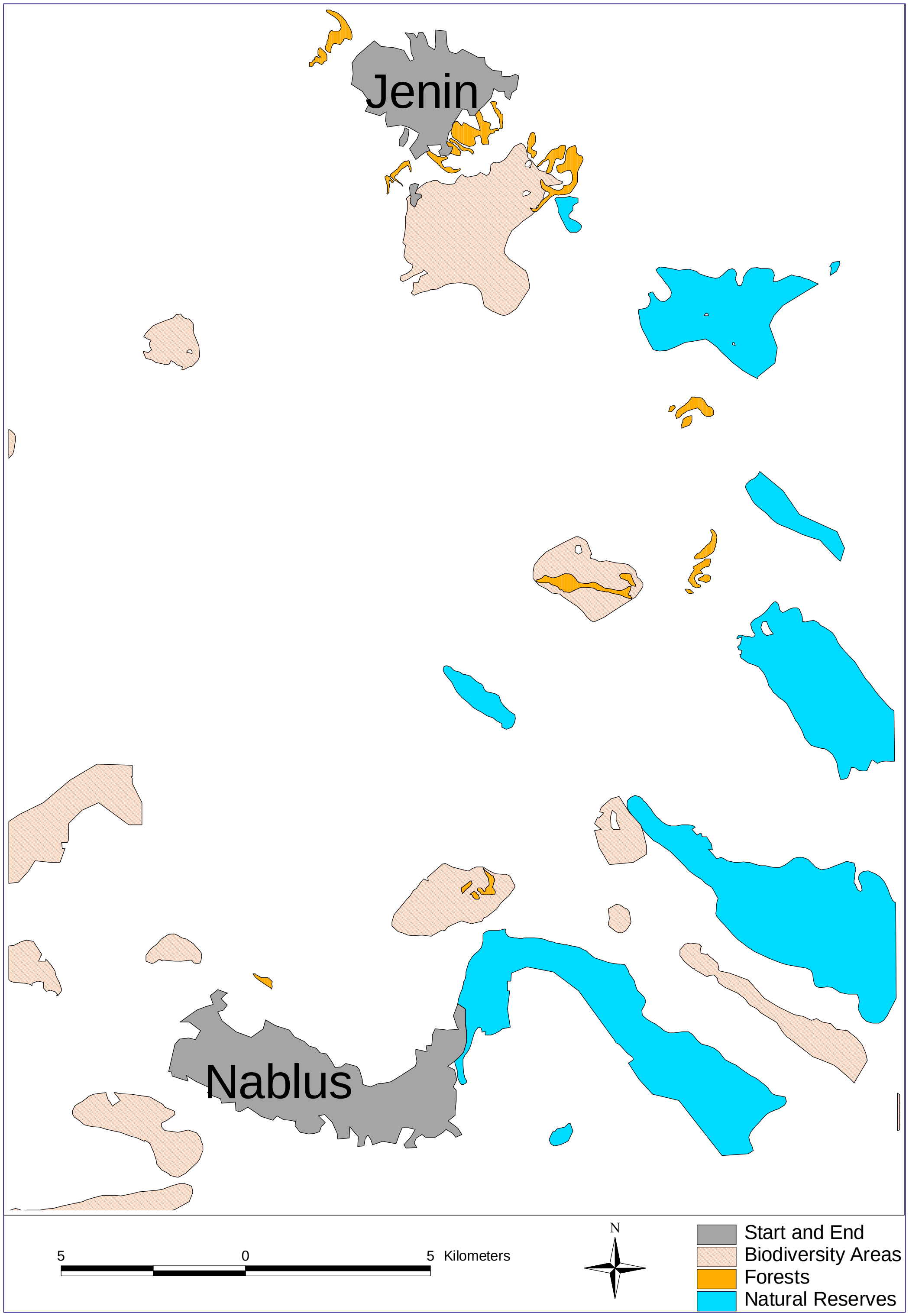


Figure (10) Existing Biodiversity Areas, Forests, and Natural Reserves

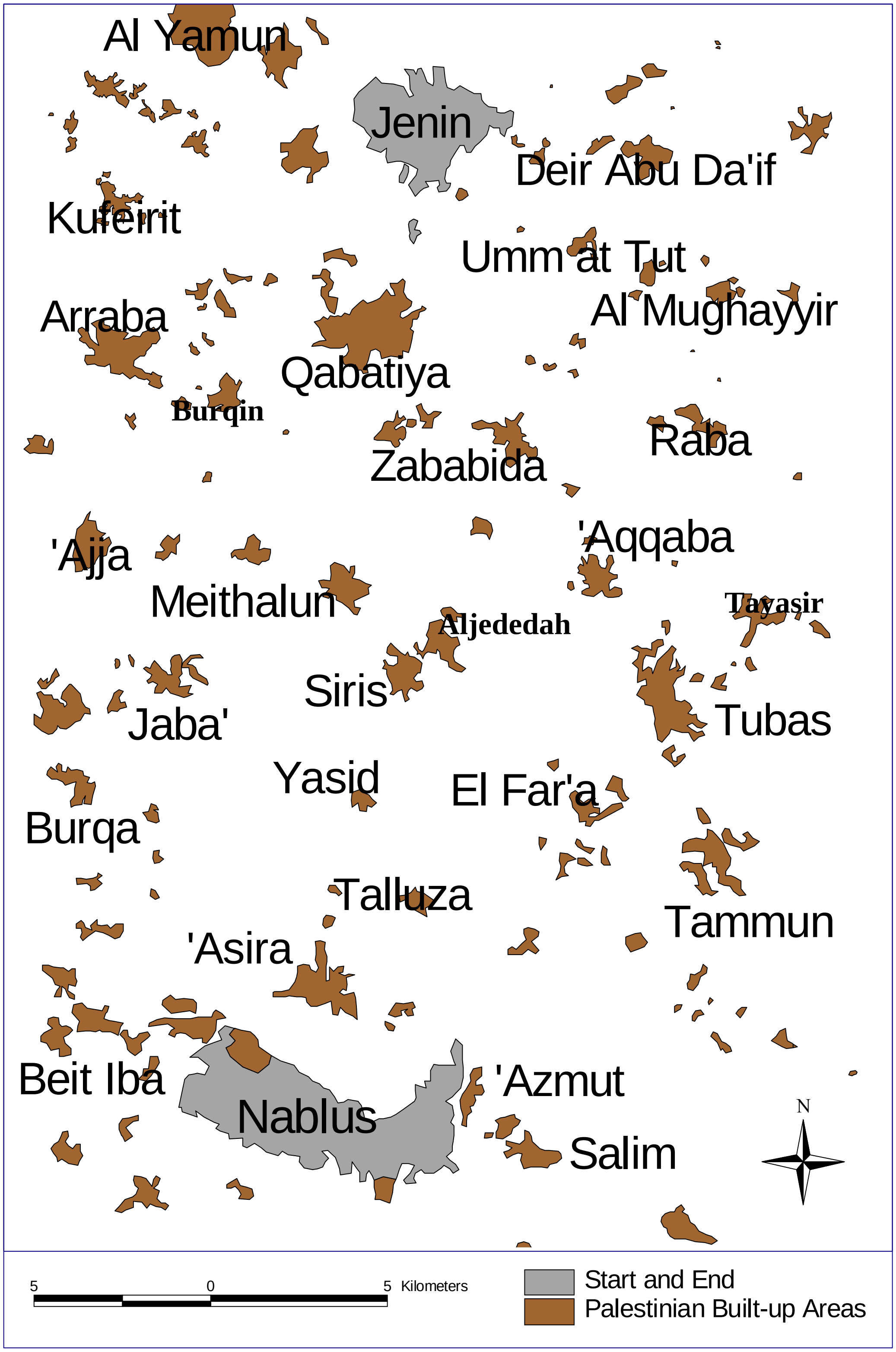


Figure (11) Palestinian Built-up Areas in the Study Areas

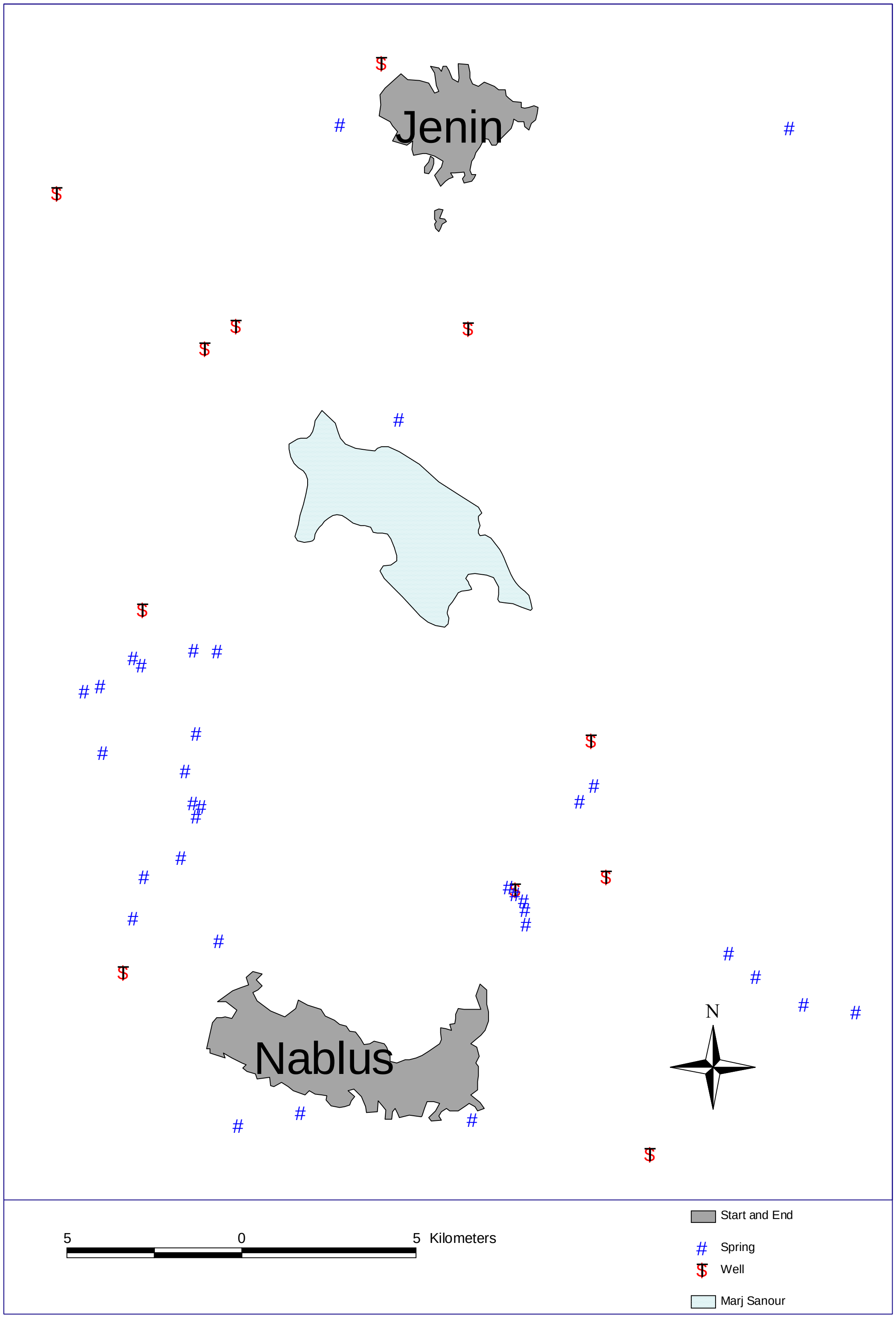


Figure (12) Existing Water Resources in the Study Area

4.3.6 Israeli Settlements and Separation Wall

There are 15 Israeli settlements and military sites in the study area. These settlements occupy approximately 7.8 km^2. While, the Separation Wall isolates about 75 km^2 in its two parts; the western built part 3.4km^2 and the eastern planned part 68.4km^2. Data about Israeli settlements was obtained from MOPIC and about Separation Wall from PGIC as polygon layers as shown in Figure (13).

4.3.7 Existing Roads

The major north-south road is located in the study area. From Nablus the road leads to the northern part of West Bank to connect Nablus city with Jenin City. This road goes through western part of the study area. There is another road connects two cities that passes through Tubas and Qabatya towns in the eastern part of the study area. Data of existing roads was obtained as line layer from MOPIC as shown in Figure (14).

4.3.8 Cultural Sites

The study area of this application exists in the northern district of Palestine that played a considerable role throughout the whole history of the country. More than 450 cultural sites are available in the study area. This large number is justified because this area is one of the most famous and richest zones in Palestine. The cultural sites layer is obtained from MOPIC as point layer as shown in Figure (15).

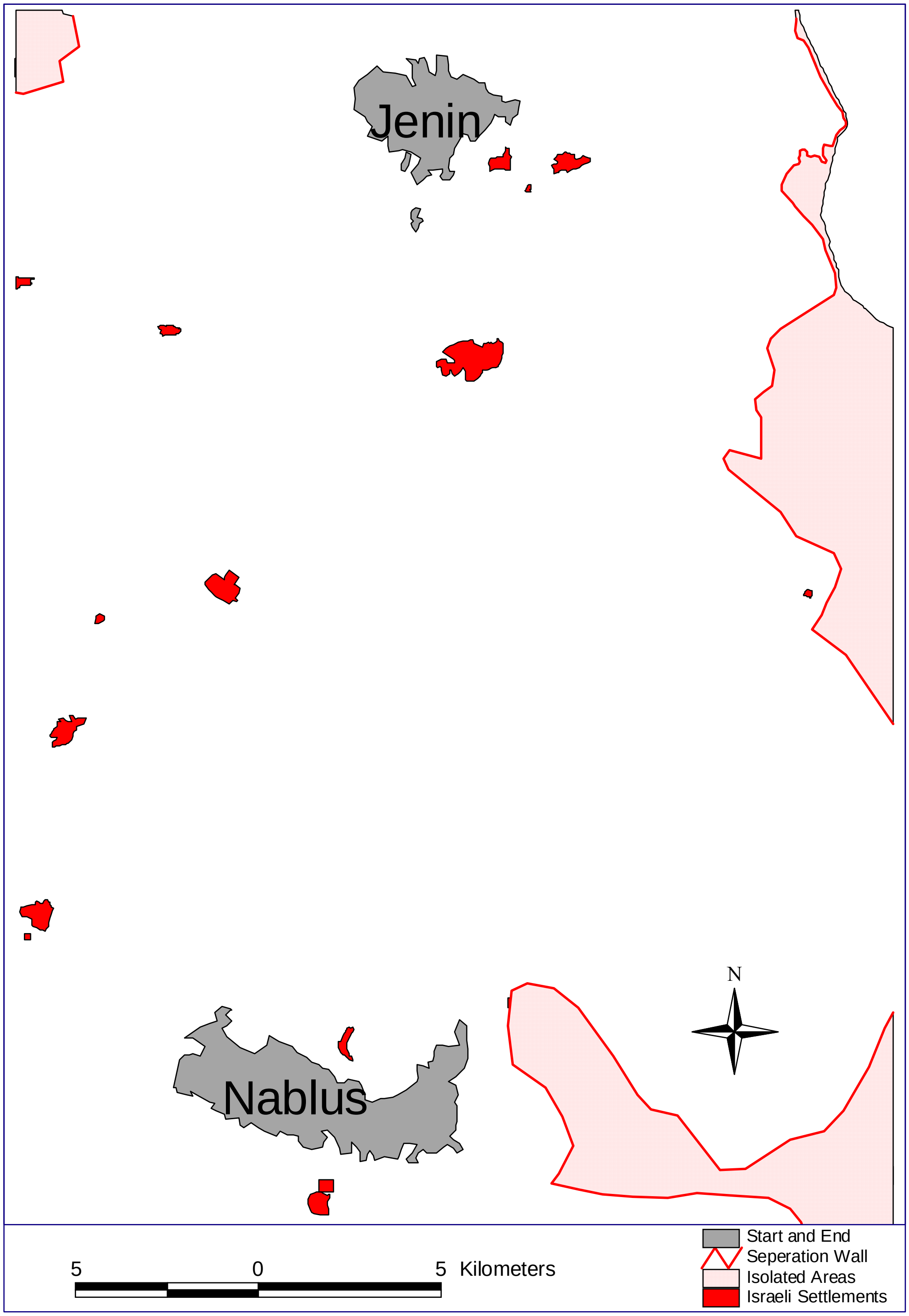


Figure (13) Israeli Settlements, Separation Wall, and Isolated Areas

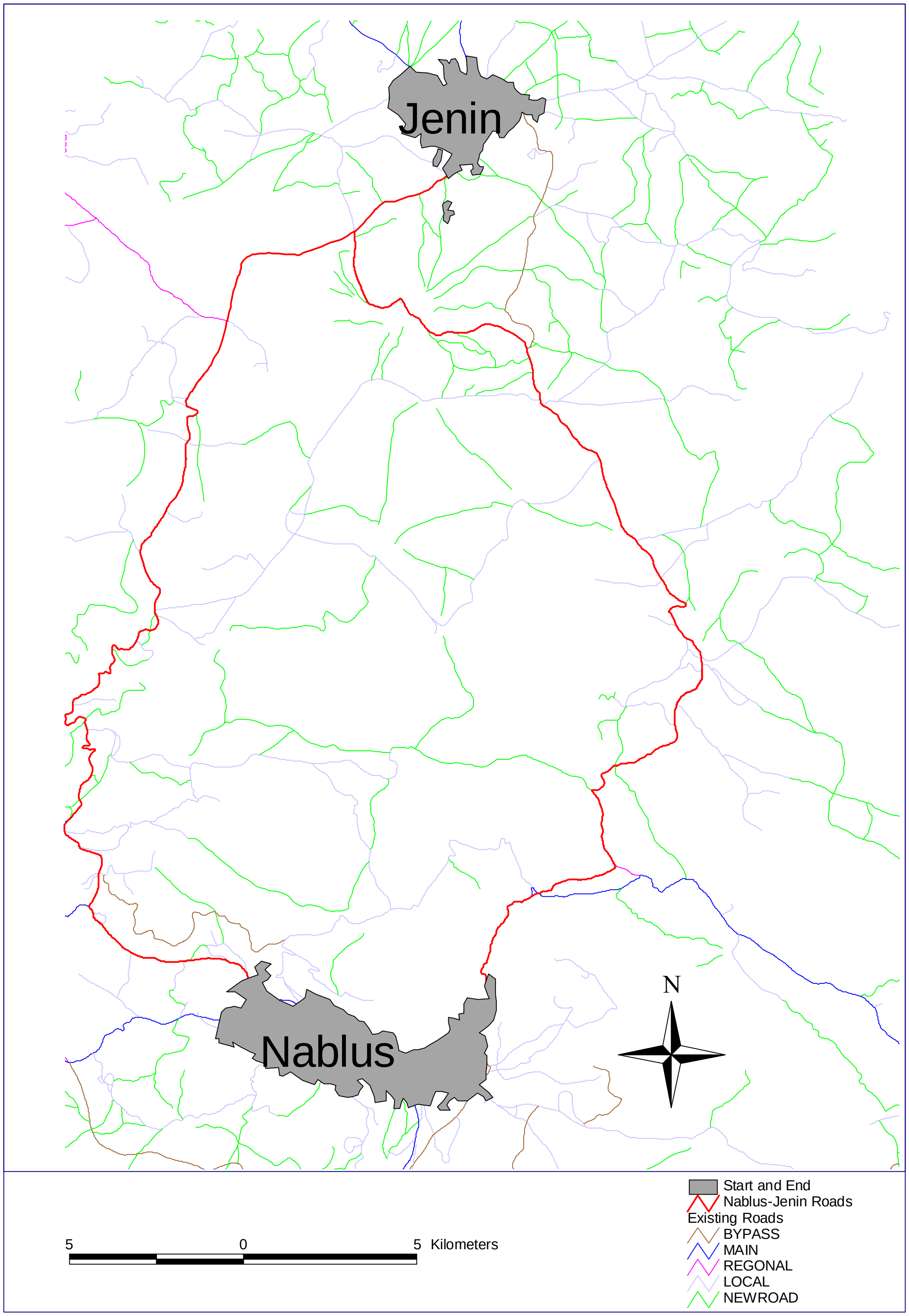


Figure (14) the Existing Road Network

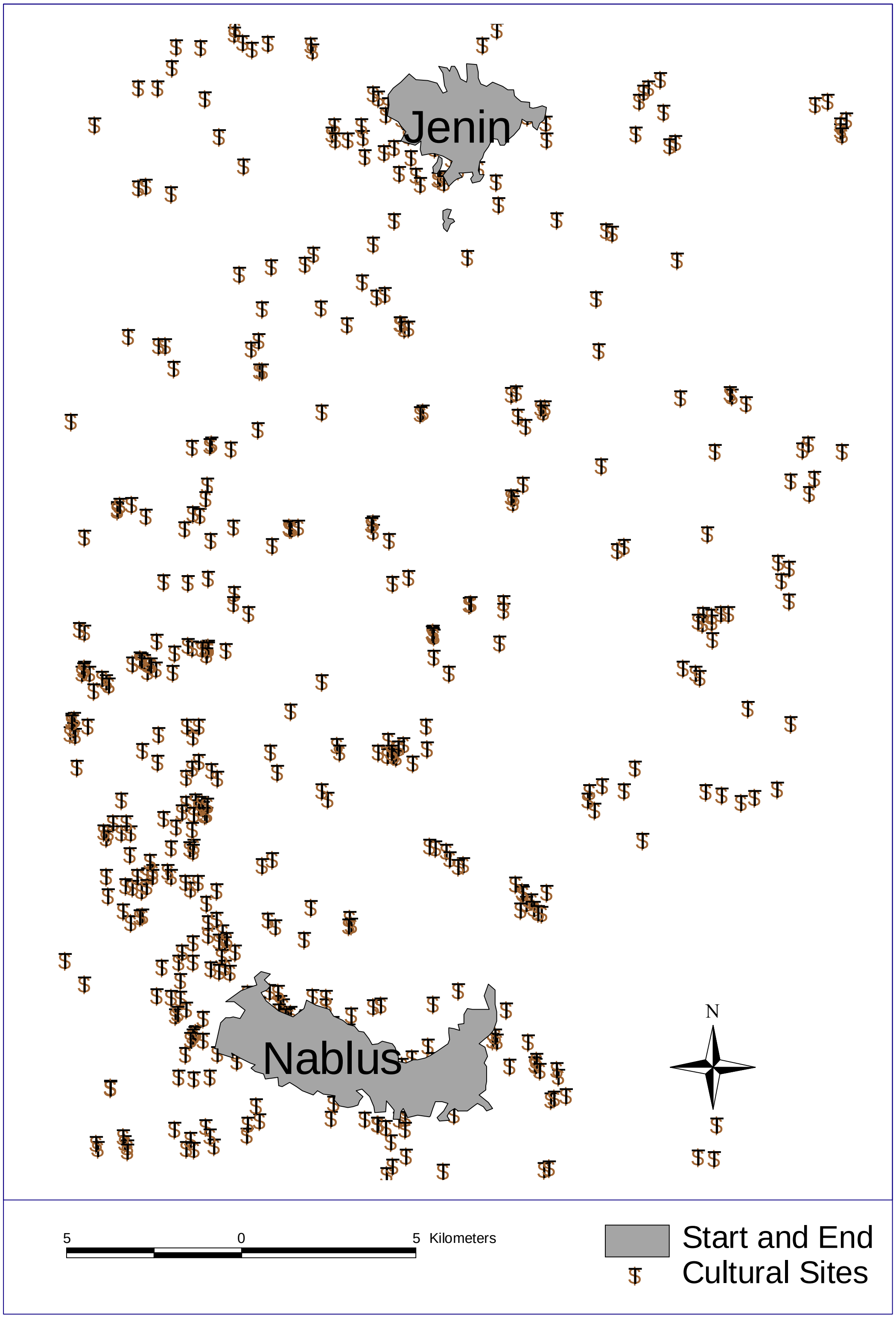


Figure (15) Existing Cultural Sites in the Study Area

4.3.9 Geology

The rocks in the study area mainly consist of carbonates that include other sediments as chert, clay, gravel and some sandstone (ARIJ, 1996). In the study area, there is a complex fault system. Most of these faults trend northwest to southwest and the majority of them are close to the vertical. The collected data related to the fault in the study area was obtained in line theme layer as shown in Figure (16) from West Bank profile (ARIJ, 1996).

4.4 Data Preparation Phase

Several processes were made on the collected data to prepare it to be input the GIS model.

1. Removing Overlap

There was an overlap between different layers of land use because each layer had been prepared separately. Therefore, any two layers will overlap in area equal the small one of them. This overlap will create a problem when impacted areas will be calculated and evaluated in the Analysis phase and the Evaluation phase respectively. That is because the impacted overlapped areas will be calculated twice.

For example, if there is an overlap between agricultural land and forest area, the impacted area will be calculated, in the Analysis Phase, as agricultural area, and the same area will be calculated as forest area. In addition, the same area will be evaluated twice in the Evaluation Process. This problem is simplified as shown Figure (17). In this figure if Layer A is put over Layer B, Layer A will completely hide B as shown in Result (A+B). While if Layer C is added to Layer D, the result will be as in Result (C+D).

Figure (16) Geologic Faults in the Study Area

This problem was solved through these sequential steps:

Step 1:

Removing the overlap between agricultural areas layer and other layers (Natural Reserves, Forest, Biodiversity, Settlement…etc) by subtracting each layer from agriculture layer.

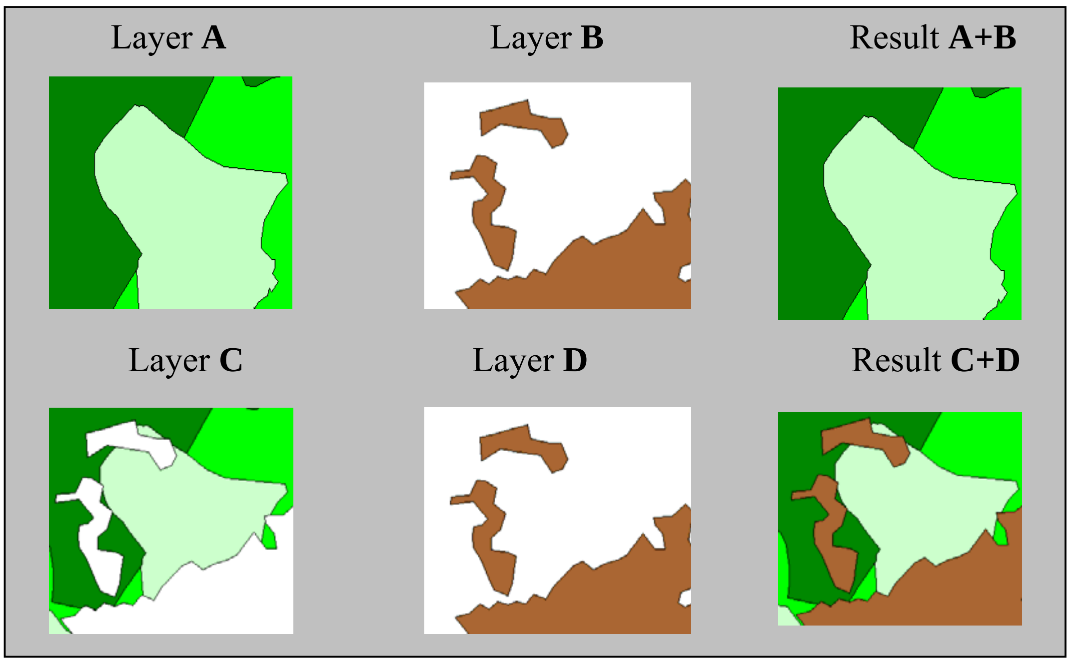


Figure (17) Simplification of Overlapping Problem

Step 2:

Subtracting all layers, that overlap the Natural Reserves layer, from this layer.

Step 3:

Subtracting all layers, that overlap the Biodiversity layer, from this layer.

Step 4:

Subtracting all layers, that overlap the Forest layer, from this layer.

Step 5:

Subtracting all layers, that overlap Marj Sanoor layer, from this layer.

Step 6:

Subtracting all layers, that overlap the Palestinian Built up Areas layer, from this layer.

The result of these sequential steps is shown in Figure (18).

2. Creating Buffer Zones

This process aims to create buffer zones around four types of features in the study area. These features and their buffer are listed in Table (4).

For political reasons, 300m buffer zones around settlement and Isolation Wall were made. These features lies in districts classified, according to Oslo agreement, as C areas which is completely controlled by Israeli Occupation Authorities. In this area, ROW is 240m according to the data

Table (4): Buffer Zone around Some Restricted Features

Feature Name	Feature Type	Buffer in (m)
Israeli Settlement	Polygon	300
Separation Wall	Line	300
Spring	Point	100
Well	Point	100
Cultural Site	Point	100

That was collected from Palestinian Ministry of Public Works and Housing, and 60m due to the ignorance of the administrative boundaries of these features. Buffer zones around other features that are point features, were selected to be 100m to protect them of being within the ROW for the proposed highway.

3. Contour Map Preparation

The obtained contour map covers all areas of West Bank and Gaza Strip. The contour lines for the study area was extracted by creating a 3D model, using ArcView 3D Analyst, for West bank and then added the study area boundaries to this model to extract a 3D model for the study area. This model was themed using legend editor with 100m interval as shown in Figure (19). Therefore, contour map with ten meter interval was extracted for the study area from the TIN, which had been generated in the previous step.

4. Permanent Forbidden and Permissible Areas Division

In this Application, study area is divided into Forbidden areas, where the suggested highway is prohibited to pass through, and Permissible areas, where it is allow to pass through. Permanent Forbidden Areas are the areas where the suggested highway is completely prohibited to pass through in all cases and under any condition. These areas are:

a. Palestinian built-up areas

b. Israeli settlements and their 300m buffer zones

c. Isolated areas by the Separation Wall and its 300m buffer zone

d. Surface water features: Marj Sanoor

e. Point features and their 100m buffer zone

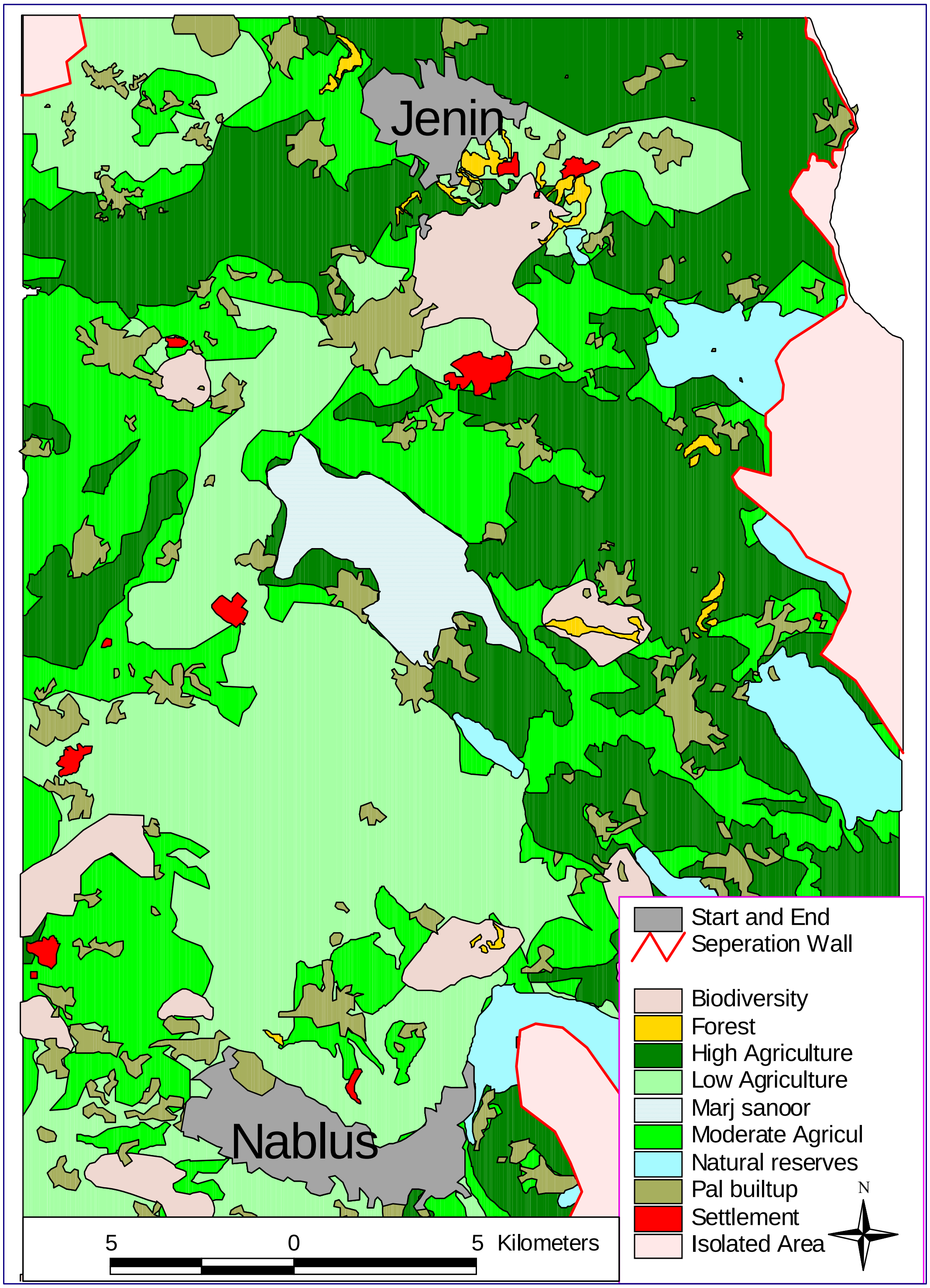


Figure (18) Final Layers of the Study Area Features

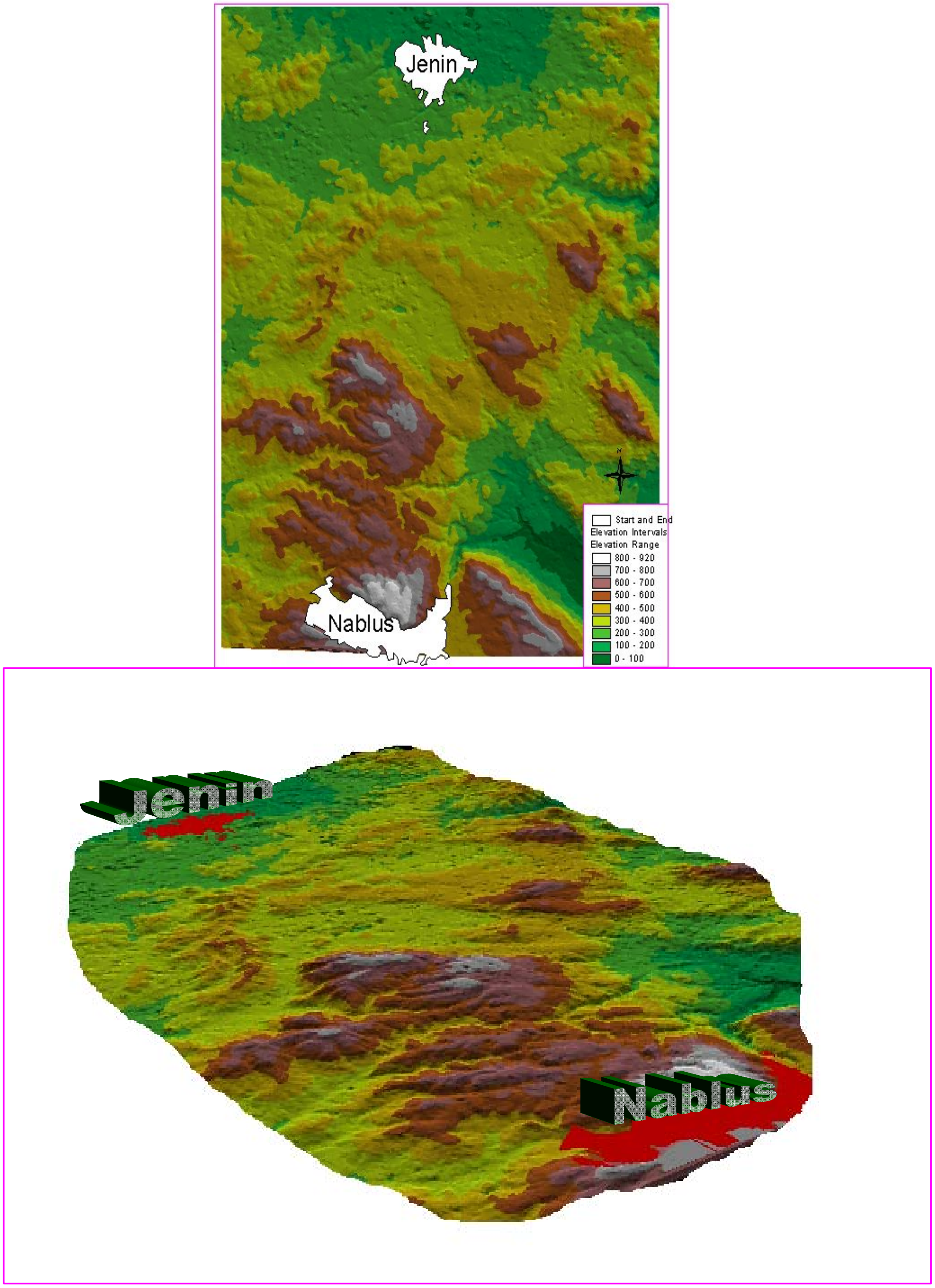


Figure (19) 3D Model of Study Area

On the other hand, the Permanent Permissible Areas are the areas where the suggested highway is completely allowed to pass through in all cases and under any condition. These areas are listed below:

a. Low Agricultural Value

b. Moderate Agriculture Value

4.5 Alternatives Generation Phase

This phase is the most difficult and important phase in the application. All limitations and restrictions will be taken into consideration to generate several alternatives of highway, one of them will be the best suggested highway. This phase consists three steps; Exploration for Continuous Path, Preliminary Centerline Selection, and Final Centerline Selection. These steps are discussed in the following sections.

Before further identifications of the possible alternatives, it has to be stated that the option related to the existing roads, Western or Eastern road, was investigated and found to be uneconomical and unreasonable for the following reasons:

- They pass through rough topography with steep slopes in both west and east parts, so it is very difficult to modify them to meet the highway standards in neither sight distance nor design speed.

- It is very difficult for these roads to be modified to have standard cross section because they pass through many built-up areas that could obstacle widening the new highway, and cause traffic congestion and safety problems.

- Improving the existing roads might significantly harm the economic conditions in the region by displacing businesses and residences. This is because the built-up areas utilize a linear development pattern adjacent to the road system and so relocation of many businesses and residences would be necessary to widen the roadway. In addition, many structures must be demolished, which is unacceptable from neither economical nor social aspects.

4.5.1 Exploration for Continuous Path

Exploration is the first step of looking for the intended route. Three alternatives were generated for this application. Two of these alternatives were generated using Red and Green Method (RGM), while the other using Graduate Color Method (GCM).

1. Generating Alternatives One and Two Using RGM

Alternative One and Alternative Two were developed in the eastern part of the study area using RGM. These two alternatives were generated through several trials of modifying the restrictions on the suggested route. The main objective of these trials is to exctract a continuous path of permissible areas between the start and the end of the suggested road.

Trial 1

In this trial the restrictions on the suggested center line are maximized. In addition to the permanent Forbidden areas, these areas were Forbidden:

- High Agriculture Value Areas
- Biodiversity, Forest, and Natural Reserves areas
- Areas of ground slopes more than 10%; here it must be noticed that (10%) is the maximum allowable slope of the ground where the

intended highway will be aligned and it is not the finish design surface of the highway. Cut and/or fill will reduce this slope to match the standard highway grades.

- Buffer zones of Wells, Springs, and Cultural sites

The remaining areas are Permissible areas, which they are either permanent Permissible or areas of slope less than 10%.

Step 1

Study area was divided according to the restrictions above. The resulted area is shown in Figure (20) the Permissible areas are not continuous in the eastern part of the study area and in the northern part. So the study, in this trial, will concentrate on the selected area. This area is surrounded by selected boundaries as shown in the same figure.

Step 2

Using Spatial Analyst Extension, the areas with slope more than 10% were extracted from the selected area in step1 as shown in Figure (21).

Results

It is noticed in Figure (21) that there are considerable gaps between the start and end (Nablus and Jenin) of the road and the permissible areas. In addition, there is no continuity among the including area parts. So no alternative has been generated in this trial and it must be modified.

Trial 2

This trial aims to reduce the gaps among the Permissible areas in trial1 and to generate a continuous path between start and end of the suggested road through these steps. The restriction on the Permissible and Forbidden areas were modified by converting Biodiversity, Forests, and Natural reserves from Forbidden to Permissible areas as shown in Figure (22). As shown in this figure there is a good but not full continuty between Nablus in the south and Jenin in the north through the western part of the study area. This continuty is borderd by blue line in the same figure.

Step 2

In this step, areas with slope more than 10% were extracted from selected area as shown in Figure (23). Spaces among parts of Permissible areas are still available. These spaces are the result of rough topography in the selected areas that contains slopes steeper than 10%.

Step 3

Here is a trial of connecting between parts of Permissible areas by craeting (50m) buffer zones around each part of these areas as shown in Figure(24).

Results

The spaces are reduced but continuous path cannot be obtained yet. As shown in Figure (24) there are several seperation between Permissible areas inside the blue square. Therefore, major modifications must be done to avoid the steep slopes in the western part of the study area.

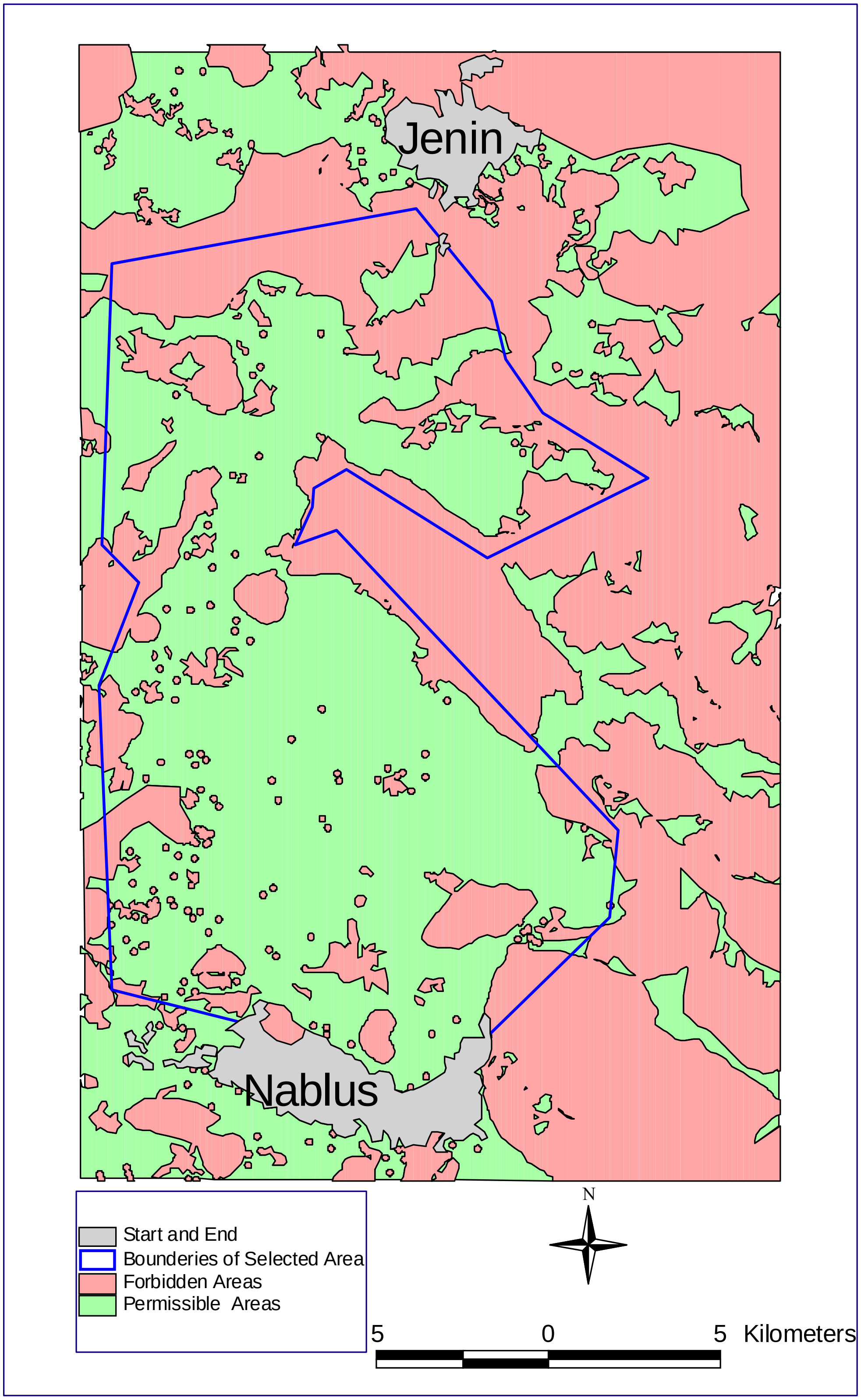


Figure (20) Forbidden and Permissible Areas for Trial1

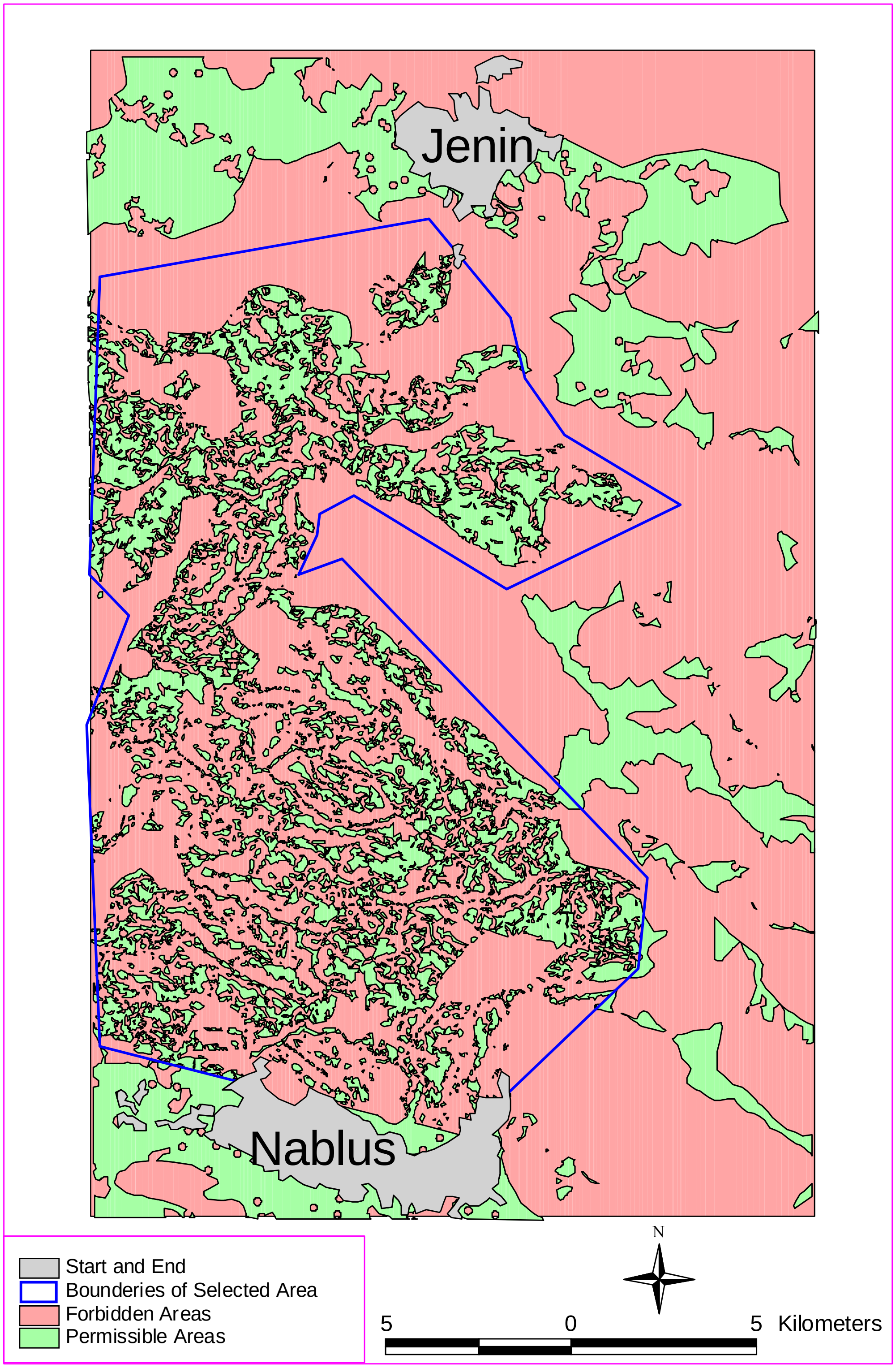


Figure (21) Final Forbidden and Permissible Areas for Trial 1

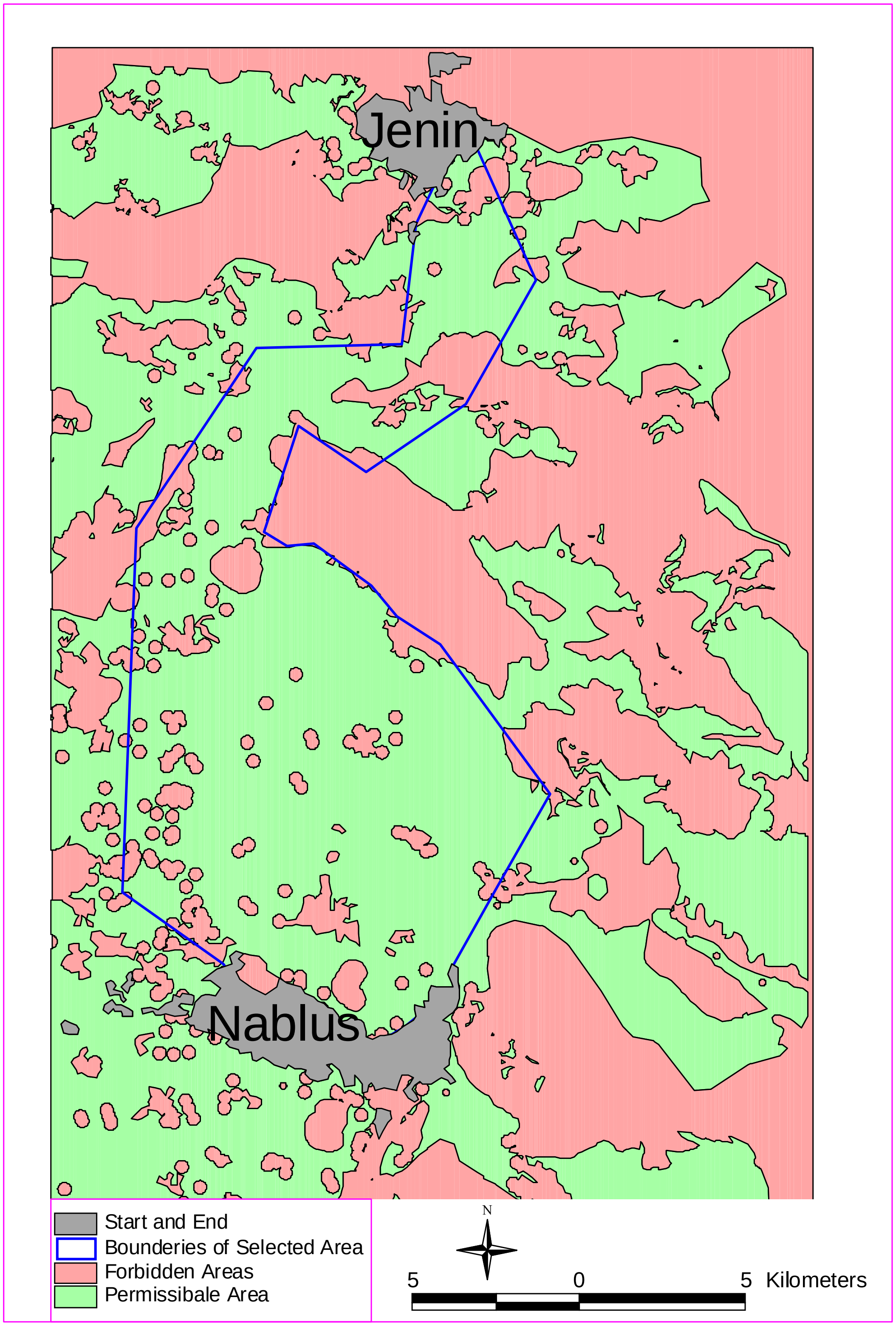


Figure (22) Forbidden and Permissible Areas for Trial 2

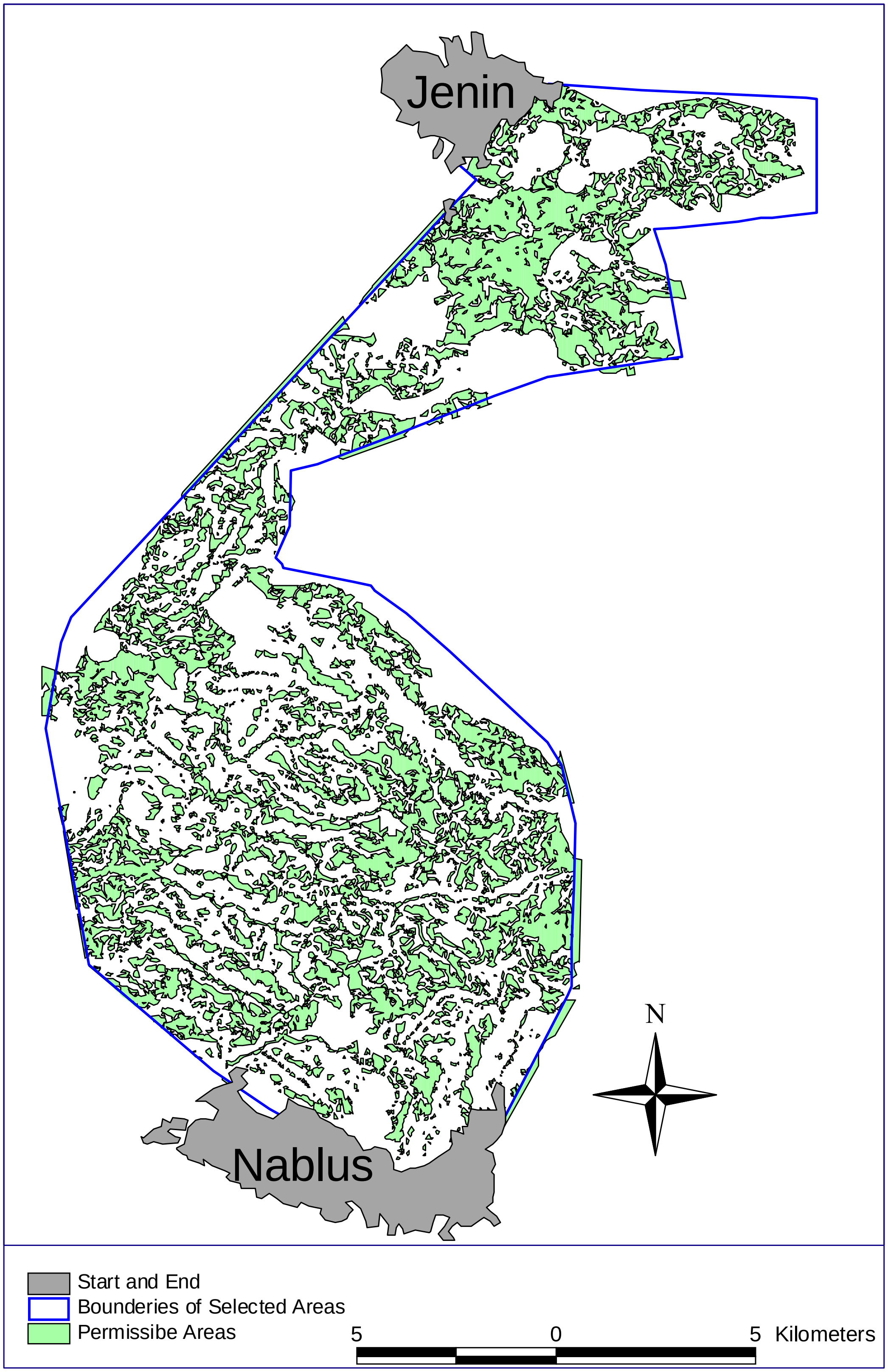


Figure (23) Net Selected Area in Trial 2

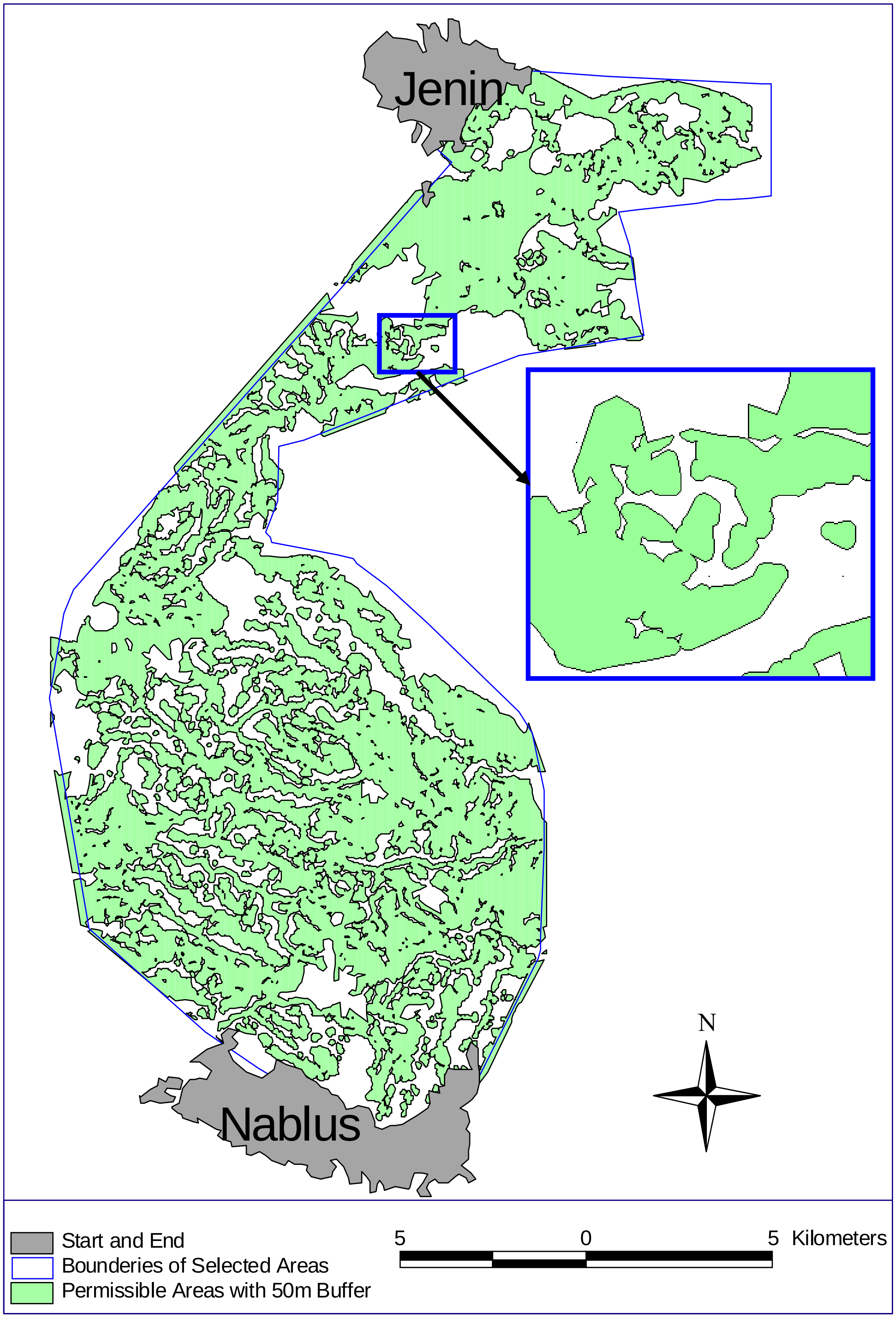


Figure (24) Selected Permissible Areas with 50m Buffer in Trial 2

To avoid the rough topography of the western parts of the study area, the study was steered towards the eastern parts that have almost gentle slopes. High agricultural value lands, in this trial, were considered as Permissible areas. The new conditions of this trial are listed bellow:

1. Forbidden Areas:
    - Permanent Forbidden Areas
    - Areas with slopes more than 15%
2. Permissible Areas:
    - Permanent Permissible Areas
    - High agricultural value lands
    - Biodiversity, Forests, and Natural Reserves
    - Areas with slopes less than 15%

The same steps were followed to generate new alternatives in the selected area shown in Figure (25). Two continuous paths were extracted in this trial as shown in Figure (26).

2. Generating Alternative Three Using GCM

Alternative Three was developed in the middle part of the study area using GCM. In this method, a continuous strip was generated through three steps as explained bellow:

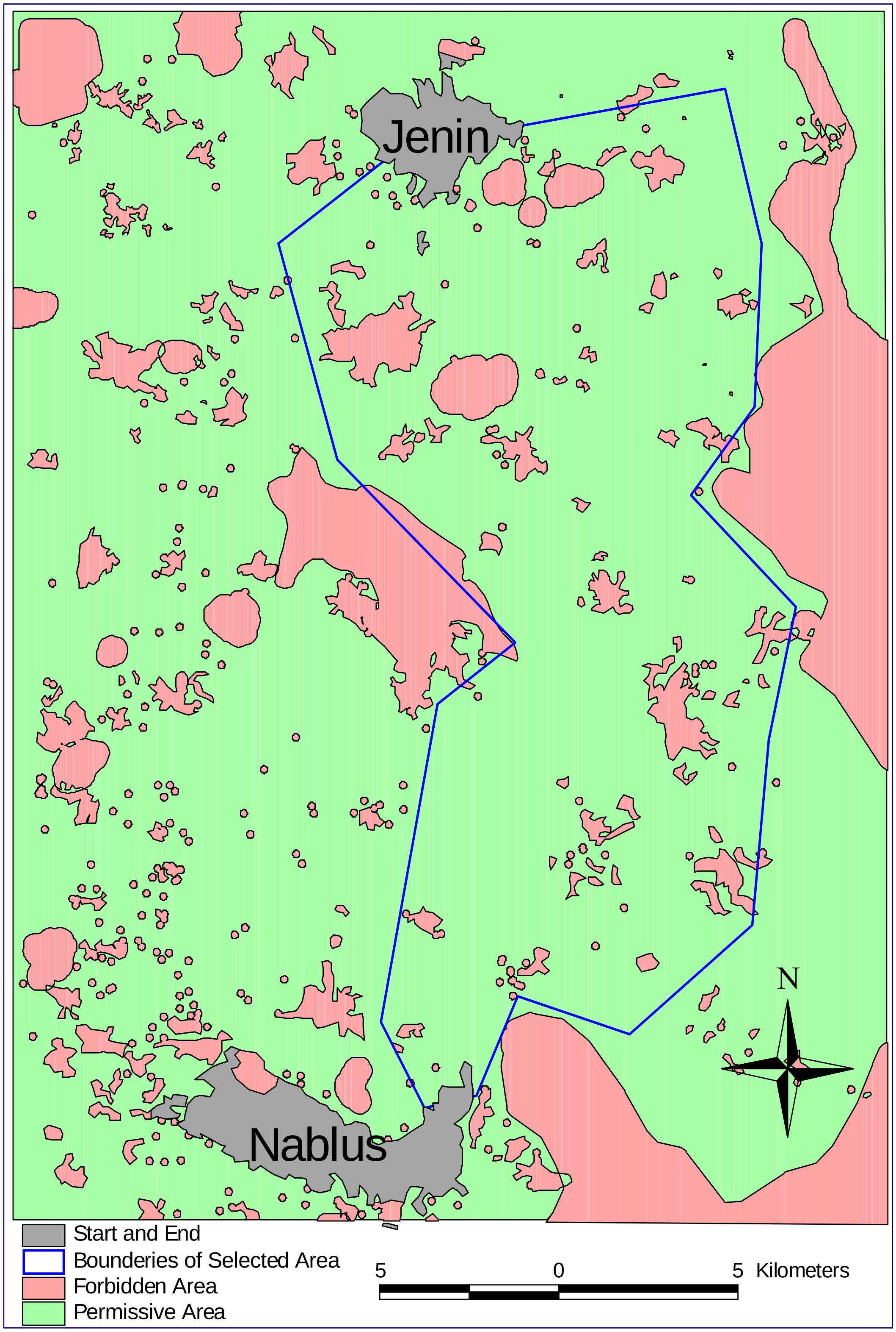


Figure (25) The Permissible and Forbidden Areas According to Trial 3

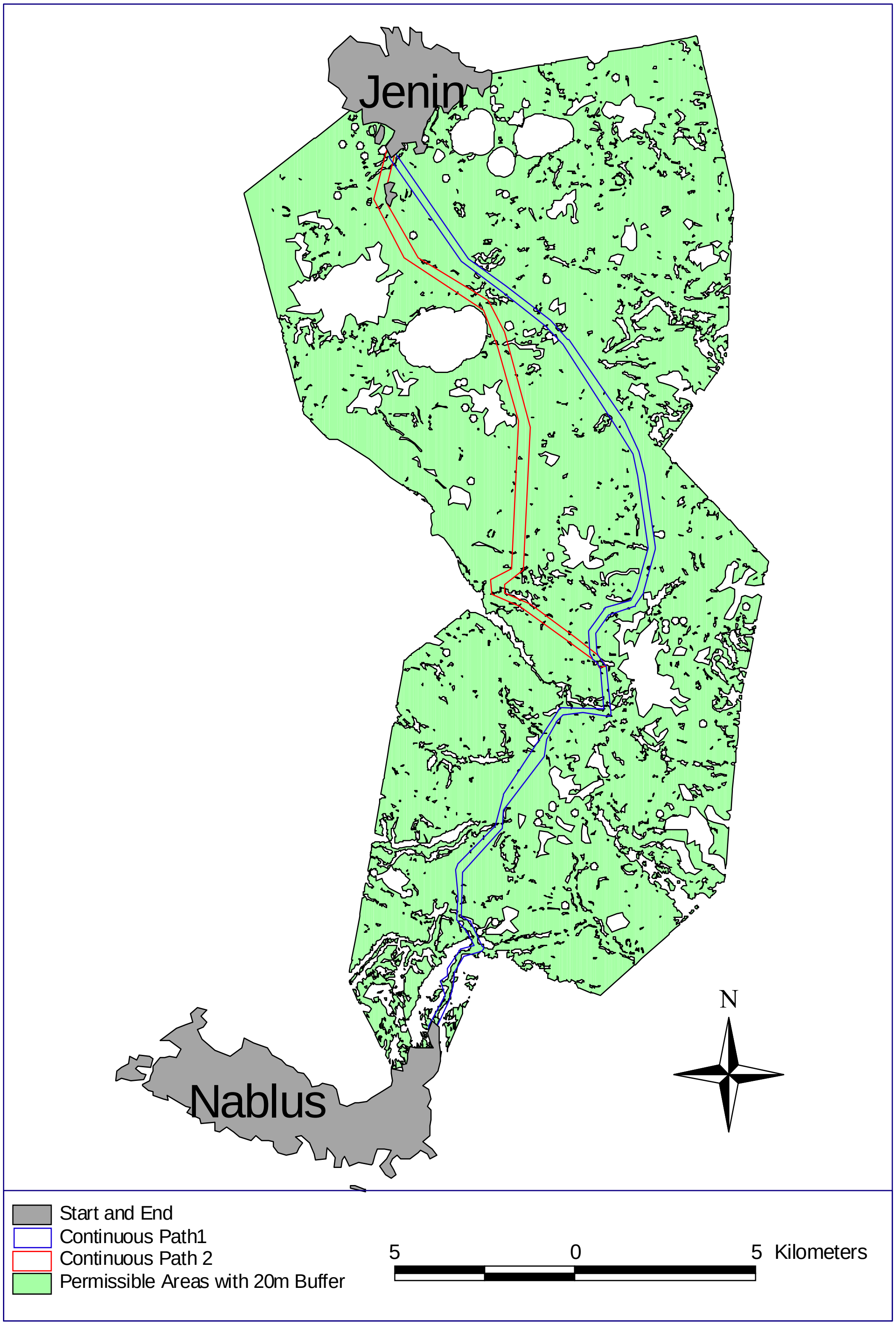


Figure (26) Extracted Continuous Paths in Trial 3

Step 1:

The study area was classified to five classes according to its sensitivity. Each class was given different color that is graduated from dark red for the permanent Forbidden areas and areas with slope more than 25% to dark green to the permanent Permissible area. Figure 27 shows the classified areas as follow:

Class 1: This class contains the permanent Forbidden areas and areas of slope more than 25%. This class is completely restricted so the road is completely forbidden to pass through this class.

Class 2: Bright red color and contains the following areas:

- High agricultural value lands
- Areas with slope ranging between 15% to 25%

Class 3: This class is given orange color and contains the following areas

- Biodiversity, Forest, and Natural Reserves
- Areas with slope more than 10% and less than 15%

Class 4: Contains Moderate agricultural value and areas with slope between 5% and 10%. It took bright green color

Class 5: Contains Low agricultural value and areas with slope between 0% and 5%. This class is the most preferable for the road to pass through and it took dark green color.

Step 2:

A strip of 500 to 1000m in width was selected by examining the areas of graduated color map with all layers considering the output of Step 1.

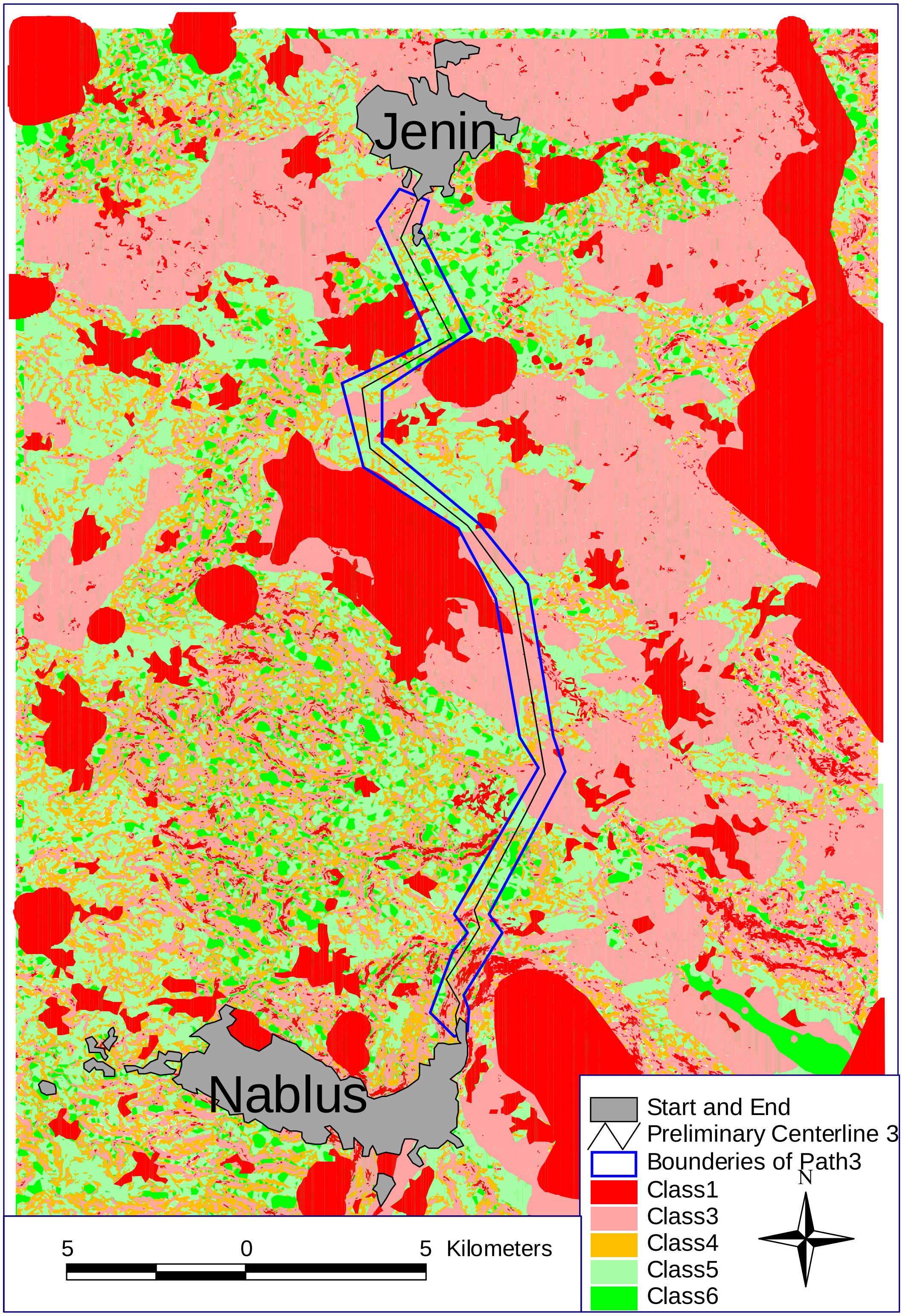


Figure (27) The Study Area Classified According to the GCM

This strip was selected depending on the complete avoidance of the dark red color and giving the priority to the green color.

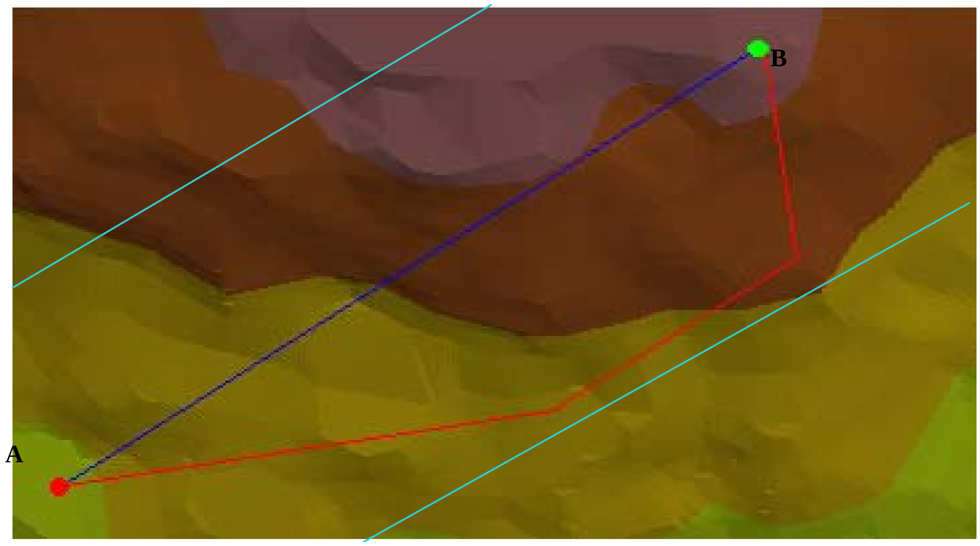
Step 3:

A Preliminary centerline of suggested highway alternative was drawn within the selected strip in the previous step as shown in Figure (27). This centerline will be modified in next two phases Preliminary, and Final Centerline Selection Phases, respectively.

4.5.2 Preliminary Centerline Selection

A 3D model for selected area was made for Alternative One. The borders of the continuous path were added to this model and the preliminary centerline was determined using Profile Extractor extension (PE). In this step, PE helped in selecting the best centerline within the continuous path boundaries, which had been generated in the previous step and added to the 3D model. In addition, PE helped in selecting centerline with least slope by generating an immediate profile for each suggested segment of the preliminary centerline. Sample of this step output is shown in Figure (28) and the preliminary centerlines of Alternatives One and Two are shown in Figure (29).

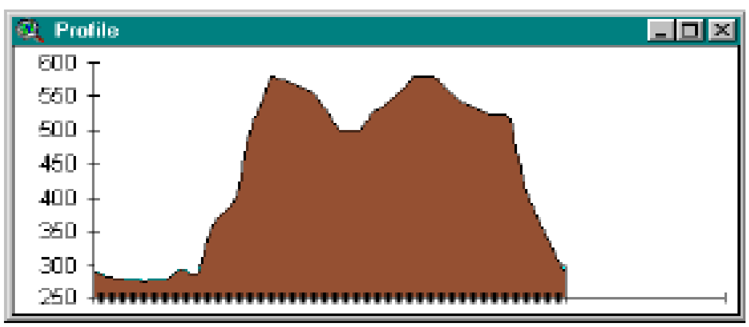
The preliminary centerline is out of the selected continuous path in one place. In this place, the continuous path is located in a deep Wadi in the north of Nablus, which was very clear in the 3D model. The preliminary centerline moved to the west of the selected part as illustrated in the same figure. Other parts of the preliminary centerline are completely within the continuous path. The same steps were followed for Alternative three as shown in Figure (1) Appendix C.



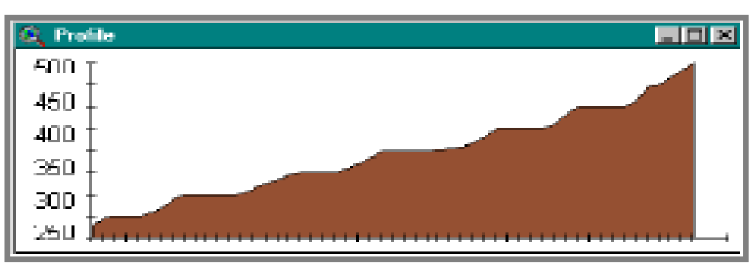
Continuous Path Boundaries

First Suggested Line between A and B

Second Suggested Line between A and B



a) Immediate Profile of Blue Line by PE



b) Immediate Profile of Red Line by PE

Figure (28) Sample of Using PE in Selecting the Preliminary Centerline

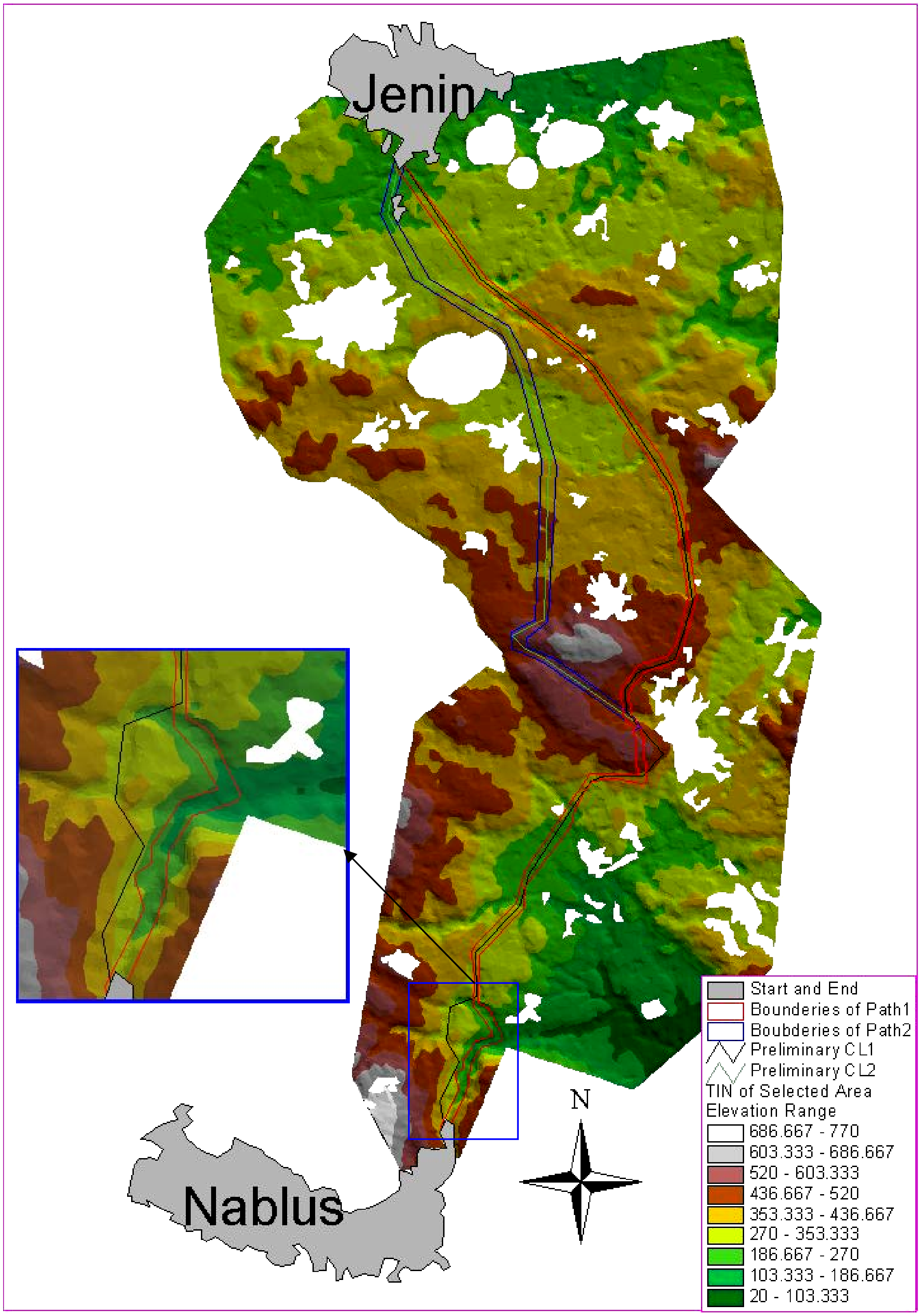


Figure (29) Preliminary Centerlines of Alternative One and Two

4.5.3 Final Centerline Selection

The final location of the centerline was determined for each preliminary centerline that had been generated in the previous stage, using contour map with 10m interval.

The final centerline of the first alternative is shown in Figure (30). Limited modifications were done to reduce the length of the centerline or to remove the zic-zac places. Final centerlines of Alternative Three is illustrated in Figure (2) Appendix C.

4.6 Design Phase

After these in detailed phases, the final centerlines were ready to be designed in Softdesk (SDSK) CADD software. Using special extension in ArcView, the input of SDSK software was converted from shape files to dxf files. These files contain:

1. Final centerline of each alternatives
2. Strip of DTM points, one km in width, this strip represented the ground topography of each alternative

In SDSK software, horizontal and vertical alignments were designed and the design surface was generated, depending on the following design consideration, assumptions, and criteria.

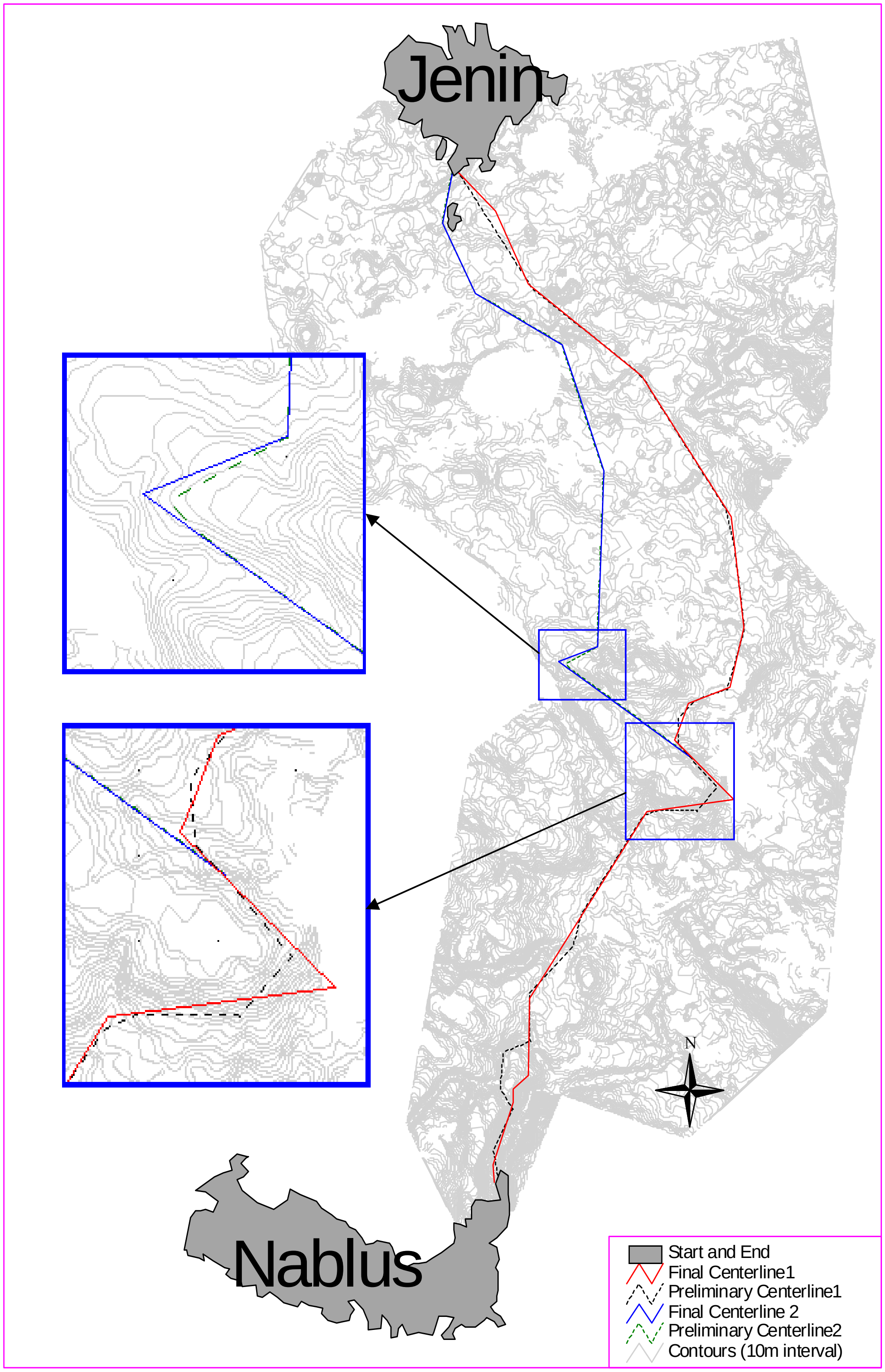


Figure (30) Final Centerlines of Alternatives Two and Three

4.6.1 General Design Considerations and Assumptions

The contour map that was used in the study with 10m contour interval. This interval was not large enough to produce detailed geometric design of the generated highway alternatives. On the other hand, this study did not aim to design the cross section elements, such as travel lanes, median, or drainage facilities, because the main objective of this study is to select a proper route but not to design it in detail. Therefore, referring to Geometric Design of Nablus-Tubas Highway Study, which was done on a suggested highway between Nablus and Tubas, ROW and cross section elements were obtained (Gbr, Hassouneh, and Qanazei, 2004). These criteria, considerations, and assumptions were applicable for all alternatives generated in this application.

Functional Classification

The proposed highway is classified as a rural principal arterial. It is rural because it goes through rural areas and it is principal arterial because it connects between the two major cities of Nablus and Jenin with population more than 25,000 people, (Garber and Hoel, 2002).

Right of Way

Referring to the Geometric Design of Nablus-Tubas Highway Study the recommended ROW was 40m with width of paved area 24m, (Gbr, Hassouneh, and Qanazei, 2004). Paved area is divided as listed in Table(5).

Table (5) The Cross-section Components

Components	Four Travel lanes	Median	Two Shoulders
Total Width (m)	15	3	6

It should be noticed that 40 meters width is the minimum ROW that could increase to reach (84 m) depending on the cut and fill depth and on the side slopes as explained.

Cut and Fill Depth

For technical and economical reasons, maximum cut and fill depth is used as 30m (Gbr, Hassouneh, and Qanazei, 2004).

Side Slopes

According to AASHTO, it is recommended that side slopes for flat and rolling terrain to be (2:1) and (1:1.75) for steep terrain with cut and fill depth exceeds 6m, (AASHTO, 2001). In this study, a (2:1) slope was used as the general side slope for both cut and/or fill but it may reach a slope of (1:1) in some parts of designed alternatives, where steep slopes of topography are available. According to these conditions the minimum ROW equal 40m and the maximum ROW will reach 84m as illustrated in Figure (31).

Design Speed

Design speed is the selected speed to determine the various geometric features of the roadway and it depends on three factors (Garber and Hoel, 2002):

1. Functional classification of the highway.

2. Topography of the area in which the highway is located.

3. Land use of the adjacent area.

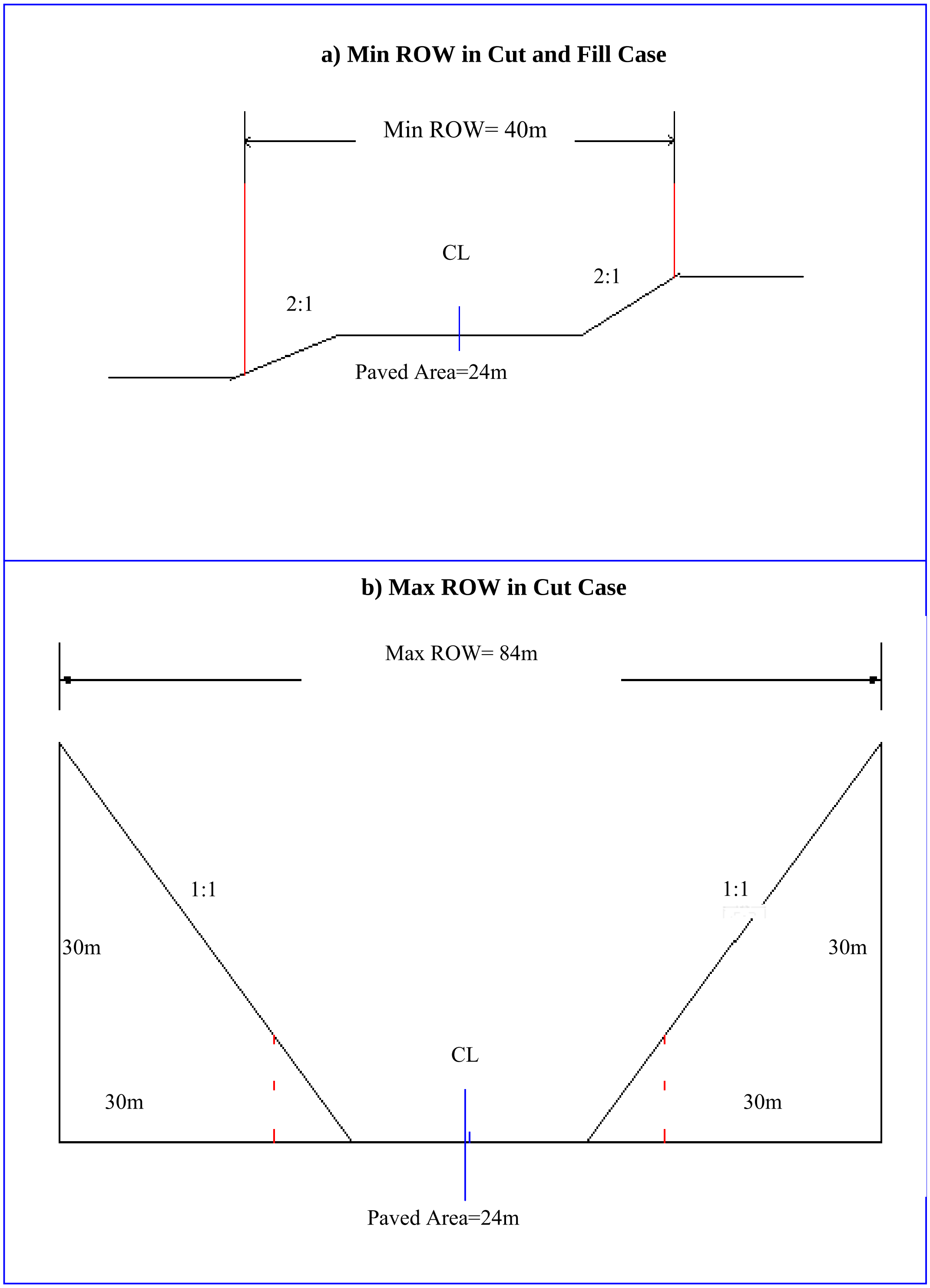


Figure (31) ROW Cases

In this study, the proposed highway is classified as a rural principal arterial and the topography of the area, in which the highway is located, is rough, design speed for these conditions is normally ranged from 60 km/h to 120 km/h, (Garber and Lester, 2002). In this study, the speed used is 80 km/h due to the rough topography and high construction costs.

4.6.2 Horizontal Alignment Design

The minimum radius of a horizontal curve depends on the design speed of the highway V, the superelevation e, and the coefficient of side friction fs, (AASHTO, 2001). This relationship is shown below:

$$R_{min} = \frac{V^2}{127(e_{max} + f_s)}$$

For the highway alternatives in this study, the design speed is 80 km/h, the selected maximum rate of super elevation emax=8%, and the side friction fs =0.14, so the minimum radius of curvature Rmin = 230 meters.

4.6.3 Vertical Alignment Design

Sight Distance

For the highway alternatives in this study, stopping sight distance is necessary to determine the length of vertical curve. PSD is not a criterion in this study because the highway alternatives are two lanes each direction.

Grades

Grades in rural arterial generally are in range of 4 % to 7 %, depending on the terrain classification (AASHTO, 2001). In the study area, very rough terrain is available, so there are grades more than 7 % and the maximum grade reach to 9 % in some parts of designed alternatives.

Minimum Length of Vertical Alignment

Length of Vertical Alignment depends on the sight distance as shown in Table (6) below, (AASHTO, 2001).

Table (6) Equations for the Minimum Length of Crest and Sag Vertical Curve

Curve Type	Minimum Length Equation	
	S>L	S<L
Crest	2S-404/A	$AS^2/404$
Sag	2S-(120+3.5S)/A	$AS^2/(120+3.5S)$

S: sight distance (m).

A: a algebraic difference.

L: minimum length of vertical curve (m).

The previous equations can be written as:

L=kA

K: the length of the vertical curve per percent change in A

A: algebraic difference of grades, Gl -G2

For the highway alternatives, with design speed of 80 km/h, K values are shown in Table (7) (AASHTO, 2001).

Table (7) Rate of Vertical Curvature for Crest and Sag Vertical Curves

Curve Type	SSD (m)	Rate of Vertical Curvature K	
		Calculated	Design
Crest	130	25.7	26
Sag	130	29.4	30

Depending on the previous criteria, the following elements were designed:

1. Horizontal Alignments: After the final centerline of each alternative was imported from ArcView to SDSK, the horizontal curves were designed. Therefore, the designed centerline with its curves was exported to the ArcView to check if there is any interaction between the new centerline and the Forbidden areas. The new three centerlines didn't pass through any forbidden area. After this chick, each centerline was exported to SDSK to continue the design of vertical alignment.

2. Vertical Alignments: These vertical alignments were designed using the profile of each designed centerline. The resulted vertical curves were used to generate the design surface points in the next step.

3. Design Surface: this surface contains the elevation point of the designed roads and the points of cut and fill boundaries. A sample of cut and fill boundaries of Alternative One is shown in Figure (32).

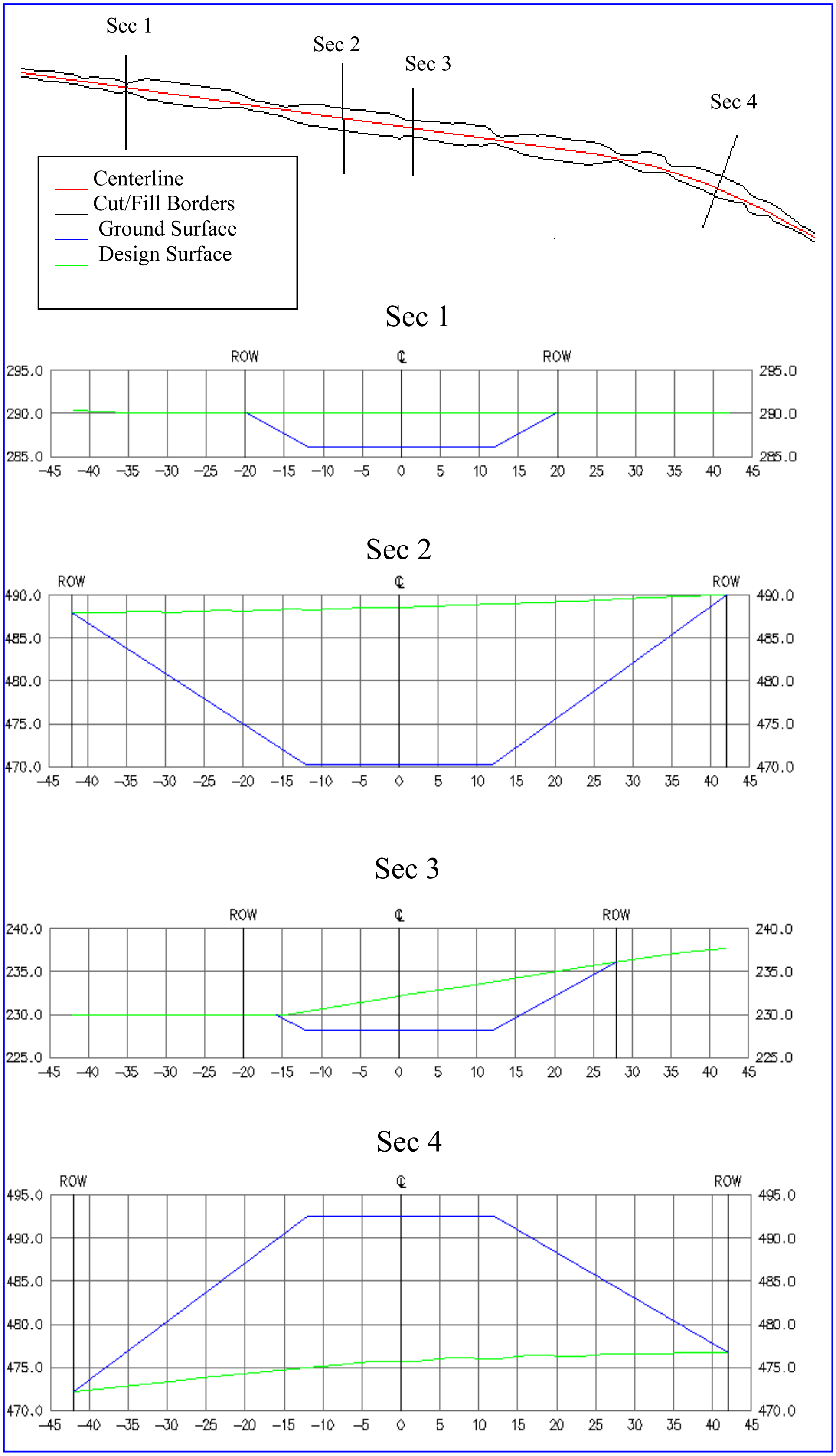


Figure (32) Cut and Fill Boundaries and Cross-sections

4.7 Analysis Phase

In this phase, all calculations of earthworks, impacted areas, lengths, populations served by each suggested highway, and other calculations are done. These calculations are done using the output of Design Phase, which were imported from SDSK software and converted to shape files. Sample of these data for Alternative One are shown in Figure (33) and listed below:

1. Designated centerlines
2. Design points which represent the design surface

Cut and fill area as polygon, this polygon took the length of the centerline and its width ranged from the end of pavement (EOP) to 84.0m.

Impacted Areas Calculations

Each one of the generated highway alternative is expected to impact areas on the ground. These impacted areas will have length of the centerline and their width ranging between minimum ROW (40m) and the maximum width of cut and fill area (84m) as shown in Figure (34).These areas were determined in two steps:

Step 1

Creating buffer zone for each centerline, these buffers represent the minimum ROW (40m). Then merge this buffer with the cut and fill area layer. The result of this step represented the impacted areas boundaries layer.

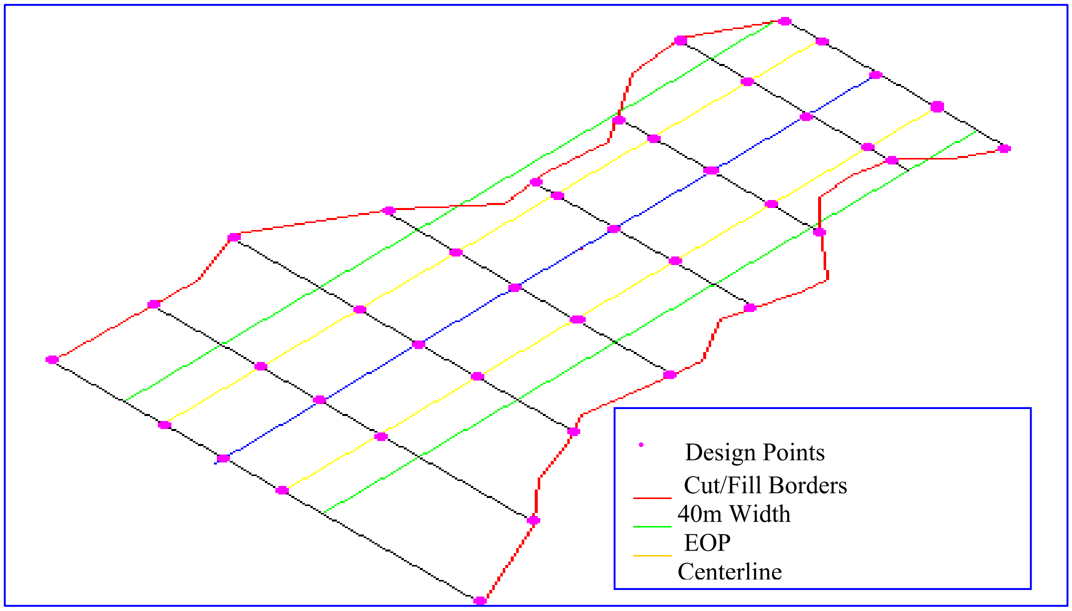


Figure (33) Sample of Imported Data from SDSK to ArcView

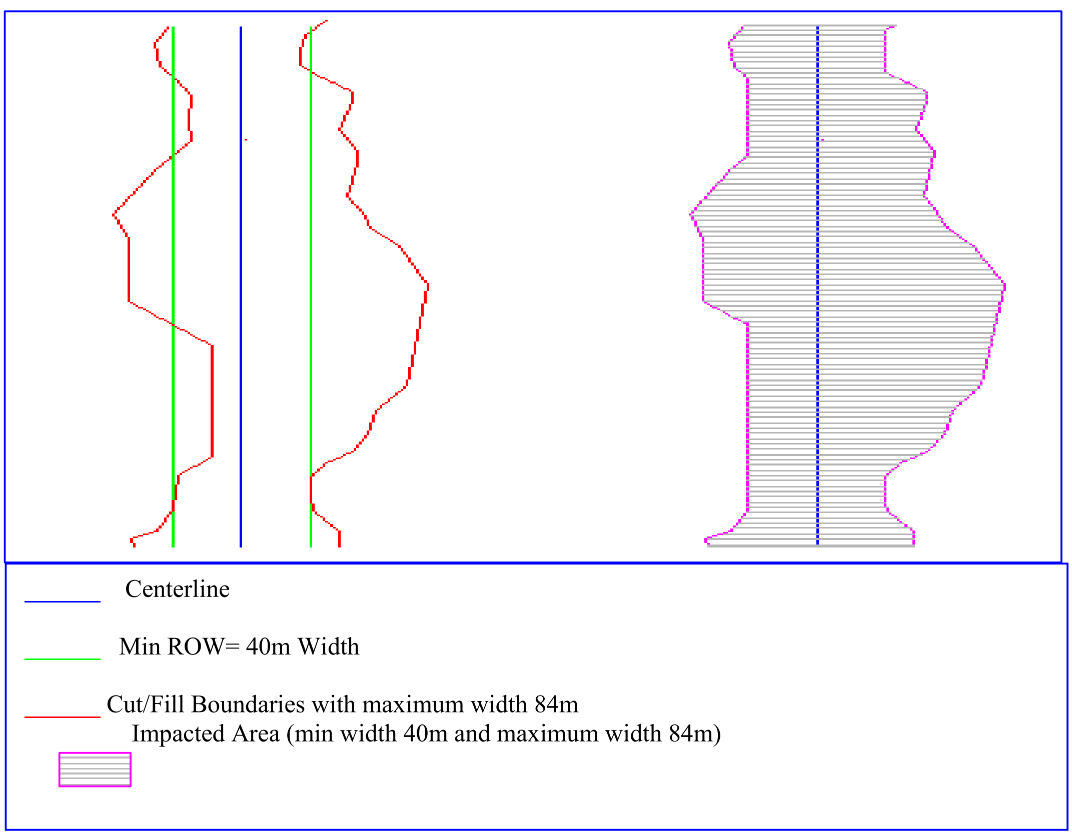


Figure (34) Impacted Area Simplification

Step 2

The impacted area boundaries layer, which was obtained in the first step, is laid over the base map of land use of the study area. This layer is clipped with base map to produce a new layer. This new layer had the impacted area boundaries and classified according to the land use as shown in Figure (35) for Alternative One. The impacted areas for Alternative Three are presented in Figure (3) in Appendix D.

Cut and Fill Calculations

Cut and fill volumes are the volumes between the design surface and the ground surface as shown in Figure (36). The design surface is the surface of the paved area of the highway and it is represented by the design points. The second surface is the ground surface that represents the real topography and it was built using the contour lines. Using 3D Analyst, cut and fill volumes were calculated and represented in maps that show the places of cut and fill. These maps are automatically connected to attributes that contain the values of cut and fill volumes. Figure (37) shows the results of this process for Alternative One and the other alternatives are shown in Figure (1) and Figure (2) in Appendix D.

Population Served within Five Kilometers

Population served by the suggested highway were estimated by selecting all built-up areas within 5 km from the centerline of each alternative. Figure (38) shows the output map of this process for Alternative one. The results of other two alternatives are presented in Figure (4) and Figure (5) in Appendix E and the numbers of served people are listed in Table (1) to Table (3) in the same Appendix for all alternatives.

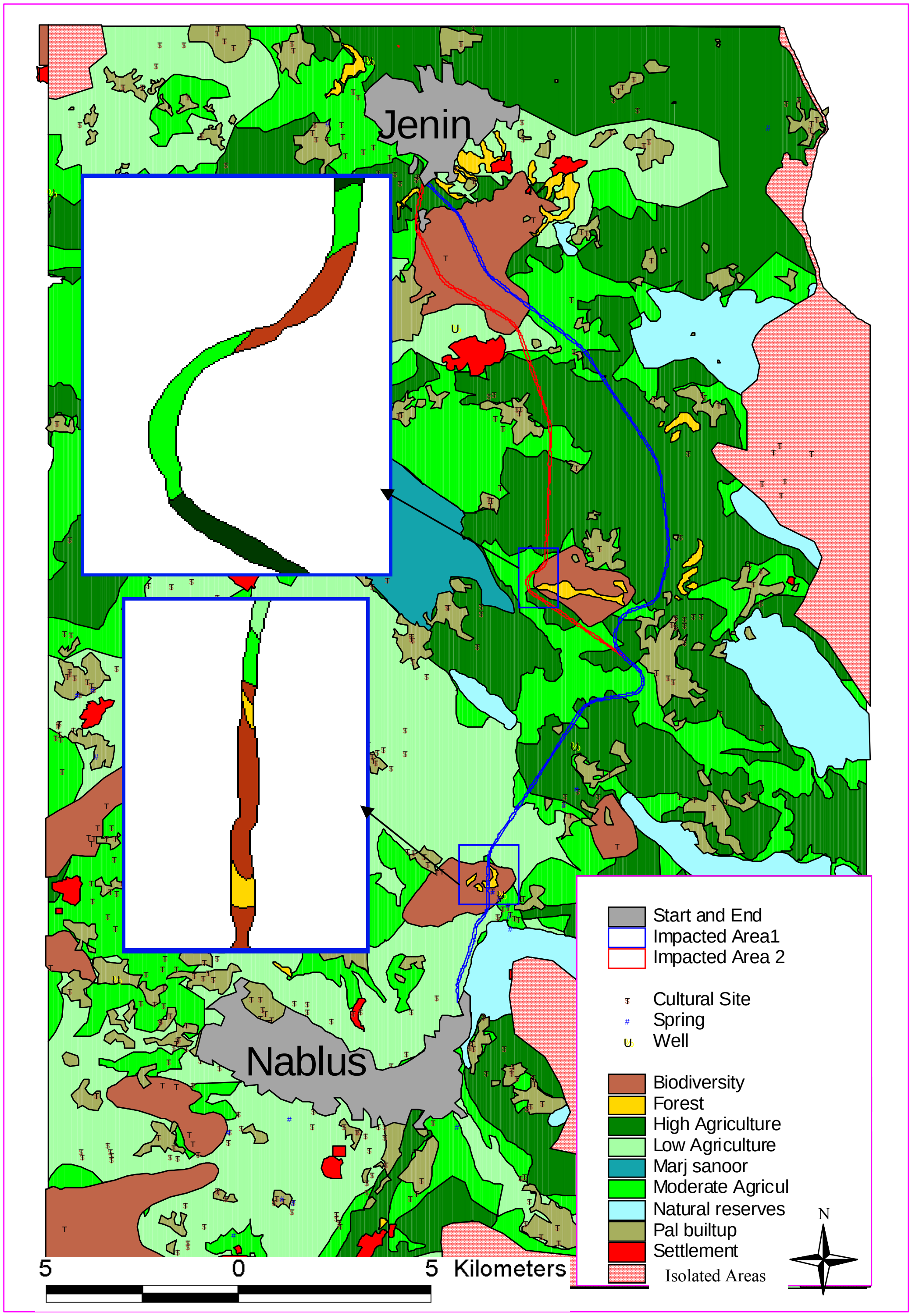


Figure (35) Impacted Areas of Alternatives One and Two

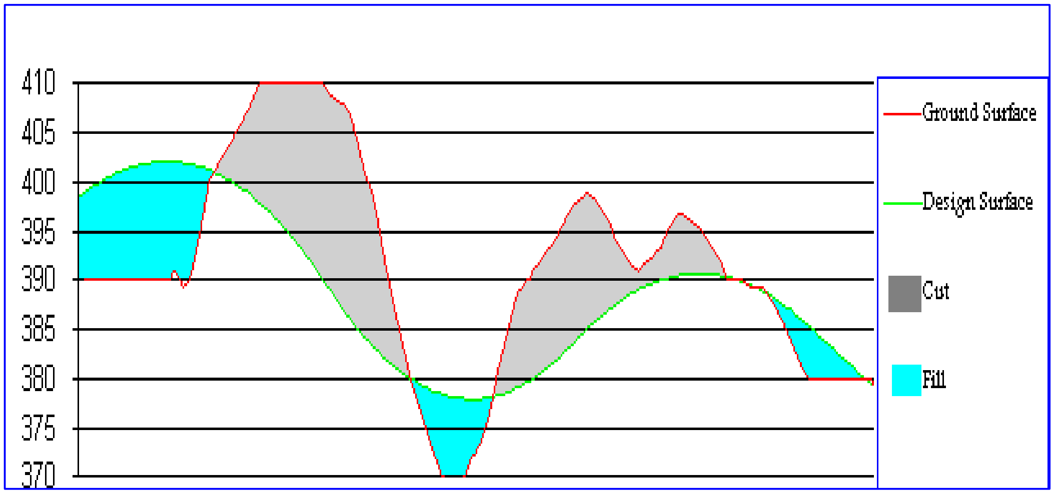


Figure (36) Cut and fill between the Design and the Ground Surfaces

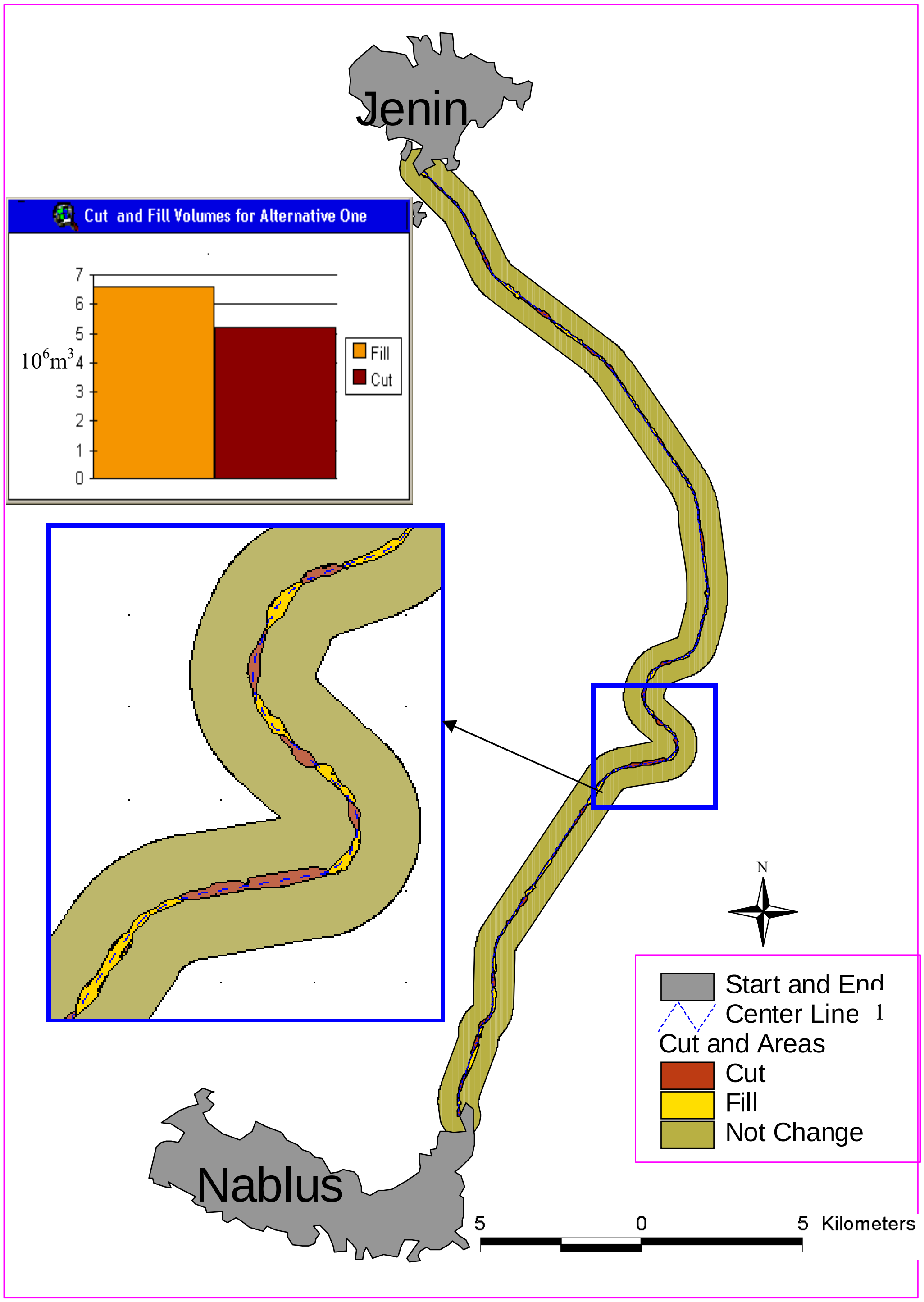


Figure (37) Cut and Fill Output of Alternative One

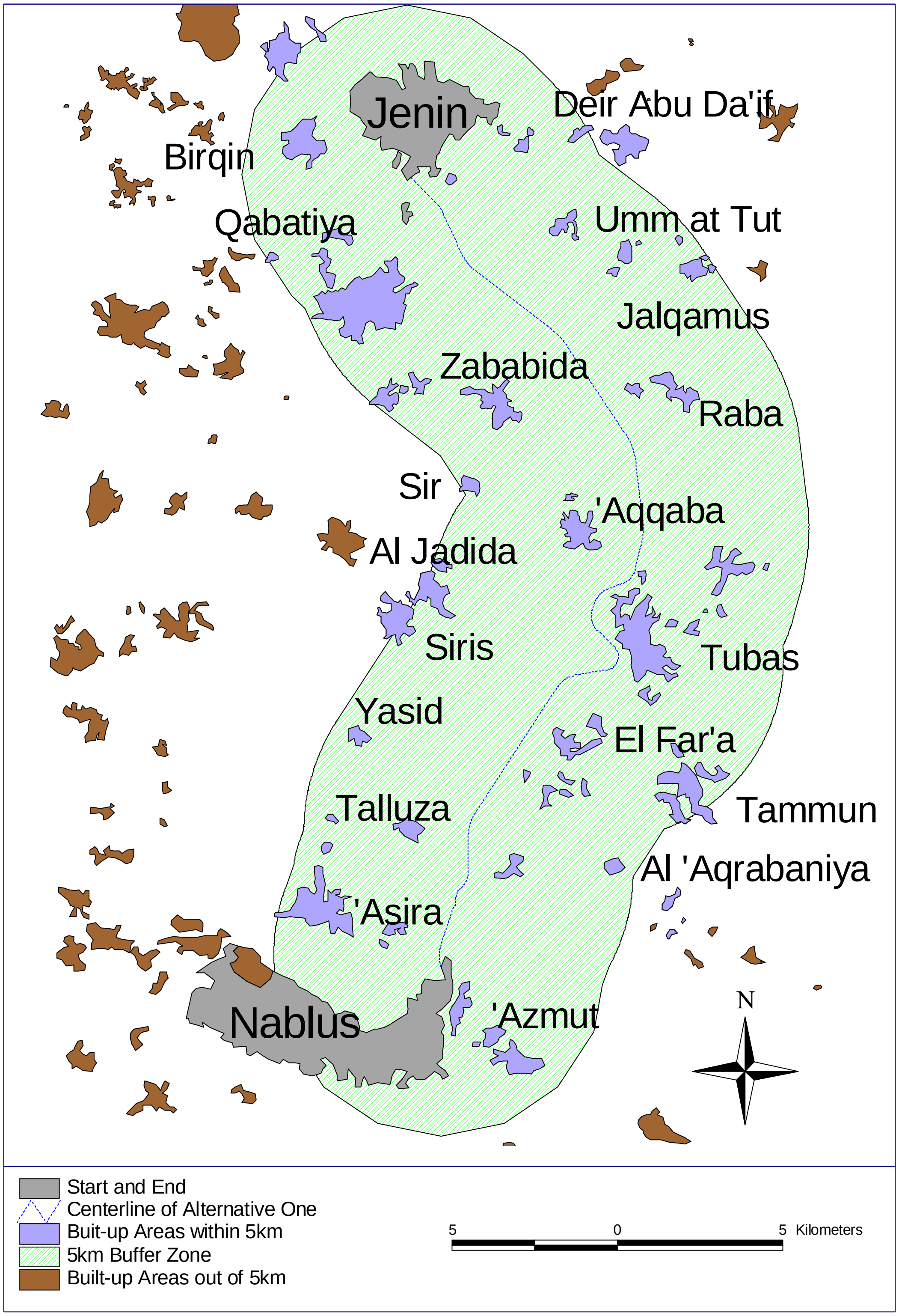


Figure (38) Built-up Areas Served by Alternative One within Five km

Impacted Areas by Traffic Noise

In this step, there are no detailed traffic noise calculations. The areas that are located within 150 meters were classified as impacted noise areas (USDOT, 1995). This step was done by creating 150m buffer zone around the paved boundaries of each alternative as shown in Figure (39).

Number of Crossed Geological Faults

Numbers of faults that are crossed by centerline of each alternate highway were determined. Figure (40) shows the faults crossed by Alternative One. Alternatives Two and Three are shown in the Appendix E in Figure (6) and Figure (7), respectively.

Other Calculations

Cultural sites were classified as permanent forbidden as well as the water resources so no one of these features were located within the ROW of the different alternatives as shown in Figure (41). In addition, the length of each alternative was determine using ArcView.

Table (8) presents a summary of the absolute impacts in several categories by each alternative.

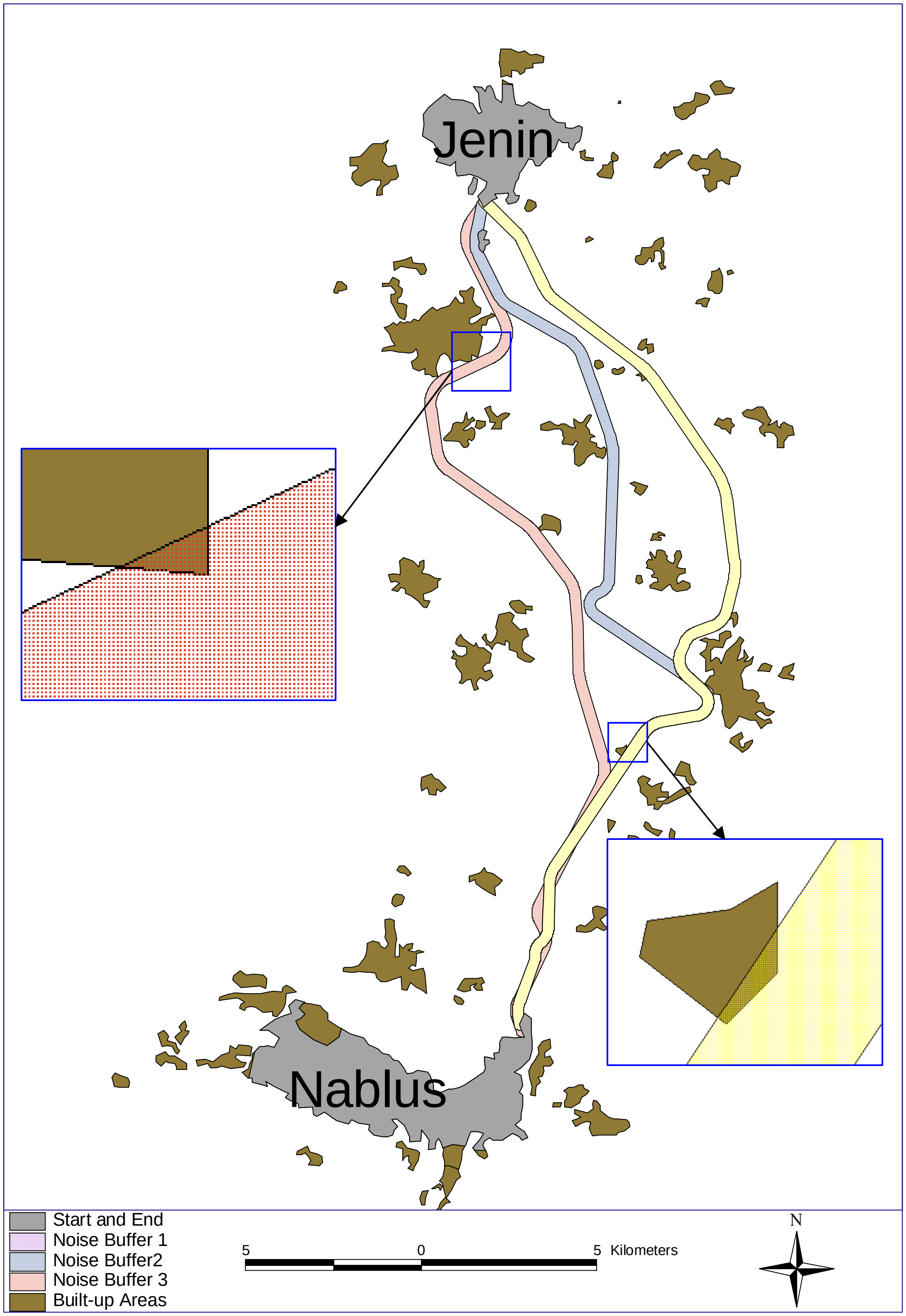


Figure (39) Areas within 150m Noise Zone of All Alternatives

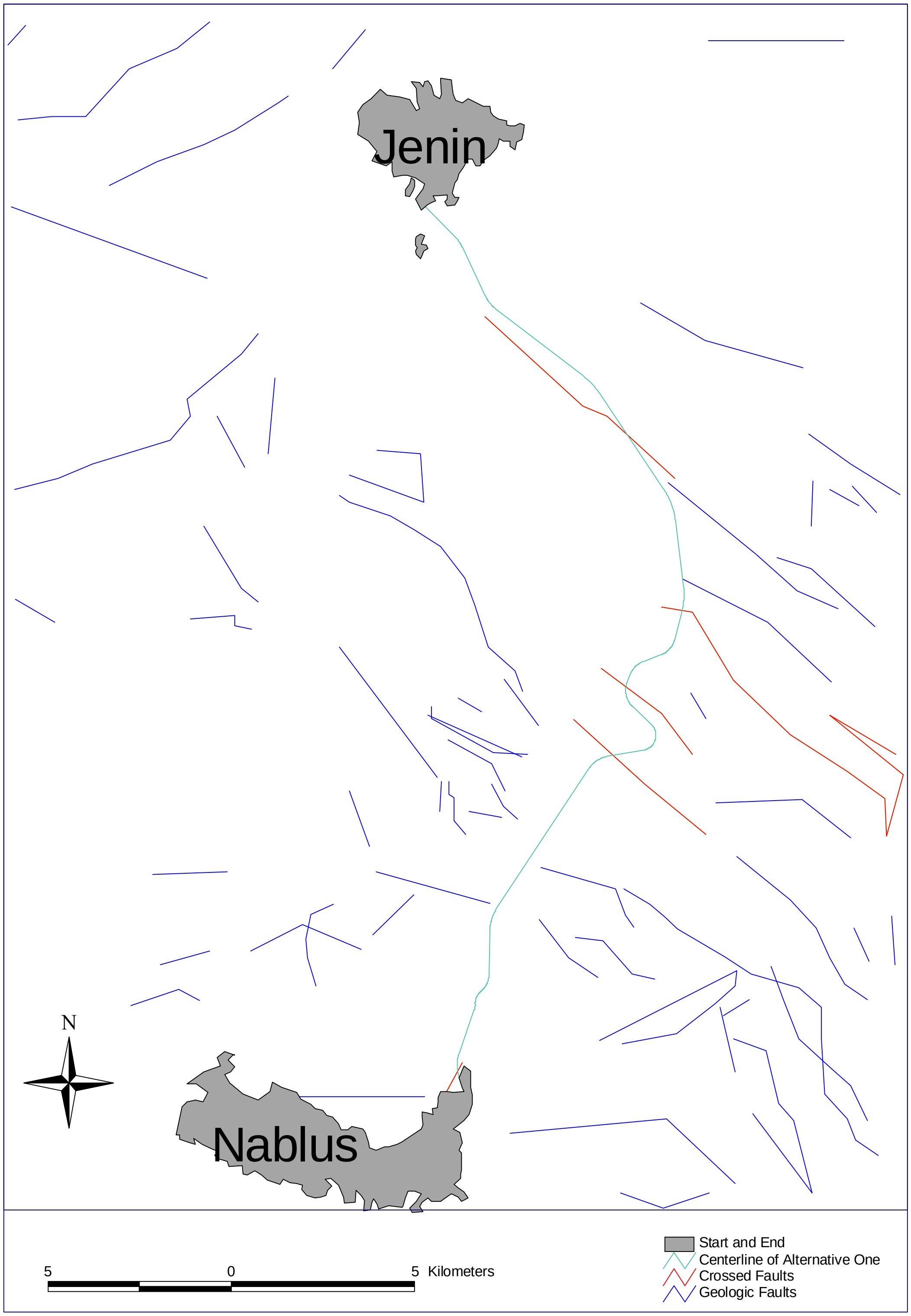


Figure (40) Faults Crossed by Alternative One

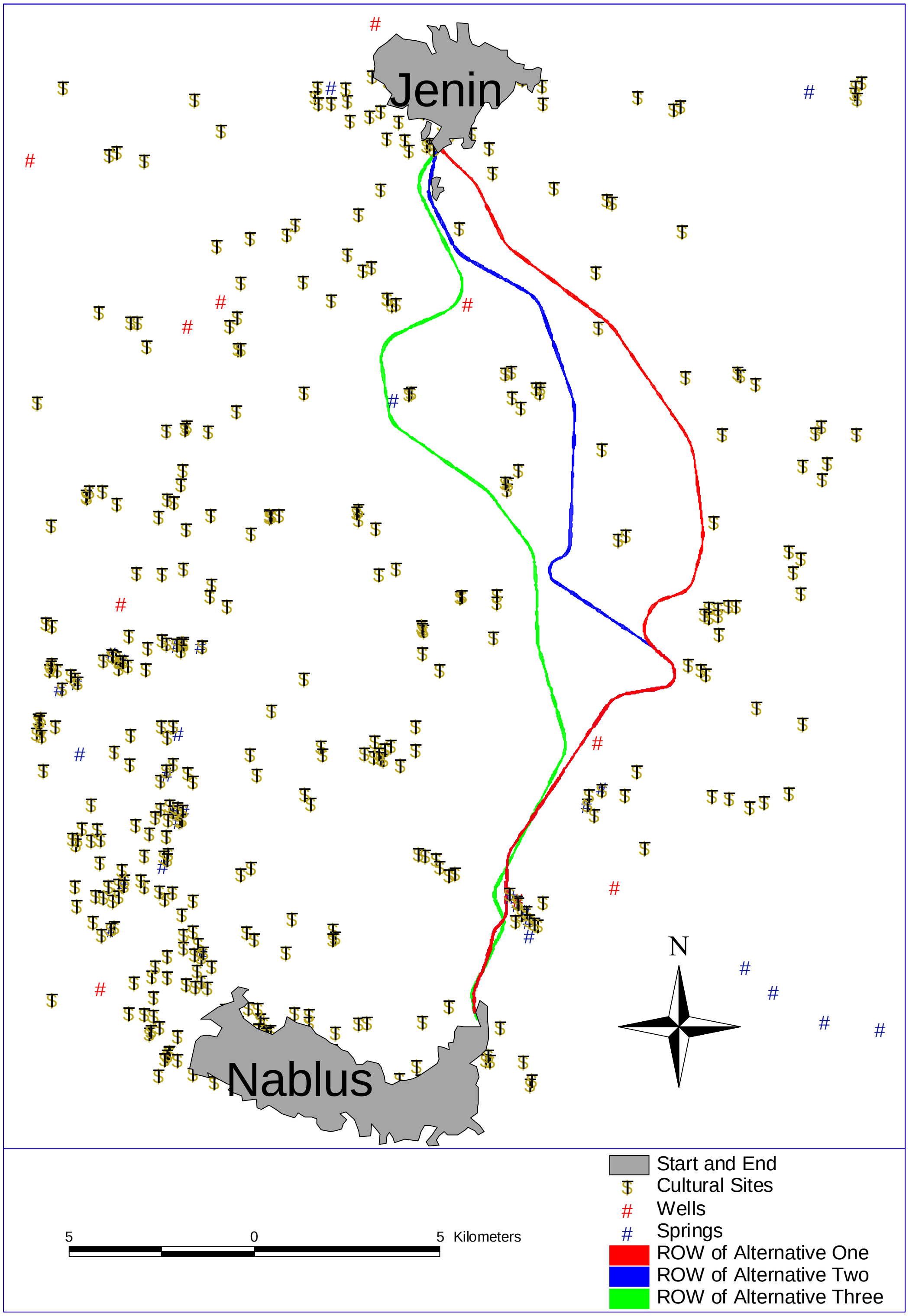


Figure (41) All Alternative with respect to the Point Features

Table (8) Final Results of the Analysis Phase

Impact Category	Unit	Alternatives			Chart*
		Alt.1	Alt.2	Alt.3	
High Agriculture	dunum	714.7	685	395.8	1
Moderate Agriculture	dunum	384.0	377	579.1	1
Forest	dunum	11.3	14	16.5	1
Biodiversity	dunum	288.9	413	218.0	1
Natural Reserves	dunum	0	0	0	-
Total Areas	dunum	1664.0	1800	1676.3	1
Water Resources	number	0	0	0	-
Cultural Sites	number	0	0	0	-
Geological Faults	number	4	2	4	-
Length of Highway	km	29.4	29.2	27.6	-
Cut and Fill	10^6 m^3	11.7	13.9	14.3	2
Population in 5 km	thousand	138	144	143	3
Noise Areas	dunum	23.17	8.85	1.73	4

*Note: Results of the analysis phase are illustrated in charts

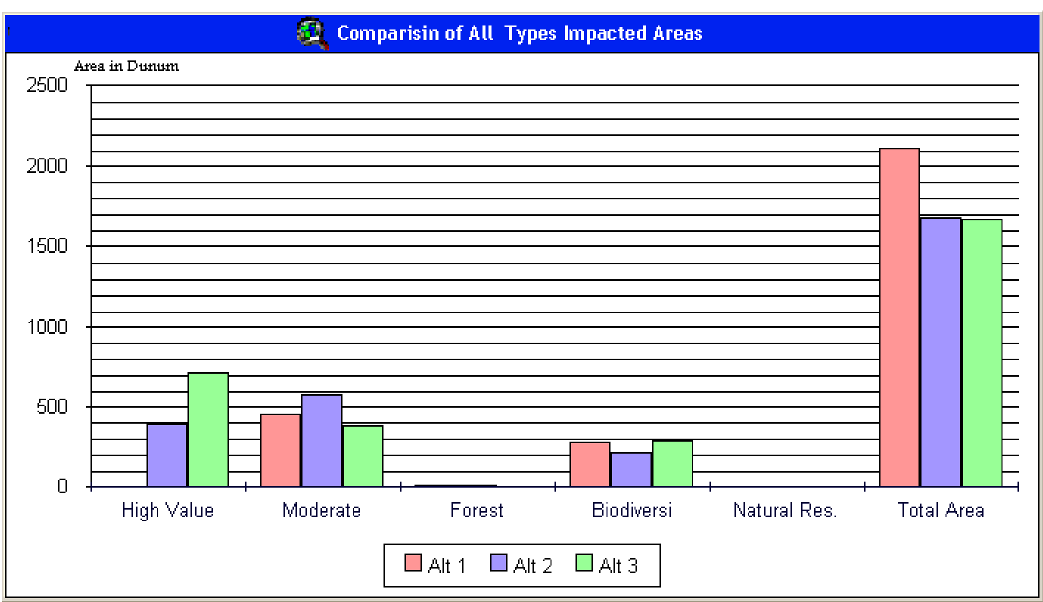


Chart (1) Different Categories of Impacted Areas for All Alternatives

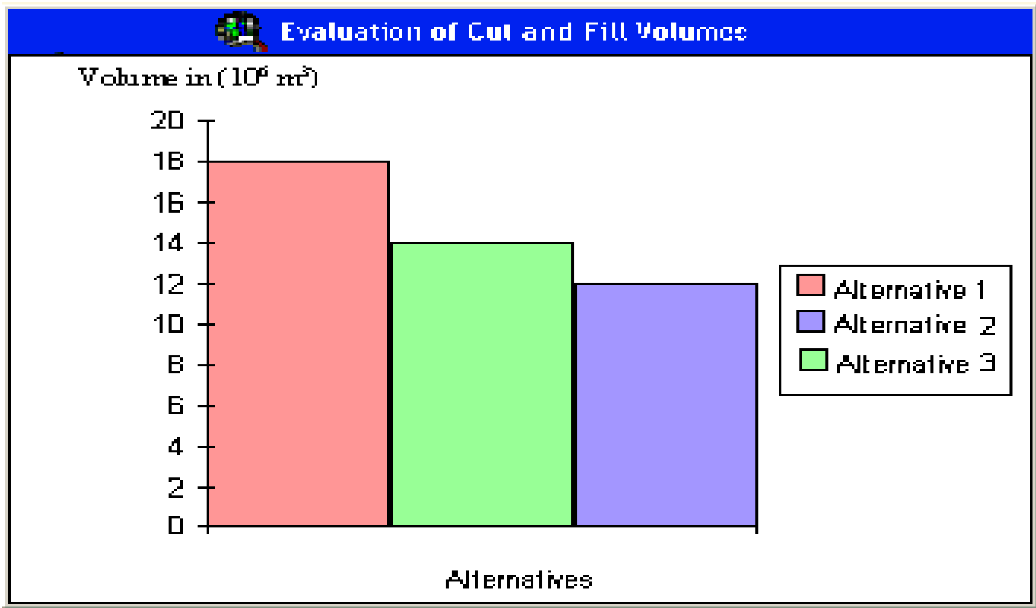


Chart (2) Cut and Fill Volumes of All Alternatives

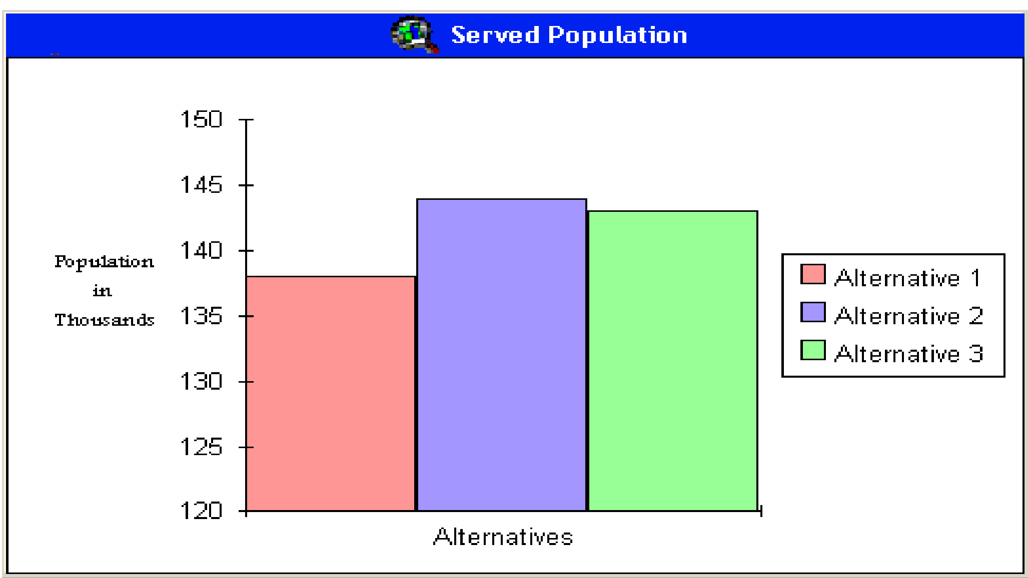


Chart (3) Served Population within 5 km of All Alternatives

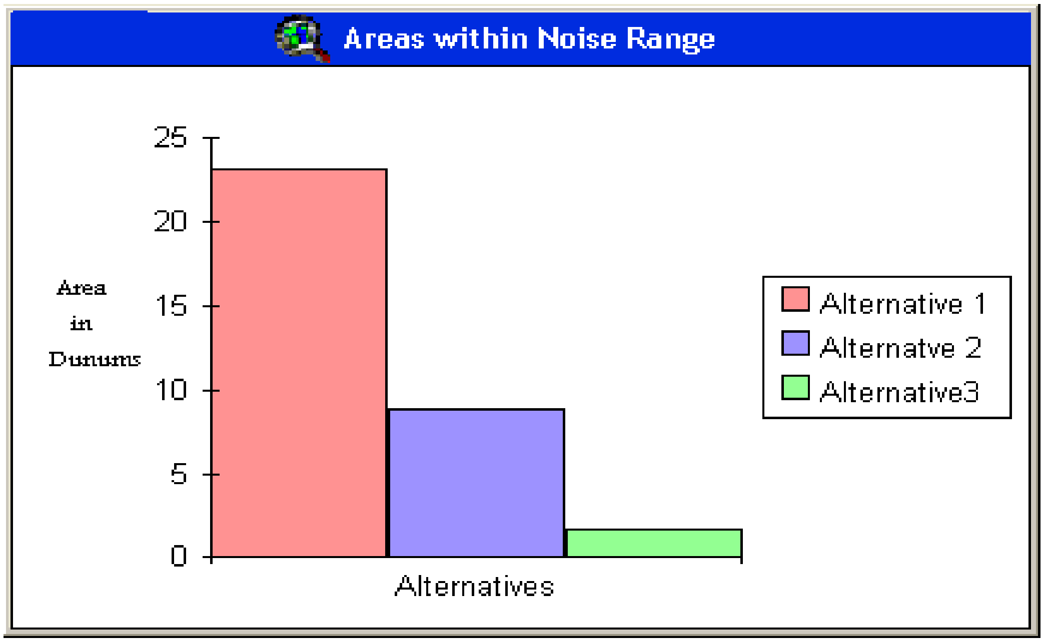


Chart (4) Areas within the Noise Rang for All Alternatives

4.8 Evaluation and Final Selection Phase

In this phase, advantages and disadvantages of each Alternative are listed. In addition, the relative amounts of impacts were estimated using weighted values for each category based on their importance. The final results of this process are listed in Table (9). These results were used to select the best one of the three alternatives.

4.8.1 Advantaged and Disadvantages of All Alternatives

Alternative One

This alternative was generated in trial three as presented earlier. In this trial, high agricultural value lands classified as permissible areas. Therefore, this alternative was allowed to pass through the eastern part of the study area which has middle rough and flat topography as shown in Figure (26). This path gives these advantages and disadvantages:

Advantages

1. Least impacts to forests
2. No impacts to natural reserves
3. Least required total areas
4. No impacts to water resources
5. No impacts to cultural sites
6. Smallest cut and fill volumes

Disadvantages

7. Most impacts to High Agricultural Lands
1. Most impacts to Moderate Agricultural Lands
2. Longest route
3. Least served population within five kilometers
4. Most areas within noise range
5. Maximum number of crossed faults

Alternative Two

Alternative Two was developed in the same conditions of the first alternative. These two alternatives share the same route for more than 12 km, from Nablus to Tubas. This Alternative has these advantages and disadvantages:

Advantages

1. Least impacts to Moderate Agricultural value
2. Minimal impacts to Natural Reserves
3. No impacts to water resources
4. No impacts to cultural sites
5. maximum number of served population within five kilometers

Disadvantages

1. Most impacts to biodiversity areas
2. Most required to total areas

Alternative Three

This Alternative was generated using Graduate Color Method. In this method, the study area is divided according to it sensitivity. Alternative three passes through the middle part of the study area that gives it these advantages and disadvantages:

Advantages

1. Least impacts to high agricultural value
2. Least impacts to biodiversity areas
3. No impacts to natural reserves
4. No impacts to water resources
5. No impacts to cultural sites
6. Shortest route length

7. High number of served population within five kilometers

8. Least areas within the noise range

Disadvantages

1. Most impacts to moderate agricultural lands

2. Most impacts to forests

3. Largest cut and fill volumes

4.8.2 Final Selection

Final selection was made depending on the results of the analysis phase that are listed and evaluated in Table (9). The results show that Alternative One and Alternative Two almost have the same overall points, because they shared the same route for about 12.7 km. After their separation in the west of Tubas, Alternative One affects more high agricultural lands, about 522 dunum, while Alternative Two affects 492 dunum causing an increase in the overall points of Alternative One by 45points. On the other hand, Alternative Two penetrates 333 dunums of biodiversity areas, while Alternative One penetrates 209 dunums, giving 108 additional points to Alternative Two. Also, Alternative Two serves more population than Alternative One but it could not reduces the final number of overall points of Alternative Two.

Alternative three collects least number of overall points so it is the best alternative. This is because this alternative consumes just 395 dunums of high agricultural value land which is less than what Alternative One and Two that damages. This large difference is the main factor that gives Alternative Three the preferences in addition of serving high number of population.

Table (9) Estimation of the Relative Amount of Impacts Using Weighting System

Impact Category	Unit	Weight	Alternative1		Alternative 2		Alternative 3	
			Value	Points	Value	Points	Value	Points
High Agriculture	10 dunum	15	71.47	1072	68.5	1028	39.58	594
Moderate Agriculture	10 dunum	6	38.40	230	37.7	226	57.91	347
Forests	10 dunum	9	1.13	10	1.4	13	1.65	15
Biodiversity	10 dunum	9	28.89	260	41.3	372	21.80	196
Natural Reserves	10 dunum	9	0	0	0	0	0	0
Total Areas	10 dunum	1	166.40	166	180.0	180	167.63	168
Length of Highway	km	6	29.4	176	29.2	175	27.6	166
Cut and Fill	10^6 m^3	10	11.7	117	13.9	139	14.3	143
Population in 2 km	thousands	-6	138	-828	144	-864	143	-858
TOTAL POINTS				1204		1268	770	

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

Chapter Five

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This study aimed to use GIS as a tool for route location and highway alignment application. There are several GIS packages available, but there is no one designed especially for this application. ArcView was customized for such application in this study, using external extensions. Applications were then tested the utility of the customized ArcView. This study was applied to find the location of a proposed highway that connects Nablus in the south with Jenin in the north of a selected study area, for which all relevant data was collected. Data included information about the study area, such as agricultural, forest, biodiversity areas, natural reserves, and water resources. This data also included information about the built-up areas either the Palestinian built-up areas or Israeli settlements in the study area. Other data was collected about the cultural sites, geological faults, Separation Wall, and the isolated areas.

Based on the study results, the following conclusions are made:

1. The developed GIS model has demonstrated the potential of using GIS technology as a tool to assist in route location and highway alignment applications.

2. It has been shown that using GIS in route location and highway alignment can be flexible and has the capability to expand easily and accommodate any additional required data layers, such as soil and geological features, to represent the real world, where the

highway will be aligned. On the other hand, the model can take additional data and layers that comes from the future plans of the study area.

3. The importance of the developed model came from the interaction between 3D-Analyst and Spatial Analyst extensions when the slope of the topography was considered in selecting the best route. The division of the study area according to its slope and merging the different slope areas with the forbidden and permissible areas prove the importance.

4. Interface with CADD software (Softdesk) allows interaction with the capabilities of GIS model, because ArcView is very limited in design features. This allows for the design of horizontal and vertical alignments.

5. This study proved to be a good analytical tool in conducting the impacts of suggested highway on the environment elements such as agricultural areas, biodiversity areas, forest areas, and on water resources. This will help in reducing the negative effects on these areas and resources.

6. The developed model showed high capabilities of dealing with 3D in two ways:

a) determining the preliminary centerline and avoiding the topography with steep slopes using Profile Extractor Extension PE;

b) showing the designed highway in 3D and simulating a driving experience, thus giving a trial simulation of the highway before it is constructed and visual checking the sight distance.

5.2 Recommendations

The application of GIS technology in the route selection and highway alignment is still in the development stage, where the developed model is not fully complete. It is hoped that with the continued process of usage, improvement, and modifications, will result in experience gaining in the use of the GIS technology, and will aid engineers and planners in all different stages of highway location and design project. This study has shown the potential of GIS as a tool for route location and highway alignment. Consequently, the development of a comprehensive GIS model for this application and other transportation applications should be pursued. Recommendations for further studies are presented below:

1. It is recommended to concentrate the efforts to develop GIS extensions for the design of highway, so that the highways can be designed without using CADD software. Therefore, GIS will help engineers and planners in the suggestion, design, analysis, and evaluation of highway alignment.

2. It is recommended to develop a GIS model to be a decision making tool. So that, this model can, on one hand, automatically analyze and calculate the earthworks volumes as well as the different impacted areas. On the other hand, the developed model can select the best alternative using an input impact weighting system.

3. It is recommended to improve the weighting system so that it

contains more detailed information about the geology of the study area and about noise pollution as well as air pollution.

4. It is recommended that 3D Analyst and 3D Incontrol extensions be used in calculating and determining the sight distance. This is because 3D Incontrol has the ability to show the real topography in 3D as well as the ability to simulate driving in the designed highway.

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APPENDICES

Appendix A

GIS SOFTWARE

GIS SOFTWARE

Introduction

In this study, ArcView 3.2 and its extensions were selected to be the main software. It is a GIS software with the ability of capturing, storing, updating, manipulating, analyzing, and referencing the information which describes the ground surface of the study are. ArcView connect the features of different layers with its attributes so it is very useful in highway alignment selection, especially in the analysis and evaluation phases.

Different types of extensions were used in this study to improve and expand the capabilities of ArcView. These extensions are listed in the following sections.

ArcView Extensions Used

Extensions are Avenue scripts, the programming language of ArcView, which extends ArcView to allow the user to enhance his/her working environment with additional objects and customization independent of the current project. Two types of extensions are available in ArcView:

- Built in extensions
- External extensions

The user can also create his/her own extensions to achieve the objectives.

(A) Built-in Extensions Used

This type of extensions can be loaded and unloaded through the extension dialog. Mainly two built-in extensions are used in this study:

1. CADD Reader Extension:

CADD data is a main part of the data used in this study, so this extension is useful to support viewing, querying, and analyzing these data. This extension is useful also to import the designed horizontal and vertical curves that have been designed in the CADD software.

2. Geoprocessing Extension:

This extension is useful to determine the impacted areas by the new highway. This extension helps the user to aggregate the similar affected areas depending on their attributes. It is also useful to clip the affected areas based on the different areas such as agricultural, biodiversity areas, etc. This is a brief description of some tasks that can be done using this extension:

- Dissolve features based on attributes

Dissolve process is used to remove boundaries or nodes between adjacent polygons or lines that have the same values for a specified attribute.

- Merge themes together

Merge process is used to create a new theme containing two or more adjacent themes of the same features type.

- Clip one theme based on another

Clip operation is used to cut out a piece of one theme using another theme.

- Intersect two themes

Intersect process is used to integrate two spatial data sets while preserving only those features falling within the spatial extent common to both themes.

- Union two themes

This operation combines features of an input theme with the polygons from an overlay theme to produce an output theme that contains the attributes and full extent of both themes.

(B) External Extensions Used

Large number of external ArcView extensions is available either through GIS web sites on the internet, or on CDs. These extensions can be installed and added to the extension's list in ArcView. Mainly, four external extensions are used in this study. These extensions are:

1. 3D Analyst Extension

ArcView's 3D Analyst extension supports 3D analysis of surface data. Also it can show 3D terrain using 3D Viewer windows. It supports various highway surface-areas, volumetric, and profile analyses. 3D Analyst works with two-theme classes; Triangulated Irregular Networks (TINs), and 3D shape files.

TINs

Triangulated Irregular Network (TIN) replicates much of the functionality of grids in a vector context. A TIN models terrain with triangular facets of varying shape and size. Each facet's three XYZ nodes (vertices) define its slope and aspect. A TIN has a complex data structure, since it must store 3-dimensional coordinates for each node and maintain appropriate topological relationships between adjacent triangles. A TIN can incorporate XYZ data from multiple sources. A typical TIN might start with a set of XY and elevation Z. The TIN could also incorporate additional lines representing roads or streams, or polygons representing boundaries or other areas.

3D Shapefiles

3D Analyst also supports 3D shapefiles with features defined by XYZ vertices. The generated TINs can be shown in 3D scene so it will be useful to show the new highway in 3D as shown in Figure (1).

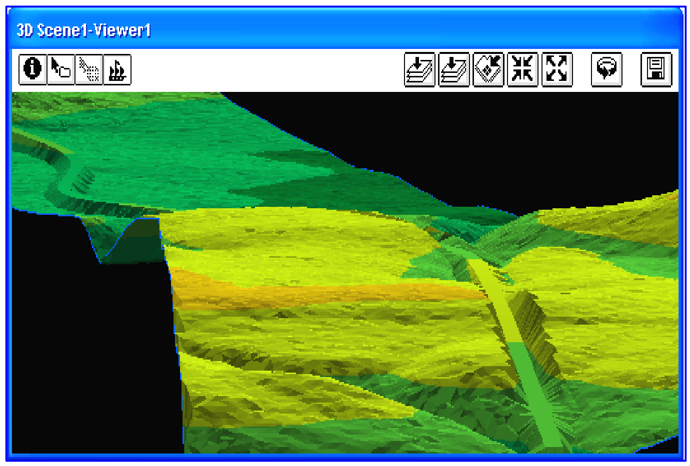

Figure (1) Generated 3D Scene of Highway

3. Spatial Analyst

The ArcView Spatial Analyst is a tool for helping the users to discover and understand spatial relationships in their data. This discovery and understanding can be as simple as viewing and querying data or as complex as creating an integrated custom application.

The main component of the Spatial Analyst is the grid theme. The grid theme is the raster equivalent of the feature theme. The Spatial Analyst also presents generic spatial analysis functionality on grid and feature themes. Many tasks can be done by this extension as distance determination and analysis, density calculations, cells statistics, area tabulation, map query and calculations…etc.

3. Profile Extractor Extension

Profile Extractor (PE) extracts cross section profile from a TIN, PE has many practical uses. It can be used to give a profile in suggested road alignment to know how steep will the road be. Moreover, it is great for presentations, to show any data with a three-dimensional (z) value. The user can draw cross section line, select existing one, move selected line or its ends or rotate a line around its middle point. PE draws the profile into a chart as shown in Figure (2). PE can be run from 3-D Analyst environments, and works with TIN.

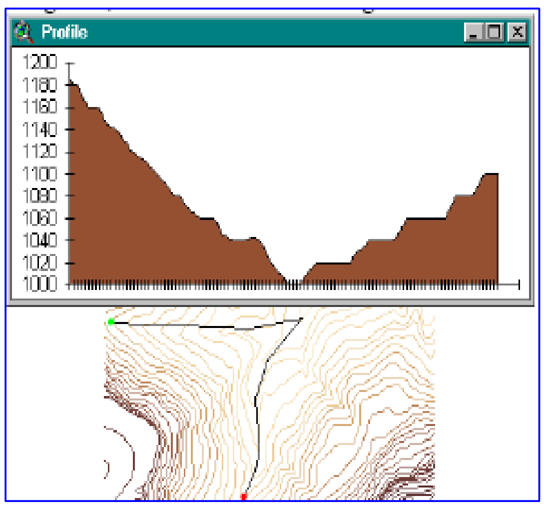

Figure (2) Sample of PE Output

4. 3D Incontrol Extension

3D Analyst is a great extension of ArcView. The user can put his data (TINs, 3D Shape files) in its viewer, see it in 3D navigate, rotate etc. 3DInControl tries to give the user control over the positioning of the Observer and Target. The user can walk interactively (or along predefined path) through 3D scene he has created after setting the location for the Observer and Target interactively on the 3D scene or associated view. In this study, this extension is to be used in the final stages, after the generated alternatives are designed, to simulate driving through the designed highway. Figure (3) shows an example of using this extension.

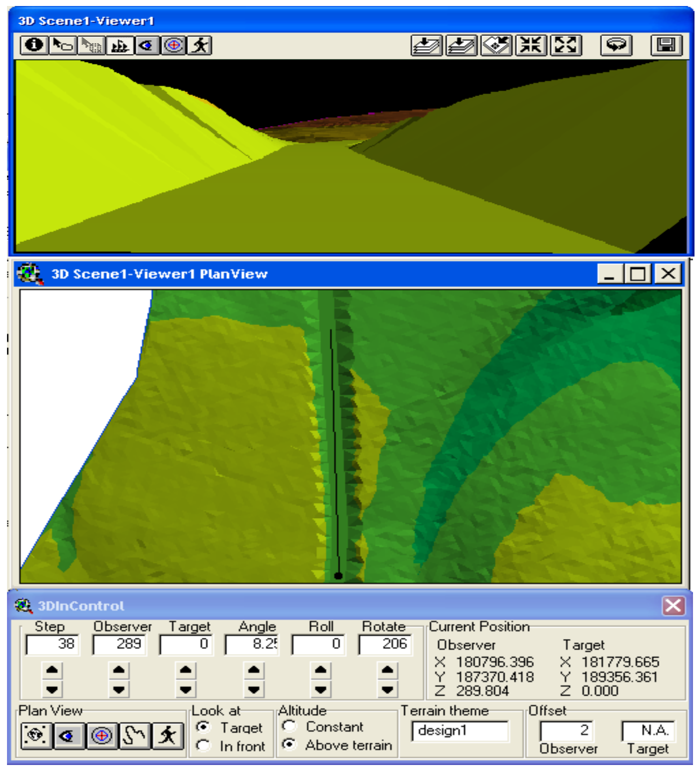

Figure (3) Example of Using 3D Incontrol

Appendix B

DATA COLLECTION

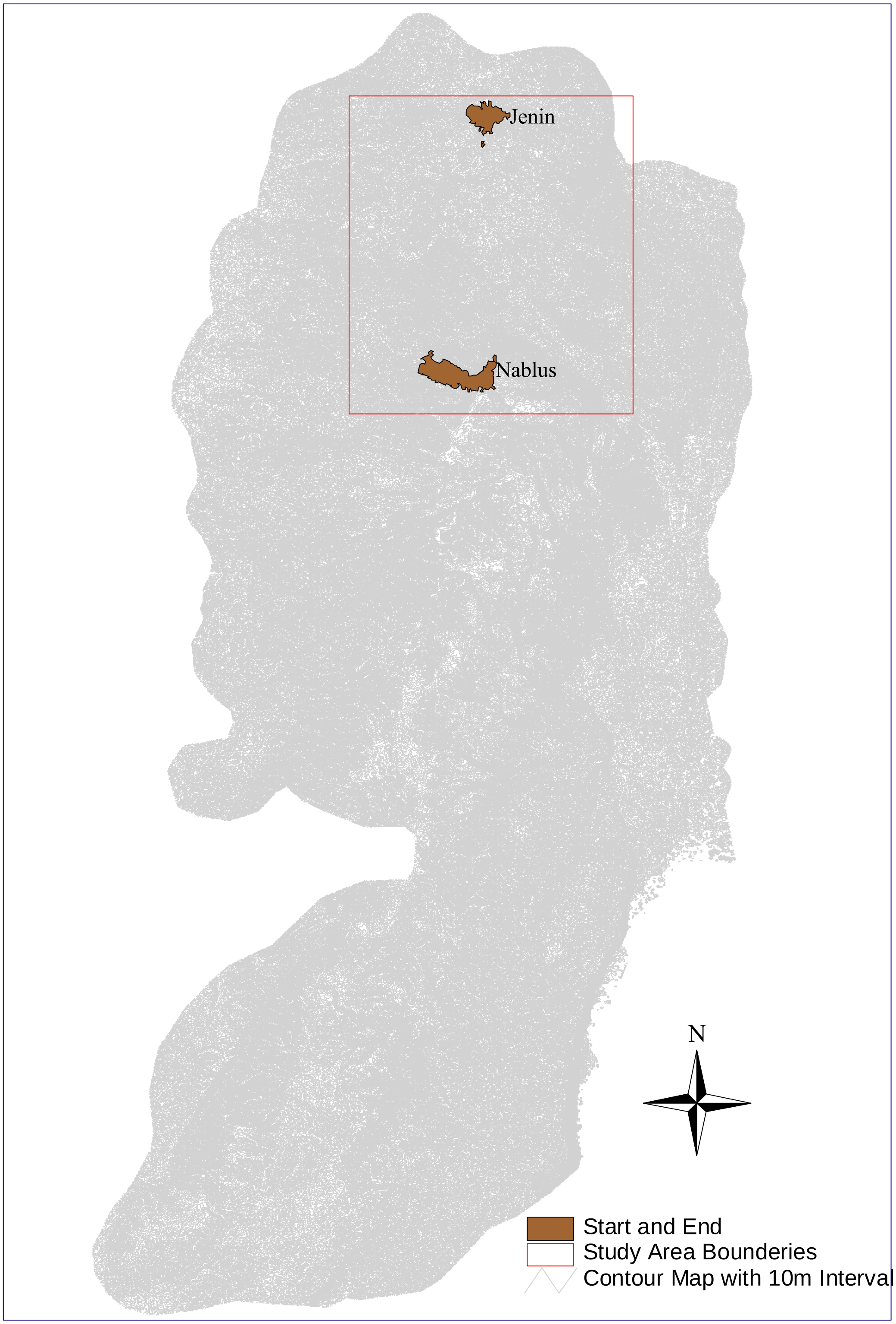

Figure (1) Contour Map of West Bank with Ten Meters Interval

Table (1) Projected Population of the Study Area from PCBS (1999)

Built-up Area Name	Projected Population in 2005	Built-up Area Name	Projected Population in 2005
Al Yamun	17134	El Far'a Camp	5906
Kafr Dan	5265	Wadi al Far'a	2405
Mashru' Beit Qad	399	Tammun	10726
Al 'Araqa	2187	Burqa	4151
Beit Qad	898	Yasid	2360
Al Hashimiya	973	Beit Imrin	2950
At Tarem	410	Nisf Jubeil	521
Jenin Camp	12570	Sabastiya	2992
Jalbun	2566	Ijnisinya	576
'Aba	171	Talluza	2761
Kafr Qud	934	An Naqura	1708
Deir Abu Da'if	5449	Al Badhan	2451
Birqin	6074	Deir Sharaf	2842
Wad ad Dabi'	381	'Asira	7994
'Arab as Suweitat	517	An Nassariya	1395
Kufeirit	2518	Zawata	1957
Umm at Tut	1032	Al 'Aqrabaniya	922
Ash Shuhada	1790	Qusin	1786
Jalqamus	1922	Beit Iba	3366
Al Mughayyir	2306	Beit Hasan	1228
Al Mutilla	270	Beit Wazan	1154
Bir al Basha	1350	Beit el Ma Camp	5188
Qabatiya	20274	'Ein Shibli	204
Ad Damayra	305	'Azmut	2806
Arraba	10285	Deir al Hatab	2326
Mirka	1601	Shihda wa Hamlan	2326
Fahma al Jadida	360	Sarra	2978
Raba	3128	Salim	5236
Al Mansura	155	Balata Camp	18175
Misliya	2318	'Iraq Burin	794
Az Zababida	3976	Tell	4882
Fahma	2511	Beit Dajan	3690
Az Zawiya	723	Madama	1708
Sir	792	Burin	2650
'Ajja	5298	Beit Furik	10714
'Anza	2065	'Asira al Qibliya	2354
Sanur	4389	'Awarta	5986
Meithalun	7212	Huwwara	5970
Al Jadida	5022	Jenin	36813
al 'Asa'asa	480	'Aqqaba	6238
Siris	5102	Tayasir	2463
Jaba'	8960	Ath Thaghra	265
Al Fandaqumiya	3462	Tubas	16526
Silat adh Dhahr	6443		

Appendix C

ALTERNATIVE THREE FIGURES

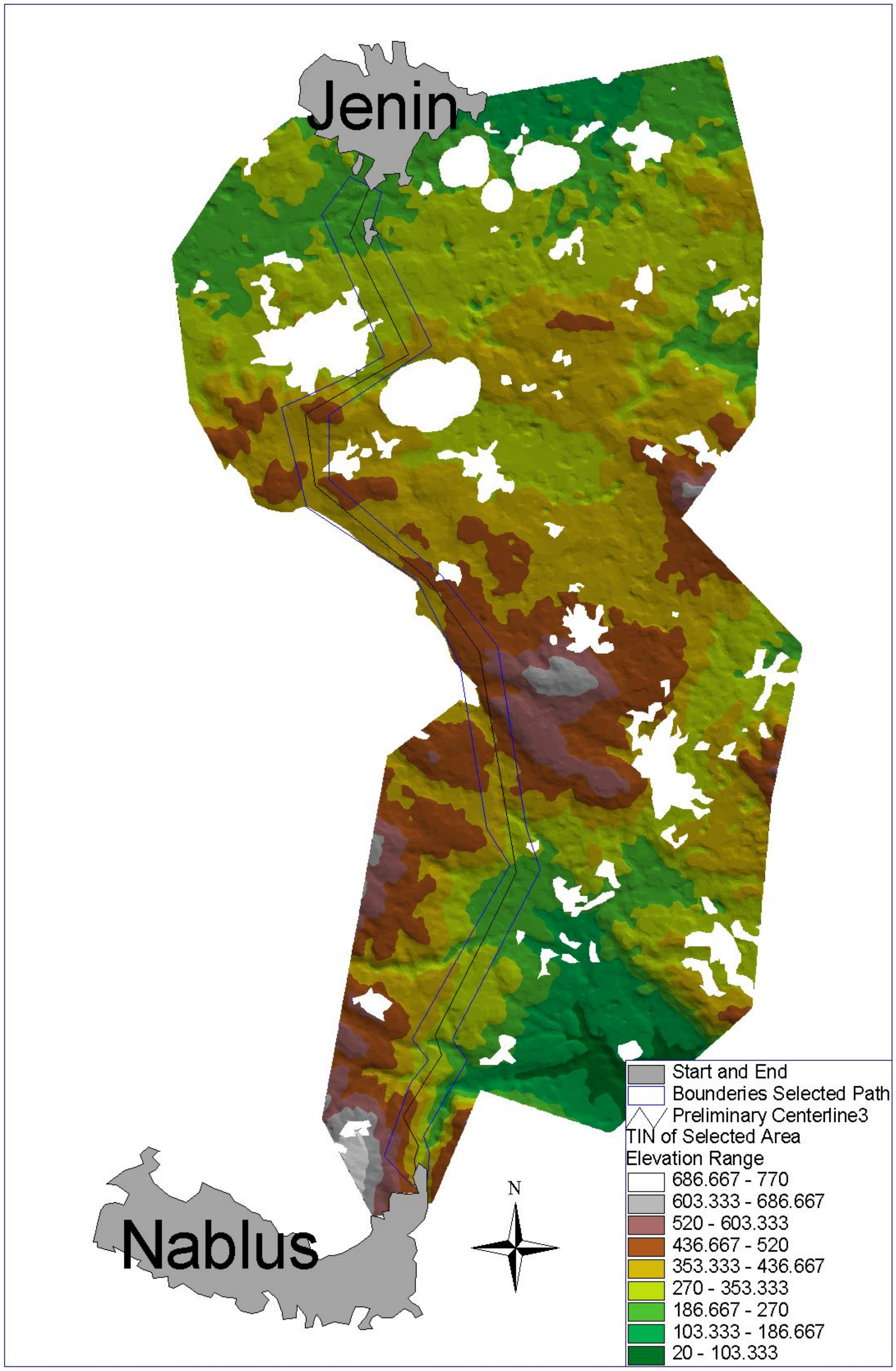

Figure (1) Preliminary Centerline of Alternative Three

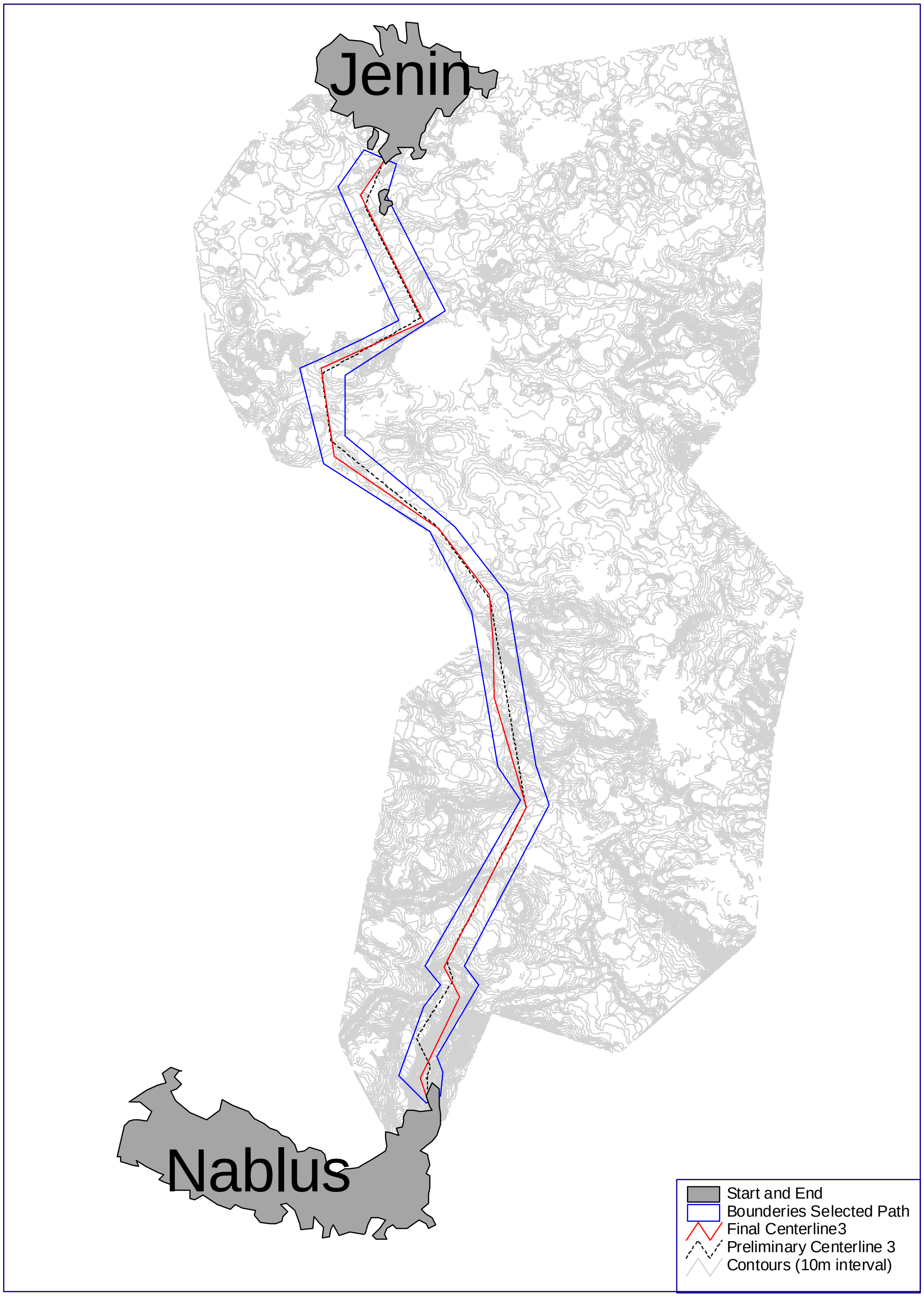

Figure (2) Preliminary Centerlines of Alternative Three

Appendix D

ANALYSIS PHASE OUTPUT

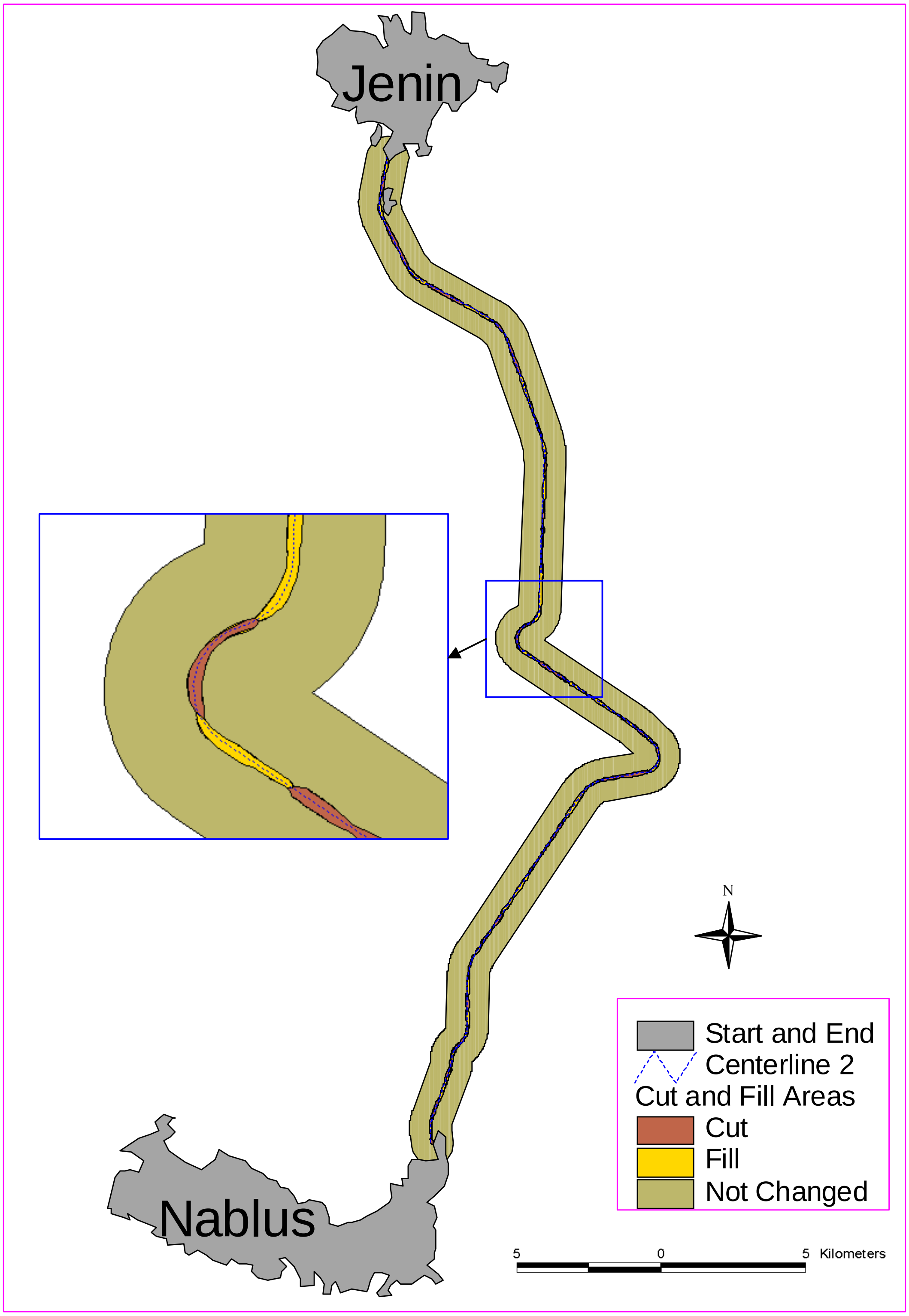

Figure (1) Cut and Fill Areas of Alternative Two

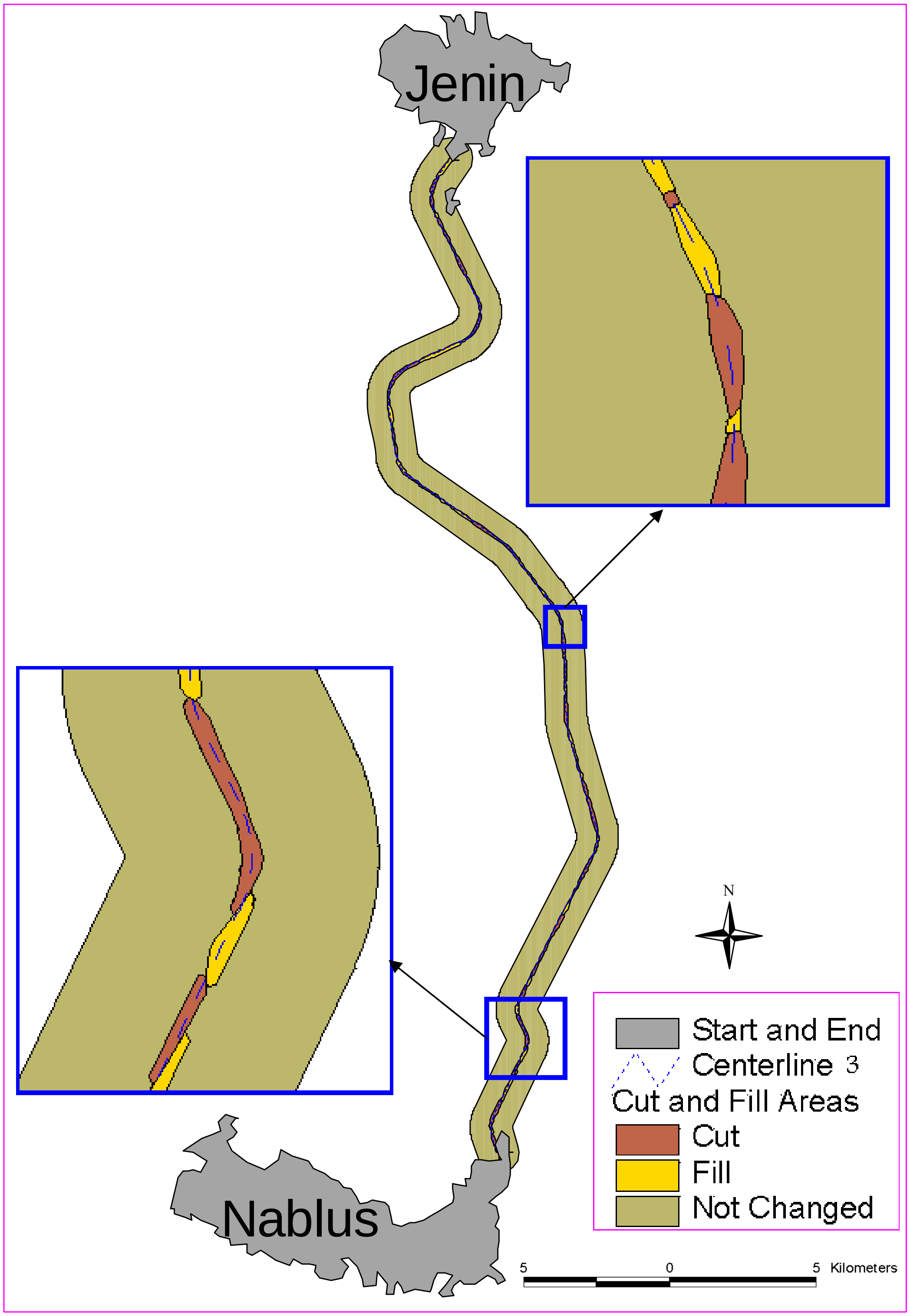

Figure (2) Cut and Fill Areas of Alternative Three

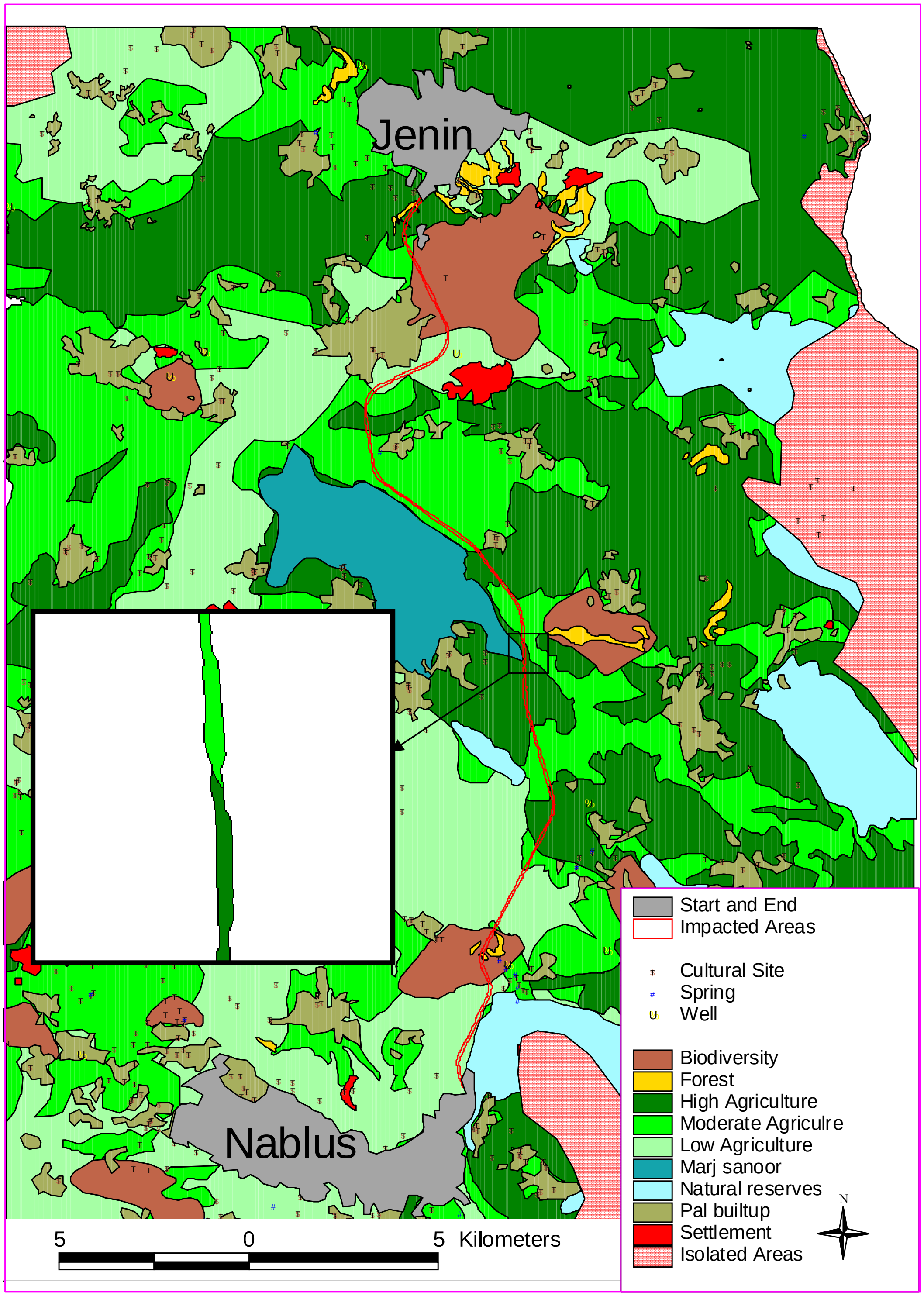

Figure (3) Impacted Areas of Alternatives Three

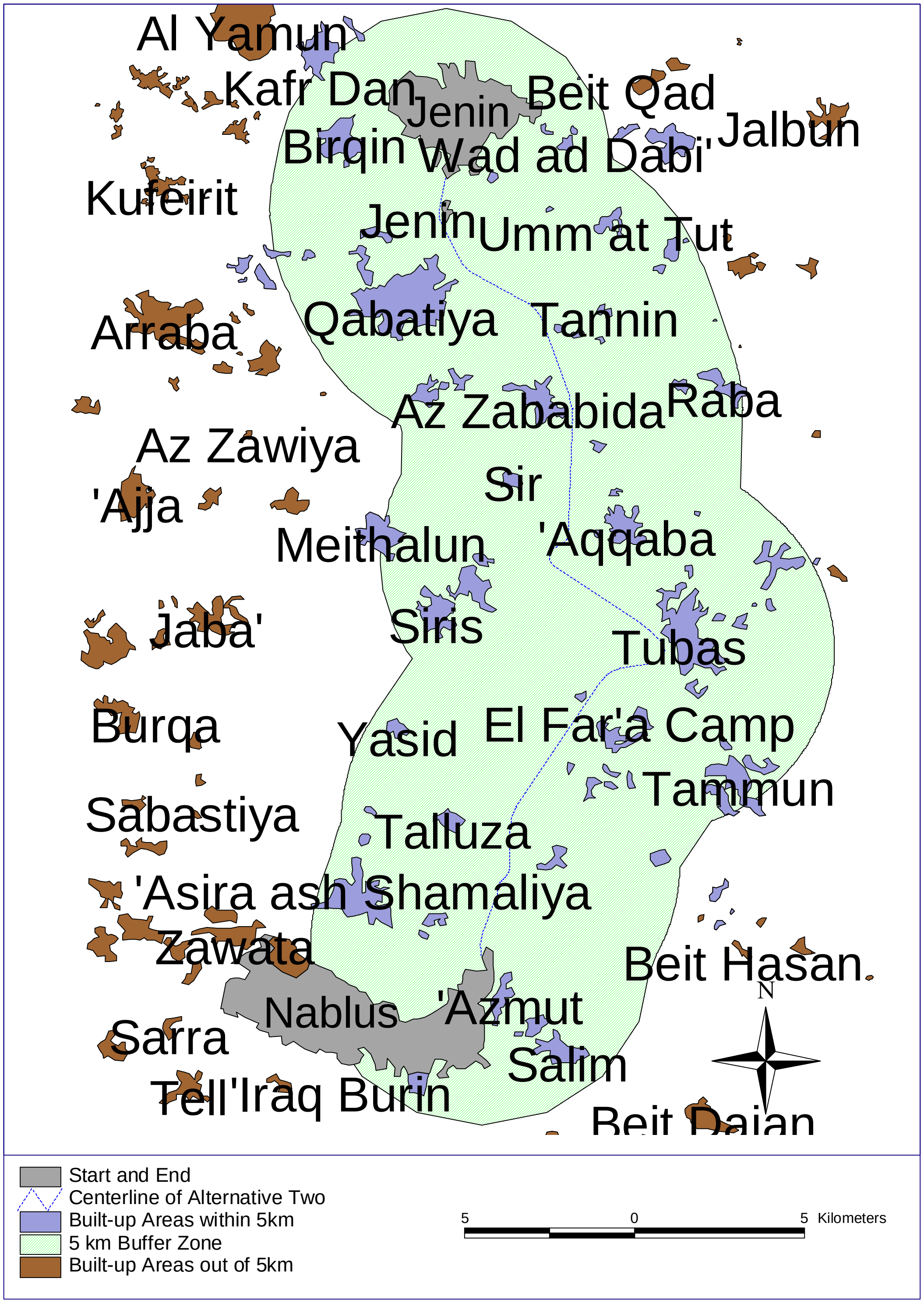

Figure (4) Built-up Areas Served by Alternative Two within Five Km

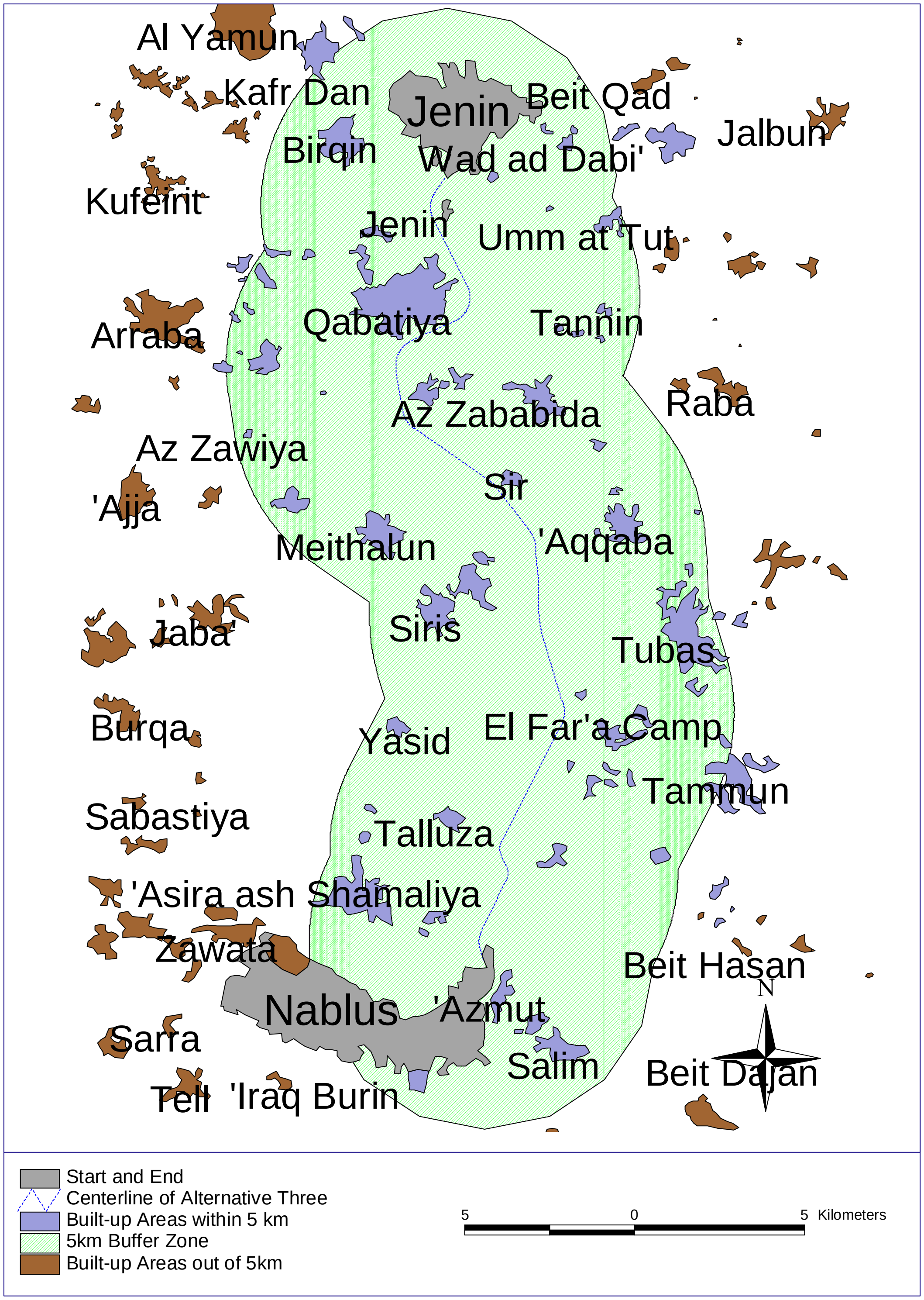

Figure (5) Built-up Areas Served by Alternative Two within Five Km

Table (1) Served Populations by Alternative One

Built-up Area	Population of 2005
Kafr Dan	5265
'Aba	171
Deir Abu Da'if	5449
Birqin	6074
Wad ad Dabi'	381
'Arab as Suweitat	517
Umm at Tut	1032
Ash Shuhada	1790
Jalqamus	1922
Al Mughayyir	2306
Qabatiya	20274
Raba	3128
Misliya	2318
Az Zababida	3976
Sir	792
Al Jadida	5022
Siris	5192
'Aqqaba	6238
Tayasir	2463
Ath Thaghra	265
Tubas	16526
Ras al Far'a	720
El Far'a Camp	5906
Wadi al Far'a	2405
Tammun	10726
Yasid	2360
Talluza	2761
Al Badhan	2495
'Asira ash Shamaliya	7994
Al 'Aqrabaniya	922
'Azmut	2806
Deir al Hatab	2325
Salim	5236

Table (2) Served Populations by Alternative Two

Built-up Area	Population of 2005
Kafr Dan	5265
Jenin Camp	12570
'Aba	171
Deir Abu Da'if	5449
Birqin	6074
Wad ad Dabi'	381
'Arab as Suweitat	517
Umm at Tut	1032
Ash Shuhada	1790
Jalqamus	1922
Bir al Basha	1350
Qabatiya	20274
Raba	3128
Misliya	2318
Az Zababida	3976
Sir	792
Meithalun	7212
Al Jadida	5022
Siris	5102
'Aqqaba	6238
Tayasir	2463
Ath Thaghra	265
Tubas	16526
Ras al Far'a	720
El Far'a Camp	5906
Wadi al Far'a	2405
Tammun	10726
Yasid	2360
Talluza	2761
Al Badhan	2451
'Asira ash Shamaliya	7994
Al 'Aqrabaniya	922
'Azmut	2806
Deir al Hatab	2326
Salim	5236
Balata Camp	18175
Jenin	36813

Table (3) Served Populations by Alternative Three

Built-up Area	Population of 2005
Kafr Dan	5265
Jenin Camp	12570
'Aba	171
Deir Abu Da'if	5449
Birqin	6074
Wad ad Dabi'	381
'Arab as Suweitat	517
Umm at Tut	1032
Ash Shuhada	1790
Bir al Basha	1350
Qabatiya	20274
Ad Damayra	305
Mirka	1601
Al Mansura	155
Misliya	2318
Az Zababida	3976
Az Zawiya	723
Sir	792
Sanur	4389
Meithalun	7212
Al Jadida	5022
Siris	5102
'Aqqaba	6238
Tubas	16526
Ras al Far'a	720
El Far'a Camp	5906
Wadi al Far'a	2405
Tammun	10726
Yasid	2360
Talluza	2761
Al Badhan	2451
'Asira ash Shamaliya	7994
Al 'Aqrabaniya	922
'Azmut	2806
Deir al Hatab	2326
Salim	5236
Balata Camp	18175
Jenin	36813

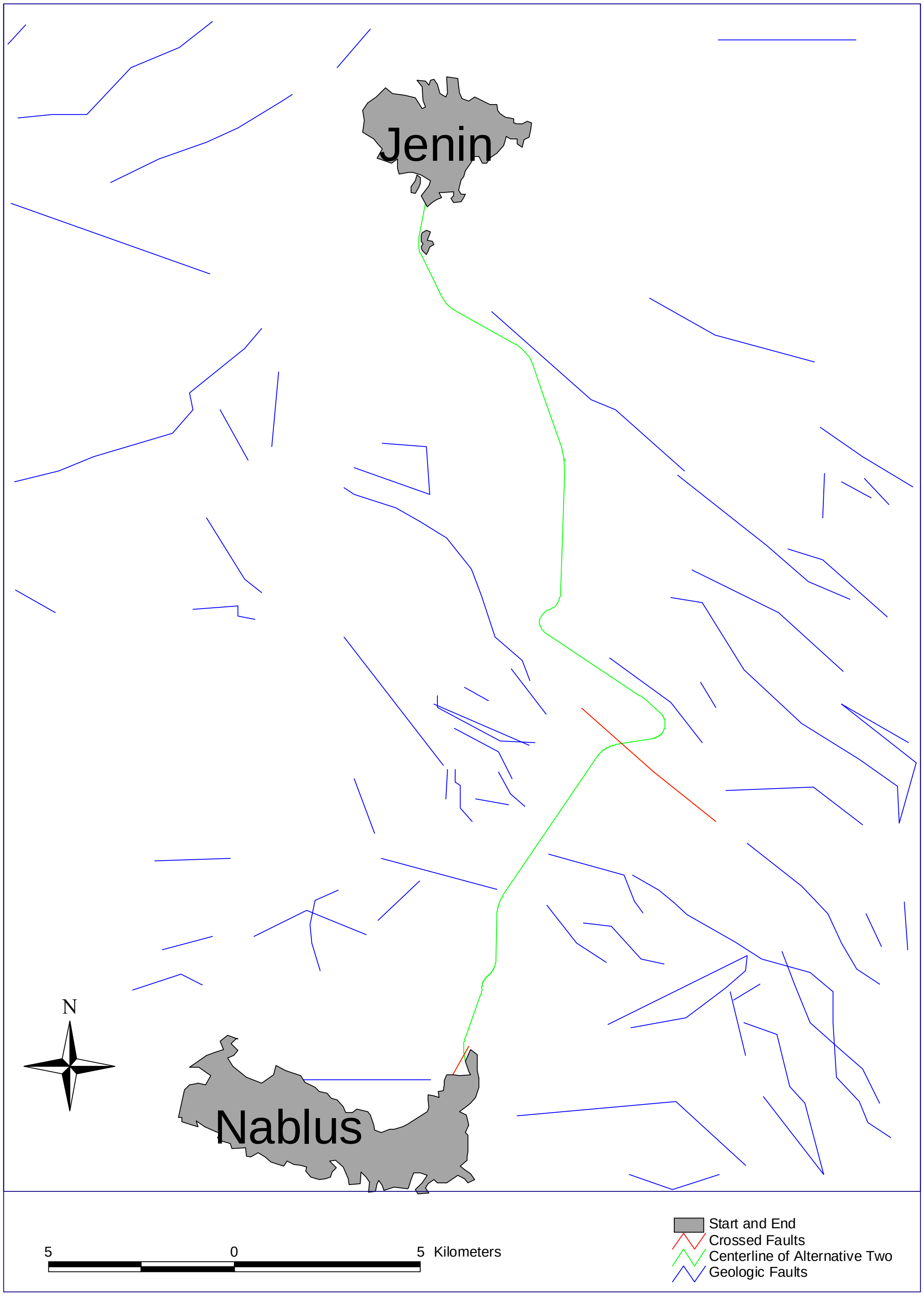

Figure (6) Crossed Faults by Alternative Two

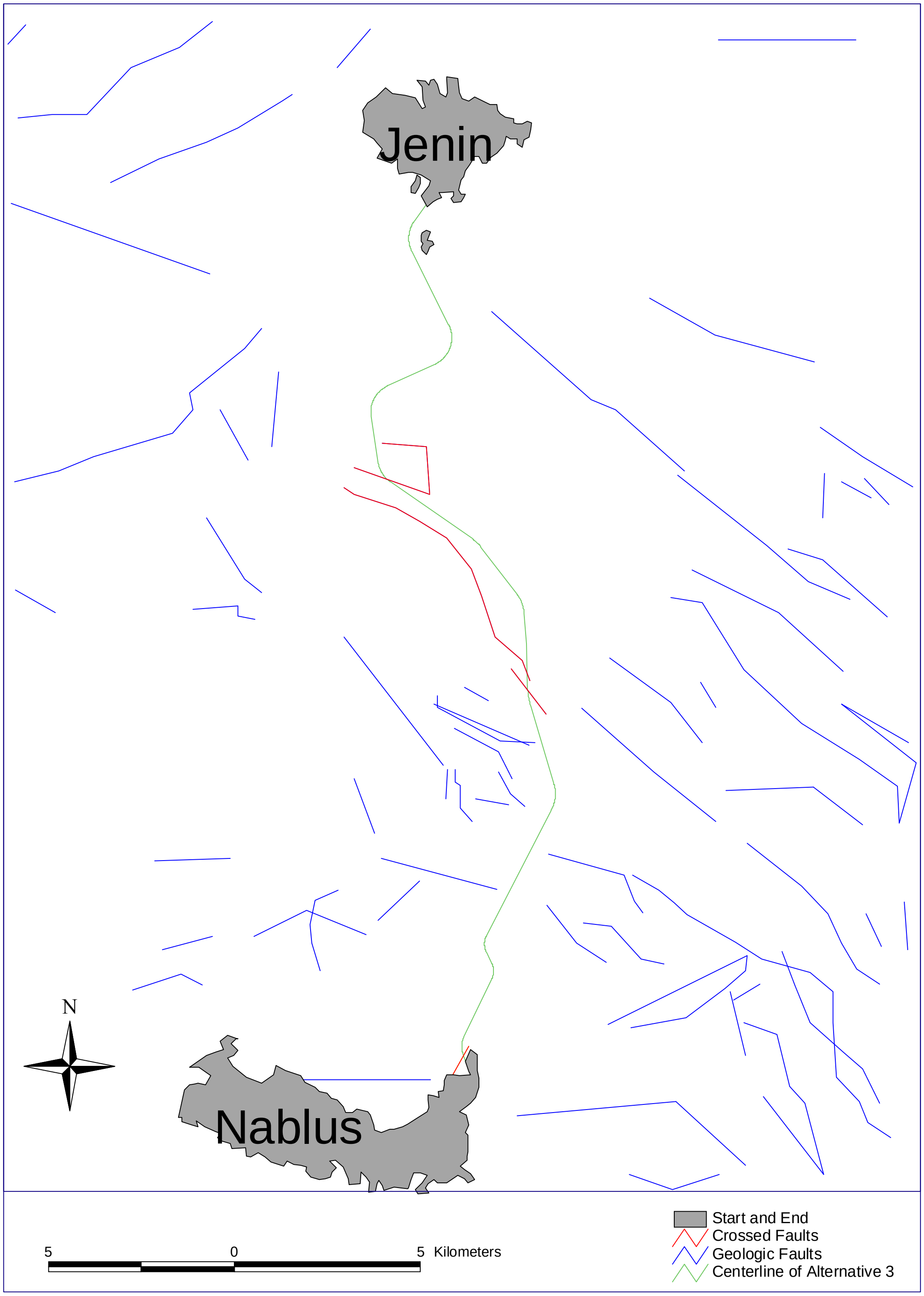

Figure (7) Crossed Faults by Alternative Three

في هذه الدراسة ظهرت امكانيات هذا النموذج في المراحل الاولية من اقتراح الخيارات بحيث تم تجنب المناطق الحساسة المختلفة والتي تم تحديدها مسبقا. كما ظهرت امكانيات النموذج من خلال امكانية الحصول على مقطع طولي لأي مسار يتم اقتراحه، و بالتالي ساعد هذا النموذج في اقتراح مسارات باقل كميات قطع وطم من ناحية، وأقل ميل من ناحية أخرى.

في المراحل النهائية للدراسة أظهر النموذج دقة عالية في تحديد وتحليل الأضرار التي الحقها كل واحد من الخيارات المقترحة ومن ثم تقييم هذه الاثار واختيار المسار الافضل. وقد تبين من نتائج هذا البحث ان هناك امكانية كبيرة لاستخدام انظمة المعلومات الجغرافية (GIS) كاداة فعالة في اختيار افضل مسار لطريق مقترح باقل الاضرار المتوقعة.

استخدام انظمة المعلومات الجغرافية (GIS)

كأداة لاختيار مسار طريق مقترح

اعداد

عماد بشير سلامة دواس

اشراف

أ.د سمير عبدالله ابو عيشة

الملخص

تعتبر عملية اختيار افضل مسار لطريق مقترح عملية معقدة بسبب كثرة المتغيرات التي يجب احذها بالاعتبار عند اختيار المسار وذلك لتحقيق افضل النتائج . ومن اهم هذه المتغيرات تلك المتعلقة بالنواحي البيئية والاقتصادية والسياسية، مناطق التجمعات السكنية، الطبيعة الطبوغرافية والجيولوجية لمنطقة الطريق المقترح، يمكن تمثيل هذه المتغيرات بسهولة من خلال استخدام انظمة المعلومات الجغرافية (GIS).

تم الاستفادة في هذه الدراسة من امكانيات انظمة المعلومات الجغرافية (GIS) والتي تتمثل في القدرة العالية على التعامل مع الخرائط المختلفة ودمجها واعداد التحليلات المكانية المختلفة باستخدام الجداول المربوطة مع كل طبقة من الطبقات التي تحتوي خرائط منطقة الدراسة.

في هذه الدراسة تم انشاء نموذج لاختيار افضل مسار لشارع مقترح و تم استخدامه في اقتراح عدة مسارات. وبعد تصميمها باستخدام برنامج (Softdesk)، تم استخدام النموذج في تحليل وتقييم الاثار السلبية الناتجة من كل مسار ومن ثم اختيار المسار الافضل الذي له اقل تاثير سلبي على الجوانب البيئية والاقتصادية والسياسية. وقد تم فحص النموذج من خلال استخدامه في دراسة لشارع مقترح بين نابلس وجنين في شمال الضفة الغربية وذلك بعد اقتراح ثلاثة خيارات لهذا الشارع باستخدام النموذج.

جامعة النجاح الوطنية
كلية الدراسات العليا

استخدام انظمة المعلومات الجغرافية (GIS)
كأداة لاختيار مسار طريق مقترح

اعداد
عماد بشير سلامة دواس

اشراف
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