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# The Use of GIS in Ecological Planning

## (A Case Study of Mount Desert Island)

Master‘s Thesis

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I hereby declare that I worked out this thesis on my own using the cited literature.

Olomouc, April 21, 2004

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# CONTENT:

*„The application of GIS is limited only by the imagination of those that use it.“*

Jack Dangermond, ESRI.

# 1. INTRODUCTION

Geographic Information Systems (GIS) and their applications have already established themselves as one of the most suitable, effective and cost efficient tool for deliberate ecological planning. It may assist planners and other people deciding about the future development of our landscape to produce the right information for multi-objective decision making. It enables them to apply various methods of mapping, monitoring and analyzing of all types of data that has a geographical or spatial aspect. It provides the possibility of conecting information from different sources and making analytical and synthetical operations that are of significant importance in the development of planning methods.

One of the central aims of this work is to demonstrate one possible way of using GIS analysis to prioritize places that may be of certain importance from an ecological planning perspective. This developed GIS model tries to indicate areas that have considerable conservation priority or, on the other hand, areas that are suitable for further development at a macro scale. This work began in the form of a project conducted as part of my GIS for Comprehensive Planning and Land Use Planning classes during my studies at the College of the Atlantic, Bar Harbor, Maine, USA in the 2002-2003 academic year. The project served as a contribution to the Comprehensive Plan for the Town of Mount Desert in 2003.

Landscape as an open ecosystem is not bound within socio-economic boundaries, so the idea was to look at the landscape not only within the Town of Mount Desert itself, but within a broader geographical area in a regional context. Thus, the studied area was extended over the whole Mount Desert Island, an island on the east coast of Maine.

Mount Desert Island is a region of natural and socio-economic characteristics that may occur at any place in the world but also has characteristics that are very different from those found in the Czech Republic. A brief explanation of the conditions that are typical

for Maine and Mount Desert Island will be made in this study. Nonetheless, I believe that the main principle of the GIS model and the planning methods can be used with appropriate modifications for any other area, including the Czech Republic.

It is important to add that the study was created under the notion of human ecology. Human ecology is an emerging multidisciplinary science concerning all aspects of human experience and everything in the environment that defines quality of life. It combines ecological affairs with social values. In one of his essays McHarg (1998) suggested that human ecology must aspire to a synthesis, including physical, biological, social processes and cultural adaptive responses. Its aim is to solve problems that exert an important influence on human development and must be approached from different disciplinary perspectives; such is the case of this work.

# 2. OBJECTIVES

The general aim of this work is to demonstrate one possible way of using Geographic Information Systems for purposes of ecological planning. To fulfill this basic objective, a lot of specific data and detailed information has to be gathered and many additional problems concerning the particular study area as well as GIS technology itself has to be explained. The basic aim of the study can be elaborated in more detailed objectives. These are:

- to write a brief overview of the basic characteristics of GIS technology, some of its specific extensions, e.g. Spatial Analyst, and its potential to be an effective tool for ecological planning;
- to characterize the typical rural development of the study area (Mount Desert Island, Maine, USA) and to explain sprawl, its nature, causes and consequences;
- to gather that quantity of information and datasets about the study area that are of significance from the ecological planning perspective and which would be useful to the local developers;
- to describe basic natural and socio-economic characteristics of Mount Desert Island which play an important role in decision-making about any further development in the region;
- to create or to transform collected GIS data layers, to perform advanced GIS cell-based analysis and to produce a suitability model for the area under study that would assist planners and decision-makers in identyfying the general geographical areas that have either high conservation priority or high development suitability at a regional scale;
- to further develop the standard GIS method that might be used in the beginning of the planning process and to document the type of work that these spatial analysis require;
- to demonstrate a methodology and a tool for not only compiling data but also for applying the values of various stakeholders;
- to appraise the potential of this methodology for implementation in the planning process in the Czech Republic.

# 3. GEOGRAPHIC INFORMATION SYSTEMS

GIS is one of many information technologies that have transformed the ways scientists and planners conduct research and contribute to society. In the few past decades these information technologies have had tremendous effects on research techniques specific to the discipline, as well as on the general ways in which scientists communicate and collaborate (Foote and Lynch, 2000). These systems allow people to collate and analyze information far more readily than would be possible with traditional research techniques.

Most of the objects and events of the real world are located in certain place on Earth or at least, they are somehow related to it. These objects do not exist in space alone but together with many others. They are mutualy related, intertwining and influencing each other. An understanding of the position and spatial relation between these objects plays an important role in solving the problems that occur in many areas of human activities. In the real world it means that we need to work both with information about the object and also with information about its location. These types of data are called geographical or spatial data and can be maintained by Geographic Information Systems.

## 3.1 Explanation of the Term

Geo Data Institute in their GIS Awareness Booklet (1993) suggests that an understanding of what Geographical Information Systems represent may be also helped by considering the component parts of the term separately.

### 3.1.1 Geographic

GIS work primarily with geographic or spatial features. As was mentioned previously, these are objects which can be referenced or related to a specific location in space, no matter whether they are physical, cultural or economic in nature. Features on a map for instance are graphic representations of spatial objects in the real world. Symbols, colours and line styles are there to stand for the different spatial features on a two-dimensional map.

Computer technology has been able to assist in this mapping process through the development of automated cartography and computer asisted design. Computer programs

can now accomplish a broad variety of tasks in a much shorter time than it would take cartographers and draughtsmen to complete (Foote and Lynch, 2000).

### 3.1.2 Information

Information in GIS represents the large volumes of data which are dealt with. All real world objects have their own particular set of characteristics or descriptive attributes. These types of non-spatial alphanumeric data are called atribute data and they need to be, together with locational information, stored and managed for all spatial features of interest. Historically maintained as paper files, computer technology has enabled much more efficient handling and management of information within automated database management systems (GDI, 1993).

### 3.1.3 Systems

Whereas complex environments are broken down into their component parts for ease of understanding and handling, they are considered to form an integrated whole. The term system is used to represent the system approach taken by GIS. Computer technology has aided and even necessitated this approach so that most information systems are now computer based. Computer systems are becoming indispensable for the storage and manipulation of the increasing volumes of data, the handling of complex spatial algorithms and the integration of data of different scales, projections and formats. All of which are essential to GIS (GDI, 1993).

## 3.2 Other Definitions

Different authors offer different definitions of GIS. However, some of them miss the true ability of GIS to synthesize information and be a powerful tool in making decisions. The most well-known definitions are the following.

Tomlin's (1990) definition taken from Geographic Information Systems and Cartographic Modeling states:

> A geographic information system is a facility for preparing, presenting, and interpreting facts that pertain to the surface of the earth. This is a broad definition . . . a considerably narrower definition, however, is more often employed. In

> common parlance, a geographic information system or GIS is a configuration of computer hardware and software specifically designed for the acquisition, maintenance, and use of cartographic data.

Star and Estes' (1990) definition of GIS in their book Geographic Information Systems: An Introduction:

> … an information system that is designed to work with data referenced by spatial or geographic coordinates. In other words, a GIS is both a database system with specific capabilities for spatially-reference data, as well [as] a set of operations for working with data . . . In a sense, a GIS may be thought of as a higher-order map.

Environmental Research Institute (1990) uses the following definition in Understanding GIS: The ARC/INFO Method:

> … an organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information.

Probably the most complete explanation is offered by Huxhold (1991) in his Introduction to Urban Geographic Information Systems:

> The purpose of a traditional GIS is first and foremost spatial analysis. Therefore, capabilities may have limited data capture and cartographic output. Capabilities of analyses typically support decision making for specific projects and/or limited geographic areas. The map data-base characteristics (accuracy, continuity, completeness, etc) are typically appropriate for small-scale map output. Vector and raster data interfaces may be available. However, topology is usually the sole underlying data structure for spatial analyses.

## 3.3 GIS *v*. Other Computer Programs

Geographic Information Systems are usually computer based with an emphasis on preserving and utilising the inherent characteristics of spatial data, by handling both components of spatial data: the physical location in space and the set of characteristics associated with that location. There are many other computer programs (e.g. CAD, DBMS)

which can use spatial data. However, they are usualy not able to combine spatial and attribute information and they do not include the additional ability to perform spatial operations (Cowen, 1988).

CAD systems (Computer-Aided Design or Computer-Assisted Drafting) provides software and techniques for input, display and visualization of spatial data. These systems were proposed for drafting and design and are used mainly by architects and engineers. They handle spatial data as graphics rather than as information. While they can produce high-quality maps, generally they are less able to produce complex spatial analyses (Foote and Lynch, 2000).

DBMS (Database Management Systems) include methods for representing data in digital form and procedures for system design and handling large volumes of data, particularly access and update. GIS tend to handle the two elements of spatial features separately, the spatial relationships being represented by graphical display and the attribute information being stored within a database. The GIS thus needs the ability to relate the attribute information to the spatial locality.

## 3.4 GIS Representation of the Real World

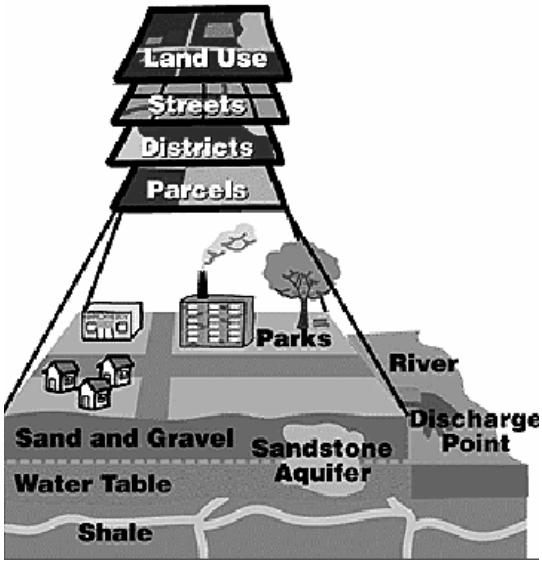
The environment of the real world is far too complicated to be presented as a whole by any information system. Thus certain areas of interest are usualy selected to be used for given purpose. Once a particular application area has been chosen the next task is to select those features which are relevant to the application and to capture information about their locations and characteristics. All these sets of features can be considered to form separate thematic maps which are referred to as layers, coverages, or levels (see fig. 1)

This means, for instance, that all the hydrological features are held on one layer and all the roads on another. This allows for separate display and processing when necessary, but does not prevent cross referencing between data layers during query and analysis. A number of data layers are thus built up into a “sandwich” within the GIS (Cowen, 1988).

It is very important that the layers are precisely registered on a grid or a locational reference system, such as latitude and longitude. Each seperate layer is also carefully overlaid on the others, so that every location on one map is relatively precisely matched to the corresponding locations on all the other maps. In addition, single locations or areas can be separated from the surrounding area by simply cutting all the layers of the desired

location from the larger map. Whether for one location or the entire region, GIS offers a means of searching for spatial patterns and processes (Foote and Lynch, 2000).

Figure 1: GIS layers (ESRI, 2000)




Considering the representation of the real world objects within an individual GIS layer, each one can be displayed as one of the three basic types of spatial features: point, line, polygon (GDI, 1993).

- Point is an object that occurs at one physical location in space and which has only one reference coordinate. Examples include trees, buildings, sampling locations, elevation points, etc.
- Line is an object which spans between points and thus requires at least two reference coordinates, its start and finish, to define its spatial location. Examples include roads, rivers, migration paths, pipes and cables, etc.
- Polygon is an object which has area and is defined by a continuous closed boundary. A number of coordinates are required to define its boundary. Examples include fields, lakes, states and counties, vegetation types, etc.

Some features may also be represented as a surface. It is a feature which requires three dimensions to define it. Thus a vertical z value needs to be added to a series of spatially distributed x, y coordinates. The z value may represent physical terrain, population density or rainfall, for example.

## 3.5 GIS Data

There are two basic types of digital data format within GIS; vector and raster. They differ in the way they were collected, the character of their storage in database, the way the attribute information is assigned to a spatial location, their purpose, and the spatial operations they enable. Most GIS software today enables conversions between the two formats or will at least allow users to display vector data over-top of raster data, provided that the latter is geo-referenced first.

### 3.5.1 Vector Data

Vector data are spatial data in the form of x, y coordinates. Each feature has a coordinate or a set of coordinates to refer to a particular location within a specific positional referencing system (Tomlin, 1990). Spatial objects are thus defined by points, lines and polygons, in a similar way to conventional paper maps and drawings. A vector data format can provide a flexible and accurate representation of an object due to the fine resolution obtainable with coordinate points. Vector structures also tend to incorporate the topology and other spatial relationships between the individual entities and are therefore ideally suited to representing linked networks such as pipe or road systems. It is very accurate for the measurement of areas or lengths Every feature of the vector structure carries its ID number to which the attribute information is assigned. Computer data storage is very economical but certain operations such as overlay analysis and proximity calculations have high computational requirements, which result either in slow operations or high hardware specification requirements. Typical examples of vector data format are results of map digitalization or GPS collected data.

### 3.5.2 Raster Data

Raster data are expressed as a matrix or array of grid cells or pixels that cover the earth's surface. Each coordinate or value is represented by a cell of various size in the regular array of cells. Thus, in contrast to vector data, the position of spatial objects can

thus be defined only to the nearest cell (Tomlin, 1990). Only one item of information is available for each location within a single layer so that multiple items of information will require multiple layers. A typical raster database will have as many layers as there are items of information (Cho, 1995).

A raster data format provides information at a much lower resolution since data can only be located to the nearest grid cell. However, there is a direct relation between positional and attribute information. Due to assigned coordinations, a pixel (digital picture with its mutualy connected neighboring cells) can be detected and its thematic content called up. Raster is especially suited to representing traditional geographic phenomena that vary continuously over space, such as elevation, slope, or precipitation.

Computer storage tends not to be economic, although data compression techniques are improving the situation. Operations such as overlay, buffering and neighborhood analysis are, however, more efficiently accomplished with a raster structure. Raster structures are ideal where the source data is raster-based, such as satellite or scanned photogrammetric data, and particularly where the data also need to be output to a raster device. Examples of data in raster format include scanned paper maps, digital aerial photographs or satellite images.

## 3.6 Basic GIS Functionality

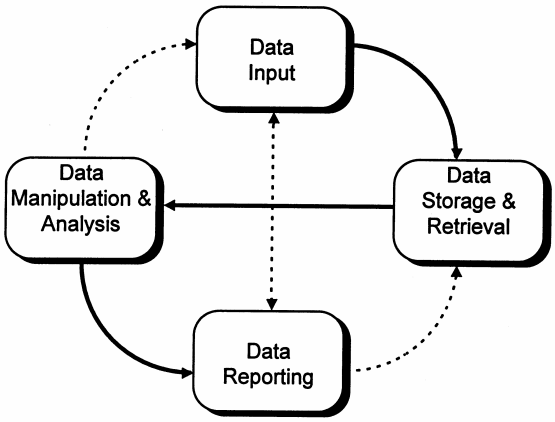
GIS have the ability to perform numerous tasks utilising both the spatial and attribute information stored within them. It is these often very sophisticated functions which are the real strength of a GIS. This functionality, represented in fig. 2, can be subdivided into four main groups (Cho, 1995):

1. Data input
2. Data storage and retrieval
3. Data manipulation and analysis
4. Data reporting

To be considered a true GIS, the software system must include all four of the functions noted above and must perform efficiently in all four areas. Thus, digitizing systems which concentrate on data capture with minimal data storage / retrieval capabilities, remote sensing and image processing systems and thematic mapping systems

do not qualify as GIS because one or more of the four ingredients are missing. In future it is thought that modelling capabilities should be included as a mandatory function of any true GIS (Marble, 1984 in Cho, 1995).

Figure 2: Basic GIS functions (Cho, 1995)




### 3.6.1 Data Input

Data input includes acquisition of data in both digital and analogue form and its transformation into an appropriate standardised format for entry into the GIS. Data sources include paper maps, satellite images, aerial photographs, field notes and other paper records. These need to be converted into a digital form, if they are not already, before the GIS can make use of them. Procedures such as digitizing, scanning, vectorisation to name a few are involved in this conversion process.

### 3.6.2 Data Storage and Retrieval

GIS enable to create, utilize and update large databases. The data are stored and indexed within a database system which facilitates access to the data and its management. Database management tends to be at the core of a GIS ensuring controlled and coordinated data retrieval and analysis. Ideally the data set should be structured in such a way as to be independent of the applications which access it (GDI, 1993).

### 3.6.3 Data Manipulation and Analysis

GIS allow users to manipulate with spatial data not only at the individual entity level but also at the level of sets of entities. Some examples of set operations are cut, paste, delete, join, selection, etc. Attribute information may be manipulated as well. Examples of attribute data manipultion include the retrieval of data values for selected features, the computation of attribute means and the calculation of statistical summaries and samples.

Geographic analysis requires a close association between the spatial elements and their attribute data. GIS provide the technology to perform sophisticated analysis which makes use of the links between the two. Queries to a GIS can thus be graphics driven or data driven. Graphics-driven queries involve spatial based searches for objects and retrieval of the associated attribute data, or point and query functions to select displayed features and retrieve the associated information. Data-driven queries involve the use of data values selectively to display the matching spatial features or the use of attribute values to determine shading pattern or colour coding of the relevant spatial elements (ESRI, 1990).

### 3.6.4 Data Reporting

Data reporting includes data output and presentation either in the form of an interactive computer display of the graphic and/or attribute data or as traditional paper maps, tables, graphs and reports (GDI, 1993). Commonly used output devices include pen plotters, ink-jet printers, electrostatic plotters, laser printers and screen copiers. Export to other systems such as statistical packages, word processors and multi-media programs require the GIS to be able to convert internal data into other standard formats.

## 3.7 Raster Analysis, Modeling and Map Algebra

Since this study deals predominantly with raster data and the developed methodology is using map algebra and comes from traditional overlay method, it is crucial for a better understanding of the described processes to explain the principles of raster analysis and map algebra.

### 3.7.1 Raster Analysis Base

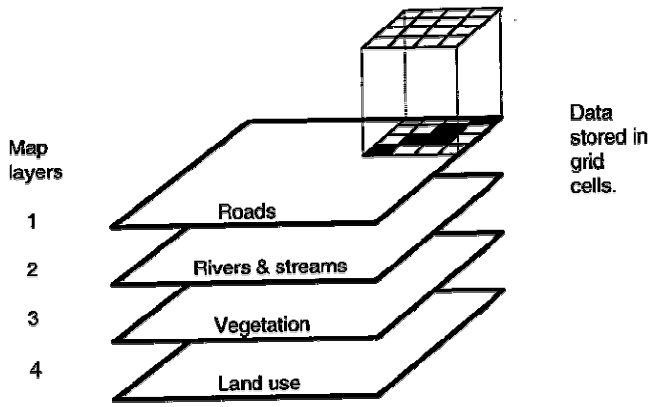
ArcGIS Spatial Analyst provides a broad range of powerful spatial modeling and analysis features. Using ArcGIS Spatial Analyst it is possible to create, query and analyze

cell-based raster data, derive new information from existing data, query information across multiple data layers and fully inegrate raster cell-based data with a traditional vector format (ESRI, 2001).

In a raster GIS the map data files are arranged as a matrix of evenly spaced grid cells or rasters. The cells are ordered in a rectangular array of rows and columns (Cho, 1995). The identity of each cell is thus referenced by its pair of row and column numbers. All map overlays in a single database are registered and referenced to the same grid matrix. The map matrix is also tied to real-world locations and features on the earth's surface. This matrix representation of real-world locations will thus allow GIS functions and operations to be performed on the data.

A map layer contains data that describes a single characteristic (e.g. roads, streams, vegetation etc.) for each location within an area (see fig. 3). Only one item of attributal information is available for each pixel within a single layer so that multiple items of information will require multiple layers.

Figure 3: Grid cells in raster layers (Cho, 1995)




### 3.7.2 Map Algebra

Map algebra is a language that is used for performing spatial analysis. It is a relatively new expression for processes based on working with layers that represent the surface of the Earth. The layers interact according to mathematical models. Applying a map algebra to input layers produces a new layer, which may be a paper map sheet or an electronic dataset displayed on a computer screen. Regardless of the mechanism, the result

allows the users to explain complex phenomena, predict trends, model what-if scenarios, etc. (Bruns and Egenhofer, 1997).

The term map algebra embodies the process of combining map layers, representing distinct but coincident themes according to a mathematical model. Map algebra in the GIS environment is considered to be originated by Tomlin (1979, 1983, 1990) and is composed of variables, expressions and functions, using exact syntax. In order to perform advanced spatial analyses, it applies conventional statistical and mathematical operations to the grid cell data sets. Some examples of these manipulations and transformations include the following:

- Reclassification: Data sets may be reclassified by dividing up a continuous range of values into discrete levels of classes. Based on contiguity, cells with the same values are classed into similar classes.
- Distance and connectivity: Paths define the line of progress along contiguous cells in any direction and a measure of distance is given by the number of cells so traversed. Connectivity on the other hand simply is a measure of linkage of the paths so defined. A further use is that of viewsheds — to assess inter-visibility among locations.
- Characterising neighbourhoods: This operation seeks to determine slope, aspect and orientation of cells. From these data it is also possible to produce profiles of the grid cells.
- Overlay: This can include set-theoretic ideas of intersection and union or cover. Thus, areas may be reformed based on given values of cells at different map levels. Alternatively, arithmetic operations such as add, subtract, multiply and divide may also be performed on the cellular data.

All of these types of map algebra data manipulation and transformation have been used in this work.

### 3.7.3 Spatial Modeling

By means of map algebra analytical operations, ArcGIS Spatial Analyst provides a robust tool for creating sophisticated spatial models for many different geospatial problems. Spatial modeling types can be divided into the groups of representation and

process modeling. The first ones describe stationery phenomena of the environment, the second may emphasize the process point of view but is often use to predict what will happen if some action occurs (ESRI, 2001). Some examples of spatial models include:

- Distance Modeling: for instance involve finding optimum or shortest way from one place to another;
- Hydrologic Modeling: may predict where the water in some area will go;
- Surface Modeling: may include prediction of certain types of pollution level in specific region; and
- Suitability Modeling: (the modeling this study mainly deals with) might help to calculate optimal site locations by identifying possible influential factors, creating new datasets from existing data (e.g. slope, etc.), reclassifying the data to identify areas with high suitability, and finally aggregating these into one logical assesment of optimal suitability.

## 3.8 Potential of GIS

Abler (1987) described the potential of GIS technology and predicted its future use in geographical analysis:

> GIS technology is to geographical analysis what the microscope, the telescope, and computers have been to other sciences.... (It) could therefore be the catalyst needed to dissolve the regional-systematic and human- physical dichotomies that have long plagued geography and other disciplines which use spatial information.

GIS has the potential to link geography with other sciences including the social ones. The use of GIS with other technologies, such as remote sensing and computer science, has helped geography cross over into other fields such as ecology, land use planning, resource management, anthropology, and many others. The implications of connecting a broad range of sciences dealing with spatial information were articulated decades ago, perhaps most convincingly by McHarg (1969) in his landmark book entitled *Design With Nature*.

GIS have enabled McHarg's visions to become a reality. Their appeal stems from the ability to integrate great quantities of information about the environment and to provide

a powerful repertoire of analytical tools to explore them. The ability to separate information in layers and then combine them with other layers of information is the reason why GIS hold such a great potential as research and decision-making tools.

# 4. RURAL LANDSCAPE AND DEVELOPMENT IN MAINE

The study area, Mount Desert Island, is located in the state of Maine, on the east coast of the USA. It consists predominantly of a rural type of landscape, no cities occurs on the Island. Rural land in the whole of New England has its typical nature and reveals specific traits that have not been much changed for decades. The traditional character of the rural landscape and especially the major issues of new and spreading development that has been occuring during the last twenty yeras must be explained to better understanding some of the analyses that are demonstrated in this study.

The traditional character of the Island rural landscape is well decribed in Charles Elliot's report from 1904. He sees it as "...a landscape of a rare beauty...which contains a variety of woods, pastures, cultivated fields, gardens, farms, barns, and houses...a landscape that is on the whole more interesting than the monotonous sweep of an unbroken forest" that takes place in unoccupied parts of Maine. Due to the Island's location and its maritime influences some of the major occupations of the year-round inhabitants are fishing, lobstering and boat-building. Thus boats, piers, harbors and other traits connected with these activities are some of the typical features of the Island's landscape.

Mount Desert Island is valuable from the ecological point of view as well, therefore Acadia National Park was established on a significant portion of its area. While surrounded by the ocean, the entire fabric of Acadia is interwoven with a wide variety of freshwater, estuarine, forest, and intertidal resources, many of which contain plant and animal species of international, national and state significance. The mountains, steep slopes and rocky shore are the dominant features of the landscape and the activities associated with the park are very important elements in the social and economic life of the local communities.

Concerning the traditional type of development in Maine and on Mount Desert Island, small towns and villages with their typical atmosphere and architecture of wooden houses are the most usual. The nature of the rural villages and the attitude of the local communities to them can be characterized by the quotation of Former Maine Governor Angus S. King, Jr. (in SPO, 1997): "There is no finer creation than the New England village. It is testament to the livable community - a community of neighborhoods, churches, shops and town hall. It is testament, too, to the countryside that surrounds it. The contrast between village and countryside in Maine is as crisp as a fresh apple, picked on a fine fall day. We savor both." Main Street is a typical but today obsolete model for

development of the centers of Maine's rural towns and villages. Kunstler (1996) specified the pattern of Main Street as a: mixed use of buildings and public space, inhabited by people with diverse income, apartments and offices located over the stores, moderate density of houses, scaled to pedestrians, vehicles permitted but not allowed to dominate, buildings detailed with care, and built to last.

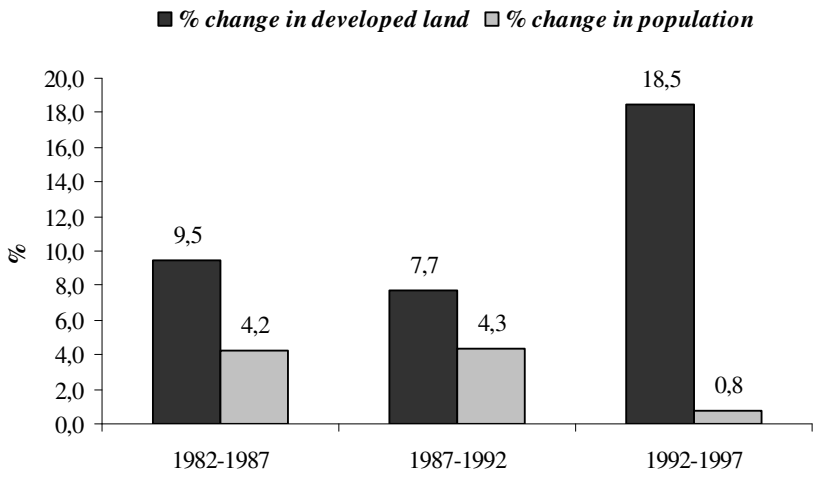
The majority of people in Maine prefer to live in the countryside rather than in cities, due to the qualities of life that are associated with rural living. One of the main reason for the attractivnes of these areas is termed "rural charm" (Kunstler, 1998). It is the opportunity to live in connection with the rich patterns of other organisms, namely plants and animals, and their interactions with natural patterns like the seasons or the cycles of day and night. Despite, or perhaps due to, the fact that most of the American people highly value countryside in Maine, rural areas across the state of Maine are disappearing. Many people are moving from cities and larger towns to rural regions. However, the rate that land is being developed, and more importantly, the way that land is being developed, is leading to the loss of most of these desirable characteristics that are associated with rural landscape.

## 4.1 Sprawl Development in Maine

The Maine population is spreading out. Outlying towns, those located a 20-30 minute drive from major service centers, are growing faster than any other areas in the state of Maine (Rowan, 2003). Between 1960 and 1990 the populations in these areas doubled. Furthermore, land development occurres at a much higher rate (fig. 4) than the population increase (MLWRC, 2002). The population shift from higher to lower density development is changing Maine's rural land use pattern. Planners usualy term this pattern of development as "sprawl".

Sprawl is the process of spreading out in an awkward or uneven way, especially so as to take up more space than is necessary. As a pattern of growth, it is a leapfrogging of development that goes beyond the reach of existing municipal services, consuming large amounts of land and, in the process, prematurely converting rural lands to urban or suburban use (Richert, 1997).

Figure 4: Percentage Change in Population *v*. Land Developed in Maine 1987-1997




Downs (1998) looked inductively at all the criticisms of sprawl in the literature, and derived those traits which cause them. Such traits are:

- unlimited outward extension,
- low-density residential and commercial settlements,
- leapfrog development,
- fragmentation of powers over land use among many small localities,
- dominance of transportation by private automotive vehicles, low walk-ability
- no centralized planning or control of land-use,
- widespread strip commercial development,
- great fiscal disparities among localities,
- segregation of types of land uses in different zones.

Most of these traits are characteristic for all the places where the sprawl type of development has been identified.

### 4.1.1 More Statistics

The rapid pace of the sprawl progress in Maine can be documented using demographic statistics. The following data were taken from the State Planning Office, Maine Facts and History Statistics, and Maine Land & Water Resources Council. The State

Planning Office recognizes 95 service center communities and additional municipalities in Maine, where 78% of the state's jobs are located. In 1960, 65% of the Maine population used to live there. In 2000, it was less than 50%. These people are now commuting to their jobs from remote rural areas. From 1960 to 1990 the state's population grew by 261,000 people. The increase of 211,000 people (81% of the total) occured in high growth towns in rural areas, away from traditional service centers. Most of the growth is not caused by a high birth rate but by the migration of people moving from central communities to low density dvelopment. During the 1980's and 1990's, net migration to the rural communities exceeded 60,000 people. Net migration to the centers seemed to be barely even. A little more than 50% of Maine's population live in the traditional service centers communities. These are spread over the less than 20% of the organized land and include around 30% of the state's road system. Over 30% of the population lives in outlying growth towns, consuming about 50% of the organized land, with more than 50% of the road system.

### 4.1.2 Causes of Sprawl

Although sprawl is recognized as one of the major problems threatening the life of communities in the state of Maine many people see advantages of this type of settlement rather than the disadvantages that are commonly associated with it. Richert (1997) pointed out that sprawl is a highly democratic form of development for home buyers and those seeking business locations. It maximizes their choices, creates competition and assures a range of prices for different locations and different types of housing in the marketplace. That is why it is supported by market, as well as, political forces. Concerning housing, Maine society can be characterized by specifically strong individualism and consequently a desire for space and privacy, which can be found in the low density development of rural areas. In combination with advances in telecomunication technology and the low cost of fuel, it creates a significant force, drawing people from central communities to the more remote countryside.

However, while the public might express hostility for the concept of sprawl it continues. Everyone making a decision to move to a rural area undoubtedly does so in his or her family's best interests. Not many are aware of the fact that they are imposing costs society-wide by making such a decision. Despite the possible benefits that sprawl development can have it brings seldom formally recognized negative impacts to the rural communities.

### 4.1.3 Costs of Sprawl

The Maine State Planning Office (1997) has identified three basic costs that sprawl and the processes associated with it impose on communities: fiscal costs to taxpayers and governmental services, environmental costs, and costs to a community's character.

#### 4.1.3.1 Fiscal Cost

One of the major reasons why people move to rural areas, apart from the different life-style, are the lower property taxes. However, after all other expenses associated with living in outlying growth areas are summed, it is obvious that the "invisible" costs, such as higher expenses for gasoline, car maintenance or insurance bills, have more than offset the savings in property taxes. That is because population shifts and changes in development contribute to changes in travel patterns. Due to the suburban development pattern, the Maine population's dependence on privately owned vehicles for almost every need is reinforced. From 1987 to 1994 Maine municipalities accepted new roads at a rate of 100 miles a year (SPO, 1997).

As more people move into an area it starts to feel less like the country. Owing to higher expenses for services, taxes begin to rise and people again move further into the country where taxes remain low and open space available. This pattern demonstrates how the individual desire to reduce living expenses ends up increasing the property taxes and living costs for the entire community. Spreading out contributes to increased local and state spending by requiring the creation of new roads, schools, safety facilities, and other services in rural areas, while requiring the continued support of older, underutilized public facilities in increasingly depopulated centers. From 1984 to 1994 property taxes collected in growth towns increased by 89% after adjusting for inflation - twice the rate of the budget increase in service center communities (Richert, 1997).

Low density development in remote areas requires the construction of an extensive road system. Sixty-three percent of the total road mileage is located outside of the service center and other urban communities. In service center communities there is an average of about 43 housing units per mile of public road. In the outlying communities there are only about 19 units per road mile (SPO, 1997).

Concerning schools, the numbers of elementary and secondary school students in Maine are decreasing. However, between 1970 and 1995, 46% of the state school budget was used to build new capacity in schools in remote growth towns (MLWRC, 2002).

While many schools in service centers were closed for lack of children new ones were built in outlying areas. Expenditures for school busing increased as well, despite the decline in student numbers. The money used to bus children to school might have been used to purchase school equipment. The case with public safety facilities is similar. Even though criminality declined by 17% from 1980 to 1993, the number of police officers and police budget expenditures increased. This is due to the need to add new patrols to serve people living in outlying areas.

#### 4.1.3.2 Environmental Cost

Sprawling land development is known to have cumulative impacts on the environment. The types of environmental problems range from the consumption of open space and habitat fragmentation and loss, polluted water runoff which affects both surface and ground waters, to air pollution from higher rates of automobile use.

##### 4.1.3.2.1. Habitat Loss and Fragmentation

Sprawl induced destruction, degradation and fragmentation of habitat is one of the driving forces behind today's alarming decline in real numbers of species not only in Maine. According to the Sierra Club (1998), habitat destruction is the leading cause of species endangerment, threatening 80% or more of federally listed species. Indeed, it is at least part of the reason why more than 95% of listed species are imperiled. Habitat destruction and degradation is a factor in the decline of every category of species. For example, an examination of recovery plans for 98 plant species currently listed as threatened or endangered, revealed that habitat loss due to human activities was the primary cause of endangerment of 83% of the species. For migrant bird populations, the decline of close to 40% is directly linked to habitat destruction. For amphibians, declining populations are linked to habitat destruction, the introduction of exotic species, water pollution and ozone depletion. Habitat destruction was also a contributing factor in the extinction of at least 73% of freshwater fish in North America and the leading threat to fish species currently considered threatened, endangered or of special concern.

The construction of new road structure and low density development is a significant source of landscape and habitat fragmentation. The construction of new roads and houses breaks up large diverse ecosystems into smaller parts. The extinction of ecosystem types and component species may cause increased patchiness of the landscape resulting in lower population sizes and decreased connectivity. As a result, inhabitants may experience

decreased dispersal abilities and lowered gene flows between populations (Roman *et al.,* 2001). With amphibians, for example, even a single road across their habitat may be enough to create genetically divergent groups (Terris, 1999) which may end up with a lack of genetic variety within each subgroup resulting in degenerative inbreeding. Fragmentation of habitat may also separate a species from its feeding or breeding grounds, which results in higher sensitivity to stress. In some cases, not even the first generation survives. Or, a species may survive only until the first environmental stress, such as a drought, occurs, when it is trapped in a small and isolated area. Generally, the more fragmented, the more vulnerable to any stress an ecosystem is (Forman & Godron, 1986).

#### 4.1.3.2.2 Water Runoff

The hydrological features of undeveloped land, is valuable not only from a biological and ecological point of view, but represents important sites for recreation and sources of drinking water. It has been evident for some time that sprawl development causes serious water pollution problems. In Maine, it increases the amount of nonpoint source pollution in lakes, streams and wetlands. Low-density, automobile-dependent development creates unnatural surfaces, such as roads, pavements, parking lots, which are impervious. Transportation-related hard surfaces account for over 60% of the total imperviousness in suburban areas (May, 1997). The large number of hard surfaces created by traditional suburban development fundamentally alters the local movement characteristics and availability of water. The loss of forests, meadows, streams, and wetlands, which is associated with sprawl, and the road-building and creating of other impervious surfaces instead of natural areas, prevents rain and snowmelt from soaking into the ground. Under natural conditions, rainwater filters into the ground, feeding rivers through springs and seepage during dry periods, and recharging underground aquifers. Under the conditions of sprawl development, precipitation runs off impervious surfaces much more rapidly and in much greater volume than under natural conditions. The result is a decrease in groundwater flows into streams, less recharge into aquifers, an increase in the magnitude and frequency of severe floods, and high stream velocities that cause severe erosion and mobilize large quantities of sediment, damaging water quality, aquatic habitat, and infrastructure (Otto *et al*., 2002).

Impervious surfaces also cause pollutants to be washed off and ultimately deposited into the receiving streams and lakes. Increased pollution has multiple consequences on surface waters including compromising its quality as drinking water. Pollutants stimulate

algal blooms, increase water temperature and decrease visibility in lakes. Tracking the consequences of increased development and pollution loads in lakes relative to increased development within a lake's watershed could provide an indicator of the health of Maine's lakes relative to the impact of sprawl (MDF, 2002). Fortunatly, according to Maine's Department of Environment Protection, 97 % of Maine's lakes, which are recognized as significant, were, in 1998, only slightly affected by pollutants and were fully swimmable. However, 749 miles of the 31,752 total miles of rivers, streams and brooks in Maine were estimated to not fully support one or more of their designated uses – which include fishing, aquatic life and swimming (MEPC, 1998). In addition, of about 1.8 million acres of tidal flats and waters in this state, about 15%, or 270,000 acres are closed to shellfishing. While septic tanks, straight pipes, bacterial contamination, and toxins play a role, much of the problem is a result of non-point source runoff caused by sprawl (Buck, 1998).

#### 4.1.3.2.3 Air Pollution

The traditional quality of life in rural Maine is associated with clean air. However, Maine's air quality is heavily affected by the fact that it is downwind of both major energy production plants in the Midwest, and the urban transportation corridors of Boston and New York City. Most monitoring activities measure the impact of these sources of pollution rather than local emissions (MEPC, 1998). Thus, there is lack of data on local emissions. However, it is clear that an increase in car use results in an increase in air pollutants in these areas. Mobile sources, including automobiles, contribute to the presence of hazardous air pollutants, such as nitrogen oxides, as well as the formation of ground-level ozone. The concentrations of ozone in Maine's air do exceed threshold levels for plant damage on an episodic basis (MEPP, 1996). Nitrogen oxides are of concern due to their potential for soil acidification and the resulting imbalances in nutrient cycling as well as their role (along with that of sulfur oxides) in the acidification of some lakes.

#### 4.1.3.3 Cost to the Community Character

Current sprawl patterns also change the very nature of the communities themselves. Land previously organized for production is now organized for consumption (Richert, 1997). Those places which were formerly working landscapes – whether in agriculture, forestry, fishing, or other natural resource based industries – are now devoted almost entirely to commuters (Rowan, 2003). Owing to the spreading development, many traditional historic "anchors" in town centers, such as traditional neighborhoods, "Main

Streets", stores, post offices, or churches, and other historic buildings, that presented the specific identity of a place, have been changed for roads and subdivisions. This creation of a sense of no-where, due to the lack of planning, has led to the loss of people's connection to their landscapes and to each other.

Some may discount the concept of "rural character" as a platitude unimportant in the face of issues such as regional economics, but in fact the character of these towns is unavoidably intertwined with these other issues, not to mention being important in its own right (Rowan, 2003). The environment and the aesthetic arrangements that surrounds us can have a profound impact upon both our physical and mental health. Such things as the chemical composition of the air, the nature of the light, the arrangements of objects we are surrounded by, how pleasant we consider our surroundings, all influence our mental functions and how we perceive the environment and those around us (Hiss, 1990). Kunstler (1998) even asserts that the living arrangement Americans now think of as normal is bankrupting them economically, socially, ecologically and spiritually. He identified the physical setting itself – the cartoon landscape of car-clogged highways, strip malls, tract houses, parking lots, junked cities, and ravaged countryside – as not merely the symptom of a troubled culture but in many ways a primary cause of its troubles.

### 4.1.4 Solving Sprawl

Sprawl is undoubtedly occuring in Maine and both benefits and costs are associated with it. The questions is whether the costs outweigh the benefits that Maine's inhabitants perceive as deriving from this type of development. The problems of sprawl are still not widely recognized or acknowledged. There is still a need for a statewide dialogue among Maine residents, planners, environmentalists, ecologists, and municipal officials, which could help to find solutions. However, some alternative strategies which could prevent a sprawl pattern of development and its costs have already been developed. One of them is refered to as Smart Growth. The Sierra Club (2000), in its report called *Smart Choices or Sprawling Growth* defines Smart Growth as "intelligent, well-planned development that channels growth into existing areas, provides a public transportation option, and preserves farm land and open space."

Otto *et al*. (2002) emphasize several basic principles which are included in the Smart Growth concept. These principles are the following:

- mixing land uses;
- taking advantage of cluster building design;
- creating a range of housing opportunities and choices;
- fostering walkable, close-knit neighborhoods;
- promoting distinctive, attractive communities with a strong sense of place;
- preserving open space, farmland, natural beauty, and critical environmental areas;
- strengthening and direct development towards existing communities;
- providing a variety of transportation choices;
- makeing development decisions predictable, fair, and cost-effective;
- encouraging citizen and stakeholder participation in development decisions.

In 1997 the State Planning Office suggested several research directions that might be taken to prevent sprawl. Besides reducing the regulatory burden of in-town development and investing in town and village centers, it highlighted the need for comprehensive regional planning. In the past decisions about new development were too often made on a case-by-case basis, without considering regional implications. The State Planning Office is retooling its Growth Management Program to help municipalities to work together to plan important decisions that affect growth regionally.

Through comprehensive regional planning, towns must review existing conditions, predict future needs, and develop policies and strategies for guiding future decisions. These policies must address a range of issues such as the protection of natural resources, the provision of affordable housing, the local economy, historic resources, and overall community character (Quintrell, 1990). The heart of regional planning is the designation of "growth areas", those areas which are highly suitable for development and "rural areas", those having a high conservation priority. Demonstrating the possible use of GIS in identifying growth and rural areas was the major goal of this study.

# 5. COMPREHENSIVE PLANNING IN MAINE

Comprehensive planning in Maine began during the 1990's. Over 300 communities developed comprehensive plans pursuant to the Planning and Land Use Regulation Act (30-A M.S.R.A. §4301 *et seq*), commonly referred to as the Growth Management Act. This groundbreaking law established a program that for the first time provided state funding for comprehensive plans, and set forth goals and other criteria that communities were challenged to meet (SPO, 2002).

For many municipalities, the comprehensive planning efforts of the 1990's were their first efforts at working with a broad group of citizens in developing a planning document that was truly comprehensive. And it was the first time that the state endeavored to make cities and towns take a hard look at their growth patterns with an eye toward the enactment of strategies that might more effectively guide development. The result was a new generation of comprehensive plans, most of which designated "growth" and "rural areas," recommended measures for managing and directing growth relative to these areas, and included an array of other policies and strategies aimed at addressing local issues and state and regional goals.

Some of the major state goals for comprehensive planning aim:

- to encourage orderly growth and development in appropriate areas of each community, while protecting the State's rural character, making efficient use of public services and preventing development sprawl;
- to plan for, finance and develop an efficient system of public facilities and services to accommodate anticipated growth and economic development;
- to protect the quality and manage the quantity of the State's water resources, including lakes, aquifers, great ponds, estuaries, rivers and coastal areas; and
- to protect the State's other critical natural resources, including without limitation, wetlands, wildlife and fisheries habitat, sand dunes, shorelands, scenic vistas and unique natural areas (SPO, 2002).

A commonly held rule of thumb for the time period after which the comprehensive plan would have to be evaluated and updated, is five and ten years respectively. Using an

outer limit of ten years also makes sense because this is the length of the planning period as defined in the statute, and most plans use that time frame for the purposes of projections and need/issues identification. Beyond a decade, plans become particularly outdated, as their projections, identified issues and proposed strategies become less accurate or relevant.

## 5.1 Comprehensive Plan for the Town of Mount Desert

In 2003, the Town of Mount Desert began the evaluation and updating process of its comprehensive plan. The Town of Mount Desert Planning Board encouraged professional planners, citizens and students to participate in the preparation of the plan. As a student of the College of the Atlantic, I was involved in the process and my task was to contribute to the creation of the new comprehensive plan by conducting GIS spatial analysis to identify "growth" and "rural" areas.

### 5.1.1 Growth Areas

Growth areas are those areas where the municipality will direct growth and development estimated for the next ten years. This includes residential as well as commercial development, such as retail stores and hotels, and industrial development. For growth areas, municipalities must be prepared to provide public services. In rural areas, public services do not necessarily include water and sewer systems, but might include roads, fire protection, and school bus services. In designating growth areas, consideration should be given to where such services can be efficiently provided (Quintrell, 1990; SPO, 2002). The amount of area within the growth areas must be large enough to accommodate the projected growth and the land should be suitable for future growth. The suitability of land in accommodating future development should be based on physiography, the soil characteristics of the area, the availability of water resources, the ability of the land and existing sewer system to accommodate sewage disposal, and the area's proximity to existing development and major transportation routes.

### 5.1.2 Rural Areas

Rural areas are those areas intended for resource production and other allied land uses as well as the long-term protection of significant areas with natural, cultural, scenic, or recreational values. Included in these areas are those rural landscapes important to the

character of the municipality. Development in these areas must be compatible with these values. Their purpose is to provide the long term protection of irreplaceable natural or cultural resources. Rural areas deserve different management in order to protect and maintain these rural characteristics. Rural areas may vary among municipalities depending on local conditions. In the majority of the municipalities, rural areas should be those primarily containing significant natural and ecological resources, such as wildlife habitats, unfragmented ecosystems, or resources for human production activities, such as traditional agriculture, forestry, and other natural and cultural resources.

# 6. SUITABILITY ANALYSIS

Suitability analysis is a general process which helps to evaluate optimal use of a certain place or area by identifying those factors likely to have an influence on it. In this work suitability analysis was divided into two parts: a model of development suitability and a model of conservation priorities. Criteria for the performed analyses as well as the methodology are described in this section. Some of the study area's characteristics are briefly explained and the concepts and procedures of the individual analyses are documented.

## 6.1 Criteria for the Performed Suitabilty Analysis

The first step to be taken before the suitability analysis can take place is the definition of the study area for which the data needs to be gathered and the suitability model created. Although the boundary lines of the Town of Mount Desert are precisely defined, neither natural nor cultural processes respect the human-defined socio-economic boundaries. Planning at the municipality level cannot address problems which occur at a regional scale. In addition, the State Planning Office in its Planning and Land Use Regulation Act highly encourages planning within the regional context as the only possible way to manage growth efficiently. Thus, I decided to use the most obvious natural boundary of the Island, and to extend the study area, for which the analysis process was to have been conducted, to the entirety of Mount Desert Island.

The next step was to choose the appropriate characteristics and factors of the study area which would, in the form of digital data layers, be taken in account within the process of identifying growth and rural areas. These criteria had to be considered from several points of view:

- relevance of the data for defining limits and growth potentials of the study area;
- correspondence of the criteria with Planning and Land Use Regulation Act and with State Goals;
- correspondence of the criteria with values of local communities;
- accessibility of the data, their accuracy, and possibility to be incorporated into the suitability model;

- simplicity – using criteria, assumptions, and operations that would fulfill the given purpose but still be understandable for people that are not specifically trained in sciences and in GIS.

## 6.2 Overview of Used Land Characteristics

After consideration of the above mentioned criteria, research of the available spatial data, and consultancies with professional developers and members of the Town of Mount Desert Planning Board, ten natural and social characteristics were chosen for identifying growth and rural areas on the Mount Desert Island. For the model of Development Suitability (Growth Areas) these were:

- landscape physiography – slope – its impact on suitability for building development;
- pedological characteristics – suitability of different soils for residential development;
- permeability of soils and surficial geology – impact of human activities on ground water resources;
- cost of sprawl – proximity to existing service centers, development, and transportation routes; and
- sewer system – possibility of areas to be hooked up to existing sewer systems.

For the model of Conservation Priorities (Rural Areas) these were:

- wildlife habitats – proximity to some species habitats identified by the Beginning with Habitat Program;
- habitat suitability – US Fish & Wildlife Sevice ranking of habitat suitability;
- hydrology – proximity to streams, ponds, wetlands, and shore; protection of riparian vegetation;
- fragmentation – effect of roads to the landscape integrity; protection of large undeveloped blocks of land; and
- prime agricultural soils – protection of areas with soils that could be potentialy used for traditional farming activities.

Only the characteristics listed above will be further described in this study. Apart from the study area's geographic location no other characteristics of Mount Desert Island need to be covered at this time.

## 6.3 Methodology

There is no precisely defined universal methodology for suitability analyses, since the aims of suitability analyses and a study area's characteristics are diverse. However, suitability modeling has a relatively long history. It began with paper map overlays and was then greatly enhanced by the development of computer technologies. The origins of the method, the way in which it is employed here, and some of the technical aspects are described in this section.

### 6.3.1 Origins of the Method

The method of suitability analysis is based on the overlay method that was developed in the 1960's by McHarg (1968) and that has been used in many planning applications since that time. In *Plan for Valleys* McHarg stated the credo that describes the motives behind the analysis:

> The area is beautiful and vulnerable; development is inevitable and must be accommodated; uncontrolled growth is inevitably destructive; development must conform to regional goals; observance of conservation principles can avert destruction and ensure enhancement; the area can absorb all prospective growth with out despoliation; planned growth is more desirable and as profitable as uncontrolled growth; public and private powers can be joined in partnership in a process to realize the plan.

McHarg discusses the effects of what is now called sprawl and advocates a means of sustainable development. His method consists of a thorough and multidisciplinary analysis of a region's ecological sensitivity. The method gages a site's suitability for different types of development and use.

He analyzed the situation with respect to "social [or human] values", the benefits and costs to society caused by human activities such as the construction of new development. The creation of ecological inventories is the basic assumption behind the use

of the analysis. These data, together with the concept of fitness, constitute the greatest immediate utility of the ecological model. Ecosystems can be viewed as fit for certain prospective landuses in a hierarchy. It is then possible to identify environments as fit for ecosystems and land uses. The more intrinsically an environment is fit for any of these, the less adaptation is necessary. The result is one of maximum-benefit/minimum-cost.

The practical approach within the described notion can be conducted through the use of map overlays. The overlay method uses a series of maps depicting environmental factors, land features, and socio-economic characteristics for a given study area (CSISS, 2001). A separate map (or map transparency) is produced for each variable of concern, with categories on each map based on those values relating to the measures of suitability, capability, or acceptability. Shading on the maps is in proportion to the values for each map, with the darkest gradations of tones representing areas with the greatest value, and the lightest tones associated with the least significant value. When the individual maps are superimposed upon one another over the original map, the composite map clearly depicts the areas with high or low suitability for the purpose of the study. The darkest areas show the areas with the greatest overall social values, and the lightest with the least, following the format of each individual layer.

The overlay method is quite useful, as a first cut approach, in identifying certain types of effects and in depicting the area over which those effects will be experienced. In addition, it allows for some comparison of alternatives and for the identification of the effects of mitigation measures. This is accomplished by changing the values assigned to different categories and by varying the factors included in the overlay maps, in conjunction with alternative designs.

### 6.3.2 Map Overlays in GIS Environment

One reason why environmental factors have played such a small role in both planning and design in the past stems from the lack of a method to quantify and display information about the natural environment in any immediately meaningful way. In the days before advanced computer technology, there were few ways to store, process, or present large amounts of spatial data. Today, advances in computer mapping, especially the application of Geographic Information Systems and the development of Tomlin's (1990) map algebra concepts, have facilitated McHarg's approach enormously.

The fundamental principle of the overlay method in GIS is the same. Instead of presenting social values and the suitability of different areas by shading, they are represented by pixels with different attribute values in the raster data layers. GIS enables users to conduct spatial overlay analysis much efficiently, precisely, and in a shorter time. New complicated data layers that could not be included before, are today possible to take into consideration.

Curently, McHarg's approach forms the basis of many complex analyses and reports performed with GIS. There are efforts to develop standard GIS methods which could be used and applied on real planning projects. Some of these efforts are those made by Kroot (Maine Department of Environmental Protection) and Longsworth (College of the Atlantic), and the team of COA GIS students, which I had the opportunity to be a part during the 2002-2003 academic year.

In this study, McHarg's method was further developed with the use of GIS and map algebra concepts, several new suitability models were created, and the suitability analysis was adjusted for the specific purposes and expressed social values of the community of the Town of Mount Desert and the whole study area of Mount Desert Island.

### 6.3.3 Land Characteristics Rating

The way in which the land characteristics described in section 6.2 are used in the developed GIS models is based on the essential concept of social values discussed in the previous chapter. The data for each of the considered data layers, in the form of a thematic map, was ranked in 5 classes according to the value that the area possesses from the view of either development suitability or conservation priority. For example, if we accept the need for preventing sprawl and managing growth in an orderly way as a general social value, then the areas that are closer to existing service centers and development clusters are suitable for building new development more than areas further away. In the same manner, if we consider biological diversity to be a significant value that has to be preserved for the future, then the areas with wildlife habitats and their buffer zones possess higher conservation priority than the areas without them. In this way, these characteristics can become components of the GIS spatial analysis model and thus add values either to the development suitability side of the model, which tends to design the "growth" areas, or to the conservation priority side of it, which tends to identify the "rural" areas.

The 5 classes were chosen naturally for all the data layers because of the simplicity and consistency of the analysis process, and also because it is a conventional way in which professional planners weight map features. Within the raster (GRID) data format, the ranks are represented by the attribute values of the individual pixels. Also, the values of various stakeholders can be applied through this approach. This can be accomplished by multiplying some of the categories (data layers) by a certain factor. Thus, these data layers are weighted and the final model is shifted towards the chosen criterion. Different scenarios and alternatives can thus be created and compared. The model built in this study implemented the weight ratings described below:

Ranges 1 through 5:

- 1 is low - very poor for development and/or very good for conservation
- 5 is high - very good for development and/or very poor for conservation

Three weighted models have been created:

Suitability for Development

- 1 is very low suitability for development
- 5 is very high suitability for development

Conservation Priorities

- 1 is very low conservation priority
- 5 is very high conservation priority

Final Analysis Summary

(a combination of suitability for development and conservation priorities models)

- 1 is very high conservation priority
- 2 is high conservation priority
- 3 is marginal lands
- 4 is high development suitability
- 5 is very high development suitability

### 6.3.4 Technical aspects

This work used several key environmental data layers which were either made available for the study area, or in some cases, the digital data layers were isolated from

other data, or newly created, e.g by digitizing the paper map documents. The sources of each data layer will be adduced during the following chapters.

For the purpose of the spatial analysis, new data layers were derived from the originals. These derived layers were generated in the form of terrain models, hydrology models, fragmentation models, habitat models, and the like. The models were classified into standard value-weighted GRID's, as was mentioned above. The creation of these models involves converting vector data to raster, generating specifed GRIDs (such as distance GRIDS), reclassifying data to standardize input and output values and making the data understandable through the application of cartographic design principles, using look-up tables, and using the raster calculator to compute map algebra. Standard data management methods were implemented throughout the spatial analysis processes.

The data coverage of the shoreline of Mount Desert Island and Island's of MDI municipal towns was used as a mask for all the spatial analysis. The analysis mask limits the extent of the spatial operations. The shore data layer was created from USGS 24k DLG (Digital Line Graphs) data representing mean high water or high tide. The original 24k USGS DLG files were obtained by the National Park Service of Acadia National Park. DLG files were converted to Arc/Info coverages by the NPS and provided to College of the Atlantic under a cooperative agreement between NPS and COA. Relative to accuracy of used data layers and extent of the study area, 5 meter cell size (size of the pixels in raster data outputs) was chosen for all generated models.

Several different types of software were used for the purpose of this study. The main GIS programs and their extensions are listed below.

ArcGIS 8.1 and ArcGIS 8.3

- ArcMap – all map-based tasks, including cartography, editing, map analysis, etc.
    - Spatial Analyst extensions
    - 3D Analyst extension
- ArcCatalog – data management
- ArcToolbox – GIS tools for geoprocessing

ArcView 3.1

- Network Analyst extension

A broad variety of GIS operations, wizards and tools were used throughout this study. The tables below provide a list of the basic wizards/tools (tab. 1) and Raster Calculator actions (tab. 2) used in the analysis. The wizards listed below have numerous configuration options which cannot be covered in this study owing to its limited extent. Similarly, all the technical details of the data derivation and spatial analysis cannot be described here. Only the basic principles of the performed analysis will be mentioned in those sections concerning individual models.

Table 1: List of primary wizards/tools used in the analysis

| **Wizard name** | **ArcGIS Extension** |
|---|---|
| Create TIN from features | 3D Analyst |
| Convert TIN to Raster | 3D Analyst |
| Surface Analysis - Slope | Spatial Analyst |
| Surface Analysis - Hillshade | Spatial Analyst |
| Convert Features to Raster | Spatial Analyst |
| Options | Spatial Analyst |
| Classify | ArcEditor, Spatial Analyst |
| Reclassfiy | Spatial Analyst |
| Classification | ArcEditor, Spatial Analyst |
| Joining data | ArcEditor |
| Buffers | ArcEditor |
| Geoprocessing | ArcEditor |
| Service Areas Analysis | Network Analyst |

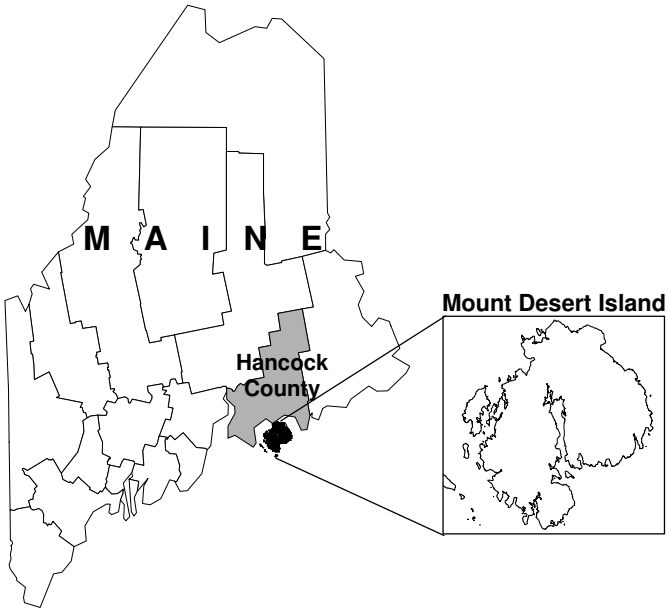
Table 2: List of actions computed in the Spatial Analyst Raster Calculator

| **Action** | **Description** |
|---|---|
| Output grid = input grid | Used to create a subset of a GRID |
| Eucdistance | Creates an euclidian (straight line) distance GRID |
| Select | Used to create a new GRID derived from selected Values of en existing GRID |
| Reclass | Used to assign new values to the GRID's value attribute table |
| Addition of GRIDS | Used to add multiple GRIDS together |
| Subtraction of GRIDS | Used to subtract one GRID from another GRID(s) |
| Multiply | Used to multiply multiple GRIDS together |

## 6.4 Study Area Location and Accessibility

Mount Desert Island is located in Hancock County, Maine, USA (see fig. 5). Hancock County is surrounded by Waldo County to the west, Penobscot County to the north, and Washington County to the east. The Island is situated roughly one-third of the way down the Maine coastline and sandwiched between Blue Hill Bay to the west and Frenchmen's Bay to the east, both coastal waterways known for their scenery and good sailing conditions. Mount Desert Island covers an area of roughly 294 $km^2$ and its geographical bounding coordinates in decimal degrees are: West: - 68.493324; East: - 68.171876; North: 44.446248; South: 44.189126

Figure 5: Mount Desert Island Location




The biggest administrative centers are Ellsworth, 15 km to the north, and Bangor, 80 km in the same direction. Maine's largest city, Portland is 270 km to the southwest of the Island. Canada is approximately 140 km to the northeast and Nova Scotia about 160 km due east. The cities of Boston, New York and Philadelphia are all within a day's drive of the Island. Thus, the Island is higly accessible to a large number of visitors drawn by the unique landscape character and by Acadia National Park.

Accessibility to the Island is enhanced by a major airport located in Bangor, as well as a smaller airport located just north of the Island in Trenton. A year-round ferry service

from Bar Harbor to Yarmouth, Nova Scotia also exists. Major bus lines service Ellsworth daily and Bar Harbor during the summer season. Most of the visitors are brought to the Island by major interstates, such as Route I-95, which pass through Bangor, and by secondary roads, such as Route 1. However, there is only one vehicular access point onto the Island by Route 3, which comes southward from Ellsworth, and crosses over Mount Desert Narrows and onto Thompson Island ultimately joining Mount Desert Island to the mainland (McHarg, 1991).

## 6.5 Model of Development Suitability

Five different land characteristics that define suitability for development were taken into consideration: landscape physiography, soils, permeability, cost of sprawl, and public sewer system (see section 6.2). In this section, these characteristics for Mount Desert Island are described and analyzed from the ecological planning perspective. Areas were assigned values ranging from 5 – very high development suitability, to 1 – very low development suitability.

### 6.5.1 Landscape Physiography – Slope

Mount Desert Island is the largest of over a hundred islands along the Gulf of Maine. Its physiography is unique to the lowland section of the eastern seabord of North America because the only coastal mountain range of this region is located there. The Mount Desert Range stretches in the southwest-northeast direction for a distance of over 15 km and exhibits the highest elevations of coastal North America. The highest peak of the Mount Desert Range, Cadillac Mountain, reaches the elevation of 466 m asl.

In general, the highest summit elevations on Mount Desert Island are along the northeast portion of the mountain range (400 – 450 m asl) and the lowest summit elevations are along the southwest portion (elevs. 290 – 310 m asl). Approximately 5 % of the Island's surface is above 300 m asl, and approximately 20 % is above 150 m masl, nearly all of which is within Acadia National Park.

Most of the physiographic features of the Island demonstrate a north-south orientation and are predominantly linear in nature with ridges decidedly steeper on the southern end. This is a result of scouring caused by repeated Quaternary glaciation which has had the most recent geomorphological impact on the Island relief. Glacial processes also created significantly steepened slopes along most of the east and west flanks of the

mountains, several of which are nearly vertical. The rapid rebound from glacial retreat and subsequent rise in sea level resulted in the submergence of the coast and a "drowned topography" (McHarg, 1991). Another determinant of physiographic character is the varied jointing in the rock, a pattern of horizontal joint planes which dip gently southeast and vertical joint planes which trend north-south and east-west. This jointing has an effect on the natural formation of several Island physiographic features, such as the coastal morphology.

#### 6.5.1.1 Planning Concept

The planning theory behind this analysis is represented by slope being a limiting factor for construction of new development. The State Planning Office suggests that areas over 20 degrees of slope are highly unsuitable for development due to the technical difficulties and fiscal costs associated with building on steep slopes. Similarly, completely flat areas (0 – 2 degrees of slope) are unsuitable for development owing to the reduced drainage abilities of the flat slope areas.

In terms of GIS, the slope model can be generated by the slope function of surface analysis in ArcGIS Spatial Analyst. It calculates the maximum rate of change between each cell and its neighbors. For example, the steepest downhill descent for the cell (the maximum change in elevation over distance between the cell and its eight neighbors). Every cell in the output raster has a slope value. The lower the slope value, the flatter the terrain; the higher the slope value, the steeper the terrain. The output slope dataset can be calculated as per cent slope or degree of slope (ESRI, 2001). When the slope angle equals 45 degrees, the rise is equal to the run. Expressed as a percentage, the slope of this angle is 100%.

#### 6.5.1.2 Overview of the Slope Analysis Procedure

The US Geological Survey (USGS) CONTOURS data created by the Maine Office of Geographic Information Systems (MEGIS) was used as primary data input for this analysis. CONTOURS contains contour lines for Maine from USGS 1:24,000 scale quadrangles. In accordance with the source, units were in feet or meters and intervals were at 10 to 20 feet, or 3 meters. The purpose of contours data is for determining drainage, use with Arc/Info Grid module for hydrology studies, determining slope and delineating watersheds.

The data coverage of the shoreline of Mount Desert Island and the islands of MDI municipal towns that also served as an analysis mask, was used as a base height for the slope analysis. It was necessary to add a new ELEVATION field with value of 0 to its attribute table and thus this data could serve as the 0 contour line.

The first step was to extract the contours for Mount Desert Island only from the original data through the Geoprocessing Wizard functions. Second, the tin (triangular irregular network) layer was created in 3D Analyst extension. ELEVATION field of the two data sets were set as a height source and "hard line" function set for triangulating. The tin vector layer was then used to generate Hillshade model in Spatial Analyst and 3D model using ArcScene modul to serve as better visualization of the Mount Desert Island georelief. Then, the Slope analysis itself was generated from tin in Spatial Analyst extension. Values of the generated slope GRID ranged from 0 to 89 degrees. This does not communicate clearly which cells within the GRID are suitable for development and which cells are not. The raster representing degree of slope needed to be assigned values of 1 to 5 to represent suitability. The cells with degree of slope of 0 – 2 and >20 were given the value of 1 – the least suitable for development. The remaining cells were divided into the next four classes. Table 3 shows the values of slope grouped into five ranges under the Degree of Slope heading, and the new value that was assigned under the Weight Rating. The Reclass operator was used to replace existing values of slope with the new values of development suitability.

Table 3: Weight rating in the slope analysis

| **Weight rating** | **Degree of Slope** |
|---|---|
| 1 - Least suitable for development | 0-2 and > 20 |
| 2 - Low | 15 - 20 |
| 3 - Medium | 10 - 15 |
| 4 - High | 5 - 10 |
| 5 - Most suitable for development | 3 - 5 |

Paper representations of the results of the performed analysis – Hillshade Model, 3D Model, and Slope Analysis follow.

# Hillshade Model of Topography

*Mount Desert Island*


The Hillshade function enhances the visualization of a surface. It determines hypothetical illumination values for each cell in a raster by setting a position for a hypothetical light source and calculating the illumination values of each cell in relation to neighboring cells.

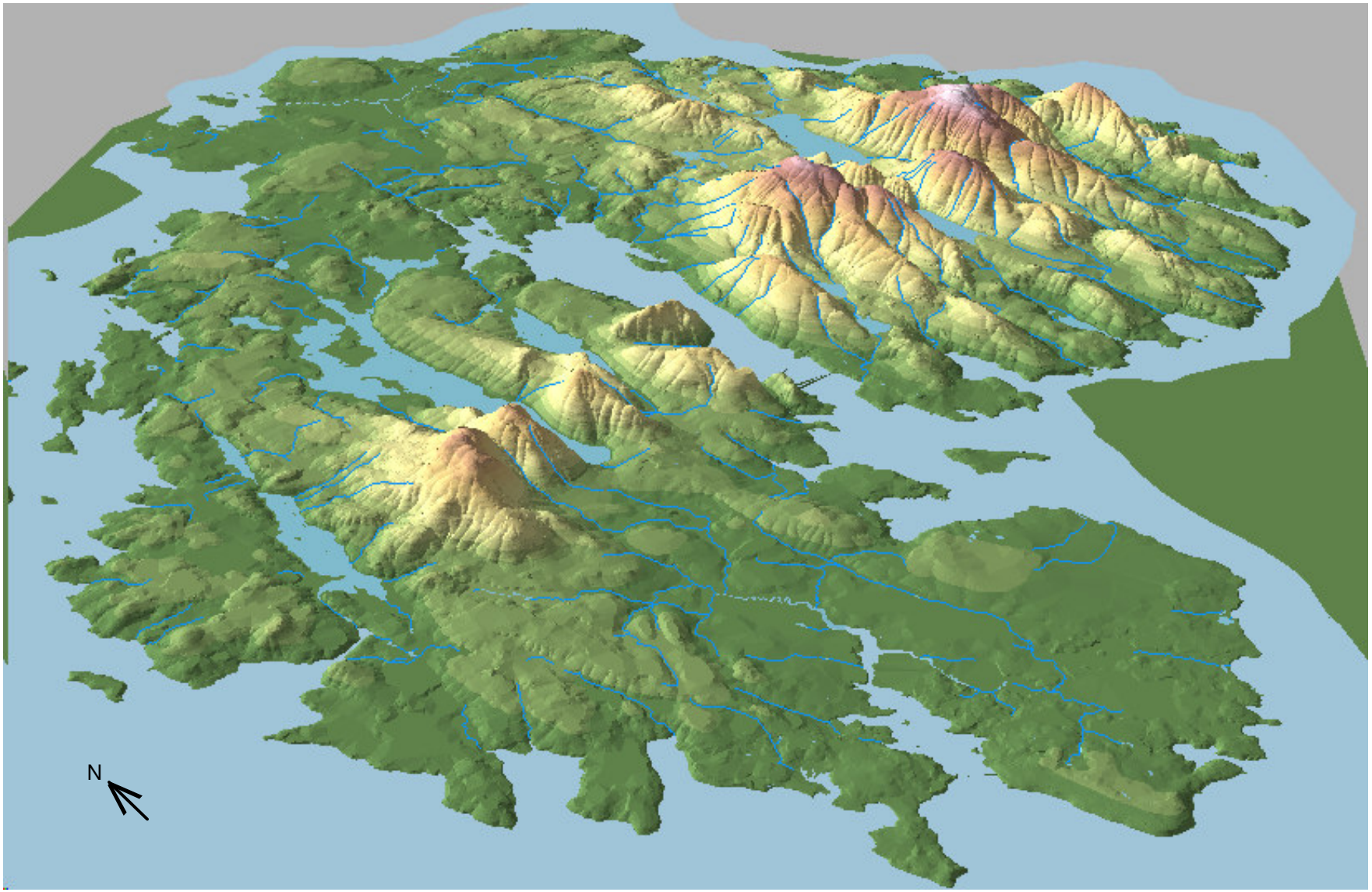
0 1 250 2 500 5 000 Meters

Projected Coordinate System:
NAD_1983_UTM_Zone_19N

Data Source: COA GIS Database
Prepared by Tomas Vaclavik
College of the Atlantic & Palacky University
January 2004

# 3D Model of Topography

*Mount Desert Island*

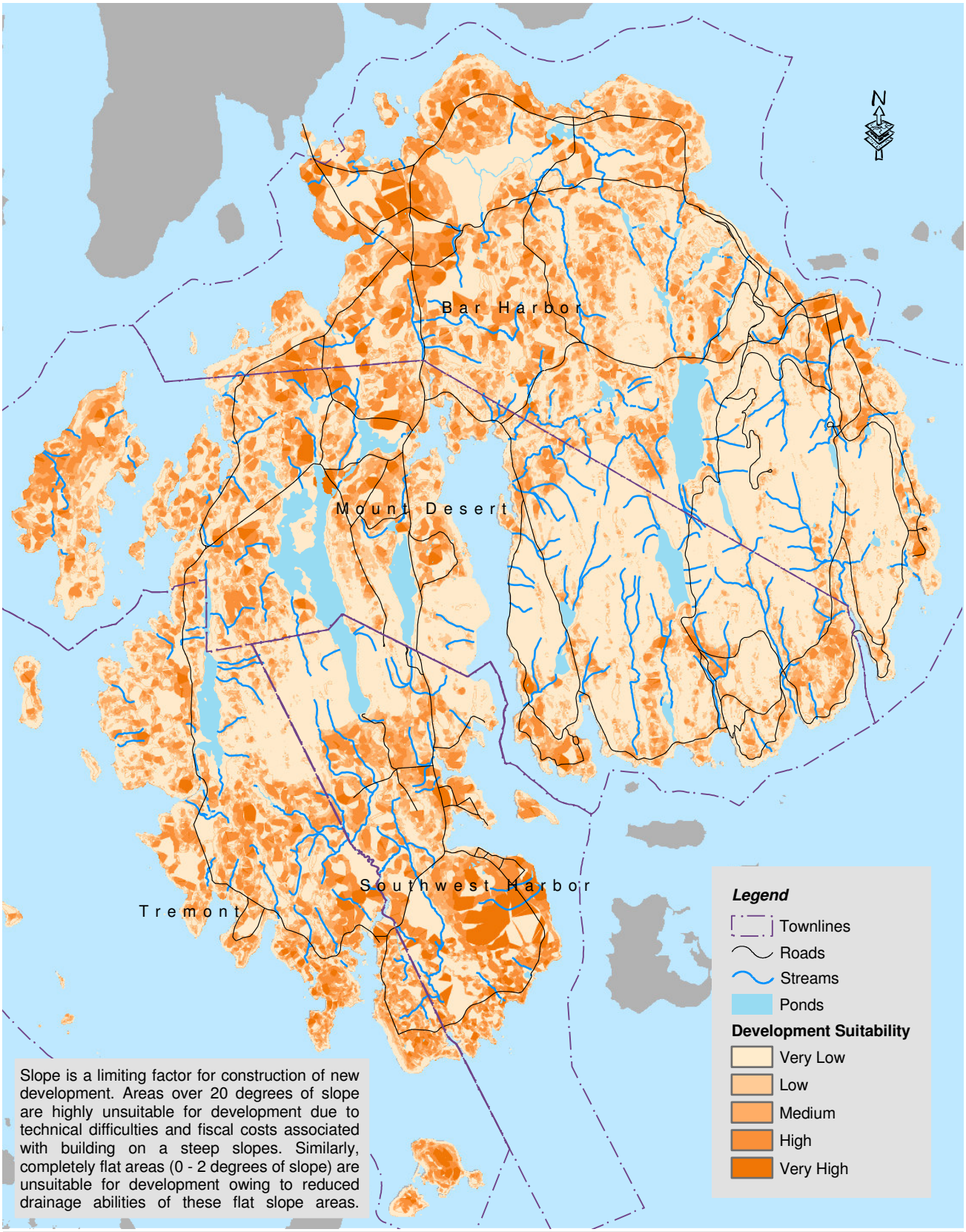



3D model is another type of surface topography visualization. It stores z-values within the features' geometry. This 3D model was created in ArcScene modul using TIN data calculated from digitized contour lines. Z factor of 0.8 is used in this model.

Data Source: COA GIS Database
Prepared by Tomas Vaclavik
College of the Atlantic & Palacky University
January 2004

# Slope Analysis

*Mount Desert Island*




Slope is a limiting factor for construction of new development. Areas over 20 degrees of slope are highly unsuitable for development due to technical difficulties and fiscal costs associated with building on a steep slopes. Similarly, completely flat areas (0 - 2 degrees of slope) are unsuitable for development owing to reduced drainage abilities of these flat slope areas.

0 1 250 2 500 5 000 Meters

Projected Coordinate System:
NAD_1983_UTM_Zone_19N

Data Source: COA GIS Database
Prepared by Tomas Vaclavik
College of the Atlantic & Palacky University
January 2004

### 6.5.2 Pedological Characteristics

Soil development and composition is intimately linked to a number of factors including bedrock lithology, topography, regional hydrology, and weathering regimes on the Island. Soil forms a thin layer over outcrops of bedrock. But these soils are poorly developed and are not laterally continuous throughout the Island. Thin soil profiles indicate that pedogenesis may be complicated by the presence of tills and the general lack of organic materials normally generated through the decomposition of forest litter.

Soils within the study area are of four Soil Orders: Entisols, Spodosols, Inceptisols, and Histosols (Gilman, 1988). Soils on the mountains are of the Order Entisol. Entisols are broadly described as soils with weakly developed subsurface horizons. This means that erosion, weathering, and often the steep topography are able to wash away the soil before it can develop further. The subsurface color of these soils is generally light, indicating a lack of clay and organic matter. These soils are generally infertile and shallow.

Spodosols are probably the most common Soil Order on the Island, occuring in both lowland and upland locations. Spodosols form mostly on coarse textured, acid parent materials. Vegetative species low in metallic ions, such as pine trees, seem to encourage the development of Spodosols. Acidic vegetation form strong organic acids which wash downward and leach organic matter and oxides of aluminium, with or without iron oxides, downward, and deposit them deeper in the soil. This forms the characteristic Spodic horizon.

Inceptisols show few diagnostic horizons, but are generally more developed than Entisols. They are thought to form quickly and result mostly from the alteration of parent materials. Inceptisols in this particular landscape have formed in the lowlands.

Histosols are characterized by high organic carbon, and are typically formed in a water-saturated environment, such as wetland or bog. These cool, anaerobic conditions slow decomposition, allowing the accumulation of organic matter. When artificially drained these soils are very productive.

The Natural Resource Conservation Service has delineated soils series for Mount Desert Island. The Series designation is the most specific unit of the classification system and was mapped down to areas of about three acres. The Soil Series Groups that can be found on the Island are: Lithic Udorthents, Typic Haplorthods, Lithic Haplorthods, Aeric Haplaquods, Typic Haplaquepts, Aeric Haplaquepts, Dystric Eurtrochrepts, and Terric Borosaprists.

#### 6.5.2.1 Planning Concept

The pedological characteristic of a study area is a valuable part of any suitability analysis because soils are limiting factors for building development. Although in terms of the technical ability needed to develop a property, development may occur virtually anywhere, the type of soil, its thickness, water regime and other parameters significantly influences its suitability for such activities. For example, a soil that is too shallow or saturated for part of the year might be poor for the dilution of septic systems and thus unsuitable for development.

Soil data are often difficult for the untrained to use due to the nature and complexity of the soil data itself. That is why the Natural Resource Conservation Service (formerly the Soil Conservation Service) rates soils series for use potentials. Examples of the uses for which the soils are rated are suitability for dwelling, septic system suitability, prime farmland, and such. The NRCS rating for residential development was used in the following analysis.

#### 6.5.2.2 Overview of the Soil Analysis Procedure

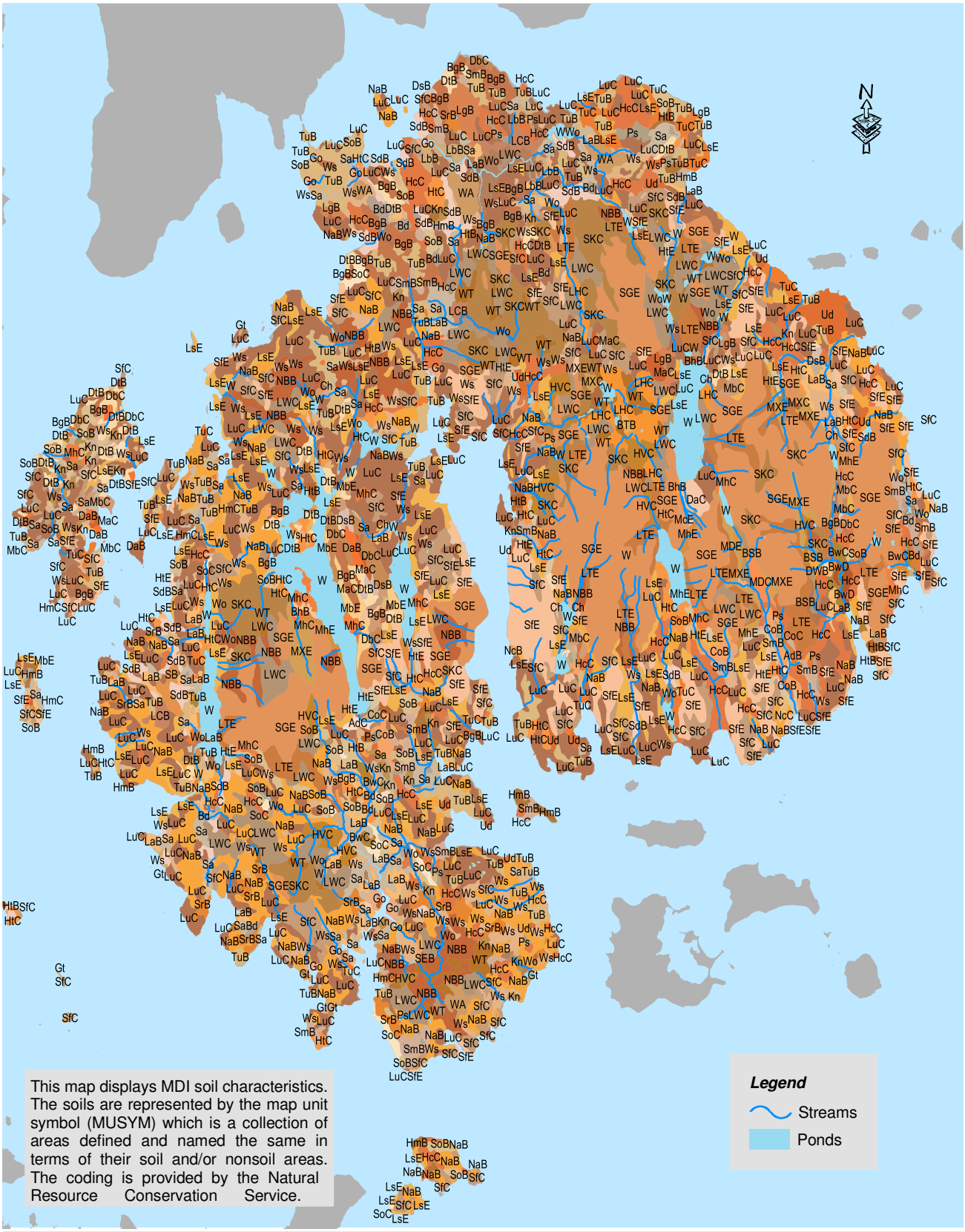
The primary data layer used in this model is the SSA_S data, originating with the Natural Resource Conservation Service. SSA_S data sets contain digital soil survey data for Maine counties at the 1:24,000 scale. This data is generally the most detailed level of soil geographic data developed by the National Cooperative Soil Survey. It consists of a broad-based inventory of soil and nonsoil areas that occur in a repeatable pattern on the landscape and that can be cartographically shown at the scale mapped. The SSA_S data for Hancock County was used for this analysis.

A map unit represented by map unit symbol (MUSYM) in the attribute table is a collection of areas defined and named the same in terms of their soil and/or nonsoil areas. NRCS provides coding for each unit that is based on soil potential to residential development. The coding is represented by 5 classes from very high to very low. This information was contained in the NRCS dbf “look up” table that was joined according to MUSYM field to the original data layer. That was the first step in the analysis. The next step was extracting data for the study area using Geoprocessing Wizard. Afterwards, the vector data layer was converted to raster in Spatial Analyst using NRCS coding as a field to be assigned to cells. Since the coding was in words and the layer had to be available for later map algebra operations, it reclassified into standard 1-5 classes, where 1 is verly low

suitability and 5 is very high suitability. Appendices representing by paper prints of the soil survey map units and the results of the performed soil analysis follow.

# Soil Survey Map Units

*Mount Desert Island*




This map displays MDI soil characteristics. The soils are represented by the map unit symbol (MUSYM) which is a collection of areas defined and named the same in terms of their soil and/or nonsoil areas. The coding is provided by the Natural Resource Conservation Service.

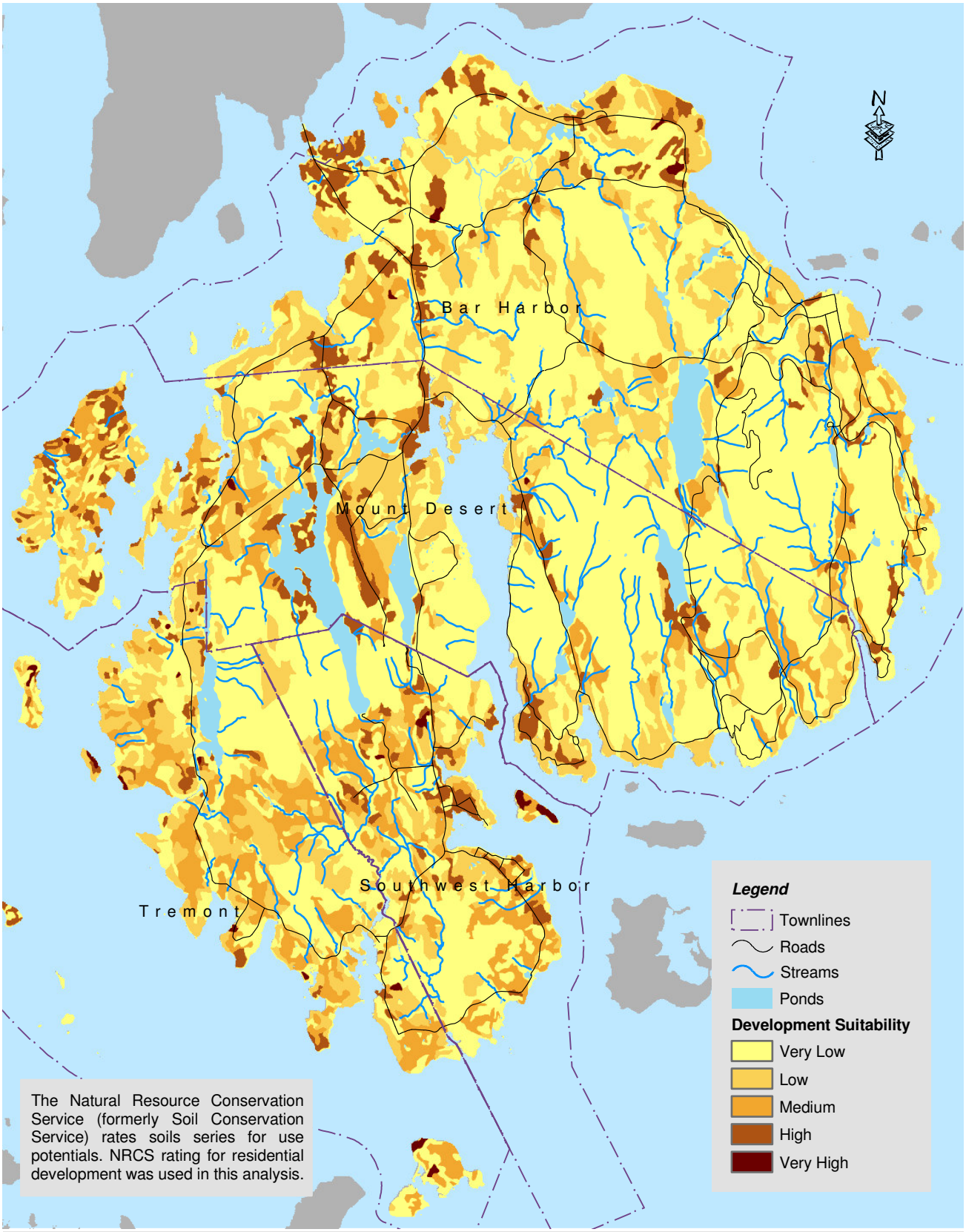
0 1 250 2 500 5 000 Meters

Projected Coordinate System:
NAD_1983_UTM_Zone_19N

Data Source: COA GIS Database
Prepared by Tomas Vaclavik
College of the Atlantic & Palacky University
January 2004

# Soil Analysis

*Mount Desert Island*




The Natural Resource Conservation Service (formerly Soil Conservation Service) rates soils series for use potentials. NRCS rating for residential development was used in this analysis.

0 1 250 2 500 5 000 Meters

Projected Coordinate System:
NAD_1983_UTM_Zone_19N

Data Source: COA GIS Database
Prepared by Tomas Vaclavik
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January 2004

### 6.5.3 Permeability of Soils and Surficial Geology

Most of the Island's residents rely solely on groundwater sources. From the surficial geology map it is apparent that Island's historical settlements were located on glacial till deposits which offered the highest yields on the Island for shallow dug wells. However, the majority of groundwater sources today are in bedrock aquifers (Gilman, 1988).

The Mount Desert Island geological structure consists of solid intrusions of granite. Ground water travels through it only via fractures in the rock. These fractures are usually fairly small and higher water yields in bedrock aquifers can be reached only by encountering multiple fractures during deep drilling. There is no model for predicting the flow of the water or where it can be found. These bedrock groundwater sources are very vulnerable to pollution associated with human activities. The level of their vulnerability often depends on the above surficial deposits and soils ensuring water filtering.

Table 4: Mount Desert Island's surficial geology and its permeability

| Category | Code | Permeability |
|---|---|---|
| Beach deposits | B | very rapid (VR) |
| Coarse-grained sediments (gravel) | CS | moderately slow (MS) |
| Delta: deposits into ocean | D | rapid (R) |
| End moraine: a ridge composed of mixed rock debris | EM | rapid (R) |
| Fine-grained sediments | FS | very slow (VS) |
| Freshwater wetland sediments | FW | impermeable (IM) |
| Outwash: deposited in meltwater streams | OW | very rapid (VR) |
| Salt marsh | SM | impermeable (IM) |
| Talus: collection of angular rocks | TA | rapid (R) |
| Till: mixture of sand, silt, clay & mixed rock debris from glacial ice | TI | moderately slow (MS) |
| Undifferentiated bedrock & areas of thin drift cover | UB | very rapid (VR) |
| Undifferentiated sediment: sediment mixed by wave action | US | moderate (M) |

Some groundwater sources are located in coarse-grained aquifers. These formations are deposits of gravelly rock material laid down by the glaciers. The particles are usually large and not well sorted, so the formation contains substantial amounts of pore space which holds a lot of water and gives it up easily. This makes the coarse-grained aquifers suitable for, but very vulnerable to, human use. Pollutants can infiltrate into them very easily, so sufficient soil filtering is critical.

The soil characteristics of Mount Desert Island have been described in the previous section. Surficial geology is concerned with the description of the types and distributions of unconsolidated sediments across the landscape. Table 4 represents the categories of the Island surficial geology and their codes as defined by Maine Geological Survey. Mentioned are also the rates of permeability of the individual deposits, which were obtained from Hancock County Soil and Water Conservation District.

#### 6.5.3.1 Planning Concept

Since the vast majority of groundwater resources on Mount Desert Island are in bedrock or coarse-grained aquifers, their future use may be endangered due to their high vulnerability, especially to pollution caused by human activities, such as building house septic systems. The type and permeability of surficial geological materials and the soils lying above them are crucial in determining how much the groundwater will be at risk. That is because the soils and sediments provide such important filtration of waters (including wastewaters) that are absorbed by the ground.

Thus the reason why the permeability of soils and surficial geology is an important factor for development suitability. The areas with slower permeability of soils and sediments that ensures sufficient filtration are suitable for development more than highly permeable areas where pollution can rapidly affect groundwater quality, or impermeable areas, where insufficient percolation may cause the overland flow of wastewater that cannot sink in faster than it is produced.

#### 6.5.3.2 Overview of the Permeability Analysis Procedure

Input data for this analysis were the SSA_A soil data mentioned in previous section and SURFI data layer that I obtained from COA GIS database. This data layer presents surficial geology polygons for Mount Desert Island, coded for surficial materials with text description. Its defined purpose is for planning and ecological research and to interact with

other spatial data. This analysis consists of two parts: the permeability of soils and the permeability of surficial geology. These two models are then synthesized.

Concerning the soil part of the analysis, data for the study area was first extracted in Geoprocessing Wizard. The information about soil permeability was taken from the Natural Resource Conservation Service in the form of a dbf "look up" table. They ranked the soil permeability into the following classes: E-excessively, SE-somewhat excessively, W-well, MW-moderately well, SP-somewhat poorly, P-pooly, VP-very poorly. The table was then joined to the original data. The subsequent data layer was exported into a new shapefile which could then be converted to raster according to its permeabilty field. For the purpose of the analysis this GRID needed to be reclassified into 5 classes, which was done as it is in the table 5:

Table 5: Weight rating in the soil permeability analysis

| **Weight rating** | **Soil Permeability** |
|---|---|
| 1 - Least suitable for development | E, SE |
| 2 - Low | W |
| 3 - Medium | MW, No Data |
| 4 - High | SP |
| 5 - Most suitable for development | P, VP |

Table 6: Weight rating in the surficial geology analysis

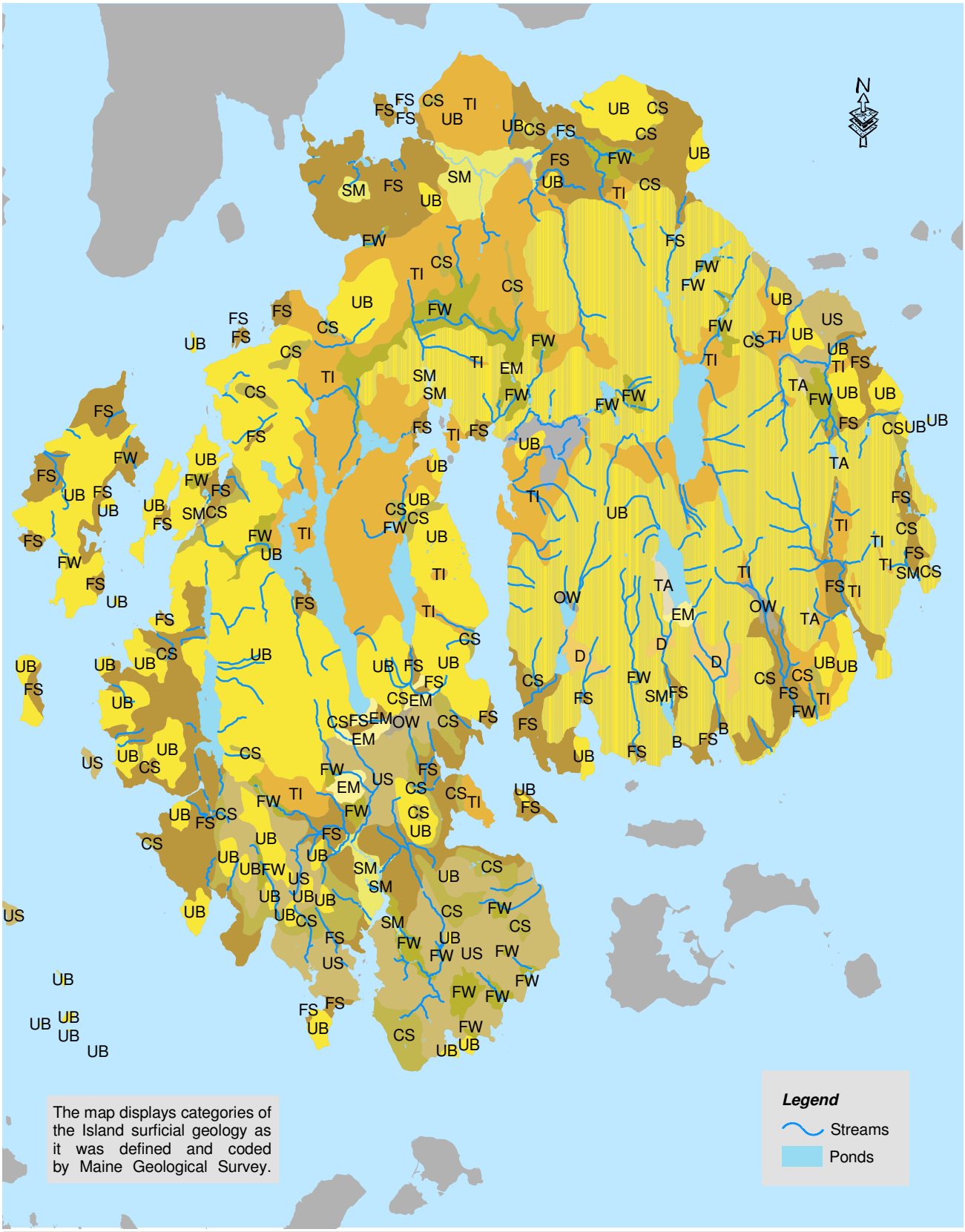
| **Weight rating** | **Surficial Geology Permeability** |
|---|---|
| 1 - Least suitable for development | IM, VR |
| 2 - Low | RA |
| 3 - Medium | M, No Data |
| 4 - High | MS |
| 5 - Most suitable for development | VS, S |

Concerning the part on surficial geology, information on permeability ranking came from personal communication with the Hancock County Soil and Water Conservation District. They ranked the surficial geology permeability into the following classes: VR-very rapid, R-rapid, M-medium, MS-medium slow, S-slow, VS-very slow, IM-impermeable. The information was added into the attribute table of the Surfi data. This data layer was then converted to raster in Spatial Analyst according the permeability of individual deposits. After consulting the issue with Island's geologist Jannet Redman, I

decided to reclassify the GRID into 5 classes as it is in table 6. The data values of both soil and surficial geology permeabilty models were finally added together in Raster Calculator and the new values then reclassified into 5 equal standard ranges. The results of this permeability analysis, together with a map of surficial geology, are represented by the following appendices.

# Surficial Geology

*Mount Desert Island*



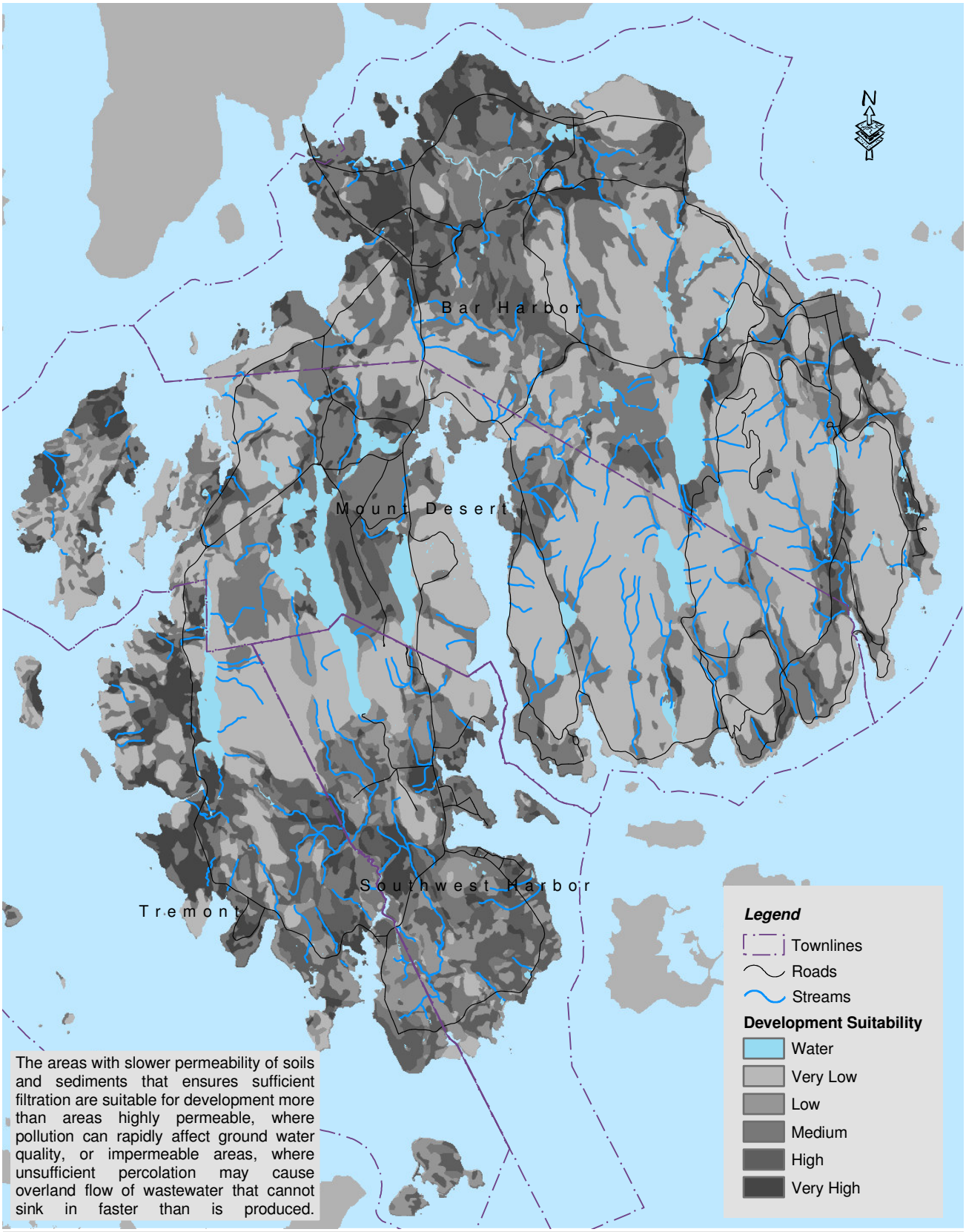

0 1 250 2 500 5 000 Meters

Projected Coordinate System:
NAD_1983_UTM_Zone_19N

Data Source: COA GIS Database
Prepared by Tomas Vaclavik
College of the Atlantic & Palacky University
January 2004

# Permeability of Soils And Surficial Geology

*Mount Desert Island*




The areas with slower permeability of soils and sediments that ensures sufficient filtration are suitable for development more than areas highly permeable, where pollution can rapidly affect ground water quality, or impermeable areas, where unsufficient percolation may cause overland flow of wastewater that cannot sink in faster than is produced.

0 1 250 2 500 5 000 Meters

Projected Coordinate System:
NAD_1983_UTM_Zone_19N

Data Source: COA GIS Database
Prepared by Tomas Vaclavik
College of the Atlantic & Palacky University
January 2004

### 6.5.4. The Cost of Sprawl

The issue of sprawl has been discussed in section 4.1. The question was whether the sprawl type of development occurs on Mount Desert Island, too.

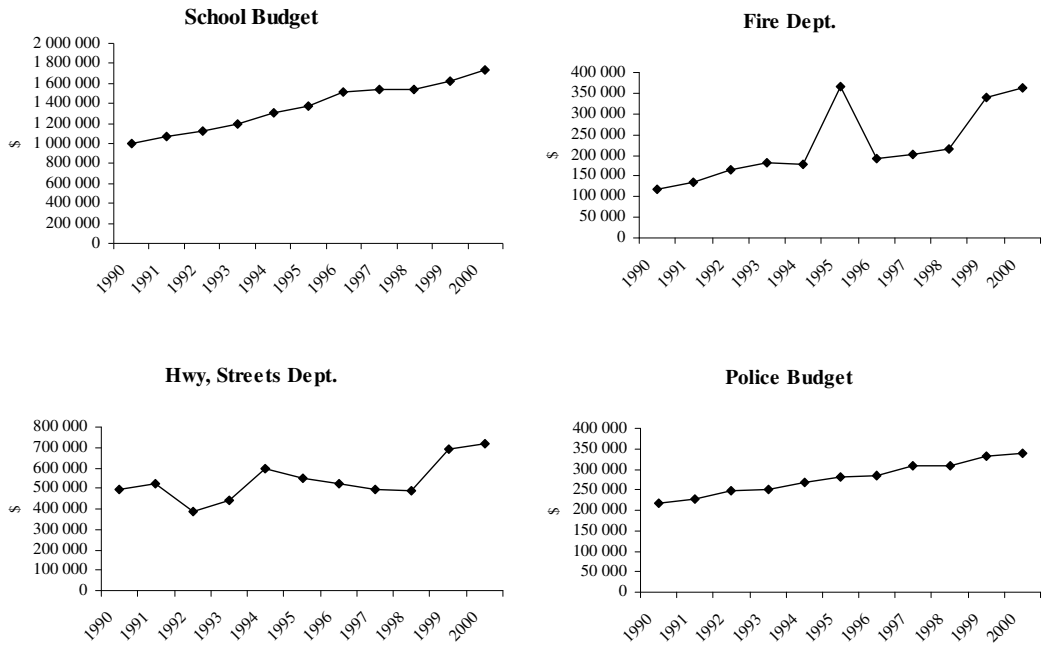
There are four town municipalities on Mount Desert Island: Bar Harbor, Mount Desert, Southwest Harbor, and Trenton. One possible way to identify sprawl development in a certain area is to analyze changes in the development patterns over a significant time period. Since sprawl is usualy characterized by dividing land into smaller lots, these changes in development patterns can be clearly observed if up-to-date property (parcel, tax) maps are compared with property maps from previous eras, and changes in parcels, especially new subdivisions, are identified. It is important to take the distance of this new development from the existing service centers into consideration.

Property maps from 1993 and 2003 for the towns of Bar Harbor and Mount Desert was obtained. A comparison of maps of these two towns were considered sufficient for identifying sprawl on the Island because they cover more than two thirds of the Island's area. Both tax maps from 1993 were already in digital form, stored in the College of the Atlantic GIS database. Since the data layers were in older NAD_1927_UTM_Zone_19N coordinate system, some alteration to NAD_1983_UTM_Zone_19N using ArcToolbox needed to be done before the intended comparison could be undertaken. Tax maps from 2003 were obtained in paper format from Bar Harbor and Mount Desert town halls and manually digitized. After they had been overlaid, new merged and subdivided lots were identified displaying changes in the patterns of development.

The comparison of parcel maps showed that in the period from 1993 to 2003 most of the new development in the Bar Harbor and Mount Desert municipalities occured outside the town centers. Specifically, from 534 new subdivisions that had been created during the past decade 450 of them are located outside the centre of Bar Harbor. Similarly, in the Town of Mount Desert 307 new subdivisions from a total of 495 occured away from existing town center.

Indirect evidence that sprawl has already found its way onto Mount Desert Island might be represented by charts displaying an increase in the Town of Mount Desert budgets (fig. 6). These increased costs cannot be caused solely by changes in development pattern although sprawl might represent a considerable portion of them.

Figure 6: Increase in the Town of Mount Desert budgets




### 6.5.4.1 Planning Concept

The problems of sprawl and its associated costs are caused by the continual shift of Maine's population from traditional towns and village centers to remote rural areas. People are moving and building new developments far away from existing service centers, such as schools, ambulances, fire stations and police stations. If we agree with Planning and Land Use Regulation Act that sprawl needs to be prevented, it is possible to conclude that areas that are closer to existing settlements and sevice centres are suitable for development more than areas located further away. This might help to reduce commuting times and traffic in rural areas.

### 6.5.4.2 Overview of the Sprawl Analysis Procedure

As input data, points that would represent traditional development centers and existing service centers on Mount Desert Island were needed. Four data layers of MDI schools, ambulances, fire stations and police stations were finally used. These data layers were created at the College of the Atlantic and stored in the COA GIS database. As some of these facilities are found in clusters, they were generalized for simplicity of analysis,

and after the traditional town and village centers were taken into consideration, a new layer of major MDI service centers was created.

Since these towns and service centers are accessible only by public roads, calculating the straight-line distances from them would not have corresponded with the real situation. Calculating the commuting distances along the road network was needed. As an input data layer RDNET coverage representing transportation network of Mount Desert Island and the lands of MDI towns were used. This layer was created from the original 24k USGS DLG files, which were obtained by the National Park Service for Acadia National Park and provided to College of the Atlantic under its cooperative agreement. For the following analysis, only publicly accessible roads were extracted.

The calculation of the service areas along the road network was performed in ArcView 3.1 Network Analyst Extension. However, this version of Network Analyst does not allow multiple service centres analysis. Thus, service areas for MDI development centers had to be calculated individually. Output vector data layers were then converted to raster, and through a complicated process manually added together in Raster Calculator of Spatial Analyst. The values of these GRIDS were then analyzed and reclassified into 5 standard classes. The criteria for defining distances from service centers that would correlate with suitability classes (see table 7) were taken and modified from "Criteria for Determining Sprawl Conditions" in *The Cost of Sprawl* (SPO, 1997) report.

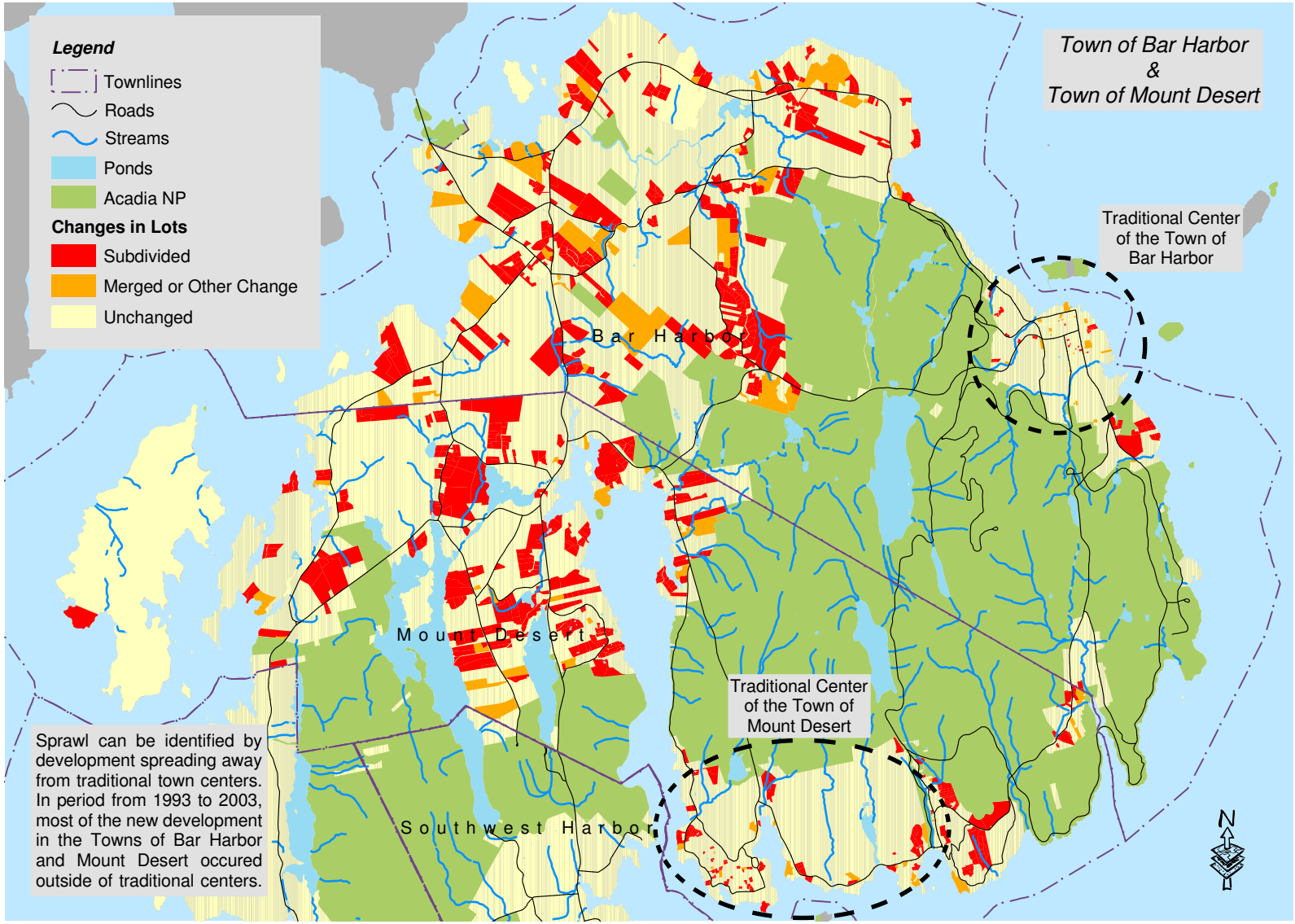
Table 7: Weight rating in the cost of sprawl analysis

| **Weight rating** | **Commuting Distances** |
|---|---|
| 1 - Least suitable for development | > 5 miles |
| 2 - Low | 5 miles |
| 3 - Medium | 3 miles |
| 4 - High | 2 miles |
| 5 - Most suitable for development | 1 mile |

Paper prints of Changes in Patterns of Development, map of MDI service centers, and the model of distances to major service centers follow.

# Patterns of Development

*Changes in Lots from 1993 to 2003*



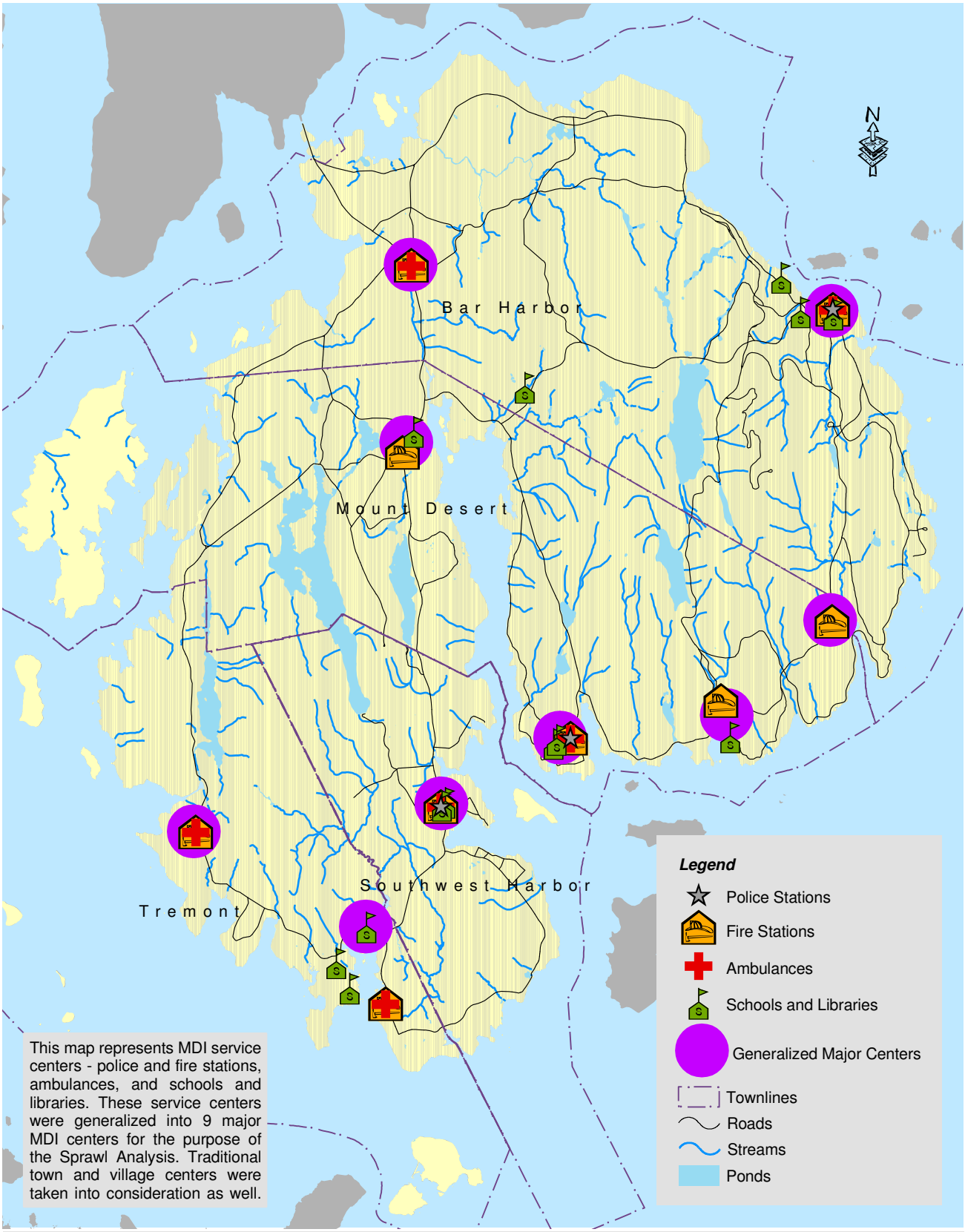

0 1 250 2 500 5 000 Meters

Projected Coordinate System:
NAD_1983_UTM_Zone_19N

Data Source: COA GIS Database
Prepared by Tomas Vaclavik
College of the Atlantic & Palacky University
January 2004

# Major Service Centers

*Mount Desert Island*




This map represents MDI service centers - police and fire stations, ambulances, and schools and libraries. These service centers were generalized into 9 major MDI centers for the purpose of the Sprawl Analysis. Traditional town and village centers were taken into consideration as well.

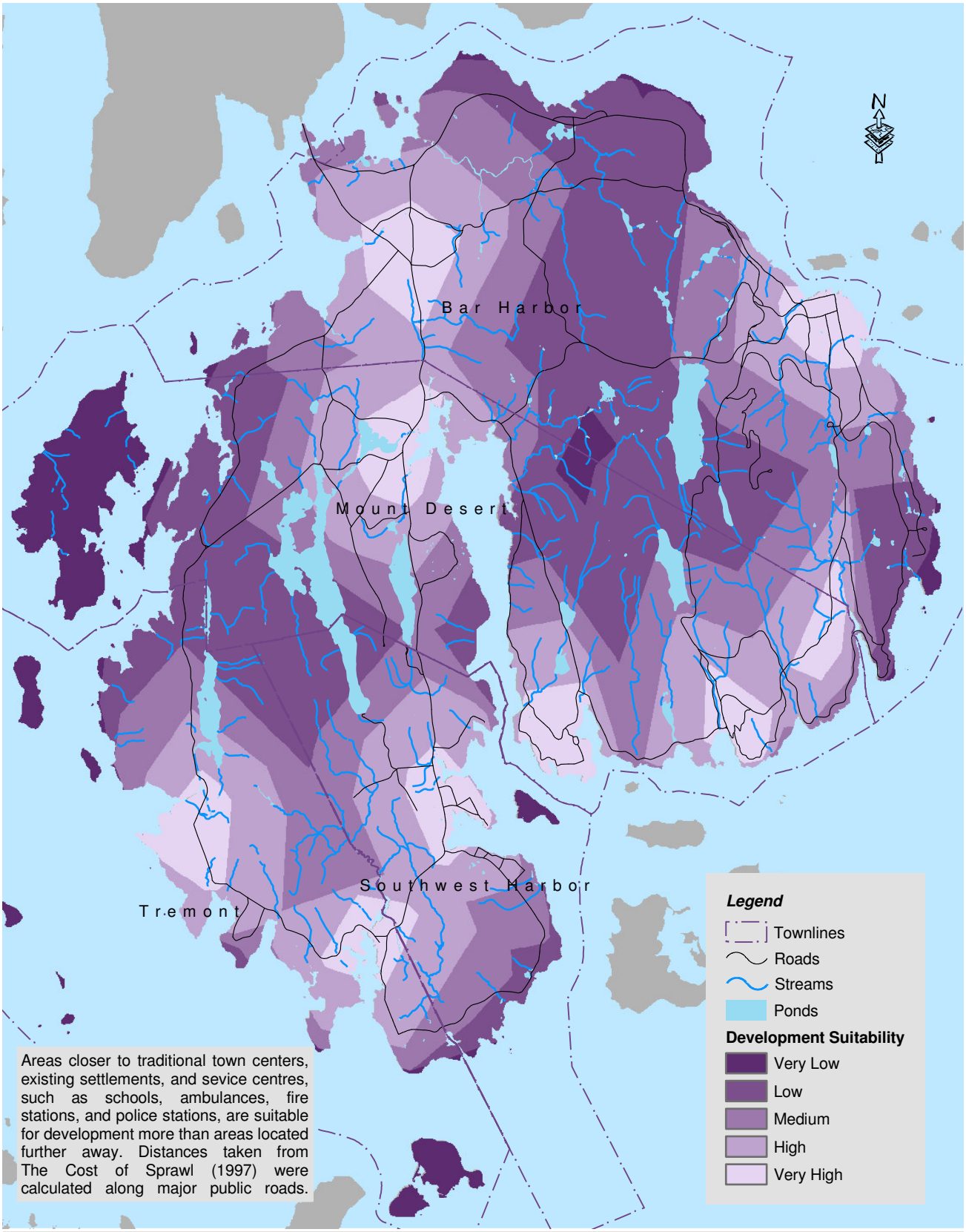
0 1 250 2 500 5 000 Meters

Projected Coordinate System:
NAD_1983_UTM_Zone_19N

Data Source: COA GIS Database
Prepared by Tomas Vaclavik
College of the Atlantic & Palacky University
January 2004

# Cost of Sprawl Analysis

*Mount Desert Island*




Areas closer to traditional town centers, existing settlements, and sevice centres, such as schools, ambulances, fire stations, and police stations, are suitable for development more than areas located further away. Distances taken from The Cost of Sprawl (1997) were calculated along major public roads.

0 1 250 2 500 5 000 Meters

Projected Coordinate System:
NAD_1983_UTM_Zone_19N

Data Source: COA GIS Database
Prepared by Tomas Vaclavik
College of the Atlantic & Palacky University
January 2004

### 6.5.5 The Sewer System

Public sewer systems on Mount Desert Island provide sevice to less than half of the sewage-producing users in each town with the exception of the Town of Tremont. Most of the Island's sewer systems began as conveyance systems which serviced the larger settlements on the Island and discharged directly into the ocean without treatment. In the 1970's, treatment plants were constructed and all sanitary sewage from public systems is now treated before being discharged into the ocean. However, most of the sewer systems on the Island are not functioning properly, suffering from deficiences in the sewerage and treatment (McHarg, 1991).

The sewer system in Bar Harbor was built in 1874 and is still partially in use. It is made of vitrified clay pipes and needs to be reconstructed. Infiltration and leakage occurs throughout the system especially during periods of high precipitation. In addition, the treatment plant nears capacity in the summer season and during peak flows untreated sewage is discharged directly to the ocean. The Town of Southwest Harbor has a sewerage system that serves approximately 500 users. Infiltration and overflow are a problem due to the age and condition of the conveyance system. The treatment plant has a capacity of about 3,500,000 l/day. The town of Mount Desert has four public sewer systems. The largest one in Northeast Harbor serves about 500 users. The other three sewer systems are located in Seal Harbor, Otter Creek, and Somesville, and in total serve an additional 350 users.

#### 6.5.5.1 Planning Concept

A public sewer system is an important facility that serves people in their settlements. If the sewer system is functioning well and the sewage is treated properly, it significantly reduces the biochemical load on and risk to the environment. A public sewer system thus becomes a notable factor in suitability for development. Areas that are currently using a sewer system, or can be potentially hooked up to it, are suitable for development more than areas that must rely on septic systems where the waste water is not treated.

#### 6.5.5.2 Overview of the Sewer System Analysis

In this analysis only those public sewer systems that are working properly, where considerable leakages do not occur, and where the sewage is treated, were taken into

account. As basic information materials provided by local towns and the Public Sewer map from McHarg (1991) were used. Parcel maps used in previous analysis provided base data layers for this analysis. The parcels on Mount Desert Island which are currently on the public sewer system or have the potential to be joined to it were selected, and a new data layer was created from them. This layer was then converted to raster in Spatial Analyst extension and the pixel values were reclassified into the standard classes. The areas currently on the sewer system were assigned a value of 5 – very high suitability, areas with potential of being hooked up to sewer system were assigned a value of 4 – high suitability, and the rest of the parcels were given a value of 2 – low suitability. The following appendix is the public sewer system analysis paper print.

# Public Sewer System Analysis

*Mount Desert Island*


Functioning public sewer system with properly treated waste water is a notable factor in suitability for development. Areas that are currently using sewer system, or can be potentially hooked up to it, are suitable for development more than areas that must rely on septic systems where the waste water is not treated.

0 1 250 2 500 5 000 Meters

Projected Coordinate System:
NAD_1983_UTM_Zone_19N

Data Source: COA GIS Database
Prepared by Tomas Vaclavik
College of the Atlantic & Palacky University
January 2004

## 6.6 Model of Conservation Priorities

In keeping with the model of development suitability, five different land characteristics were taken into consideration. Those characteristics which determine an area's conservation values are: wildlife habitats, habitat suitability, hydrology, fragmentation – roads, and prime agricultural soils (see section 6.2). An analysis for each of the land characteristics was performed. Areas were assigned values ranging from 5 – very high conservation priorty, to 1 – very low conservation priority.

### 6.6.1 Wildlife Habitat

Due to its location, complex physiography, and specific glacial history, Mount Desert Island supports a highly diversified range of wildlife habitat. Considering the zones from intertidal areas, through lowland heath, stream and wetland network and riparian areas, to upland coniferous forest, at least ten general habitats types can be found on the Island. Habitat diversity can be attributed to the changes in topography, soil characteristics, hydrological conditions, and microclimate which are highly concentrated relative to the limited land are of Mount Desert Island. The resulting mosaic of vegetative communities and hydrological features supports an unusually high concentration of wildlife species. The Island represents an important link in the shrinking chain of habitat areas supporting Maine's coastal wildlife species (McHarg, 1991).

Detailed inventory of wildlife species living on Mount Desert Island is not a goal of this study. Following are just "fast facts" about the numbers of wildlife species identified by Acadia National Park (ANP, 2004):

- Eleven species of amphibians and seven species of reptiles have recently been identified on Mount Desert Island. Two other species of amphibians and four species of reptiles have been historically reported in the park.
- Twenty-four species of fish have been found in island lakes and ponds, including several species that are introduced.
- Over 273 species of birds have been identified on Mount Desert Island and in the adjacent waters. Twenty-one wood warblers nest on the Island.
- Forty mammal species have been identified on park lands and more than a dozen other terrestrial and marine mammals have been identified on adjacent lands or water bodies.

- Over a thousand species from 18 phyla of invertebrates have been reported from the park and Mount Desert Island area.
- Insect inventories completed in the late 1940's reported over 6500 species and subspecies of insects for the Mount Desert Island area. Additional species have been identified recently.

#### 6.6.1.1 Planning Concept

Wildlife habitats identification was a part of the Beginning with Habitat program. Beginning with Habitat is a habitat-based landscape approach to assessing wildlife and plant conservation needs and opportunities (MNAP, 2002). The goal of the program is to maintain sufficient habitat to support all native plant and animal species currently breeding in Maine by providing each Maine town with a collection of data layers and accompanying information depicting and describing various habitats of statewide and national significance found in the town. These data layers provide communities with information that can help guide the conservation of valuable habitats.

The Beginning with Habitat program identified important wildlife habitats on Mount Desert Island. If we agree with the basic paradigms of conservation biology (Pullin, 2002) that loss of species is bad and biodiversity represents important social value, then it is possible to conclude that areas with wildlife species habitats on them are valuable and have higher conservation priority than areas without them.

#### 6.6.1.2 Overview of the Wildlife Habitat Analysis Procedure

Four data layers created within Beginning with Habitat program were used as input data layers for this analysis.

IFW (Inland Fisheries and Wildlife) coverage includes more than 1300 occurrence records for rare wildlife species in Maine. Buffer polygon coverage was associated with point coverage. Data is used for status assessment, species management and habitat conservation for Endangered, Threatened and other rare species. This subset of the statewide data layer was developed for use in the Habitat Consultation Areas Mapping Project (HCAMP).

CWWH (Coastal Waterfowl and Wading Birds Habitats) and IWWH (Inland Waterfowl and Wading Birds Habitats) data layers represent habitats of coast and inland waterfowl and wading birds. These data sets were developed in accordance with Maine's

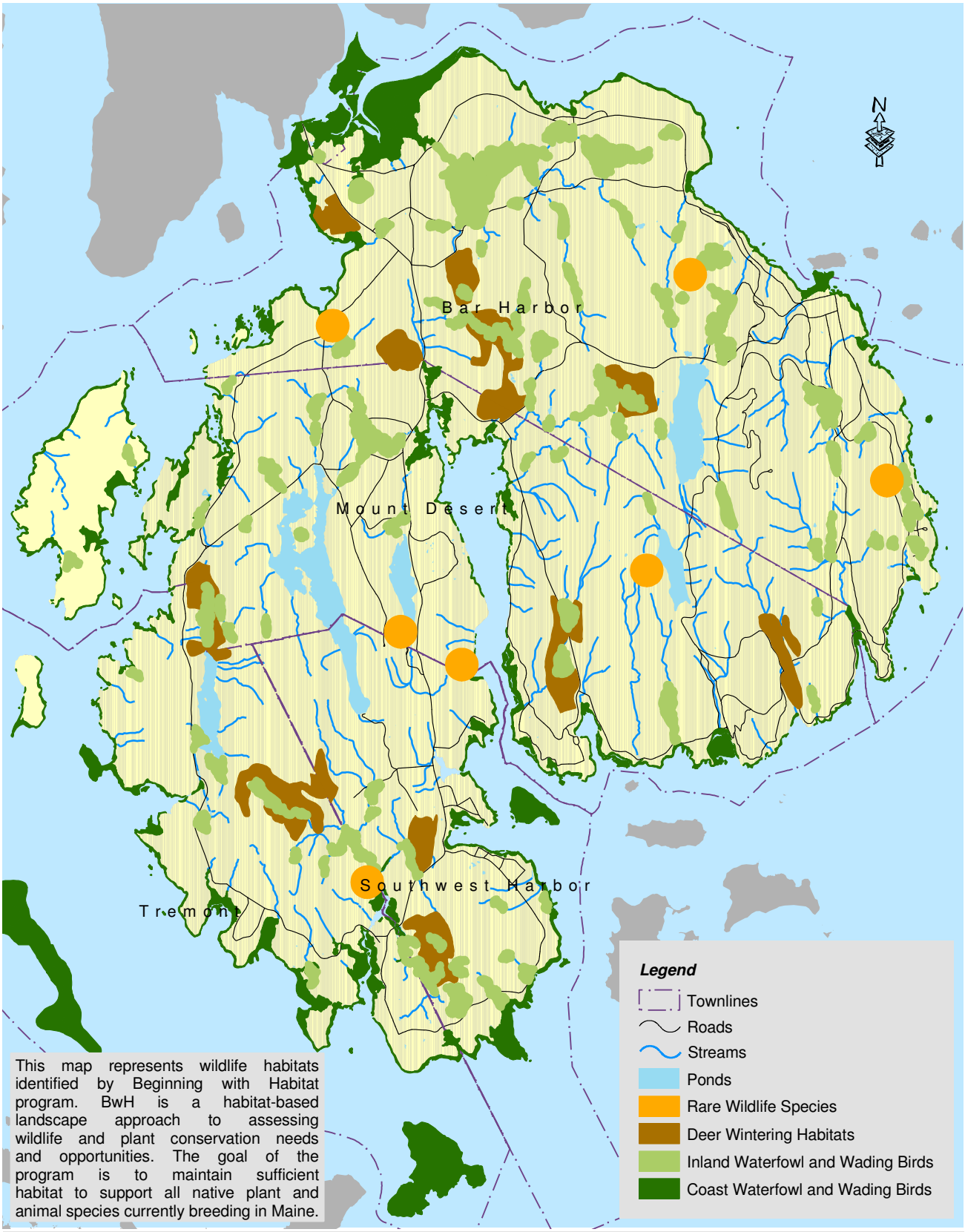
Natural Resources Protection Act (NRPA) and the Comprehensive Planning and Land Use Regulation Act (Growth Management).

DWH layer maps deer wintering areas. This data set was developed in accordance with Maine's Natural Resources Protection Act (NRPA). Under this act, the Maine Department of Inland Fisheries and Wildlife (MDIFW) is designated as the authority for determining significant wildlife habitats (SWHs).

The first step in this analysis was extracting the data for Mount Desert Island from the above mentioned coverages. Then I created buffers around individual species habitats in all four data layers. After consulting the problem with Island's biologists, I decide to use three buffers, each 61 m (200 ft.) wide. Layers were then converted to GRIDs in Spatial Analyst and reclassified into 5 classes. The value of 5 was assigned to wildlife habitats themselves. The values of 4, 3 and 2 were assigned to habitat buffers, and the remaining areas were given a value of 1. These four layers were then synthesized together in Raster Calculator – the individual values were added together. The final output layer was then reclassified into 5 standard ranks, where 5 is a very high conservation priority (areas with multiple wildlife habitats) and 1 is a very low conservation priority (areas with no mapped habitat). Appendices representing mapped species habitats and the result of wildlife habitat analysis follow.

# Wildlife Species Habitats

*Mount Desert Island*




This map represents wildlife habitats identified by Beginning with Habitat program. BwH is a habitat-based landscape approach to assessing wildlife and plant conservation needs and opportunities. The goal of the program is to maintain sufficient habitat to support all native plant and animal species currently breeding in Maine.

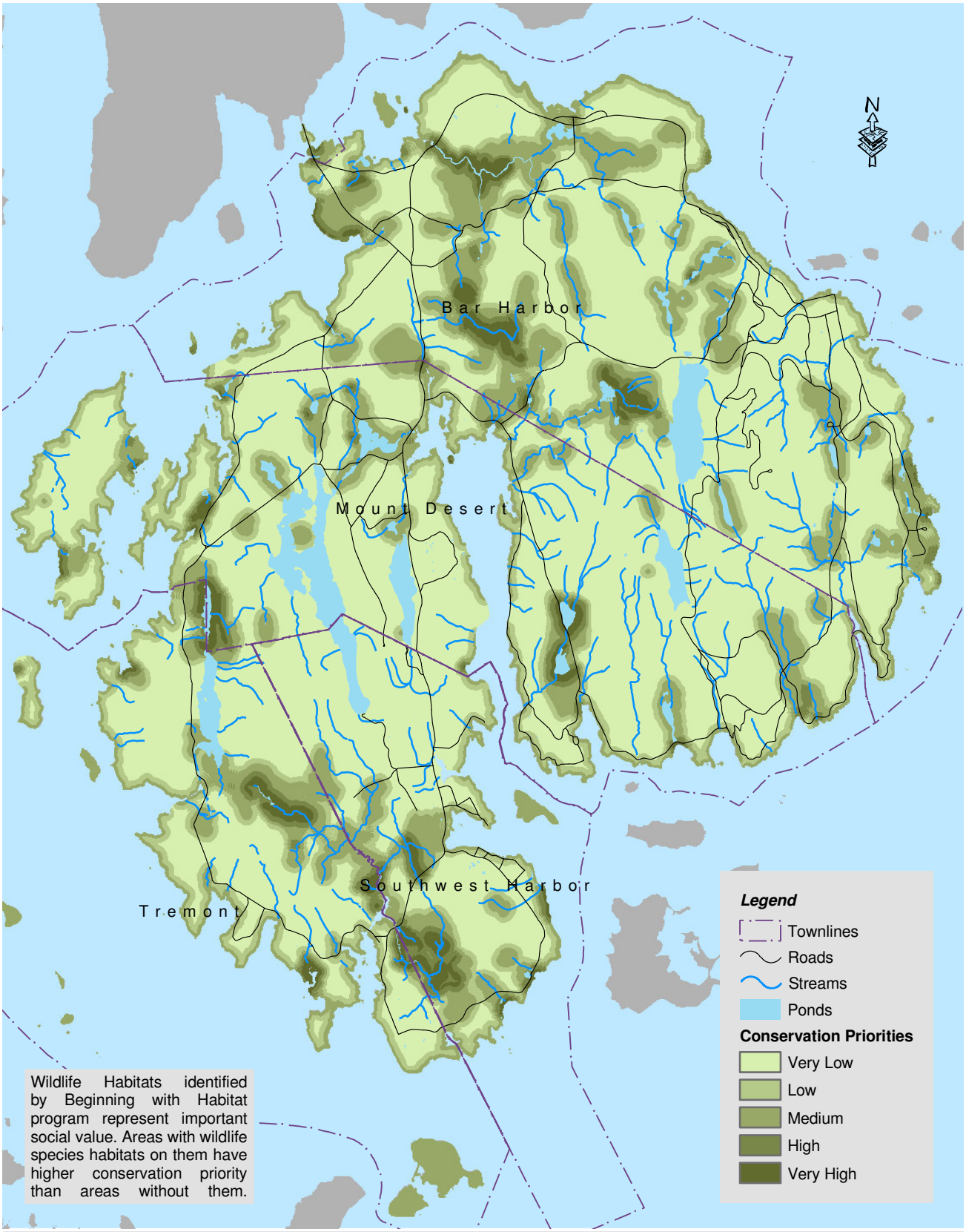
0 1 250 2 500 5 000 Meters

Projected Coordinate System:
NAD_1983_UTM_Zone_19N

Data Source: COA GIS Database
Prepared by Tomas Vaclavik
College of the Atlantic & Palacky University
January 2004

# Wildlife Habitats Analysis

*Mount Desert Island*




Wildlife Habitats identified by Beginning with Habitat program represent important social value. Areas with wildlife species habitats on them have higher conservation priority than areas without them.

0 1 250 2 500 5 000 Meters

Projected Coordinate System:
NAD_1983_UTM_Zone_19N

Data Source: COA GIS Database
Prepared by Tomas Vaclavik
College of the Atlantic & Palacky University
January 2004

### 6.6.2 Habitat Suitability

The Island's natural edge-richness determines the existing pattern of habitat areas which have not been severly altered by human activities. Habitat edges are prevalent wherever different vegetation types meet, or where vegetation meets an extensive network of streams, ponds, and wetlands. Wildlife species in these areas may use one habitat type for shelter or perching while taking advantage of food sources in the adjacent habitat. Some of the richest habitat areas on the Island are edges where the structurally complex canopy of the coniferous forest contrasts with the food availability of lowland heath or wetlands (McHarg, 1991).

The high diversity of habitat types on the Island due to the edge effect renders high suitability of these habitats for large number of species. The U.S. Fish & Wildlife Service Gulf of Maine Program has chosen 64 federally listed Endangered and Threatened species, declining neo-tropical migrants, shorebirds, waterfowl, anadromous and inter-jurisdictional fishes, throughout the Gulf of Maine, mapped their habitats, and rated these habitats according to their suitability for the species. The resulting digital maps highlight localities which have high species richness and high aggregate habitat value. This mapping also covers Mount Desert Island (Banner, 2001).

#### 6.6.2.1 Planning Concept

The USFWS data may be used to show valuable habitat for USFWS priority trust species. Its main purpose is to prioritize local and regional habitat protection, and to be incorporated into local and regional planning to help identify and protect important fish and wildlife habitat (Banner, 2001). Including the values of habitat suitability, the USFWS ranking may thus be incorporated into the conservation priorities model. Areas with high USFWS values have high conservation priority within the model.

#### 6.6.2.2 Overview of the Habitat Suitability Analysis

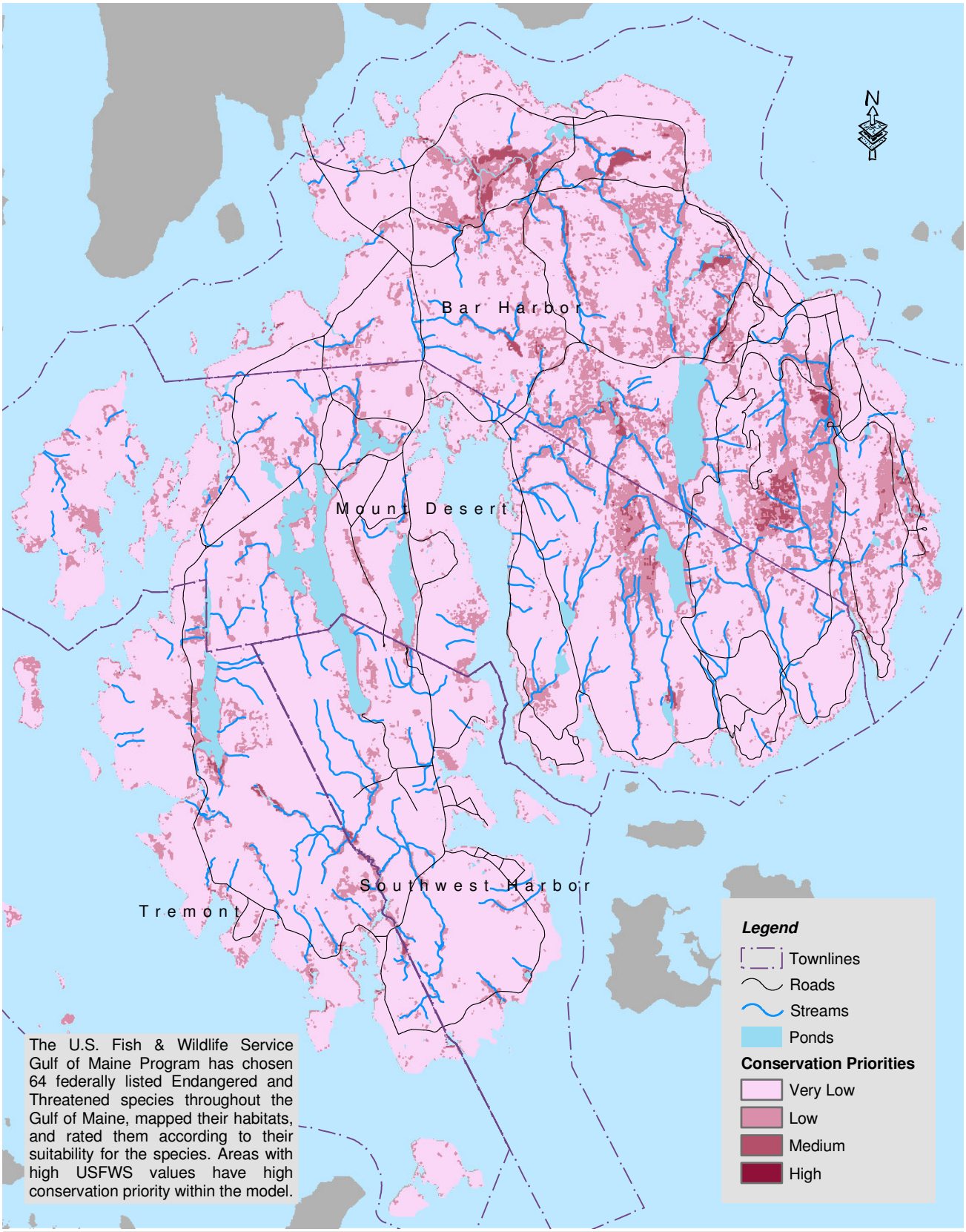
The GOMSUM data layer created by USFWS was used as an input layer. This GRID represents overall habitat suitability in the U.S. portion of the Gulf of Maine watershed for 64 priority trust species of the U.S. Fish & Wildlife Service (Banner, 2001). Habitats for each species were mapped and ranked from actual sightings or by developing habitat suitability models reflecting environmental requirements for each species. Scores for each species were then added to derive the sum of scores for all species combined. The

value for each cell reflects both the number of species using each cell and the relative habitat suitability for those species.

The suitability values of USWFS data ranges from values of 1 to 191. These values were reclassified for the purpose of this analysis into 5 equal classes. Data for Mount Desert Island were then extracted. Since the areas on MDI were not assigned values which came under class 4 (high conservation priority), only classes 1, 2, 3, and 5 are used in this model. The following is the map representing USFWS habitat suitability analysis.

# USFWS Habitat Suitability Analysis

*Mount Desert Island*




The U.S. Fish & Wildlife Service Gulf of Maine Program has chosen 64 federally listed Endangered and Threatened species throughout the Gulf of Maine, mapped their habitats, and rated them according to their suitability for the species. Areas with high USFWS values have high conservation priority within the model.

0 1 250 2 500 5 000 Meters

Projected Coordinate System:
NAD_1983_UTM_Zone_19N

Data Source: COA GIS Database
Prepared by Tomas Vaclavik
College of the Atlantic & Palacky University
January 2004

### 6.6.3 Hydrology

All water features on Mount Desert Island present a closed hydrological system. There are no waters flowing from other watersheds. The only water input comes from precipitation. The individual aquatic features can be generalized to streams, ponds, and wetlands.

Streams on Mount Desert Island are as diverse as the topography. They vary from short cascading streams in the steep mountain slope, fed by run-off or snowmelt, to larger meandering streams in the lowlands that in some cases may be affacted by tidal and saltwater. Streams on the Island are of 1$^{st}$ or 2$^{nd}$ stream order. Streams and their riparian vegetation represent important habitats and migration corridors for both aquatic and terrestrial organisms. Streams on the Island are also extensively used for various human purposes, and are consequently at risk from human activities (run-off, pollution).

There are around 250 ponds and lakes on Mount Desert Island. They were usually created as a result of glacial drift damming the vallies. These bodies vary from the largest, Long Pond, with an area of 36,500 m$^2$, to very small kettle ponds formed by large blocks of ice broken off from the glaciers, which were burried in glacial outwash sediments and later melted leaving a depression. The ponds are fed by precipitation and from run-off on the thin layer of granitic soils (McHarg, 1991). The water bodies are used for many purposes including water supply, fishing, sailing, and other recreational activities. They are vulnerable to nutrient infiltration and pollution associated with human activities (see section 4.1.3.2.2), although the water quality in most of the lakes is thus far very good because most of them are located in the National Park and lie above the threat of direct development.

Wetlands that can be found on the Island includes both freshwater and saltwater marshes, estuaries, and bogs. Marshes are flat areas where a flowing stream spreads over a large area and becomes a slow moving shallow water body. Bogs are usually low areas with stagnant slightly acidic water. Wetlands on the Island are characteristic of specifically adapted riparian vegetation, and tend to be very productive ecosystems for fish and wildlife. In addition, they play an important role in water filtering as they remove nutrients and other pollution that come from developed areas (Otto *et al.*, 2002).

#### 6.6.3.1 Planning Concept

Streams, ponds, and wetlands are recognized as important landscape features with very high social values, as they provide a broad range of indispensable social functions for the inhabitants. These functions include water supply, filtering, recreational and aesthetic function, ecosystems functions, and the like. Since hydrological features are vulnerable to pollution and degradation due to human activities, together with the riparian vegetation that buffers these areas and represent essential components of aquatic ecosystems, they call for protection against development. State regulations restrict use and development in a 200 ft. (61 m) buffer around all bodies of water and wetlands, and along coastal shorelines. In the sense of the model of conservation priorities it is possible to assume that areas with aquatic features or areas that are close to them have high conservation priorities.

#### 6.6.3.2 Overview of the Hydrology Analysis Procedure

This model applies the concept of set-backs to protect water quality, riparian habitats and scenic resources. It deals with buffers around hydrological features, including the shoreline. It uses data of MDI streams, ponds, wetlands, and shoreline.

STRMNET and PONDS data layers represent major streams and ponds on Mount Desert Island and lands of MDI municipalities. These data sets were created to define the surface water hydrology of Mount Desert Island and to serve as a digital "base map" layer. This layer was created from original the 24k USGS DLG files, which were obtained by the National Park Service for Acadia National Park and provided to College of the Atlantic under its cooperative agreement. The STWET data layer represents state protected wetlands greater than 10 sq. acres. This data was digitized from 1:50,000 maps which were obtained from the Hancock County Planning Comission. The final data set used here was SHORE data of the MDI shoreline (the same data layer as the analysis mask).

All necessary layers were of appropriate extent, so no data extraction was necessary. The first step in this analysis was converting the layers to raster. Since the proximity to hydrological features needed to be calculated, the EUCDISTANCE function in Spatial Analyst was used. This function calculates euclidian (straight-line) distance for each cell to the closest source (in this case cells representing water bodies). The output values for the Euclidean distance grid are floating-point distance values. If the cell is at an equal distance to two or more sources, the cell is assigned to the source that is first encountered in the scanning process. As soon as the distance was calculated for all four layers, the were reclassified into 5 standard classes using buffers of 200 ft. (61 m) as a

criterion, so areas up to 200 ft. from water was given value of 5, areas up to 400 ft. (122 m) from water value of 4, and so forth. Finally, these four GRIDs were added together in Raster Calculator and the output values were again reclassified into 5 equal classes. In the final output GRID, the areas with the highest conservation priorities are the ones closest to water with multiple buffers from different water features. The following are the appendices representing the map of MDI hydrology and the model of proximity to various hydrological features.

# Hydrology - Streams, Ponds, Wetlands

*Mount Desert Island*


0 1 250 2 500 5 000 Meters

Projected Coordinate System:
NAD_1983_UTM_Zone_19N

Data Source: COA GIS Database
Prepared by Tomas Vaclavik
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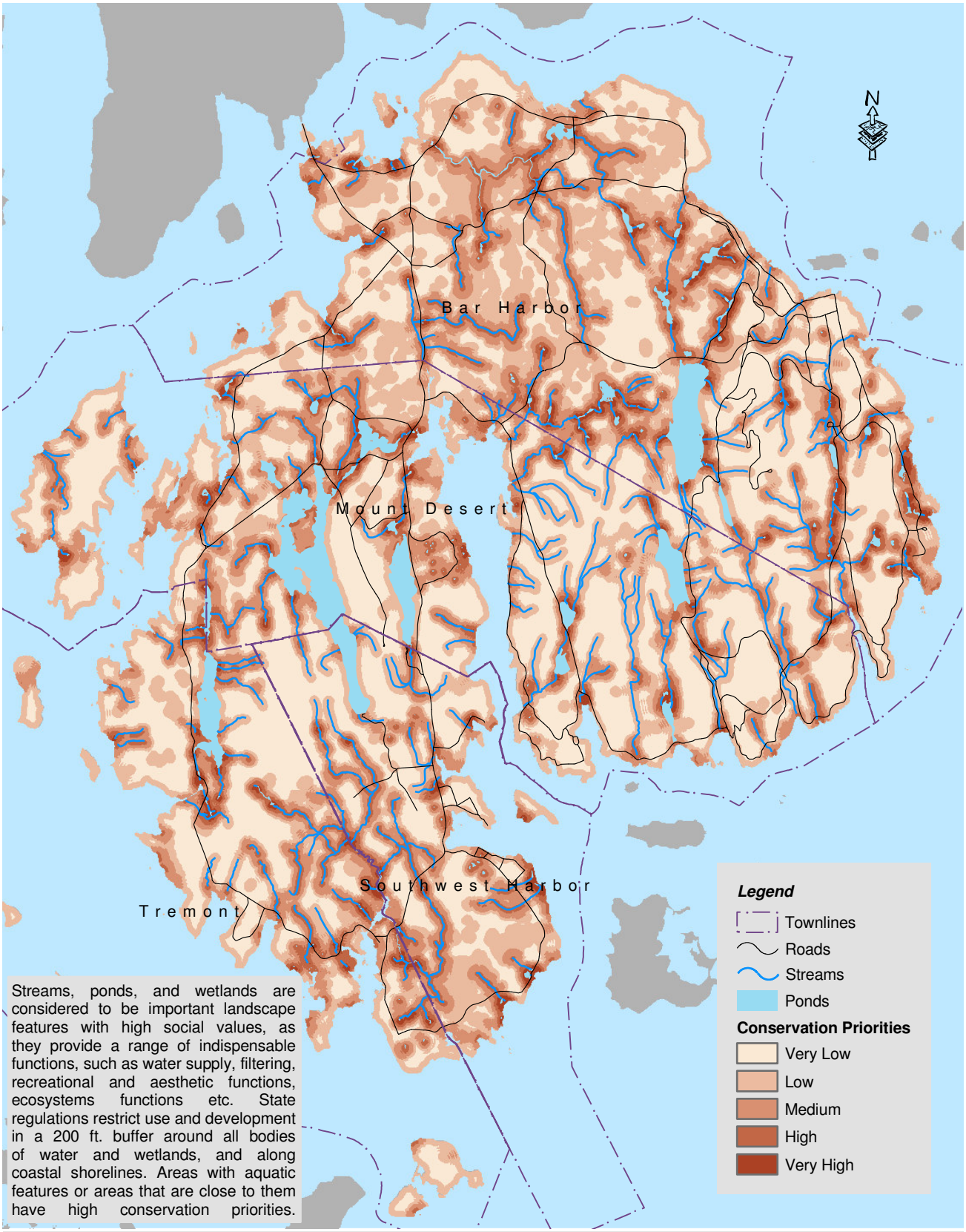
January 2004

# Hydrology Analysis

*Mount Desert Island*




Streams, ponds, and wetlands are considered to be important landscape features with high social values, as they provide a range of indispensable functions, such as water supply, filtering, recreational and aesthetic functions, ecosystems functions etc. State regulations restrict use and development in a 200 ft. buffer around all bodies of water and wetlands, and along coastal shorelines. Areas with aquatic features or areas that are close to them have high conservation priorities.

0 1 250 2 500 5 000 Meters

Projected Coordinate System:
NAD_1983_UTM_Zone_19N

Data Source: COA GIS Database
Prepared by Tomas Vaclavik
College of the Atlantic & Palacky University
January 2004

### 6.6.4 Fragmentation

Places on Mount Desert Island and the Island itself are highly accessible due to the extensive road system network. Through analyzing road network data that will be described later, it is possible to say at the outset that there are approximately 705 km of roads on the Island, from which 78 km are classified as primary roads, 172 km as secondary, 129 km as light-duty, 20 km as fire roads, 83 km of roads are carriage roads in the Acadia National Park, and 223 km of roads are unimproved roads mainly connecting individual development subdivisions with major roads. New roads are still being built to provide access to new development and also to reduce traffic congestion in the summer season which is caused by the huge influx of seasonal visitors.

#### 6.6.4.1 Planning Concept

From the landscape point of view, roads as linear features in the landscape often represent a considerable barrier for ecological processes and causes its fragmentation. Landscape fragmentation and its negative effects to various organisms has been described in section 4.1.3.2.1. Following analysis tries to asses landscape fragmentation by calculating proximity of areas to the existing transportation corridors. This analysis is based on the assumption that larger undeveloped (unfragmented) areas which are further away from roads have higher conservation priorities than smaller areas close to them. Owing to their character and minimal traffic, carriage and fire roads were excluded from the analysis as they do not present a serious barrier for organisms and often serve as their migration or foraging corridors.

#### 6.6.4.2 Overview of the Fragmentation Analysis Procedure

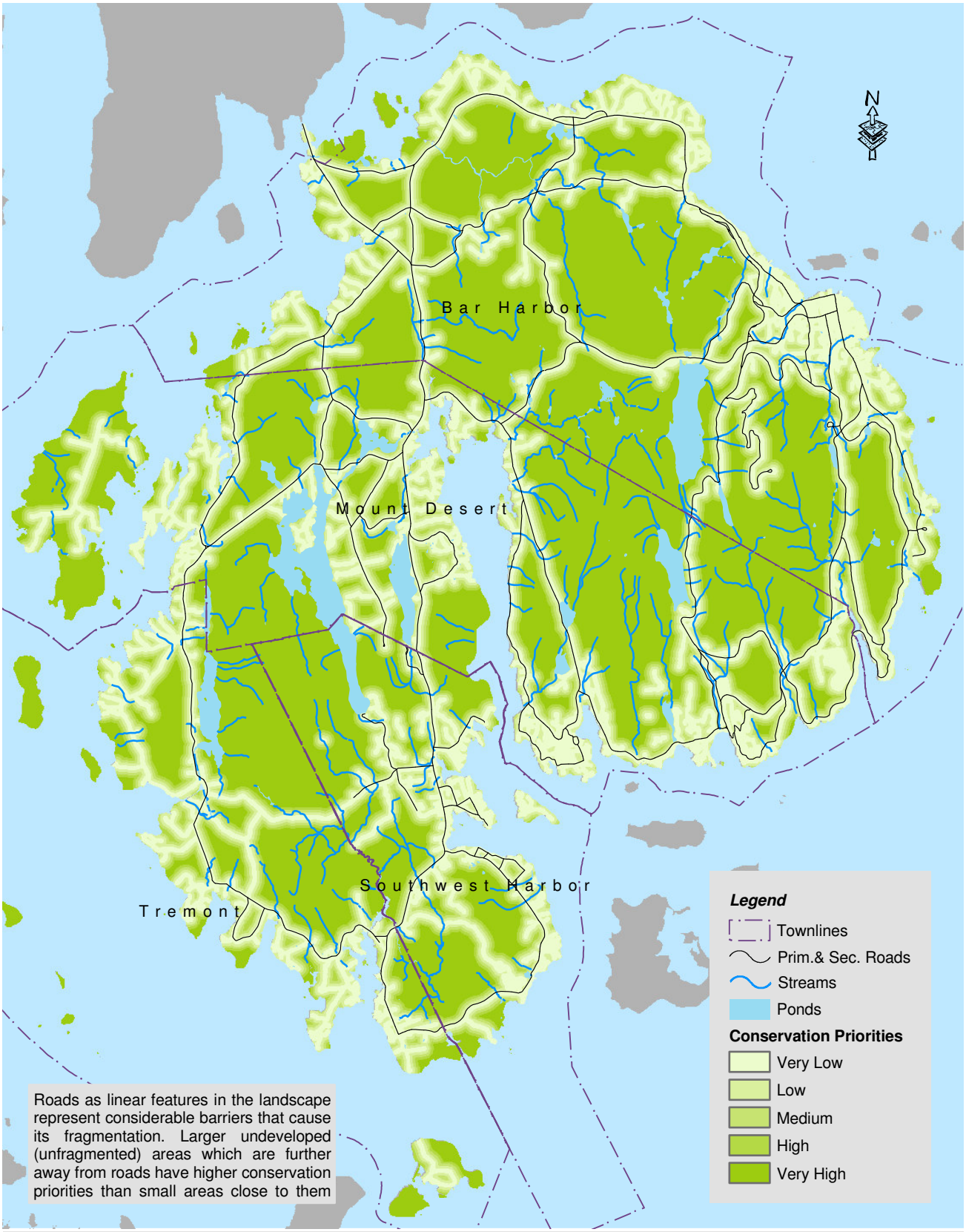
The RDNET data layer served as the primary input data for the fragmentation analysis. This data set represents the transportation network of Mount Desert and the lands of MDI municipalities. The layer was created from the original 24k USGS DLG file, which was obtained by the National Park Service for Acadia National Park and provided to College of the Atlantic under its cooperative agreement.

The first step in the procedure was the exclusion of the carriage and fire roads from the original dataset as they were not suitable for the analysis. The vector data were then converted to GRID. As in the previous analysis, the EUCDISTANCE function from Spatial Analyst extension was used to calculate the straight-line distance of individual cells

from the cells representing road network. The output raster layer was then reclassified into 5 standard ranks, where small areas in the middle of a dense road network gained lower values, and larger unfragmented areas far away from roads gained higher values. 200 ft. (61 m) buffer conventionally being used for state restrictions served as the width of the individual buffer zones. The following is the paper print displaying results of the fragmentation analysis model and MDI primary and secondary roads.

# Fragmentation Analysis

*Mount Desert Island*




Roads as linear features in the landscape represent considerable barriers that cause its fragmentation. Larger undeveloped (unfragmented) areas which are further away from roads have higher conservation priorities than small areas close to them

0 1 250 2 500 5 000 Meters

Projected Coordinate System:
NAD_1983_UTM_Zone_19N

Data Source: COA GIS Database
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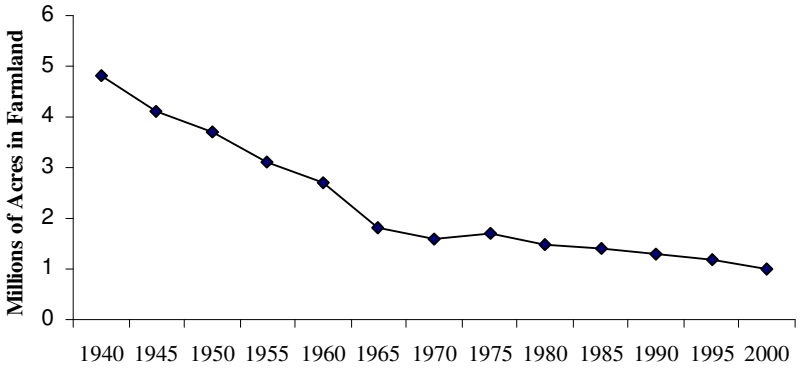
### 6.6.5 Prime Agricultural Soils

In spite of the thin layers of soil and the unfavourable climate reasonable for the short vegetative season, farming has a long tradition not only on Mount Desert Island, but in the State of Maine generally. Traditional farms in Maine are of a small size and extent, and focus mostly on producing potatoes, vegetables, blueberries, milk, eggs, and cattle. Despite the hard natural conditions, Maine farmers were once self-sufficient and able to feed local communities. However, there has been a significant decrease in the numbers of productive farms and in area of farmland over the past years. The chart below (fig. 7) taken from Maine Rural Development Council demonstrates the drop in acrage of farm land during the past sixty years.

Figure 7: Maine land in farms 1940 - 2000




Sprawl development is one of the reasons behind the loss of farmland (SPO, 1997). It not only converts farmland to other uses but also impairs the productivity and viability of the farms that remain. Ironically, it is the open fields, cows at pasture, and scenic views which farms offer that attract the very growth which then begins to limit the farm's capacity to remain an economically viable part of the working landscape. That is the irony implicit in and driving sprawl.

#### 6.6.5.1 Planning Concept

Farmland is affected by sprawl because it is easy to develop. Though at risk from the impacts of sprawl, farming also has a role in reducing it. Active farming engages large parcels of land in productive natural resource use. It provides open space, scenic views, wildlife habitat, opportunities for recreation, and if care is given and land is respected, clean air and a healthy environment. Farming also adds to the local economy through its

productive capacity. There are secondary benefits as well, such as attracting tourists, offering hunting and fishing opportunities as well as trails for snowmobiling.

These benefits place notable social values on farms and the prime agricultural soils below them. Because these areas are fast dissappearing and being built up they need to be conserved. Within the model of conservation priorities, areas with prime agricultural soils that are possible to be used for traditional farming activities have higher conservation priorities than areas without them.

#### 6.6.5.2 Overview of the Agricultural Soils Analysis Procedure

The Natural Resource Conservation Service SSA_S data layer of soils described previously served as the input data for this analysis. The NRCS identified those types of soils that have the potential to be used for traditional farming activities. They provided the information in the form of a dbf "look up" table. After the data for Mount Desert Island was extracted from the soil layer, this table was joined to it according to the MUSYM field and the output converted to raster using Spatial Analyst extension. This GRID was then reclassified according to the type of soils and new values were assigned to the cells. Areas with prime agricultural soils were given a value of 5-very high conservation priority, areas with other types of soils were given a value of 2-low conservation priority. The following appendix represents the paper print of the prime agricultural soils analysis.

# Prime Agricultural Soils

*Mount Desert Island*


Traditional farming represents important social values. It provides open space, scenic views, wildlife habitat, opportunities for recreation, and if care is given and land is respected, clean air and health environment. Farming also adds to the local economy through its productive capacity. Secondary benefits include attracting tourists, offering hunting and fishing opportunities. Thus areas with prime agricultural soills that are possible to be used for traditional farming activities have higher conservation priorities than areas without them.

0 1 250 2 500 5 000 Meters

Projected Coordinate System:
NAD_1983_UTM_Zone_19N

Data Source: COA GIS Database
Prepared by Tomas Vaclavik
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January 2004

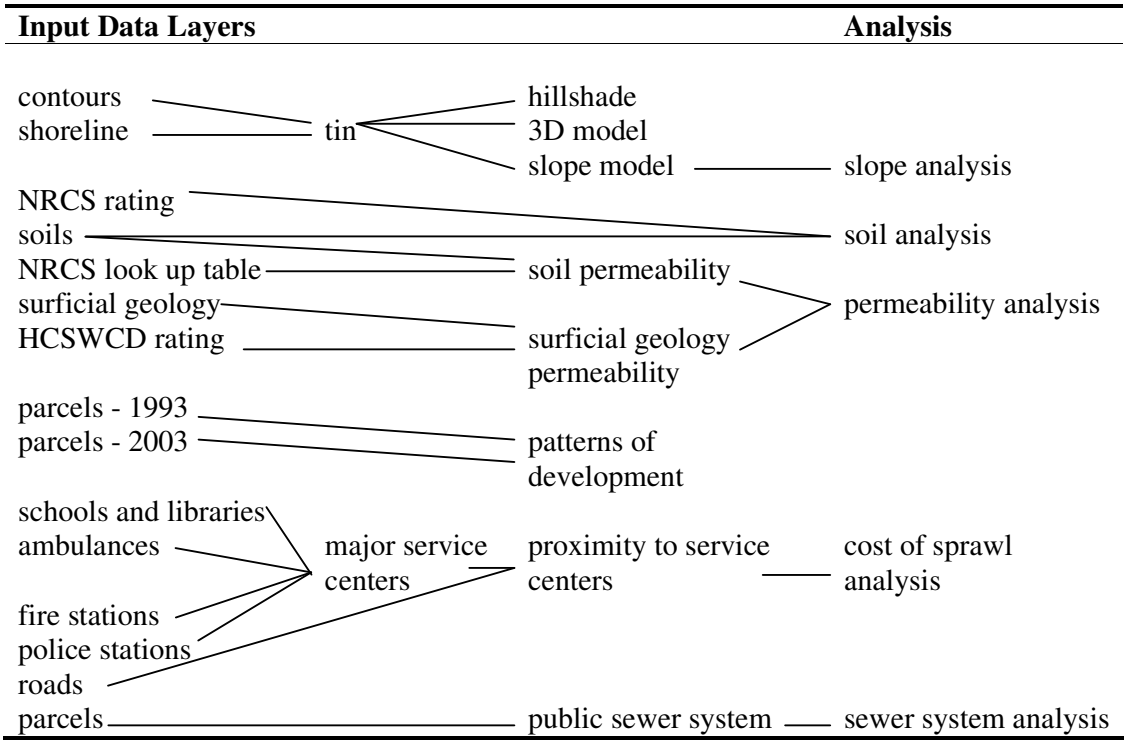
# 7. RESULTS

In the previous sections detailed GIS analysis of both natural and socio-economic land characteristics was made. The analysis of certain information is generally a reductive process. McHarg (1998) states that reductionism has proven to be so efficacious as to be synonymous with science. It is increasingly clear that reductive analysis must be complemented by creative synthesis. The results of the performed analysis described in sections 6.5 and 6.6 were synthesized and three final models were created.

## 7.1 Suitability for Development

Figure 8 represents the overview of input data used and layers created for the model of development suitability.

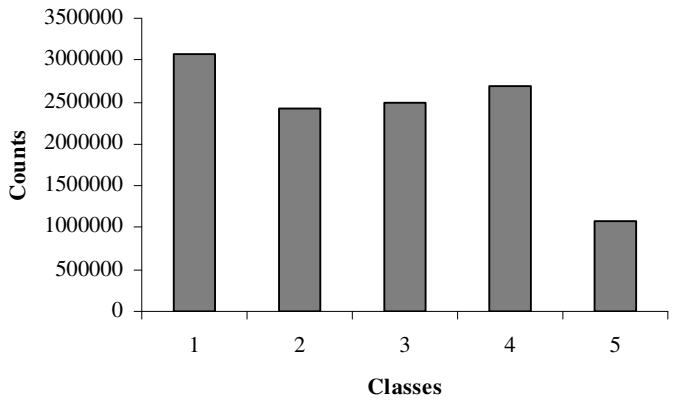
Figure 8: Data layers used in the model of development suitability




The values of the cells in the raster layers which represent individual analysis included in the model of development suitability ranges from 1-very low development suitability to 5-very high development suitability. Since the range is the same for all of the considered data

layers, the intended synthesis of these layers can be accomplished by simply adding the values together using Raster Calculator. As there were 5 layers which to be added, the output values ranged from 1 to 25. For consistency and better presentation of the results, the output GRID was reclassified back to 5 equal classes. The resulting distribution of cells (areas) in individual suitability classes is presented in fig. 9.

Figure 9: Histogram of the development suitability model




This suitability model represents a gradient of values ranging from higher numbers that indicate greater suitability for development and lower numbers that indicate lower suitability for development. Mid-range values represent marginal land for development without a unique or special condition warranting its development potential.

## 7.2 Conservation Priorities

Similarly, as in the previous model, the values of the cells in the raster layers which represent individual analyses the value range from 1-very low conservation priority to 5-very high conservation priority. To synthesize the results of the performed analysis, the values of the individual analysis layers were added together in Raster Calculator. As there were 5 layers, again the output values ranged from 1 to 25. The output GRID was then reclasified back to 5 equal classes.

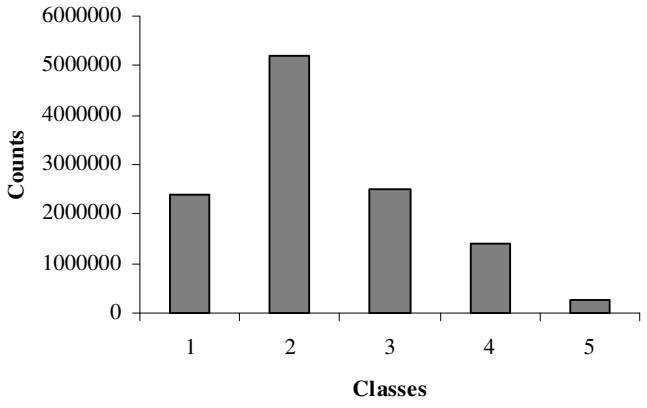
Figure 10 represents the overview of input data used and layers created for the model of conservation priorities.

Figure 10: Data layers used in the model of conservation priorities

| Input Data Layers | | Analysis |
|---|---|---|
| rare species habitats | rare species habitats buffers | |
| waterfowl and wading bird habitats | bird habitats buffers | wildlife habitat analysis |
| deer wintering areas | deer wintering areas buffer | |
| USFWS habitat suitability | | habitat suitability analysis |
| streams | proximity to streams | |
| ponds | proximity to ponds | hydrology analysis |
| wetlands | proximity to wetlands | |
| shoreline | proximity to shore | |
| roads | roads buffers | fragmentation analysis |
| soils | prime agricultural soils | prime agricultural soils analysis |

The resulting distribution of cells (areas) in individual conservation priority classes is presented in fig. 11.

Figure 11: Histogram of the conservation priorities model



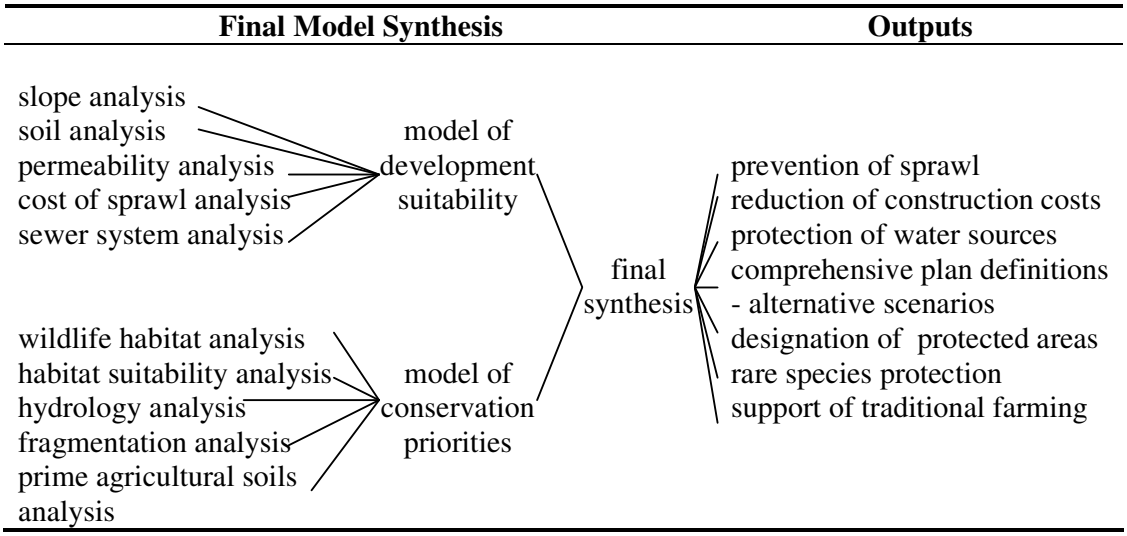

This model represents a gradient of values ranging from higher numbers that indicate greater conservation priority and lower numbers that indicate lower conservation

priority. Mid-range values represent marginal land for development without a unique or special condition guaranting its value for conservation.

## 7.3 Final Synthesis

The major aim of this work was to develop one final model (map) which would present "growth" areas (those areas with high growth potential) and "rural" areas (areas with high conservation values). To fulfill this aim, both models of development suitability and conservation priorities were synthesized into one final layer. The diagram in fig. 12 shows the scheme of the final suitability models.

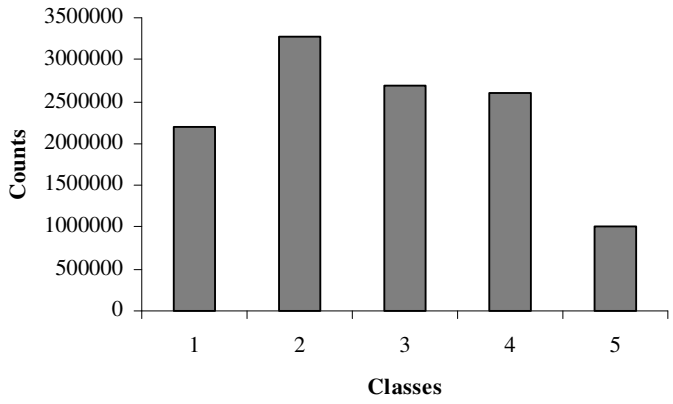
Figure 12: Scheme of the final suitability models




As input layers, the GRIDs of development suitability and conservation priorities models before they were reclassified into 5 classes were used, so their values ranged from 1 to 25. The values of the conservation priority model were then substracted from the values of the development suitability model using Raster Calculator. The output raster ranged from negative to positive values (maximum range -24 to +24). These values were finally reclassified into 5 standard classes where 1 is very high conservation priority and 5 very high suitability for development. The resulting distribution of cells (areas) in individual classes is presented in fig. 13.

This final summary model identifies the most appropriate lands on which to build and the most important areas to conserve based on documented criteria. The model represents a gradient of values ranging from higher numbers that indicate greater suitability for development and lower numbers that indicate higher conservation priorities. Mid-range values represent marginal lands for development and marginal land without a unique or special condition warranting conservation.

Figure 13: Histogram of the final synthesis




In the summary process as it was performed here, the layers representing individual analysis have the same relevance because their values ranging from 1 to 5 were simply added together. However, there is the possibility of including the values of various stakeholders and thus, to weight the final summary model towards the chosen criteria. This can be accomplished by multiplying some of the analysis layers by a factor that would represent the importance of the criteria. For example, if the town planners recognized the issue of preventing sprawl as having priority importance for development suitability, the sprawl analysis would be multiplied by a certain number. The final suitability model would then prioritize places closer to major service centers more than in the model as it was created here.

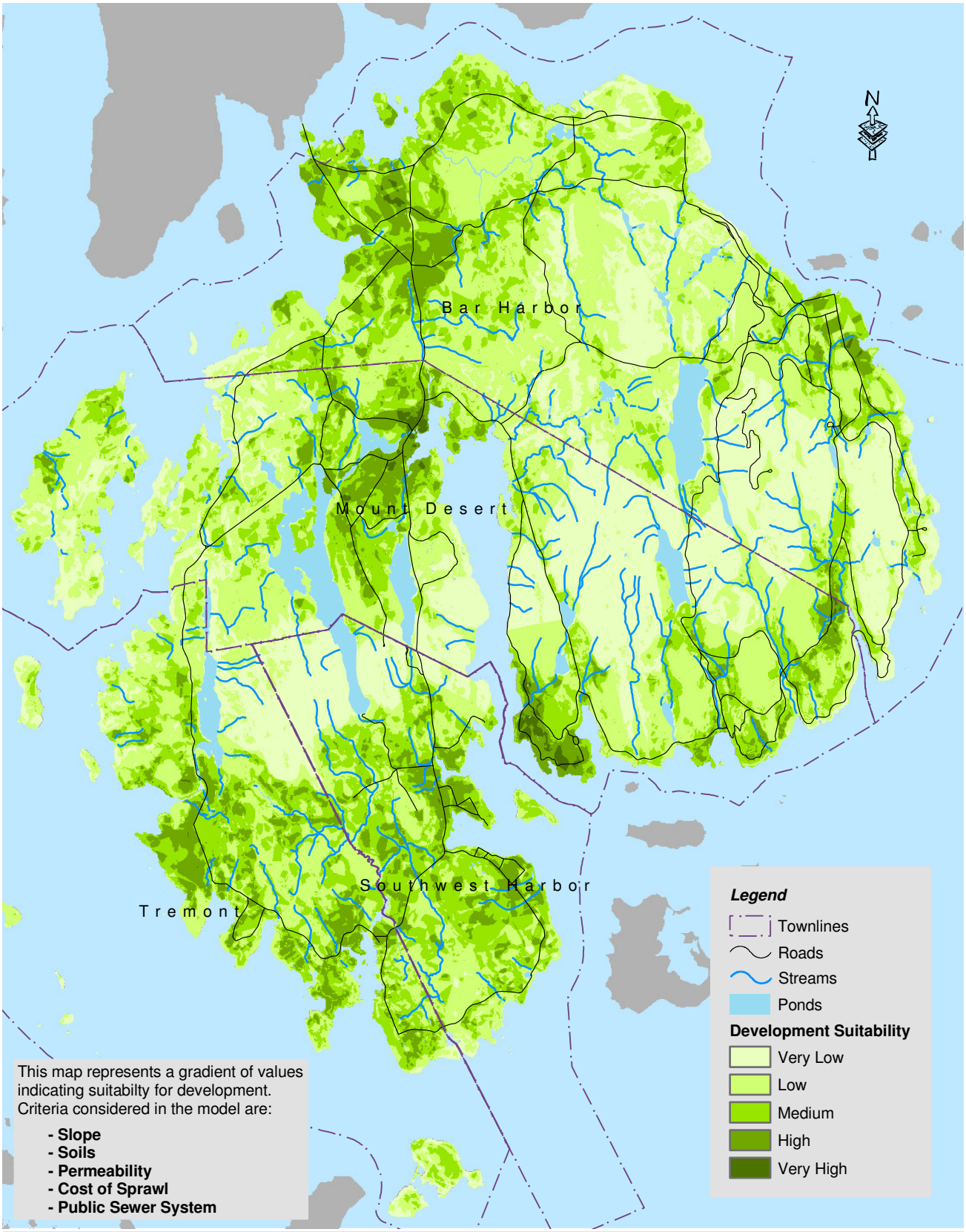
This ability determines the possible use of the method. It is the way, by which various stakeholders, if their values are taken into consideration, can intervene to planning process and enforce their interests. For example, the model of conservation priorities can be especially useful for identifying places with conservation values that are not included in

Acadia National Park and thus do not have any type of protection. This model can also help farmers to protect arable land with prime agricultural soils against new development or any other improper use. On the other hand, the model of development suitability may serve planners to prevent sprawl and associated costs. Developers can better identify the most appropriate locations for the construction of houses and thus lower the construction costs and protect important groundwater sources. However, there are areas which might have high values on both sides of these two models. For instance, some soils might be suitable for residential development and located near existing service centers, and, in the same time, they can be suitable for traditional farming activities and exist in the close distance to important hydrological features. The final suitability model representing the overall synthesis of all considered criteria has the advantage of distracting from the values of both models. The final areas which come out with very high suitability for development do not have much of a conservation value within the considered criteria.

The results of all three summary models identified and designated several hot spots of both development and conservation values on which town planners and naturalists might want to focus. The areas identified by the analysis process will not be further verbally commented upon because the graphic visualization represents the main power of GIS and is the only possible and complex way of presenting the results of spatial analysis. The appendices representing the paper prints of the development suitability and conservation priorities models and the final synthesis follow.

# Model of Suitability for Development

*Mount Desert Island*



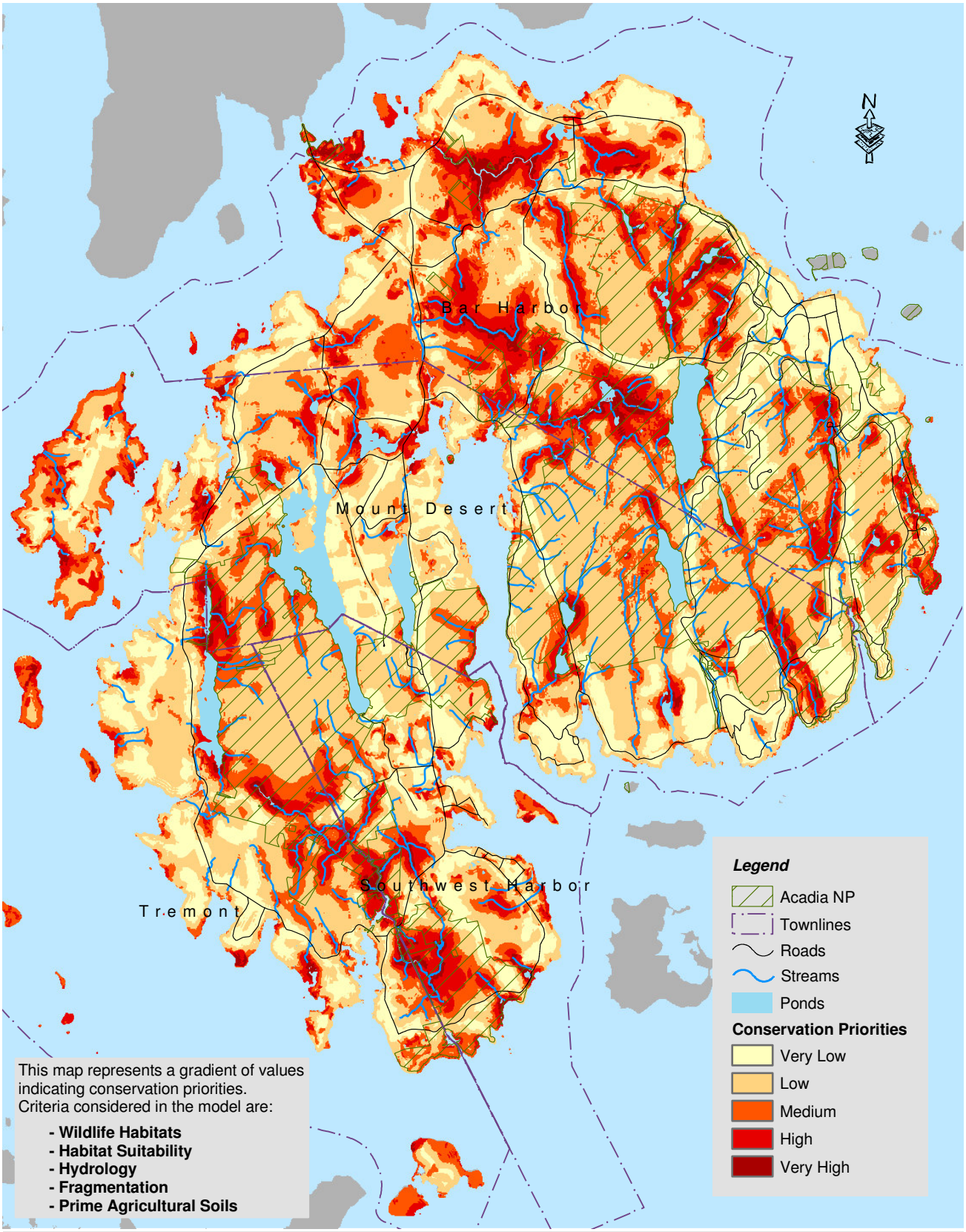

0 1 250 2 500 5 000 Meters

Projected Coordinate System:
NAD_1983_UTM_Zone_19N

Data Source: COA GIS Database
Prepared by Tomas Vaclavik
College of the Atlantic & Palacky University
January 2004

# Model of Conservation Priorities

*Mount Desert Island*




This map represents a gradient of values indicating conservation priorities. Criteria considered in the model are:

- **Wildlife Habitats**
- **Habitat Suitability**
- **Hydrology**
- **Fragmentation**
- **Prime Agricultural Soils**

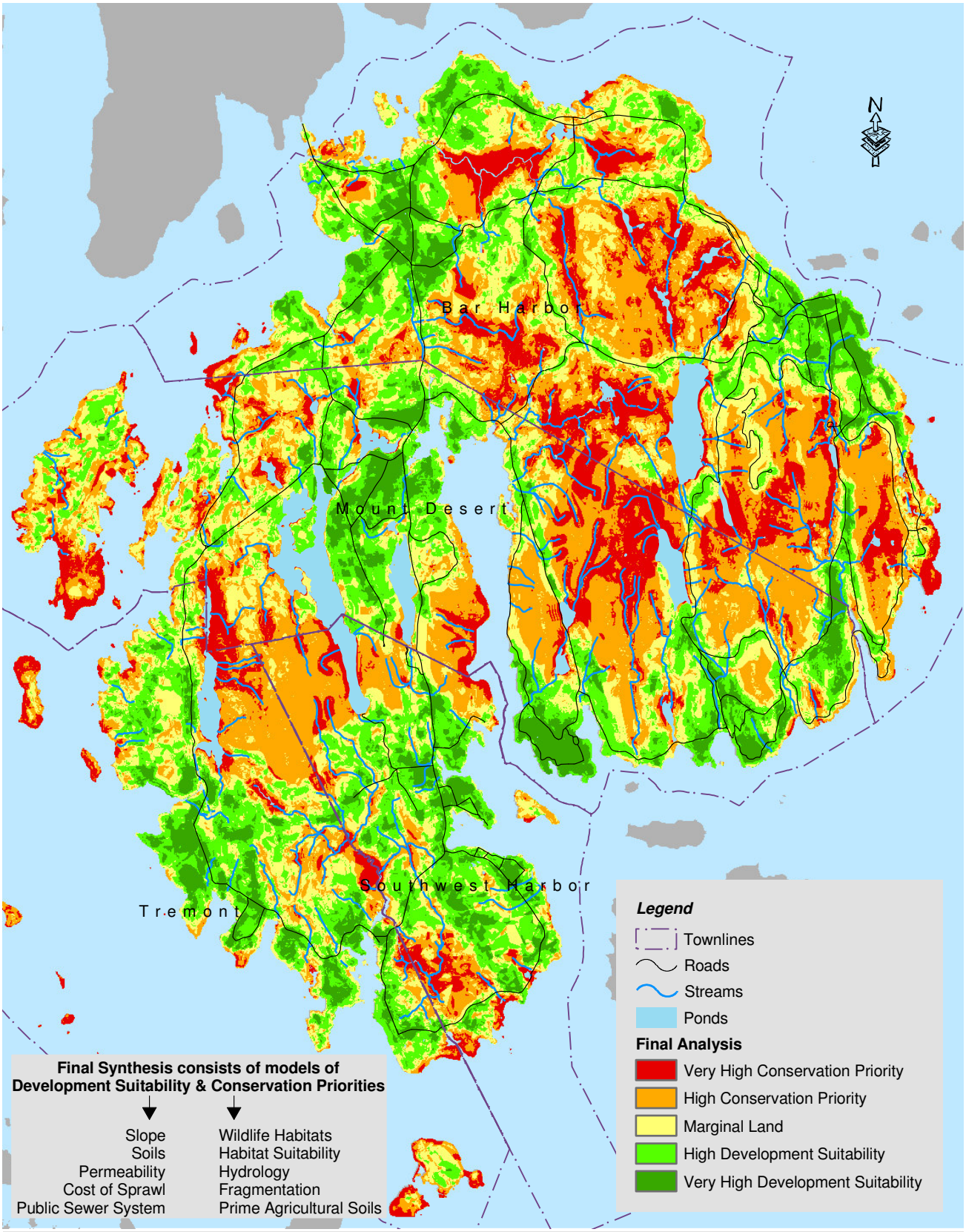
0 1 250 2 500 5 000 Meters

Projected Coordinate System:
NAD_1983_UTM_Zone_19N

Data Source: COA GIS Database
Prepared by Tomas Vaclavik
College of the Atlantic & Palacky University
January 2004

# Suitability Analysis for Development and Conservation Priorities

*Mount Desert Island*




0 1 250 2 500 5 000 Meters

Projected Coordinate System:
NAD_1983_UTM_Zone_19N

Data Source: COA GIS Database
Prepared by Tomas Vaclavik
College of the Atlantic & Palacky University
January 2004

# 8. DISCUSSION

Suitability modeling and its inherent GIS technology applications represent a powerful tool for ecological landscape planning. It provides users with a broad range of tools which significantly enhances the effectivness of analyzing and presenting spatial data. The method demonstrated allows information from different sources to be connected and used in the analyses. Although this capability represents the main power of the method for deliberate planning, there are other benefits as well as limits to the model. While the suitability model was prepared for an area in the USA its potential use in the Czech Republic is discussed here as well.

## 8.1 The Benefits of Suitability Modeling

The suitability modeling as demonstrated represents an example of a revolutionary shift in the continual evolution of GIS applications. The emphasis has turned from descriptive "geo-query" searches of existing databases to prescriptive analysis of mapped data. The dominant feature of the spatial analysis is that digital maps are conceptualized as a set of "floating maps" with a common registration, allowing one to "look" down and across the stack of digital maps. The spatial relationships of the data can be summarized or mathematically manipulated. Due to their digital fashion, these maps create a wealth of quantitative as well as qualitative processing possible. The ability to analyze and then summarize large amounts of information in the way it is needed makes this technology a very sophisticated tool for more objective decision-making in ecological planning.

As the communication of interested parties is essential in the decision-making process, another benefit is the involvement of their perspectives in the suitability modeling method. The summary suitability model as created here does not prefer any criterion above other because the layers were simply added together. However, the method enables the inclusion of values of various stakeholders and thus weight the final summary model towards chosen criteria. Weighting modifications affect the combining of the interpreted maps into an overall suitability map. Through this approach different suitability scenarios can be created and various alternatives of possible growth potentials and conservation limits of the study area compared.

The full potential for GIS in decision-making, however, has not been realized and is, at least in part, due to the inherent complexity of a developing technology, the

unfamiliar nature of its products, and the "user-abusive" nature of its use. Nevertheless, ESRI has already issued Model Builder, which is a user-friendly technology for building spatial models. Flow diagrams created with Model Builder let users save models and rerun them using different input data. Users can also rerun their models using different function parameters, thus enabling them to calibrate their models or examine how they perform using different sets of values. This study also serves as a template for a future inclusion into ArcGIS Model Builder.

## 8.2 The Limits to Suitability Modeling

Like any other model used in regional level, a suitability model is a generalized statement, or abstraction, of important considerations in a real-world situation. In spite of its various benefits, suitability modeling has its limitations. Significant limitations concern the accuracy and precision of the input data. Accuracy is the degree to which information on a map or in a digital database matches true or accepted values. Accuracy is an issue pertaining to the quality of data and the number of errors contained in a dataset or map. Precision refers to the level of measurement and exactness of description in a GIS database. Precise locational data may measure position to a fraction of a unit. It is important to realize, however, that precise data, no matter how carefully measured, may be inaccurate. Both accuracy and precision pose important issues affecting the quality of performed suitability analysis.

The criteria that were used in the suitability modeling process need to be taken into consideration as well. Not every relevant piece of information can be included in the model and not all information is relevant to either the planning purpose or the given study area. Although the model of Mount Desert Island contains the major criteria expressive of local conditions and determine the suitability of a particular area for development and conservation priorities, it only provides a base-line. There are still many important areas to which the model can be extended, such as vegetation, traditional recreational areas, lot size and zoning, air quality, human health, and other stakeholder values.

If this method is to become part of an effective and objective decision-making policy in ecological planning, the people that are making the decisions need to be aware of its limitations. GIS is a tool as is any other tool; it can be used either appropriately or inappropriately. Although based on a great deal of scientific data and rigorous GIS modeling, the final assignment of suitability values involves a large amount of subjective

judgment. Thus, if an area appears green on the final map, it does not mean it can be automatically developed. The results of the suitability modeling have to be validated and checked in the real world. Though it may represent a great advance in regional planning, GIS does not provide an artificial intelligence for land use decision-making.

## 8.3 Possible Use in the Czech Republic

Regional planning is considered to be a very useful tool in many countries in the world, including the Czech Republic, as it enhances the effectivity of land development and lowers the economical, environmental, and social costs that are associated with it. Although the conditions in the USA and the Czech Republic may be very different, the basic criteria, which serve as the inputs for regional planning, are the same. Even the issue of sprawl was identified in the Czech Republic in the 1990's by Institute for Transportation and Development Policy (Jackson, 2001). However, this type of sprawl is less extensive than in the USA due to different scale of land and state restrictions, and concerns mostly large aglomerations such as Prague. Nevertheless, deliberate regional planning is indispensable in the Czech Republic.

GIS technology is rarely being used for regional planning in this country. Since maps and other graphic visualization are needed for planning process, CAD systems often serve for this purpose, although they lack the ability of linking attribute and spatial information. Concerning the described method itself, the method of considering various landscape characteristics and creating suitability analysis, there is nothing similar in present regional planning in the Czech Republic. A large amount of various information on the study area is usually gathered for the purpose of developing a regional plan but a final summary of the data is lacking. The only output presented is usualy a "problem layout" displaying the input limits of the area. There is no objective output of development suitability based on natural characteristics as this method offers.

The potential of suitability modeling application in the Czech Republic can be seen at the beginning of the planning process. In my opinion, after appropriate modifications that would express the nature of local conditions, it could serve as a standard baseline for the"surveys and analysis" (průzkumy a rozbory) in the "regional plan documentation" (ÚPD – územně plánovací dokumentace). It could also be used to define effectively the "assignment" of a regional plan. Ecological organizations might find it very helpful for the objective of opposing proposed regional plan scenarios. It might help to deal with issues in

areas that have been neglected in the past, such as recreation, transportation, and the like. Considering the character of available data and the method itself, it might be most suitable at the level of "large land unit" (VUC – vyšší územní celek), or in the case of appropriate data, at the level of larger municipalities. However, it can only be successful if all stakeholders accept its advantages and if the method is incorporated into the regional planning methodology. This might be possible in view of the upcoming amendment of the "Building Act" (50/1976 Sb.) due to the synchronization of Czech laws with European Union legislation.

# 9. CONCLUSIONS

This work aimed at demonstrating the possible uses of Geographic Information Systems, especially suitability modeling, for the purpose of deliberate ecological planning. A brief overview of the basic characteristics of GIS technology were created, with an emphasis to the raster analysis and modeling. Some specific natural and socio-economic characteristics of the study area were described and the sprawl pattern of development was examined. A large quantity of information and data about the study area was gathered and analyzed from the planning perspective. However, the major aim of this work was to further develop the standard GIS method, which would, using advanced GIS cell-based analysis, produce a suitability model for the area under study that would assist both planners and decision-makers in identyfying the general geographical areas that have either high conservation priority or high development suitability at a regional scale.

The proper application of GIS technology does not consist of the mere collection of information and the construction of endless databases but must be followed by detailed analysis and thoughtful problem solving. Thus, ten different analyses considering both natural and socio-economic land characteristics of Mount Desert Island were performed during the work and the analysis process culminated in their synthesis into three models which identify places with high growth potential, or places which are valuable from the conservation point of view. The analysis procedures were briefly described and some land particularities that stem from the specific local conditions of the studied geographic area were explained as well. The benefits of the method, mentioning possible weighting modifications and future extensions, as well as its limits with respect to the quality and subjective character of the results presented were discussed. Finally, the potential use of suitability modeling in the Czech Republic was outlined at the end of the work.

In conclusion, the work supports the claim that the method as demonstrated may become a successful contribution for ecological planning if the following requirements are fulfilled:

- all essential and appropriate data and associated parameters are included in the model;

- all stakeholders accept the validity of the process and know that the values and weights they have assigned to each criterion have been incorporated into the model;
- the modeling process is well documented and its results are clearly understandable; and
- the modeling process is capable of being repeated.

The potential of interactive GIS modeling extends far beyond its technical implementation. It promises to radically alter the decision-making environment itself. However, while GIS technology greatly enhances decision-making capabilities, it does not replace them. In a sense, it is both a "toolbox" of advanced analysis capabilities and a "sandbox" to express decision-makers' concerns, inspirations and creativity

However, the application of this method in different countries and their societies, icluding the Czech Republic, might be complicated. Although suitability modeling represents an efficient technical tool for deliberate regional planning, it requires a certain level or type of system set-up in the country of application. If the GIS suitability analysis is to be performed at the most sophisticated level, a large amount of quality data has to be included in the analysis process and thus, the data must be easily accessible. All the information and data sets about the area under the study in this work were collected from divers govermental and non-governmental organizations and agencies, Acadia National Park database, College of the Atlantic GIS database, and GIS internet data depots. There were plenty of data about Mount Desert Island available and the vast majority was free of charge. Unfortunately, it is difficult to imagine that a suitability analysis of such extent would be easily performed for an area in the Czech Republic. There is still a lack of specific data and their collection is extremely difficult and costly. It is clear that the system of the data availability and exchange has to be altered, if we want to take advantage of the potential that GIS suitability modeling offers for sophisticated planning.

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