Topic 5

Analyzing Location

5.1 Identifying Competition Zones

Does travel-time to a store influence your patronage? Will you drive by one store just to get to its competition? What about an extra fifteen minutes of driving? … Twenty minutes? If your answer is "yes" you are a very loyal customer or have a passion for the thrill of the road that rivals a teenager's.

If you answer is "no" or "it depends" you show at least some sensitivity to travel-time. Assuming that the goods, prices and ambiance are comparable most of us will use travel-time to help decide where to shop. That means shopping patterns are partly a geographic problem and the old real estate adage of "location, location, location" plays a roll in store competition.

Targeted marketing divides potential customers into groups using discriminators such as age, gender, education, and income then develops focused marketing plans for the various groups. Relative travel-time can be an additional measure for grouping, but how can one easily assess travel-time influences and incorporate the information into business decisions?

Two map analysis procedures come into play—effective proximity and accumulation surface analysis. Previous discussion (Topic 4.2) focused on the basic concepts involved in deriving effective proximity that sets the stage for application of travel-time in *competition analysis*.
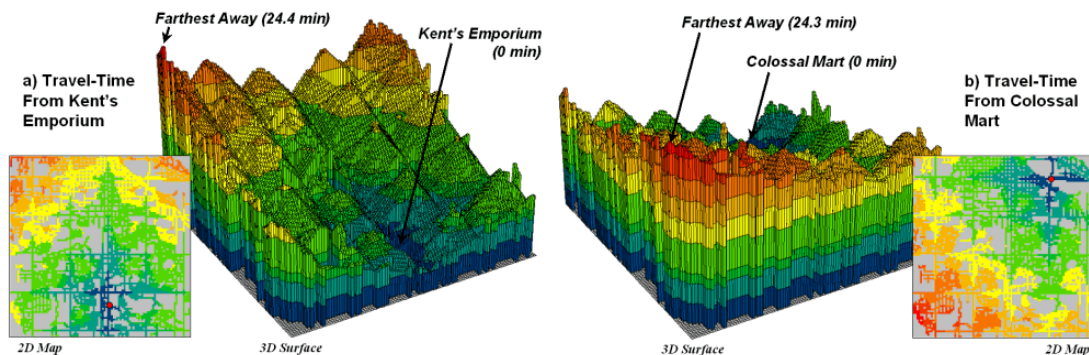

Figure 5-1. Travel-time surfaces show increasing distance from a store considering the relative speed along different road types.

The left side of figure 5-1 shows the travel-time surface from Kent's Emporium. Recall that it is calculated by starting at the store then moving out along the road network like waves propagating through a canal system. As the wave front moves, it adds the time to cross each successive road segment to the accumulated time up to that point.

The result is the estimated travel-time to every location in the city. The surface starts at 0 and extends to 24.4 minutes away. Note that travel-time surface is shaped like a bowl with the bottom at the store's location. In the 2D display, travel-time appears as a series of rings—increasing distance zones. The critical points to conceptualize are 1) that the surface is analogous to a football stadium (continually increasing) and 2) that every road location is assigned a distance value (minutes away).

The right side of figure 5-1 shows the travel-time surface for Colossal Mart with its origin in the northeast portion of the city. The perspective in both 3D displays is constant and Kent's surface appears to "grow" away from you while Colossal's surface seems to grow toward you.
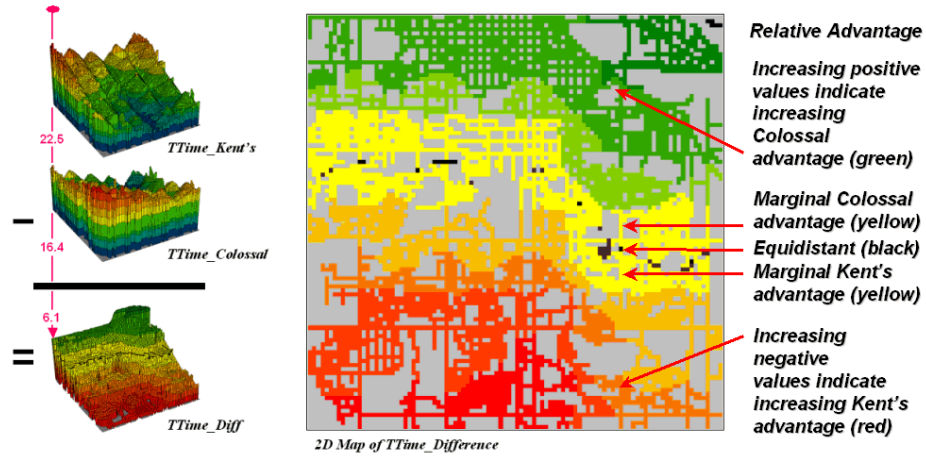

Figure 5-2. Two travel-time surfaces can be combined to identify the relative advantage of each store.

Simply subtracting the two surfaces derives the relative travel-time advantage for the stores (figure 5-2). Keep in mind that the surfaces actually contain geo-registered travel-time values and that a new value (difference) is computed for each map location. The inset on the left side of the figure shows a computed Colossal Mart travel-time advantage of 6.1 minutes (22.5 – 16.4= 6.1) for the location in the extreme northeast corner of the city.

Locations that are the same travel distance from both stores result in a zero difference and are displayed as black. The green tones on the difference map identify positive values where Kent's travel-time is larger than its competitor's—advantage to Colossal Mart. Negative values (red tones) indicate the opposite— advantage to Kent's Emporium. The yellow tone indicates the "combat zone" where potential customers are about the same distance from either store—advantage to no one.
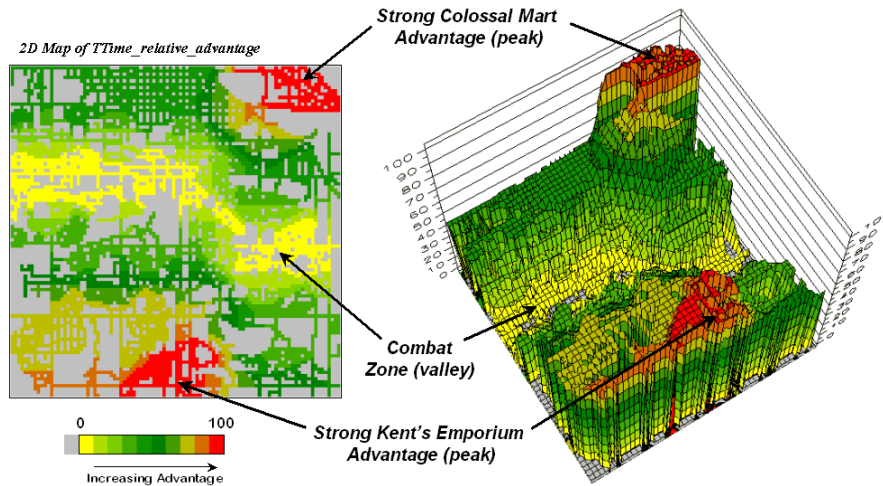

Figure 5-3. A transformed display of the difference map shows travel-time advantage as peaks (red) and locations with minimal advantage as an intervening valley (yellow).

Figure 5-3 displays the same information in a bit more intuitive fashion. The combat zone is shown as a yellow valley dividing the city into two marketing regions—peaks of strong travel-time advantage. Targeted marketing efforts, such as leaflets, advertising inserts and telemarketing might best be focused on the combat zone. Travel-time indifference means that the combat zone residents might be more receptive to store incentives—tip the scale towards one store or the other.

At a minimum the travel-time advantage map enables merchants to visualize the lay of the competitive landscape. However the information is in quantitative form and can be readily integrated with other customer data. Knowing the relative travel-time advantage (or disadvantage) of every street address in a city can be a valuable piece of the marketing puzzle. Like age, gender, education, and income, relative travel-time advantage is part of the soup that determines where we shop… it's just we never had a tool for measuring it.

5.2 Spatially Characterizing Customer Loyalty

The previous section introduced a procedure for identifying competition zones between two stores. Travel-time from each store to all locations in a project area formed the basis of the analysis. Common sense suggests that if customers have to travel a good deal farther to get to your store versus the competition it'll be a lot harder to entice them through your doors.

The *competition analysis* technique expands on the concept of simple-distance buffers (i.e., quarter-mile, half-mile, etc.) by considering the relative speeds of different streets. The effect is a mapped data set that reaches farther along major streets and highways than secondary streets. The result is that every location is assigned an estimated time to travel from that location to the store.

Comparing the travel-time maps of two stores determines relative access advantage (or disadvantage) for each map location. Locations that have minimal travel-time differences define a "combat zone" and focused marketing could tip the scales of potential customers in this area.
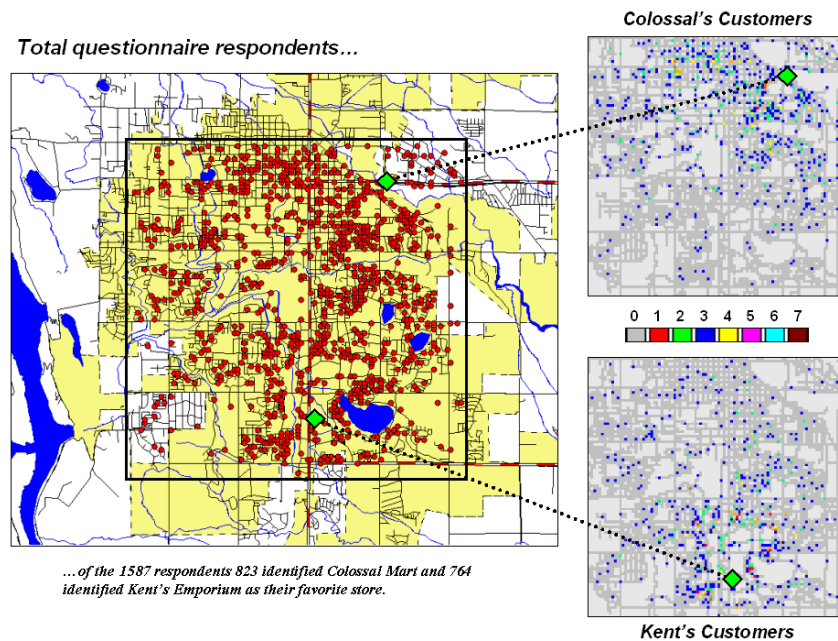

Figure 5-4. Respondents indicating their preference for Kent's Emporium or Colossal Mart.

The next logical step in the analysis links customers to the travel-time information. Figure 5-4 locates the addresses of nearly 1600 respondents to a reader-survey of "What's Best in Town" appearing in the local newspaper. Colossal Mart received 823 votes for the best discount store while Kent's Emporium received 764 votes.

More important than who won the popularity contest is the information encapsulated in spatial patterns of the respondents. The insets on the right of figure 5-4 split the respondents into those favoring Colossal Mart and those favoring Kent's Emporium. The data is imported into the same "grid analysis frame" that was used in the competition analysis—100 rows by 100 columns of 250-foot grids. Note the clustering of respondents around each store with some analysis grids containing as many as seven respondents.

The next step is to link the travel-time estimates to the respondents using grid-based map analysis. The locations of the respondents are transferred from the desktop system to the grid system as previously discussed (Topic 4.3).
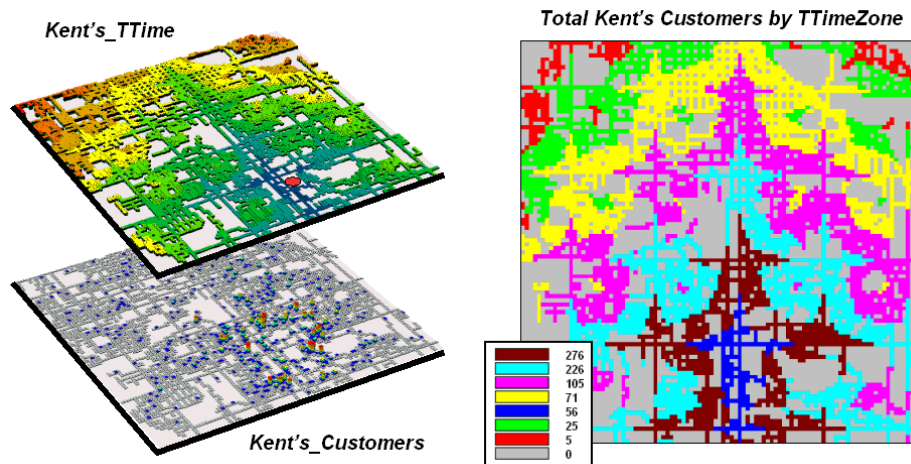

Figure 5-5. Travel-time distances from a store can characterize customers.

The bottom left map (*Kent's_Customers*) in figure 5-5 identifies the locations of the store's customers. The top map (*Kent's_TTime*) identifies a series of increasing travel-time zones emanating from Kent's Emporium. Since the maps are geo-registered their coincidence can be easily summarized.

The 2-D map on the right side of the figure reports the results of a *region-wide* summary where the total number of customers is computed for each travel-time zone. The procedure is similar to taking a cookie-cutter (*Kent's_ TTime* zones) and slamming it down onto dough (*Kent's Customers*) then computing the total number of customers within each zone.

The table in the center of figure 5-6 identifies various summaries of the customer data falling within travel-time zones. The shaded columns show the relationship between the two stores' customers and distance—the area-adjusted average number of customers within each travel-time zone.

The two curves on top depict the relationship for each store's own customers. Note the characteristic shape of the curves—most of the customers are nearby with a rapid trailing off as distance increases. Ideally you want the area under the curve to be as much as possible (more customers) and the shape to be fairly flat (loyal customers that are willing to travel great distances). In this example, both stores have similar patterns reflecting a good deal of sensitivity to travel-time.
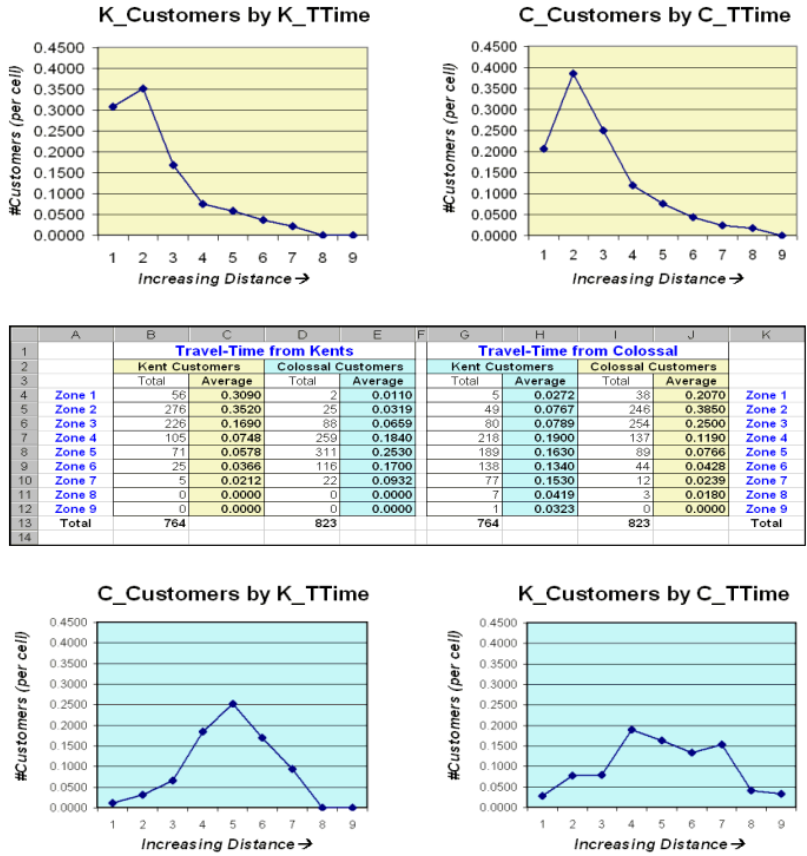
	A	B	C	D	E	F	G	H	I	J	K
1			Travel-Time from Kents					Travel-Time from Colossal			
2		Kent Customers		Colossal Customers			Kent Customers		Colossal Customers		
3		Total	Average	Total	Average		Total	Average	Total	Average	
4	Zone 1	56	0.3090	2	0.0110		5	0.0272	38	0.2070	Zone 1
5	Zone 2	276	0.3520	25	0.0319		49	0.0767	246	0.3850	Zone 2
6	Zone 3	226	0.1690	88	0.0659		80	0.0789	254	0.2500	Zone 3
7	Zone 4	105	0.0748	259	0.1840		218	0.1900	137	0.1190	Zone 4
8	Zone 5	71	0.0578	311	0.2530		189	0.1630	89	0.0766	Zone 5
9	Zone 6	25	0.0366	116	0.1700		138	0.1340	44	0.0428	Zone 6
10	Zone 7	5	0.0212	22	0.0932		77	0.1530	12	0.0239	Zone 7
11	Zone 8	0	0.0000	0	0.0000		7	0.0419	3	0.0180	Zone 8
12	Zone 9	0	0.0000	0	0.0000		1	0.0323	0	0.0000	Zone 9
13	Total	764		823			764		823		Total
14											

Figure 5-6. Tabular summaries of customers within each travel-time zone can be calculated.

The lower two graphs characterize the travel distances for the <u>competitor's</u> customers—objects for persuasion. Ideally, one would want the curves to be skewed to the left (your lower travel-time zones). In this example, it looks like Colossal Mart has slightly better hunting conditions, as there is a bit more area under the curve (total customers) for zones 1 through 4 (not too far away). In both cases, however, there looks like a fair number of competition customers in the combat zone (zones 4 through 6)—let the battle begin.

5.3 Connecting With Customers

The previous sections have dealt with competition analysis and customer loyalty based on travel-time and its geo-business applications. The following extends the discussion to "Optimal Path" and "Catchment" analysis. As a review, recall that travel-time is calculated by respecting absolute and relative barriers to movement throughout a project area. For most vehicles on a trip to the store, the off-road locations represent absolute barriers—*can't go there*. The road network is composed of different types of streets represented as relative barriers—*can go there but at different speeds*.

In assessing travel-time, the computer starts somewhere then calculates the time to travel from that location to all other locations by moving along the road network like a series of waves propagating through a canal system. As the wave front moves, it adds the time to cross each successive road segment to the accumulated time up to that point. The result is estimated travel-time to every location in a city.

For example, the upper-left inset in figure 5-7 shows a 2D travel-time map from Kent's Emporium and its corresponding 3D travel-time surface. Note that the farthest away location is 24.4 minutes from Kent's and that all other street locations have a travel-time value. The surface indicates increasing travel time as rising height and forms a bowl-like structure with Kent's Emporium at the basin—0 minutes away from itself. The colors from blue to red show 3-minute travel-time contours, analogous to increasing buffer distances from the store. However in this instance, distance is measured in time instead of simple geographic distance that assumes customers travel "as-the-crow-flies" to the store.
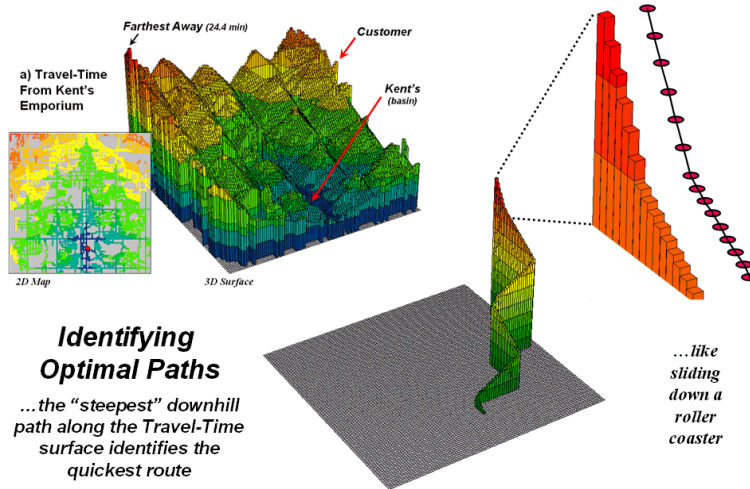
Figure 5-7. The height on the travel-time surface identifies how far away each location is and the steepest downhill path along the surface identifies the quickest route.

The lower-right inset in the figure depicts the quickest route that a customer in the northeast edge of the city would take to get to the store. The algorithm starts at the customer's location on the travel-time surface, and then takes the "steepest downhill path" to the basin (Kent's Emporium). The roller-coaster like strip shows the *optimal path* (i.e. quickest route) as a series of decreasing steps getting closer and closer to the store. The route was computed as the "steepest downhill path" along the travel-time surface—like sliding down a playground slide (enlarged portion of the strip).
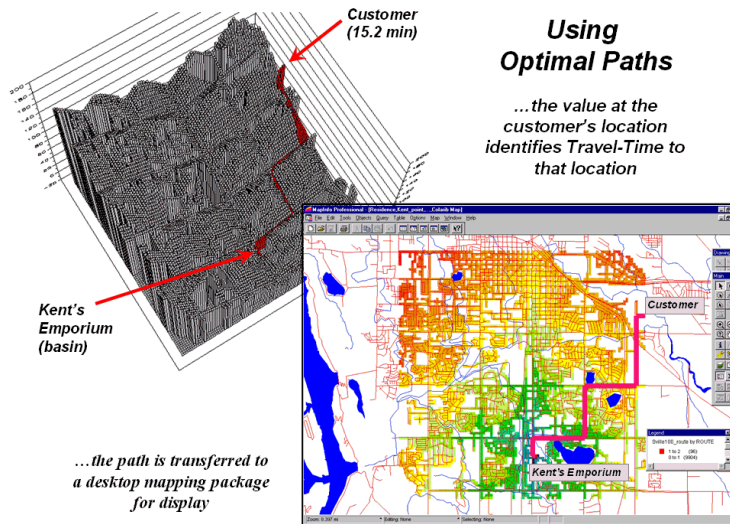
Figure 5-8. The optimal path (quickest route) between the store and any customer location can be calculated then transferred to a standard desktop mapping system.

The upper-left inset of figure 5-8 shows the 3D depiction of the optimal path in the grid-based analysis system used to derive the travel-time information. The height of the customer's location on the surface (15.2 minutes) indicates the estimated travel-time to Kent's.

At each step along the optimal path the remaining time is equal to the height on the surface. The inset in the lower-right of the figure shows the same information transferred to a standard desktop mapping system. If the car is GPS-equipped, the console could show a dot of the current position and a continuously updated reading of the remaining time to get to the destination—a perfect answer to the "…are we there yet?" question from the kids.

If fact, that is how many emergency response systems work. An accumulation surface is constructed from the police/hospital/fire station to all locations. When an emergency call comes in, its location is noted on the surface and the estimated time of arrival at the scene is relayed to the caller. As the emergency vehicle travels to the scene it appears as a moving dot on the console that indicates the remaining time to get there.
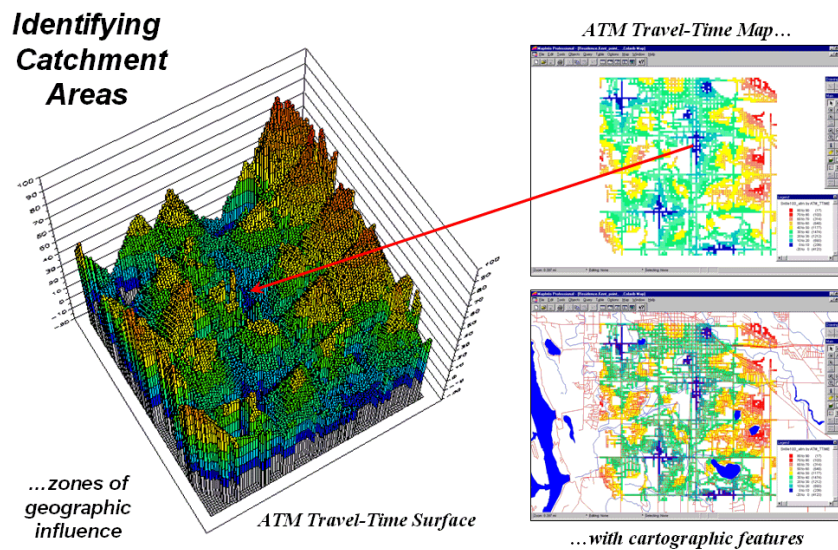
Figure 5-9. The region of influence, or Catchment Areas, is identified as all locations closest to one of a set of starting locations (basins).

Another use of travel-time and optimal path is to derive *catchment areas* from a set of starting locations. For example, the left-side of figure 5-9 shows the travel-time surface from six ATM machines located throughout a city. Conceptually, it is like tossing six stones into a canal system (road network) and the distance waves move out until they crash into each other. The result is a series of bowl-like pockmarks in the travel-time surface with increasing travel-time until a ridge is reached (equidistant) then a downhill slide into locations that are closer to the neighboring ATM machine.

The 2D display in the upper-right inset of figure 5-9 shows the travel-time contours around each of the ATM locations—blue being closest through red that is farthest away. The lower-right inset shows the same information transferred to a desktop mapping system. Similar to the earlier discussion, any customer location in the city corresponds to a position on the pock-marked travel-time surface—height identifies how far away to the nearest ATM machine and the optimal path shows the quickest route.

This technique is the foundation for a happy marriage between GIS and wireless telecommunications. As cell phones become "location aware" (GPS-enabled) it can locate itself on a travel-time surface and therefore knows "how far away it is and the best way to get there" for any point.

In the not too distance future you will be able to call your "cell-phone agent" and leave a request to be notified when you are within a five minute walk of a Starbucks coffee house. As you wander around the city your phone calls you and politely says "…there's a Starbucks about five minutes away and, if you please, you can get there by taking a right at the next corner then…" For a lot of spatially-challenged folks it beats the heck out of unfolding a tourist map and trying to navigate to a coffeehouse.

5.4 Suitability Modeling

In real estate the three most important factors are "location, location and location." While this bit of wisdom speaks to the significance of spatial considerations in real estate and development. Often location preferences can be stated in spatial terms, such as slope, aspect, visual exposure and proximity to roads. If this is the case, a suitability model can be developed that incorporates individual preferences.

Consider the simple model outlined in the accompanying figure 5-9. It identifies the suitable areas for a mountain cabin development considering basic engineering and aesthetic factors. Like any other model it is a generalized statement, or abstraction, of the important considerations in a real-world situation. It is representative of one of the most common GIS modeling types— a suitability model. First, note that the model is depicted as a flowchart with boxes indicating maps, and lines indicating GIS processing. It is read from left to right. For example, the top line tells us that a map of elevation (ELEVATION) is used to derive a map of relative steepness (SLOPE), and in turn, is interpreted for slopes that are better for a campground (S_PREF).
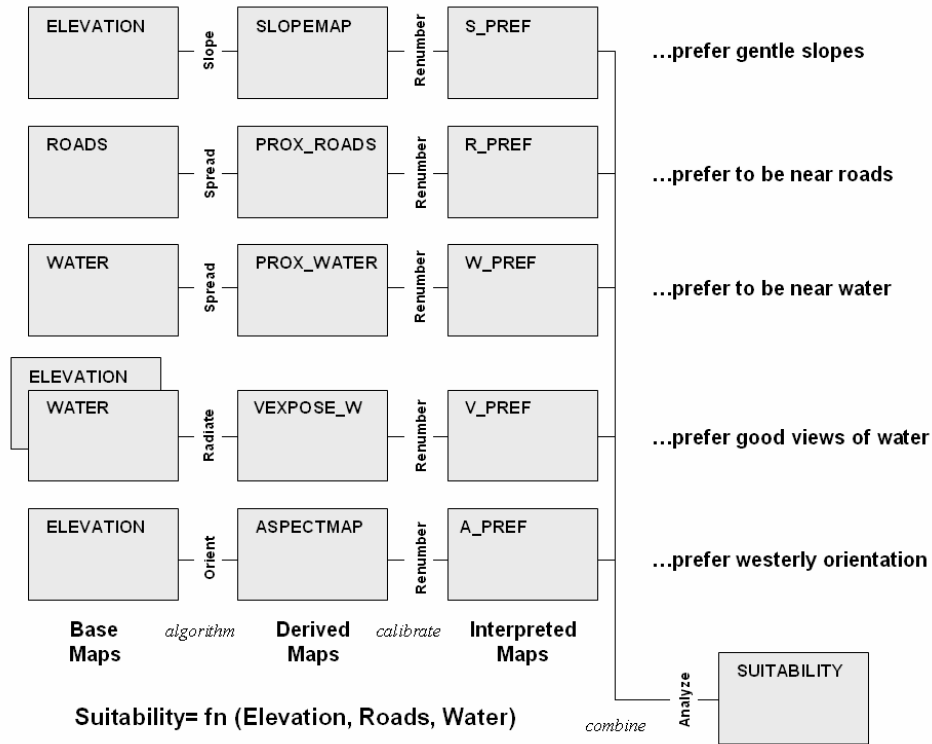
Figure 5-9. Flowchart of a model determining the most suitable locations for cabin country development.

Next, note that the flowchart can been subdivided into horizontal and vertical compartments. The horizontal sequences identify separate sub-models expressing suitability criteria— the best locations for the campground are 1) on gently sloped terrain, 2) near existing roads, 3) near flowing water, 4) with good

views of water, and 5) westerly oriented. The first two criteria reflect engineering preferences, whereas the latter three identify aesthetic considerations. The criteria depicted in the flowchart are linked to a sequence of GIS commands (termed a command *macro* including commands like *Slope*, *Radiate*, *Renumber* and *Calculate*).

The vertical compartments indicate increasing levels of abstraction. The left-most ***base maps*** section identifies the encoded maps needed for the application. In most instances, this category defines maps of physical features described through field surveys— elevation, roads and water. They are inventories of the landscape, and are accepted as fact.

The next level is termed ***derived maps***. Like base maps, they are facts, however these descriptors are difficult to collect and encode, so spatial analysis operators are used to derive them. For example, slope can be measured with an Abney hand level, but it is impractical to collect this information for all of the grid locations comprising a project area. Similarly, the distance to roads can be measured by a survey crew, but it is just too difficult. Note that these first two levels of model abstraction are concrete descriptions of the landscape. The accuracy of both primary and derived maps can be empirically verified simply by taking the maps to the field and measuring.

The next two levels, however, are an entirely different matter. It is at this juncture that GIS modeling is moved from fact to judgment— from the description of the landscape (fact), to the prescription of a proposed land use (judgment). The ***interpreted maps*** are the result of assessing landscape factors in terms of an intended use. This involves assigning a relative "goodness value" to each map condition. For example, gentle slopes are preferred locations for campgrounds. However, if proposed ski trails were under consideration, steeper slopes would be preferred. It is imperative that a common goodness scale is used for all of the interpreted maps. Interpreting maps is like a professor's grading of several exams during an academic term. Each test (vis. primary or derived map) is graded. As you would expect, some students (*vis*. map locations) score well on a particular exam, while others receive low marks.
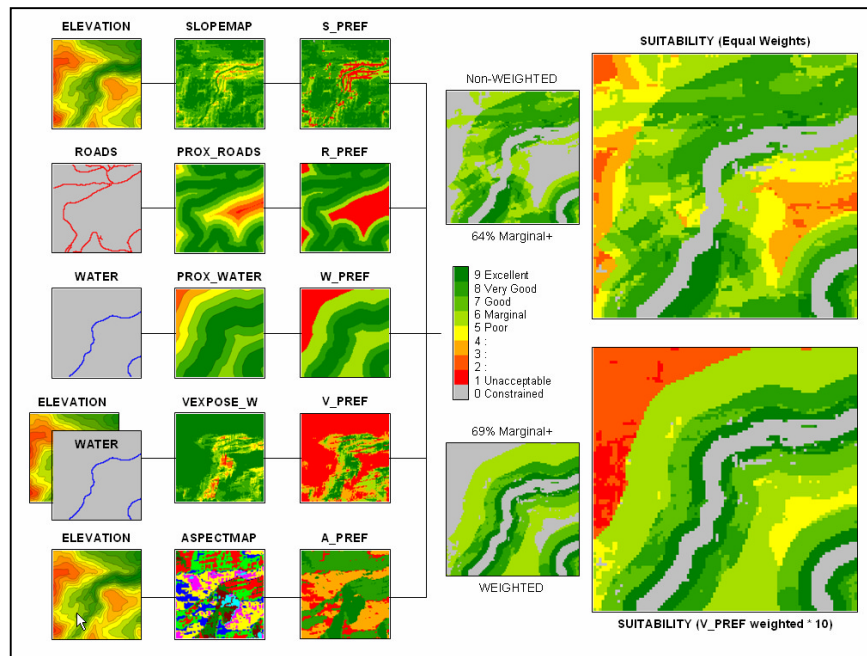
Figure 5-10. Implementation of the suitability using the case study data.

The final ***suitability map*** is a composite of the set of interpreted maps, similar to averaging individual test scores to form an overall semester grade. In figure 5-10, the upper right map inset (Suitability equal

weights) identifies the best overall scores for locating a development, and is computed as the simple average of the five individual preference maps.

However, what if the concern for good views (V-PREF map) was considered ten times more important in siting the campground than the other preferences? The lower right map depicts the weighted average of the preference maps showing that the good locations, under this scenario, have a significantly different pattern. But what if gentle slopes (S-PREF map) were considered more important? Or proximity to water (W-PREF map)? Where are best locations under these scenarios? Are there any consistently good locations?
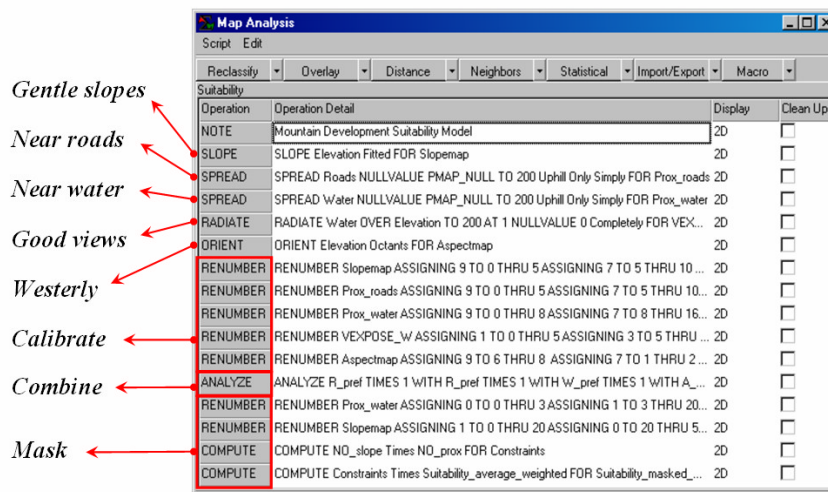
Figure 5-11. The logical sequence of map analysis operations is contained in a command script that can be easily changed to simulate different scenarios.

The ability to interact with the derivation of a prescriptive map is what distinguishes GIS modeling from the computer mapping and spatial database management activities. A command script is composed of a series of map analysis operations that reflect the suitability model's logic (figure 5-11). The individual commands can be accessed and modified to simulate different scenarios.

There are three types of model modifications that can be made— weighting, calibration and structural. *Weighting* modifications affect the combining of the interpreted maps into an overall suitability map, as described above. *Calibration* modifications affect the assignment of the individual "goodness ratings." For example, a different set of ranges defining slope "goodness" might be assigned, and its impact on the most suitable locations noted.

Weighting and calibration simulations are easy and straight forward— edit a model parameter, resubmit the macro and note the changes in the suitability map. Through repeated model simulation, valuable insight is gained into the spatial sensitivity of a proposed plan to the decision criteria. *Structural* modifications, on the other hand, reflect changes in model logic by introducing new criteria. They involve modifications in the structure of the flowchart and additional programming code to the command macro. For example, a group of decision-makers might decide that forested areas are better for a development than open terrain. To introduce the new criterion, a new sequence of primary, derived and interpreted maps must be added to the "aesthetics" compartment of the model reflecting the group's preference. It is this dynamic interaction with maps and the derivation of new perspectives on a plan that characterize spatial reasoning and dialogue.

By their nature, all development plans contain (or imply) a map. The issue is determining "what should go where," and as noted above there is a lot of thinking that goes into a final map recommendation. One cannot simply geo-query a database for the recommendation any more than it can arm a survey crew with a "development-ometer" to measure the potential throughout a project area. The logic behind a suitability

model and its interpretation from different perspectives are the basic elements leading to an effective decision. During the deliberations, an individual "solution map" is merely one rendering of the thought process.

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5.5 Exercises

Access *MapCalc* using the *GB_Smallville.rgs* by selecting **Start**à **Programs**à **MapCalc Learner**à **MapCalc Learner**à **Open existing map set**à **GB_Smallville.rgs**. The following set of exercises utilizes this database.

5.5.1 Competition Analysis

√α   Re-create travel-time surfaces for Kent's Emporium and Colossal Mart using the same procedures you used in exercise **Topic 4.5.2**.
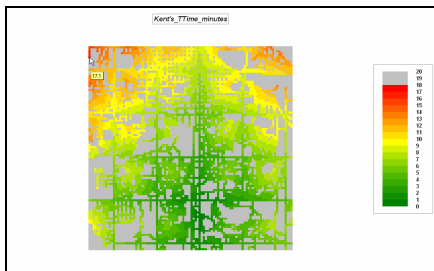
Kents_TTime_minutes
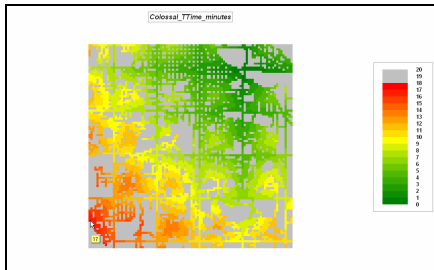
Colossal_TTime_minutes

√α   Create a "mask" of the non-road areas by selecting **Reclassify**à **Renumber** and entering the following command.
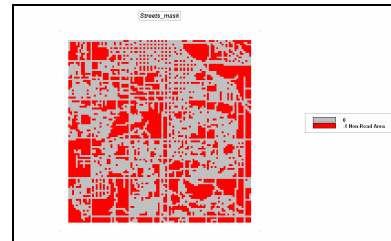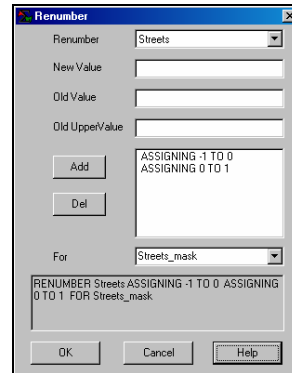
√α   Use the **Overlay**à **Cover** command to mask the non-road areas on the **Kents_TTime_minutes** map as shown below.
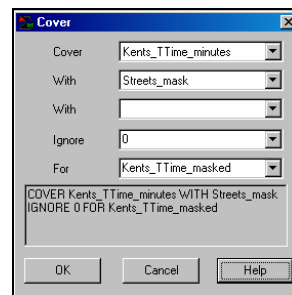
Display the Kents_TTime_masked map as 3D, Grid using 21 Equal Ranges from -1 (grey), 0 (green) to 20 (red) with a mid-range yellow inflection point.
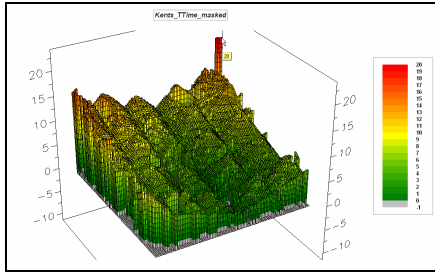
Repeat the masking procedure for the Colossal_TTime_minutes map and display with the same color pallet.
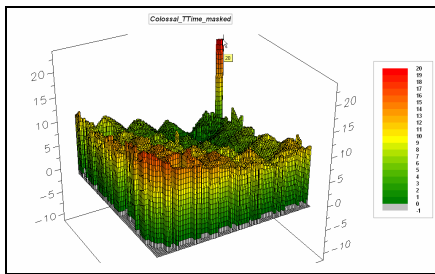
Can you explain the peculiar-looking pillar in the northeast corner of the 3D display? Hint: has something to do with disconnected streets.

√α̅ Use **Overlay**à **Calculate** to compute the difference between the two travel-time surfaces as shown below.
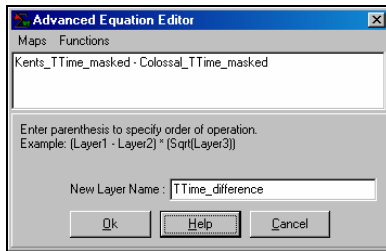
Double-click on the **TTime_difference** map's legend to pop-up the *Shading Manager.* Select **User Defined Ranges** as the *Calculation Mode* and **11** for the *Number of Ranges.* Click on the last number in the *Min [>=]* extreme left column and enter **-10**. Press the up arrow and enter **-8**. Repeat the process to enter the other range breaks— **-6**, **-4**, **-2**, **-.001**, **.001**, **2**, **4**, **6**, **8** and **10** (top of the *Max [<=]* column). Assign **red** to the -10 to -8 range, **yellow** to -.001 to .001 and **green** to 8 to 10. Press **OK** to display the as a 2D Grid.

5.5.2 Connecting with Customers

√α̅ The *Stream* command can be used to identify the quickest route from any location to the lowest point on a travel-time surface (origin). Use **Distance**à **Stream** to enter the coordinates for a customer's residence (Row **87**, Column **99**; click on the checkbox to activate direct entry; be sure to press the **Add** button) and have it "stream" over the **Kents_TTime_minutes** surface as shown below.

Display the resultant map as 2D Grid.
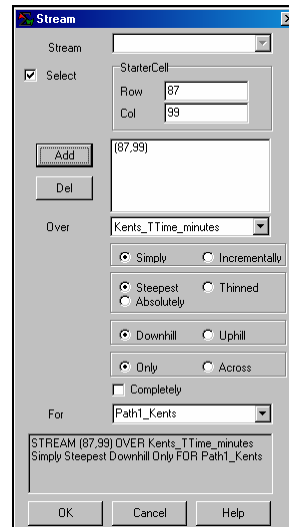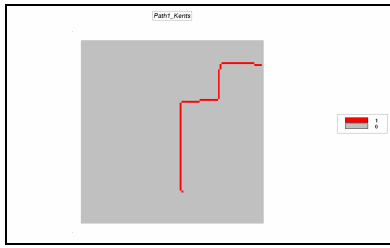
Repeat the procedure for the same customer using the **Colossal_TTime_minutes** surface to determine the best path to Colossal Mart.
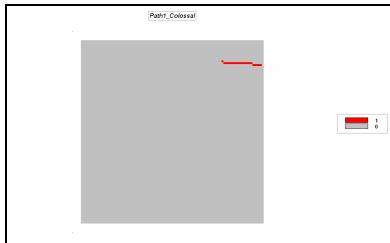
Repeat the procedure to generate best paths for another customer (Row **46**, Col **1**) to both Kent's Emporium and Colossal Mart.
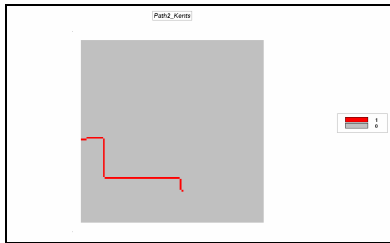
Path2_Kents

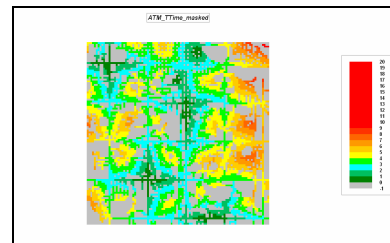

Path2_Colossal

Use the *View* tool to display the ATM map.
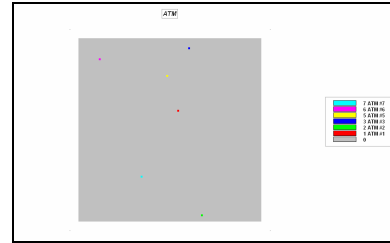
Create a travel-time surface identifying the shortest time to the nearest ATM machine for all street locations in the project area. Use Distanceà Spread and complete the dialog box as shown below.
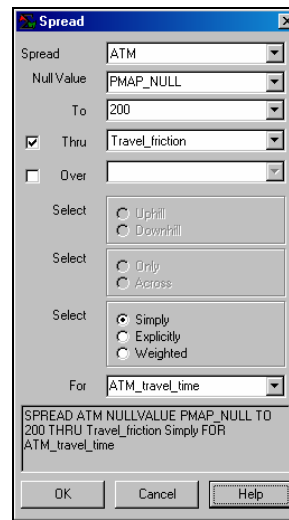
Convert this map to minutes…
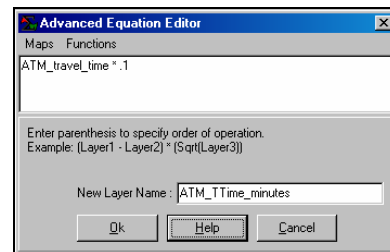
Mask for non-road areas…
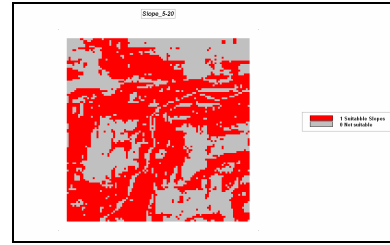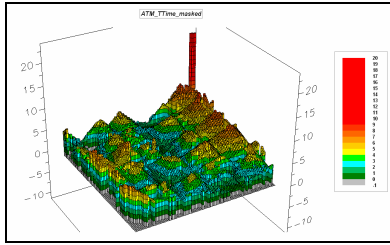
5.5.3 Suitability Modeling

📂 Press the *Open Existing File* button, choose to close the GB_Smallville.rgs database then open the **GB_Bighorn.rgs** one.

√α Create a simple model that identifies the best locations for cabin sites that "bask in the sun" (5-20% slope and southeast through west aspect).

Use **Neighbors**à **Slope** to derive a map of terrain steepness based on the **Elevation** surface. Complete the slope command as—
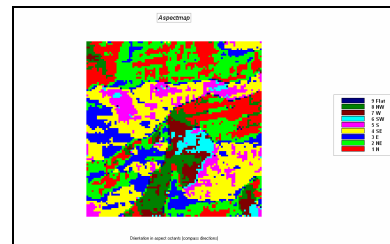
SLOPE Elevation Fitted FOR Slopemap
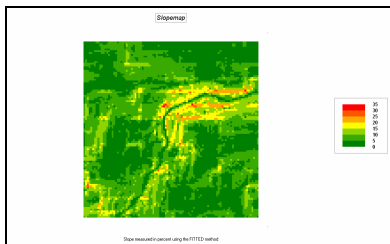
Use **Reclassify**à **Renumber** to isolate the desired locations with 5-20% slope on the **Slopemap** as a binary map (1= suitable, 0= not suitable)—

```
RENUMBER Slopemap
  ASSIGNING 0 TO 0 THRU 5
  ASSIGNING 1 TO 5 THRU 20
  ASSIGNING 0 TO 20 THRU 100
FOR Slope_5to20
```


Use **Neighbors**à **Orient** to derive a map of terrain orientation (aspect) based on the **Elevation** surface—

ORIENT Elevation Octants FOR Aspectmap

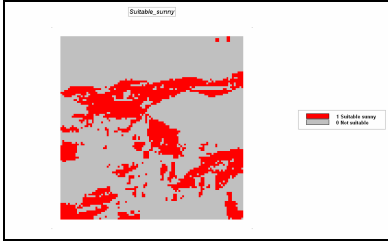Use **Reclassify**à **Renumber** to isolate the desired locations with SE to W on the **Aspectmap** as a binary map (1= suitable, 0= not suitable)—

```
RENUMBER Aspectmap
  ASSIGNING 0 TO 1 THRU 3
  ASSIGNING 1 TO 4 THRU 7
  ASSIGNING 0 TO 8 THRU 9
FOR Aspect_SE-W
```
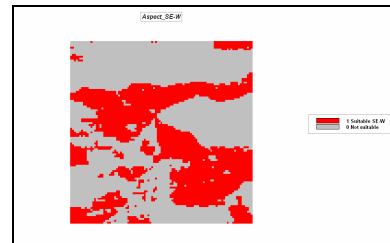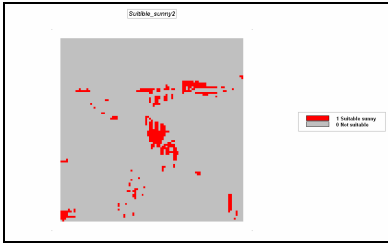

Combine the two binary suitability maps—

```
CALCULATE Slope_5to20 * Aspect_SEtoW
  FOR Suitable_sunny
```

On your own, create another scenario for suitably sunny sites by implementing the criteria steepness= 10 to 20% slope and orientation= south to west orientation.

On your own, create a proximity to Water suitability map identifying locations that are within 90 meters (3 cells) of a stream. Then use this map to identify the Suitable_sunny locations that are close to streams.
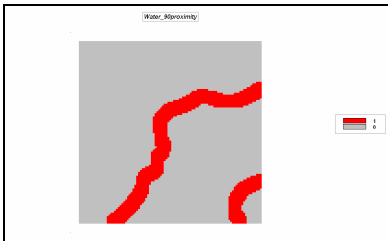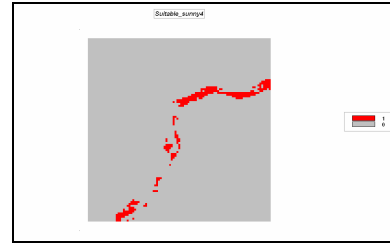

Water_90proximity Map
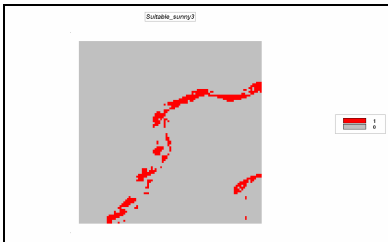
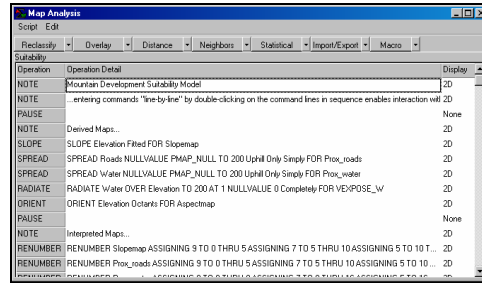*Suitable_sunny3 (within 90m of water)*

On your own, use the **Vegetation** map to update your suitability model to those locations that are—
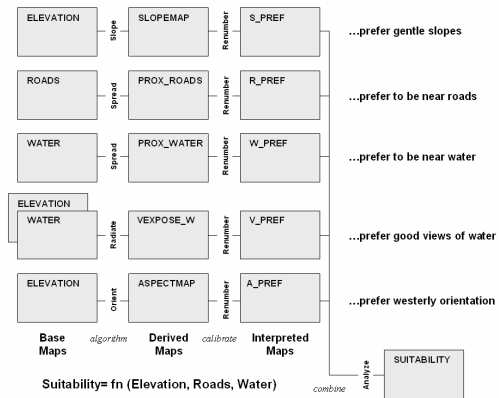 5 to 20% slope
  S to W aspect
  Within 90 meters of water
  Vegetated

$\sqrt{\alpha}$ Access the **Map Analysis** window and select **Script**à **Open**à **Suitability.rgs** in the *…\GB_Scripts* folder.


A *script* file contains a set of commands that perform a specific application—suitability model for mountain development in this case. The commands are logically sequenced like instructions in a recipe.


Scroll down the list of commands and relate the processing to the discussion and flowchart (above) in Topic 5.2.4, Suitability Modeling. Note the subdivisions of Derived Maps, Interpreted Maps and Combine Preference Maps. In addition, the script eliminates legally constrained areas that are too close to water and too steeply sloped.

Execute the script a line at a time beginning at the top and inspect each intermediate map as it is generated. In most instances a 2D Grid display is best for viewing the intermediate maps. Double-click on a map's legend to view a summary of the data values. The key to understanding the processing is the ability to interpret the map values that are generated.

Help   Use the online *Help* button with each command as need to better understand command function and syntax.
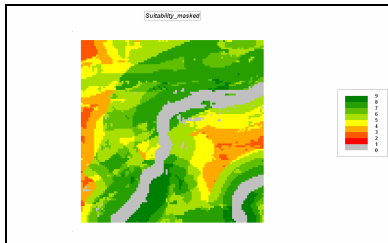
√α On your own, use the *Anayze* to create a second suitability map that treats water views (**V_Pref** map) as ten times more important.
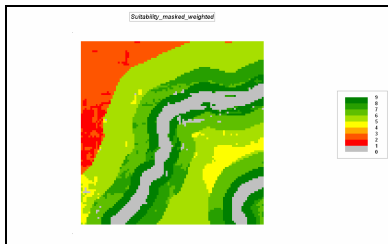
On your own, compare the unweighted (**Suitability_average** map) and the weighted one (**Suitability_average_weighted** map where V_Pref is 10 times more important). Hint: the difference between the two maps would indicate where they have the same rating (zero) and where one map has a higher (or lower) rating than the other.