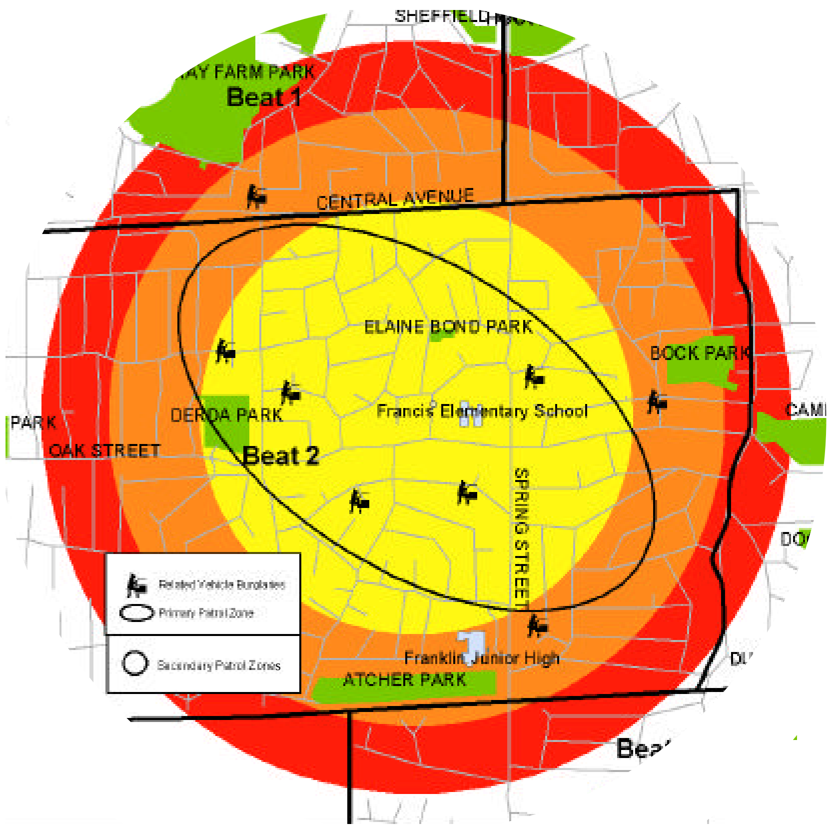
A Crime Analyst's Guide to Mapping



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Introduction

Computer mapping and geographic information systems (GIS) have become important tools for police organizations. They can help police officers analyze problems by providing up-to-date and comprehensive data related to their patrol areas. They also can organize diverse pieces of information in a coherent way to identify crime patterns. In addition, mapping and GIS:

- Can support community- and problem-oriented policing.
- Show detailed relationships between the crime, victim, and the offender.
- Show demographic and population changes.
- Assist in resource allocation.
- Integrate data from community and government sources.
- Provide effective communication tools.

Purchasing a desktop mapping system is increasingly affordable for even smaller police departments. A start-up mapping operation can be funded for less than $10,000, including hardware, software, and training. If a department already has suitable hardware, mapping start-up costs decrease significantly. Of course, mapping should be looked at as a long-term investment and additional costs will be required as more advanced mapping is undertaken. However, mapping brings substantial return on investment by bringing greater efficiency and effectiveness to departmental operations.

Purpose and Scope

Using a fictional scenario over time, this manual demonstrates the ways mapping can be incorporated into all stages of the crime analysis process, from problem identification to final response and assessment.

The manual is primarily intended for the beginning analyst working at small- and medium-sized police departments, although experienced crime mappers may learn from later chapters. The department that had not yet implemented mapping systems will find Chapter 1 especially useful, in addition to the resources section in the back of the manual. This manual is not intended as a guide to any particular software, but as a guide for understanding general mapping, GIS, and spatial analysis concepts. Readers will also get a flavor for how mapping can be used to assist police department personnel, from the chief, to investigators, to patrol officers.

Organization

This manual is divided into six chapters. Topics include:

1. Hardware, software, training, and data needed to conduct crime mapping.
2. Detailed explanation of geocoding, and key terminology. Learn ways to identify geocoding problems, and map more of your data.
3. Beginning to advanced point pattern analysis, including hot spots methods.
4. Mapping a crime series using a spatial forecasting technique called STAMP.
5. Incorporating maps into reporting and response techniques, including maps for presentation.
6. Methods for performing evaluation of the law enforcement responses.

Throughout the manual, key terms will be highlighted in bold type. Definitions of these terms can be found in the glossary in the back of the manual. A bibliography, resources page, and an appendix with larger versions of important maps and illustrations are also in the back of the manual.

Acknowledgements

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Preface

This manual is intended to transform the novice crime mapper into an expert, capable of performing advanced analysis, and speaking the language of mapping, GIS, and spatial analysis. On the next page, we will join the world of mapping from a crime analyst's point of view already in progress. Read on and welcome to the world of crime mapping.

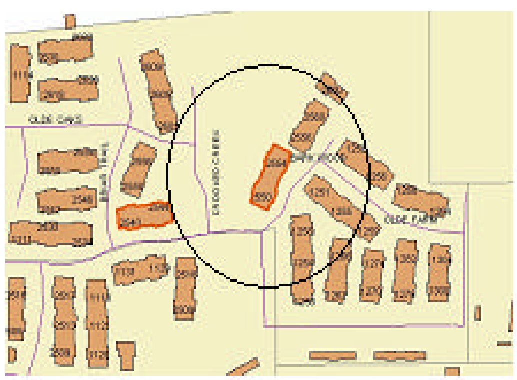
Chapter One – Beginning Crime Mapping Operations

On a brisk fall morning in the town of Beaufort, Illinois, crime analyst Officer William Dover was working on a map for Detective Bowers, who wants to determine whether a recent sex offender registrant is legally restricted from living where he does based on the distance from his home to the nearest school and day care center – to enforce Megan's Law.

Dover made the detective a map of the sex offender's home address and the closest schools and day care centers in the area. The map also included a radius circle, or buffer, of 500 feet drawn around the registrant's home, the minimum legal distance from where a registered sex offender can live.

"Well, what do you think, sporto, can the guy live there or what?" Det. Bowers asked.

"Well, *sporto*," Dover began sarcastically. "If you look at the map on my computer screen, you'll see that when a circular radius of 500 feet is drawn from the registrant's property line, it just barely clips the property line of the day-care center." The map is shown below.



"I also measured a straight line from the outer edges of the two closest parts of each property line and it's about 495 feet, give or take a few feet for the margin of error. Of course, this is the distance as the crow flies, so it doesn't factor in the topography of the area – you know, whether it's hilly or not."

"So what does that *mean*?" Det. Bowers asked.

"It means that this case is not so clear-cut. You would probably need a surveyor to be completely sure on this one," Dover said.

"Well, what good is mapping then?" the detective chided.

"Mapping can be very useful, but it can only tell you so much," said Dover. "A map should be used in conjunction with other available data and information. In this case, it certainly doesn't substitute for knowledge of the local landscape or a field survey, and, of course, officer judgment."

"I hear you," Bowers said, grabbing the map off the printer. "Thanks Dover. I'll discuss a course of action with the chief."

"Glad I could help." Dover replied.

From the day the department installed the mapping program six months prior, Dover has handled numerous requests from officers, detectives, and the chief, thus giving him the additional title of "map guy." While the chief has expressed his overall satisfaction with the mapping program, Dover's plans of using it to assist officers with actual problem solving have not materialized to this point. But that would quickly change.

As Dover closed the map, his telephone rang. Chief Meer was on the line.

"Officer Dover here."

"Dover, I need to see you in my office," the chief said, sounding a little tense.

"Sure chief, I'll be right there,"

"By the way, how are you coming with the maps for Thursday's meeting?" The chief asked. Chief Meer planned to meet with the Mayor's office on Thursday to present the department's new beat re-mapping strategy. Dover is in charge of preparing the maps for the presentation.

"They're mostly done. In fact, I just printed two of them out on the **plotter**," replied Dover.

"Good. Bring them with you."

Dover got up from his desk, made sure the donut crumbs were wiped away from his clothes, grabbed his two maps, and made his way to the chief's office. On the way, he passed Det. Bowers in the hallway. "So what did the chief say about the sex offender map?" he asked.

"He said he doesn't have time to deal with it right now," Det. Bowers replied. "It appears he has bigger fish to fry."

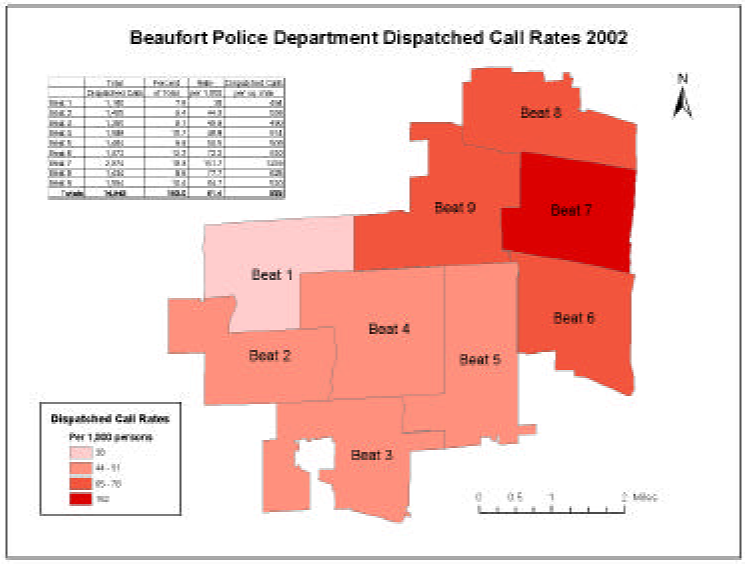
"Really?" Dover said, worry setting in.

"Yeah, and it looks like *you're* the catch of the day." Det. Bowers said, and walked away chuckling.

By the tone of his voice, Dover could sense Det. Bowers knew something he didn't.

"Chief, you wanted to see me?" Dover said, with a knock on the door.

Yeah, come on in," replied Chief Meer. "First, let me take a look at the maps." Dover unrolled the first map and draped it across the chief's desk (as shown below). "Explain to me again what this one shows so it appears I know what I'm talking about at the meeting."



Source: Beaufort Police Department, Crime Analysis Unit

Date: December 02, 2002

“Sure Chief. This is a shaded area map, or **choropleth map**, showing our rate of dispatched calls for our current beat structure. It gives us a general picture of our call volume and indicates that we had at least double the rate of calls for service in District 7 this past year compared to any other beat, as shown by both the table and the legend on the left.

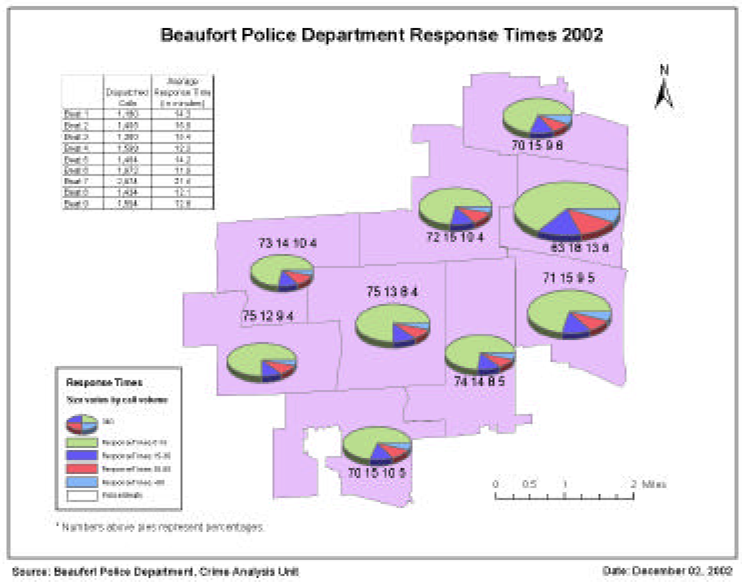
“Based on your suggestion, I used dispatched calls instead of all calls for service because it excluded things like calling in for lunch breaks, so was a more accurate way of showing workload. I also decided to use **rates per population** instead of the raw numbers, but included the data table on the map in case you get questions on the actual numbers. It shows that Beat 7 accounted for almost 20 percent of our call volume. Workloads in other beats were fairly equal.”

“How come the ranges in the legend aren’t all the same?” Chief Meer asked.

“Well, I hope you don’t get a question about that but, if you do, it’s basically because I used a **natural break** classification method as opposed to an **equal range**, or **equal count** method. That method essentially creates ranges from naturally occurring gaps in the data. I used it in this case because there was a big gap between the District 7 rate of 152 and next largest rate in District 8 at around 78. It might have been misleading if I used some other classification method."

"OK. What about the other map?"

Dover rolled up the map on top to reveal the second map (as shown below).



"This one is a map with a pie chart."

"Obviously," replied Chief Meer peering at Dover over the top of his glasses. "I may be old, but I'm not blind."

"Right. Sorry." Dover said. "It shows that our response times are the slowest in Beat 7, indicated by average response times in the table. First of all, the size of each pie varies by the call volume. In other words, the larger the pie, the more calls. Second, each individual piece of the pie shows response times in ranges of minutes; the green shows 0 to 15 minutes, the blue 15 to 30 minutes, etcetera. The legend indicates the ranges and their corresponding color, and the numbers next to each pie show the actual percentages for each slice, starting from the green on the far left to the light blue on the far right."

Chief Meer seemed to be having difficulty taking it all in. “Maybe the Mayor isn’t ready for this type of map yet,” Dover interjected.

“Yeah. Let me think about that one. I’m not sure if I’m ready for it yet either,” replied the Chief.

Dover rolled up both maps and bounded them together with a rubber band.

“OK, get me the rest of the maps by Wednesday so we can go over them as well.”

“Yes, sir.”

“There was another reason I called you in here, Dover. What else are you working on right now?”

“Other than getting the maps ready for Thursday’s meeting, I have a meeting at 10 a.m. with a crime analyst from Hamburg Ridge to help him get started with mapping. Besides that, nothing.”

“Good. Right after that meeting, I want you to make something a priority,” replied Chief Meer. “Do you know anything about this vehicle burglary problem we’re having?”

“No, sir, I don’t.”

“Well, apparently, vehicles are being broken into at a very rapid rate on the west side of town. Our troops received a lot of complaints from neighborhood block groups at last night’s meeting in Beat 2.”

That’s strange, Dover thought. *Car burglaries are usually only a problem in Beat 7, near the commercial sector.*

“I need you to get a handle on this situation fast. Find out where these burglaries are occurring, what time, what’s being stolen, and whatever else is pertinent. I told Det. Bowers that you would get him some information ASAP. The last thing we need right now is a crime spree creeping up on us in unexpected parts of town," said the chief as he paced around his office.

After three years as the crime analyst, Dover knew it was wise to keep his mouth shut until the chief was done speaking.

"Now that the beat re-mapping project is winding down, I want you to start assisting our troops again on a regular basis. I mean, you did tell me that those bells and whistles I purchased would be useful for other things, didn't you?"

The "bells and whistles" Chief Meer referred to were the mapping program. The chief was old school. He thought the best way to catch criminals was through old-fashioned hard work, hitting the streets, and following up on leads. He recognized the value of mapping technology for some administrative and strategic purposes, but beyond that he was not completely sure of its value for tactical and intelligence purposes.

"Sure, Chief. Mapping can be useful to the department in a lot of ways besides resource allocation issues. It can help patrol officers analyze problems by providing up-to-date and comprehensive data related to their patrol areas, and it can help in investigations by bringing together diverse pieces of information in a coherent way to identify crime patterns. That is what you want me to do here. In addition, it can support community- and problem-oriented policing; show detailed relationships between the crime, victim, and the offender; show demographic and population changes; and be used to integrate data from community and government sources. And finally, mapping can be an effective communication tool," Dover said, slightly out of breath and thinking he sounded a little too much like Rain Man.

"If it can be used for all that then I won't have to worry about this problem, will I?" the chief asked.

“No, sir, I’ll get right on it after the meeting and have something to Det. Bowers before the day ends,” Dover replied.

“Good. You’re dismissed,” Chief Meer said with a wave of his hand.

As Dover got up to leave, he read a quote posted on the bulletin board. ‘What we do here matters, so do it well.’ Chief Meer had many of these sayings to help motivate the troops. It always worked for Dover. Whenever he saw that quote, he felt a little more pride in the work he did. But now more than ever Dover also felt the obligation to live up to that phrase and not let the chief down.

The chief was under a lot of pressure to reverse the upward crime trend in Beaufort, driven by the increase in property crimes. Much of the increase could be attributed to the changing nature of the town. When Chief Meer took over 10 years ago, Beaufort was a sleepy town of 15,000, but the recent census showed that resident population had increased to more than 24,000. The increase in resident population in recent years was the result of several factors. First, the city council incorporated some large county areas with significant populations. Second, the mayor aggressively pursued business interests with tax breaks and incentives, including wooing a large automobile manufacturer to build a new plant in Beaufort. This created a need for local housing for plant employees.

The biggest reason for the increase in crime, however, was that Beaufort had become a bustling commercial center. Three years earlier, the small local shopping center that had contained only two anchor stores was supplanted by a regional shopping center with five anchor stores. The town planners decided to build the shopping center on some newly acquired land near a major expressway to attract shoppers across the metropolitan area. The development facilitated the growth of retail outlets near the mall and created an adjacent commercial strip on the main street leading to downtown Beaufort. Even some small office complexes sprouted up around the area. The community growth spurt dramatically increased daytime traffic in Beaufort.

It was telling when the numbers came out last January that the increase in crime for the city as a whole was driven by the increase in Beat 7, particularly in the area consisting of the new mall and surrounding businesses. In all other beats, crime went down.

Chief Meer decided that the department had to finally address the problem. They had to evaluate their current call volume based on the changing nature of the town to determine what, if any, adjustments needed to be made to the existing beat structure. Mapping would become vital to that strategy.

Once the decision was made to purchase a **Geographic Information System** (GIS) software program, Chief Meer directed Dover to look into the available options. At that time, Dover knew little about mapping. Of course, he had used maps a countless number of times, as a probationary police officer learning to navigate through the unfamiliar streets of his beat. When he applied for the crime analyst position three years ago, no one mentioned crime mapping as one of his duties. There certainly were no plans to purchase a computerized mapping program at that point.

Over the next three months he learned a great deal about mapping, mostly on site visits to various police departments and by attending monthly meetings of the **Crime Analysts of Illinois (CAI) Association** (www.crimeanalystsofil.org). The most important advice he received was to have clear goals in place to take advantage of the mapping program from day one. Some departments purchased a mapping program, but lacked a clear plan on using it, so the program remained dormant for months.

Dover also learned that data were vital to any crime mapping operation. Without data, a mapping program was useless. Dover grouped his department's data into two categories, crime data and geographic data. Knowing where to get the data was crucial. Just as important was determining its quality, accessibility, reliability, and timeliness.

Dover had been working with the department's crime data since he became the crime analyst, so he knew it well. He knew he could get digital data for all types of incidents, calls for service, arrests, traffic accidents, and more. He also knew the information was fairly reliable and that most of it could be accessed in a timely fashion. If he needed information faster than it could be obtained from the records management system, he had access to the actual police reports.

Figuring out where and how to get the geographic data was another issue. A few options existed for obtaining map data. One option was to purchase maps directly from a commercial vendor. Some companies sell street map data and bundle it with other geographic information, such as parks, water features, and institutions. A second option involved acquiring data from local planning departments. GIS professionals may be hired to create digital maps of a city's geography. For small municipalities that lack the resources to produce maps themselves, planning agencies at the county level might perform a similar function. Other government sources, such as regional planning agencies and the U.S Bureau of the Census, also may provide options for acquiring map data.

Dover also learned of the many costs associated with implementing a mapping operation. Hardware expenses comprise a significant amount of the total cost of running a crime mapping operation. Mapping requires a computer with significant processing speed and a substantial hard drive to store geographic data. The ability to print high-quality color maps for publications and presentations will necessitate the purchase of a color printer. A plotter is needed to produce large, wall-sized maps.

The largest potential software expense associated with crime mapping was a records management system. Theoretically, Dover could conduct both crime analysis and mapping without a records management system by creating his own databases. But he knew that for long-term analyses and analyses that required a greater volume of data, having a records management system in place was vital.

Statistical software programs from commercial sources also can be expensive. However, non-commercial options are available. The ***CrimeStat*** program is accessible free of charge from the National Institute of Justice's Mapping and Analysis for Public Safety (MAPS) website (www.ojp.usdoj.gov/nij/maps/). *CrimeStat* is a stand-alone spatial statistics program for the analysis of crime incident locations that can interface with most Windows-based desktop GIS programs. The purpose of *CrimeStat* is to provide supplemental statistical tools to aid law enforcement agencies and criminal justice researchers in their crime mapping efforts. Thus, the underlying philosophy behind *CrimeStat* is to provide an extension to GIS-based software for the purpose of helping researchers and analysts in their work.

Additional costs associated with crime mapping include training and other professional development opportunities. Training on the specific mapping program was vital to Dover, particularly in getting started. Intermediate and advanced courses became necessary as he undertook more advanced mapping. Training in technical writing also was invaluable, because of the necessity to clearly explain results of analyses to officers and others who use the maps that he created. In addition, training in data and crime analysis was necessary for an understanding of basic statistical techniques. Finally, a basic understanding of **cartography**, the science of map-making, is vital to any crime analyst.

Dover outlined much of the hardware, software, and training needed for crime mapping to the chief (as shown below). (A full sized version is in the Appendix).

Crime Mapping Needs Assessment: Technology

Hardware:	Start-up	Optional
Personal computer	X	
Laptop		X
Projector		X
Laser printer	X	
Color printer	X	
Plotter printer		X
Scanner		X
Server space (for storing large amounts of data)		X
Global Positioning System (GPS) hand-held device		X
Software:		
Word processing	X	
Spreadsheet	X	
Statistical (CrimeStat, SPSS, SAS)		X
Desktop GIS	X	
Base map (street map)	X	
Database manager		X
Presentation		X
Graphics		X
Internet and email		X
Records management system		X
Adobe Acrobat		X
Training courses:		
Mapping software -- Introduction class*	X	
-- Intermediate class		X
-- Advanced class		X
Technical writing (local college)		X
Introduction to cartography (local college)		X
Data or crime analysis for police agencies	X	
Miscellaneous:		
Travel to one mapping-related conference per year		X

* Some government and commercially sponsored courses are tailored to crime mapping

The department finally settled on a GIS system. Beaufort purchased a system that met the needs of the department, and was compatible with the county planning department's system – Beaufort's main source of geographic data.

Dover was not able to hit the ground running after the system was installed. His biggest problem was the poor quality of the street base map provided by the county. Dover had an inkling of the potential problems with the base map when he met with the county planning department and was informed that the street map had not been updated in a year, and its accuracy for **geocoding** could not be verified. No one had needed it for that purpose before, he was told.

Dover discovered the extent of the problem when he tried to geocode a year's worth of Part I crimes. Only about 60 percent of the addresses were mapped. It took the better part of the next three months before the department was comfortable that the program was not generating garbage, and before the 95 percent goal set by the department for matching incident data was met.

As soon as major geocoding problems no longer plagued the department, Dover was assigned the beat re-mapping project – his only project to date. With GIS as an integral tool, the department devised a strategy to divide Beat 7 into two beats. The new beat (Beat 10) consisted of the area surrounding the Beaufort Mall, Enormodome Movie Theater, and Streets of Beaufort shopping annex. It was required for the department to successfully manage the increased call volume in that area.

The police department will be presenting the proposed new beat structure to the Mayor's Office on Thursday, so Dover is printing wall-sized maps for the meeting. On top of all that, he had the added responsibility of stopping a crime spree.

As Dover made his way back to his office, he saw Det. Bowers in the hallway speaking to the desk sergeant. *Does this guy ever do anything? I now have enough work for three crime analysts. Maybe I could give him one of my jobs.*

Dover greeted them in passing. "What's up fellas?"

"Hey, Dover," Det. Bowers said. "What did the chief say?"

"He said I'll be working with you, which is never a good thing," replied Dover with a grin.

"Are you sure you still remember how to do *actual* crime analysis?" Det. Bowers asked. He and the desk sergeant snickered.

“*Crime analysis*? What’s *that*?” replied Dover heading down the hallway.

While Dover knew that Det. Bowers was joking, he realized there was some truth to what he said. Dover had been tied up with the beat re-mapping project and other administrative tasks for so long that, to date, he had not used mapping to analyze a single crime. Officers were beginning to believe mapping was only a tool for management.

As he returned to his office, Dover was determined to dispel that belief by showing how mapping can be beneficial to line officers on a daily basis. His mind was racing with the things he needed to do.

First, I need to figure out what time period I’m looking for. Then, I’ll need to determine which crime data to use to conduct my analysis. Finally, I’ll have to decide which GIS data to use.

Because the chief told him it was a recent crime pattern, Dover decided to look at the last month’s worth of vehicle burglary incidents. That way, he could compare monthly counts, which might point to any recent increases that appear to be related to crime pattern. Vehicle burglaries could be gleaned from the general theft category of crimes through use of the “method code” in the database. The method code informed him whether a theft occurred from “within” or “affixed to” a motor vehicle, of such items as stereo equipment, CD’s, cellular phones, security devices, purses, wallets, and hub caps.

Dover put together an electronic warehouse of geographic datasets, or **GeoArchive**, to have available for mapping operations. The fundamental concept of GIS is that data with common geography can be overlaid. These **layers** can be moved up or down, added or removed, made transparent, and shown only at certain scales. Many layers Dover had gotten from the county planning department. Others, such as the map of Beaufort census tracts, he was able to download from the U.S. Bureau of the Census website (www.census.gov). Still others, such as the map of all retail locations in the town, he created himself.

There are three basic types of layers using a **vector** data structure: **points**, **lines**, and **polygons**. A fourth kind of information commonly used in a GIS is known as a **raster** (**grid**-based) data structure. Dover made a list of the layers he had available, along with their potential uses for crime mapping (as shown below). (A full sized version is in the Appendix.)

TYPE OF LAYER	IMAGE	TYPE OF DATA	POTENTIAL USES
Crime Points*		Point	Crime locations, point pattern analysis (hot spots)
Buildings		Polygon	Megan's Law - sex offender location analysis
Land Parcels		Polygon	Alternative layer for geocoding in small areas
Parking Lots		Polygon	Analysis of vehicle-related crime
Street Centerlines*		Line	Geocoding, Geo-reference
Land Use		Polygon	Burglaries by type of land use, Understanding nature of crime areas
Parks		Polygon	Juvenile-related crime, Geo-reference
ATM Locations		Point	Proximity to robberies
Police Beats		Polygon	Reporting jurisdictions, Resource allocation
Retail Sites		Polygon	Retail thefts, Identity thefts, Vehicle-related crime
High Schools		Polygon	Narcotics violations, Juvenile crime, Emergency response plans, Geo-reference
Elementary Schools/Day Care		Polygon	Megan's Law analysis, Geo-reference
Digital Orthophoto		Raster	Emergency response plans, Real-world visualization
Churches		Polygon	Hate crime locations
Known Offenders		Point	Sex offenders, Parolees/probationers
Water		Polygon	Geo-reference
Expressways/High-ways		Line	Proximity to drug buys, Motor vehicle thefts
Municipalities*		Polygon	Home-town boundary, Regional crime analysis
Public Transportation		Point	Proximity to crimes
Taverns		Point	DUI's, Liquor law violations, Disorderly conducts
Census Data		Polygon	Population, Demographics, Community policing, Geo-reference
Street Gang Turf Boundaries		Polygon	Turf violence, Proximity to gang crimes

* Minimum required for basic pin mapping

By looking at his list of the available layers, Dover speculated that the following layers might be useful for analysis of vehicle burglaries: streets, expressways, beats, **land use**, retail sites, parking lots, and pawn shops. *I don't have to decide now*, Dover thought. *The great thing* *about a GIS program is that I can quickly add new layers as needed, so I can explore spatial connections and relationships between incidents and geographic features that were not apparent before. It's like giving a crime analyst a sixth sense.*

While mapping could be an important function in the crime analysis process, it is usually preceded by statistical analysis that would narrow the scope of data to be mapped. The focus would be on monthly counts of vehicles burglarized for the past year. Dover wanted to see if vehicle burglaries had risen in the previous month of November, and monthly counts would provide the appropriate answer.

Dover learned many of these statistical analysis techniques through training classes and by reading the *Incident-Based Crime Analysis Manual* developed by the Illinois Criminal Justice Information Authority (*www.icjia.state.il.us*).

Dover proceeded to extract the data from the department's record management system. After he imported the data into a spreadsheet program, Dover aggregated, or summarized, the data by month (as shown below).

City of Beaufort Vehicle Burglaries	
January	38
February	33
March	27
April	21
May	19
June	24
July	37
August	35
September	25
October	29
November	48

Upon examination of the table, it appeared that there was a definite upswing in vehicle burglaries in the past month. To summarize this data, Dover calculated a **mean** (or the arithmetic average of all the numbers), a **median** (the middle value the data, if viewed from least to greatest), and **mode** (the most common data occurrence). These statistics would show how many vehicle burglaries normally occurred per month in Beaufort over the past year.

After performing the calculations, Dover found that the mean for the monthly table of vehicle burglaries was 30 and the median was 29. Since the mean and median were very close, this told Dover that the data was not skewed by very high or very low numbers. The mode was not applicable in this situation, because there were no repeated numbers in the dataset.

Now that it was confirmed that November was substantially higher than the average for the past year, Dover decided to focus on that month. However, he needed to put the perceived jump in vehicle burglaries into a broader perspective. It would have more meaning if viewed not in isolation but compared to past data. He decided to compare the past month to a similar period last year.

After extracting the data, Dover discovered that there were 33 vehicle burglaries occurring in November of last year, and 48 in November of this year. A **percent change** was calculated using the formula *((new number – old number) / old number)) * 100.* After the numbers were plugged in to the formula, it appeared like the following: ((48 – 33) / 33) * 100. The result showed a 46 percent increase in vehicle burglaries over the same period last year. This was a situation that definitely needed to be halted immediately!

At this stage, however, Dover realized that this information did not tell him anything about where the crime occurred. To determine that, he needed to break down the data by operational boundaries, known as beats in Beaufort. From his original database, Dover extracted the November data. He then aggregated the data by beat. He also calculated the **percent of total** for each beat using the formula *beat total / grand total* (as shown below).

City of Beaufort Vehicle Burglaries by Beat - November		
	Count	Percent of Total
Beat 1	3	6.3
Beat 2	13	27.1
Beat 3	4	8.3
Beat 4	2	4.2
Beat 5	2	4.2
Beat 6	3	6.3
Beat 7	17	35.4
Beat 8	2	4.2
Beat 9	2	4.2
Total	48	100.0

As he examined the table, the figures for Beat 2 and Beat 7 jumped out at him. On one hand, Dover expected Beat 7 to contain a disproportionately large number of incidents given the nature of the beat. It was the commercial sector of town consisting of the Beaufort Mall, the Enormodome Movie Theater, and many other Beaufort businesses. It consistently contained the most crimes in Beaufort and was an attractor particularly for property crimes, such as retail theft, motor vehicle theft, and vehicle burglaries. On the other hand, Dover saw what appeared to be an inordinate number of vehicle burglaries occurring in Beat 2. Based on his recollection, the numbers for the remaining beats were usually similar to each other. Also telling was the fact that Beat 2 and Beat 7 were on the opposite ends of town from each other. Beat 7 was located on the far east side of town, while Beat 2 was located on the far west side. This suggested that the two problems were probably unrelated.

To complete his overall analysis of the vehicle burglary pattern, Dover put the burglary pattern by beat into a broader context by looking at past data, as he had done previously. To do this, two comparisons would be necessary. One comparison would show the most recent month (November 2002) compared to the mean average for the first 10 months of the year (January-October 2002), and the second comparison would show the most recent month to a similar period last year (November 2001). Dover then put them side by side for comparison in a new table (as shown below).

City of Beaufort Vehicle Burglaries by Beat				
	2002 November	2002 January-October		2001 November
	Count	Count	Average	Count
Beat 1	3	26	2.6	2
Beat 2	13	27	2.7	3
Beat 3	4	30	3	1
Beat 4	2	22	2.2	3
Beat 5	2	20	2	2
Beat 6	3	35	3.5	2
Beat 7	17	110	11	16
Beat 8	2	19	1.9	0
Beat 9	2	15	1.5	2
Totals	48	304	30.4	31

From the table, it was evident that something fishy was going on in Beat 2. The November 2002 total of 13 vehicle burglaries was far above both the average for that year and for the same period last year. Conversely, all other beats, even Beat 7, had a fairly typical number of vehicle burglaries.

Dover reviewed what he had done so far. *I've only confirmed what the chief suspected based on citizen complaints at the last beat meeting. However, there is some value in this information in that the anecdotal information is backed up by official statistics. With both types of data, I'm more convinced that a crime spree might be occurring in Beat 2.*

Dover contemplated the next logical step. One option was to alert officers in Beat 2, telling them to watch out for any suspicious looking individuals lurking around vehicles. But he quickly dismissed that plan because he could count on one finger the number of times it actually worked. It does not direct officers to look in any particular part of the beat, just the beat as a whole, which was large in size. Also, it assumes that officers are not already looking for suspicious activity in their beat. In addition, it also assumes that a pattern is confined to one beat, when in fact the problem might cut across beat boundaries.

Dover glanced at his watch. Matt Spaulding would be there shortly for their 10 a.m. meeting. With the remaining few minutes, he determined he could accomplish one more task. That task was to geocode the data. So he prepared the data for geocoding, set up the geocoding parameters, and finally ran the data through the mapping software's geocoding engine.

Sure as the sun shines, 95 percent geocoded on the first try. Geocoding is a breeze, Dover thought. *I wonder why people make such a big deal out of it?* Dover grinned, because he knew that for him, it had not always been that easy.

When he first began to map, geocoding was a process Dover dreaded. He heard countless horror stories from other departments about low hit-rates and bad data. It was a process wrought with potential problems. Then, when Dover geocoded a year's worth of Part I crime data for Beaufort, his worst nightmares were confirmed. His first attempt produced a woeful match rate of 65 percent.

He had spoken to many crime analysts who said their departments obtained at least 95 percent hit rates. He also saw an informal survey of police departments where it was reported that the average hit rate was around 87 percent. Beaufort was 22 points below the average! That was unacceptable to him, and it certainly was unacceptable to the chief. Geocoding was the life-blood of any crime mapping operation.

Dover had addressed many of the geocoding problems from the start, and over time the hit rate greatly improved. This, in turn, sped up the geocoding process and left him more time to devote to analysis – time that would be crucial if mapping was to be useful in assisting tactical responses.

Just as Dover was about to view the vehicle burglaries on the map, his phone rang. It was the desk sergeant telling him that Spaulding was there for his 10 a.m. meeting. Dover had scheduled a meeting with Spaulding at the Crime Analysts of Illinois Association meeting a week earlier. It was Spaulding's first time at the monthly meeting. He had asked a lot of questions about mapping and then had asked if someone could help him get started with geocoding. Dover could relate to his predicament because he had been in the same boat just a few months earlier. Dover did not consider himself an expert on the subject but he volunteered to help Spaulding out.

Chapter Two – Geocoding

"Hey Matt, how are you doing?" Dover asked as he walked into the front office.

"Good. How are you?" Spaulding replied.

"OK, I guess. Come on back." Dover said, leading him through the door and down the hallway.

"I really appreciate you helping me out like this," Spaulding said.

"No problem," Dover said, hoping that it was true.

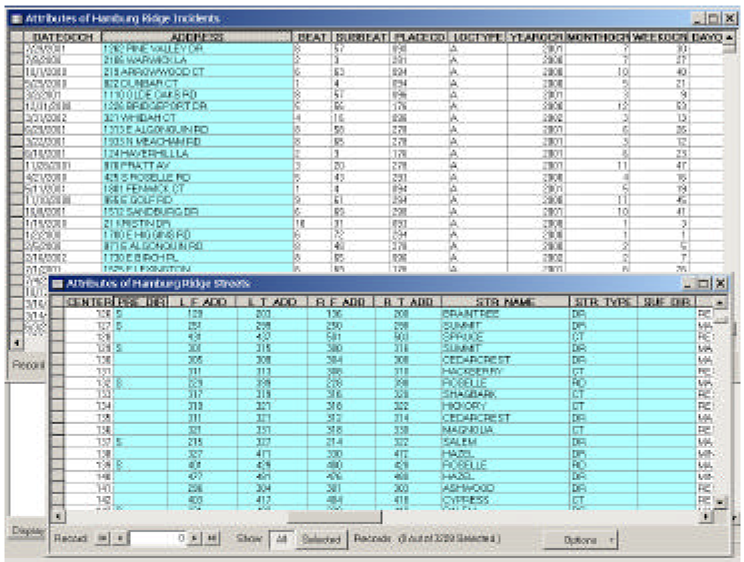
Back in his office, Dover pulled up a chair for his guest. He then loaded the disk Spaulding brought with him consisting of a street map of his town and a data file containing crime addresses, two files necessary for **address geocoding**. Geocoding literally means "coding the earth," or providing geographic reference information used for computer mapping. Address geocoding works by assigning x- and y-coordinates to tabular data such as street addresses or ZIP Codes so that they can be displayed as points on a map.

They waited a few minutes for the files to be loaded onto his hard drive, and then opened the data file. Hamburg Ridge had 1,299 Part I crimes the prior year - about 700 fewer than Beaufort. Dover also noticed that the street name, street number and other items that make up an address were already **concatenated**, or merged into one field.

"So have you *tried* geocoding with this file yet?" Dover asked.

"*I* haven't," Spaulding replied. "The previous crime analyst did but didn't do anything with it."

"So do you know what the **hit rate** was?" Dover asked. Getting only a puzzled look from Spaulding, Dover clarified. "By hit rate, I mean what percent were successfully matched or geocoded?" Matching refers to the process of comparing addresses that identify the same location but which are recorded in different lists. For crime mapping, usually one list contains crime addresses that are extracted from the department's record management system, and the second list contains street addresses of a town that are stored in a GIS database (as shown below). The more cases that match, the higher the hit rate.



"Oh!" Spaulding said, now understanding. "I think they said it was about 60 or 70 percent."

"60 percent or 70 percent?" Dover asked rhetorically and not too surprised. "In either case that's not too good. Think of it this way, if that was your grade in school, you'd barely be passing. Worse yet, if the cases that were left unmatched aren't randomly distributed in your jurisdictions, then your maps based on the data could be misleading. It could under-report crime in some areas."

"So what should I do?" Spaulding asked.

"Let's open up the mapping program's geocoding routine and test it out," Dover replied. "The first thing we have to do is specify geocoding parameters," Dover said. He then opened up the parameters dialog box and showed Spaulding an example for his program. "The main consideration in determining parameters is how high you should set your minimum match score. Since I don't know anything about your data, I'll set a strict **minimum match score** of 80. The **match score** is the score the program gives to each address based on how well the address in the crime database matches to an address in the street file. For instance, if all components of an address are correct—street number, street name, direction, and street type—the address receives a perfect score of 100. Missing or incorrect items reduce the score."

"So why did you set it at 80?" Spaulding asked. "Don't we want perfect matches?"

"That's not necessarily required," Dover replied. "Say for instance, you have an address in your town like this." Dover grabbed a piece of paper and jotted *123 Main St.*

"For the sake of argument, let's say it got entered into the database as *123 Main,* with the street type left off. If you knew that there were no other street types in your town, such as Main *Rd.* or Main *Ave.*, then you'd probably want that address to be geocoded. But if you set the minimum match score at 100, it wouldn't be automatically geocoded based on the parameter you set. Setting the score a little lower will most likely match that address."

"So, getting back to the grading analogy, you're basically looking for a grade of B or better," Spaulding said.

"You could look at it that way," Dover said. "Of course, setting the match score is somewhat arbitrary and it's a bit of a mystery what each element is worth exactly. What's important to understand is that there's a tradeoff between setting the match score too high, resulting in too few records being geocoded, and setting the minimum match score too low, resulting in erroneous matches or points being placed where crimes did not occur.

"As you work with your data more and understand it better, you can use the match score along with the hit rate to set some geocoding standards for your department. You also can see what your mapping program recommends for a minimum match score, if anything. My program suggests 75 and above for a good match."

"Okay, I think I've got it now," Spaulding said.

"So here we go," Dover began. "After you've set parameters, begin geocoding in the automatic, or **batch matching** mode. In this step, the program filters through all the addresses and matches whatever it can based on your parameters. For this amount of data, it shouldn't take more than a minute or two."

Dover then geocoded the data and it produced a hit rate of 64 percent.

"Sure enough, you were right, only 64 percent successfully matched. That's pretty pathetic," Dover said shaking his head. "Of course, you had 2 percent worth of ties and we can't assume those are accurate so really only 62 percent matched correctly."

"Great, we're going backwards," Spaulding said, exasperated. "Why can't we count ties?"

"Ties mean that your address found two potential match candidates with an equal score," Dover paused thinking for an example. "Let's say you have '150 Center St.' in your database. In your town, you have a N. Center St. and S. Center St., both with 150 as a street number. Which address would you choose to match on?"

"I guess I wouldn't know exactly," Spaulding said.

"Precisely," Dover said. "However, the program will pick one for you, probably the one that's first in the database.

"Another example is like a problem we had here. We erroneously had duplicate street ranges for "1318 E OXFORD AVE" in our street database. Two candidates tied as a result of the geocoding. These were the two options." Dover wrote down the following address ranges down in the order they appeared on the candidate list:

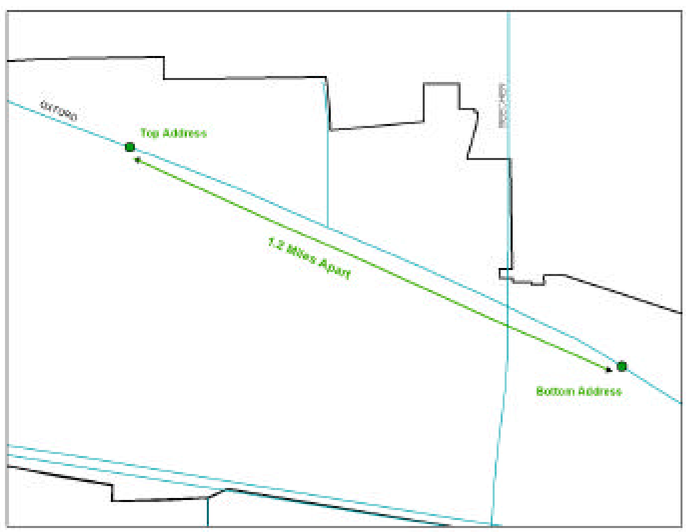
Top *1200-2100*

Bottom *1150-1350*

"The erroneous range was the top one. But if I didn't go back to verify it, the address would have been incorrectly geocoded to the top address because it appeared first in the database," he said.

"Then when I tested this on a map, first by geocoding to the top address, then geocoding it correctly to the bottom address, the two points were more than one mile apart. Let me show you."

Dover opened up the map containing the geocoding test he performed (as shown below).



"This example shows that you have to closely examine all ties," he concluded. "Next, we review the results of the misses to understand why cases were not geocoded. Since this is your first time going through this we can stop and see why some of the addresses didn't geocode."

Dover then briefly scrolled through the list of unmatched cases one by one, stopping to explain the errors as they went along.

"You see this one didn't have the correct directional identifier. It should have been east, not west.

"This one had the wrong suffix type. It should have been 'Rd' not 'Ave.'

"In this one, the street name was spelled wrong.

"This one omitted the street number altogether.

"This one had the directional switched. It was looking for 'S Water St', not 'Water St S.'

"Here's another misspelling.

"You get the idea," Dover said as they finished scrolling through the list.

"Yeah, I see," Spaulding said. "Very interesting."

"As I go through the list, I also try to look for recurring problems," Dover said. "I think I picked out two."

Spaulding interjected, gaining confidence. "One was that none of the intersections were geocoded. The second major problem was that we had numerous incidents that occurred at the Hamburg Ridge shopping mall that weren't geocoded either. But the question is what do you do about them?"

"We can handle both of them by re-specifying the parameters," Dover instructed. "I call these types of corrections, "global" fixes, because you make them once and it corrects all the related cases. Let's deal with the intersections first. Your department uses the forward slash (/) to divide your intersections, like us. But by default, the program only recognizes the ampersand (&), vertical bar (|), and at (@) symbols. So let's see what happens when we add the forward slash in the intersection divider parameter box."

"That increased the hit rate by 8 percent," Spaulding said. "So now were up to 70 percent."

Dover continued, "The second solution, or global fix, involves creating an **alias** table. For example, you had a lot of incidents at the mall, as you pointed out. Of course, what was entered into your CAD system was "Hamburg Ridge Mall" and not the actual address of the mall. It's probably easier for dispatchers that way."

"But wouldn't it be better to correct the data at the source and ask the dispatchers, officers, data entry people, or whomever to enter the actual address for the mall and not the alias?" Spaulding asked.

"Of course, it would be better that way, but you're probably not going to change the way the mall address is entered." Dover replied. "Besides, in the mean time, you can use the alias table that would replace the common name with the appropriate address. I can show you how to do that. It's fairly straightforward."

Dover then created an alias table after getting the exact mall address from Spaulding (as shown below).

ADDRESS	**ALIAS**
1800 PERIMETER DRIVE	HAMBURG RIDGE MALL

"Things to keep in mind when creating an alias table is that it's case sensitive and field properties, such as the field type and field width, have to be the same as the field properties in your reference database," Dover added. "Also, you have to re-geocode every time you create a new alias. So it's important to define as many aliases as possible beforehand.

"Let's see what happens when we use the alias table for the Hamburg Ridge Mall address." Dover then re-matched cases in automatic, or batch processing, mode.

“There we go, another 6 percent!” Spaulding exclaimed. “Now were up to 76 percent! What’s next?”

“Well, that was the easy part,” Dover said. “You still have a pretty low hit rate even after making some common fixes. That might indicate that there are bigger problems.”

“What do you mean?” Spaulding asked.

“Usually when you still have a low hit rate like that it’s an indication that there are serious problems with the base map or with the incoming data,” Dover explained. “When I first started geocoding I found that most of the problems were related to the street map that I got from the county. So once I identified where the problems occurred, I had to have the county fix the map. That’s primarily why I can attain a high geocoding hit rate today.”

Dover saw that Spaulding seemed disappointed by the prospects just presented to him. Dover also knew that it was usually at this point in the process that many analysts give up. They believe that the problem is too big for them to handle. Some resign themselves to getting low hit rates over and over while others give up the prospect of mapping altogether until someone else fixes the problems. Dover didn’t want that to happen with Spaulding. He wanted to give him hope that with a little analysis he can understand his geocoding problems, and with a little persistence he can find remedies.

“So I think you’re doing the right thing by addressing these geocoding problems from the beginning so you don’t have to deal with the same issues over and over,” Dover said.

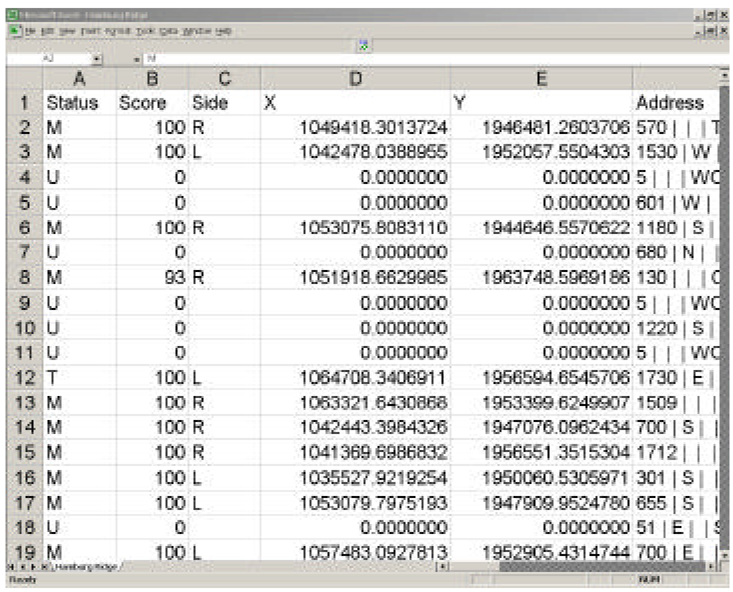
Dover outlined a course of action. “The first thing we can do is analyze whether there are any systematic errors by location. Then we can determine the most common type of problem, whether it’s coming from the crime data or the street map. Finally, we can map the errors and calculate the error rate attributed to the software program.”

“Wait a second…the error rate for the software program?” Spaulding asked.

“Yeah, believe it or not, the program does make mistakes. It sometimes places points erroneously,” Dover said. “Granted, it’s usually a minor problem. However, it’s important to get an idea what the error rate might be. I’ll show you how you can do that later.”

“So like I said, let’s start by determining if there are any systematic errors by location. Let’s see how it breaks down by police beat first.”

Dover exported the entire file of geocoded and un-geocoded cases as a database file and then brought the table into a spreadsheet program. The table looked much like this one:



	A	B	C	D	E	
1	Status	Score	Side	X	Y	Address
2	M	100	R	1049418.3013724	1946481.2603706	570 | | | T
3	M	100	L	1042478.0388955	1952057.5504303	1530 | W
4	U	0		0.0000000	0.0000000	5 | | | WC
5	U	0		0.0000000	0.0000000	601 | W |
6	M	100	R	1053075.8083110	1944646.5570622	1180 | S |
7	U	0		0.0000000	0.0000000	680 | N |
8	M	93	R	1051918.6629985	1963748.5969186	130 | | | C
9	U	0		0.0000000	0.0000000	5 | | | WC
10	U	0		0.0000000	0.0000000	1220 | S |
11	U	0		0.0000000	0.0000000	5 | | | WC
12	T	100	L	1064708.3406911	1956594.6545706	1730 | E |
13	M	100	R	1063321.6430868	1953399.6249907	1509 | | |
14	M	100	R	1042443.3984326	1947076.0962434	700 | S | |
15	M	100	R	1041369.6986832	1956551.3515304	1712 | | |
16	M	100	L	1035527.9219254	1950060.5305971	301 | S | |
17	M	100	L	1053079.7975193	1947909.9524780	655 | S | |
18	U	0		0.0000000	0.0000000	51 | E | | S
19	M	100	L	1057483.0927813	1952905.4314744	700 | E | |

Dover then explained. “As you can see the ‘Status’ field indicates whether a case is matched, unmatched, or tied. The ‘Score’ field should be self-explanatory now. The ‘Side’ field indicates whether the address fell on left side (L) or right side (R) of the street. Finally, the ‘X’ and ‘Y’ fields show the coordinates for each address. It appears that they are in **State Plane coordinates**.”

“How do you know they are in State Plane?” Spaulding asked.

"We use State Plane here, so I recognized the **coordinate system**," Dover replied.

"What exactly *is* a coordinate system?"

"Computer mapping works by assigning x- and y-coordinates to locations, for instance, a crime address, then placing a point on a map at those coordinates. This is usually at the **latitude** and **longitude** the crime occurred." An x-coordinate (longitude) is a measurement to the east or west of a fixed vertical line, like **Greenwich Mean Time (GMT)**, in Greenwich, England. A y-coordinate (latitude) is a measurement to the north or south of a fixed horizontal line, like the equator.

"Latitude/longitude is the universal reference system, but as long as the method for determining x and y is consistent, any type of system will work. That's where State Plane comes in.

"To derive State Plane coordinates, a rectangular grid is superimposed over the latitude/longitude system to produce separate grids, or zones, for each state in the U.S. Large states are divided into more than one zone. For example, here in Illinois, we have an east and west State Plane zone.

"Another coordinate system you might run across is UTM. It stands for **Universal Transverse Mercator**. It's devised similarly to State Plane, in that it consists of zones. Though, instead of covering only the U.S., it covers most of the world."

"Well, you knew which coordinates they were in because you've been doing this for awhile but how would somebody new be able to tell which coordinates they're in?" Spaulding asked.

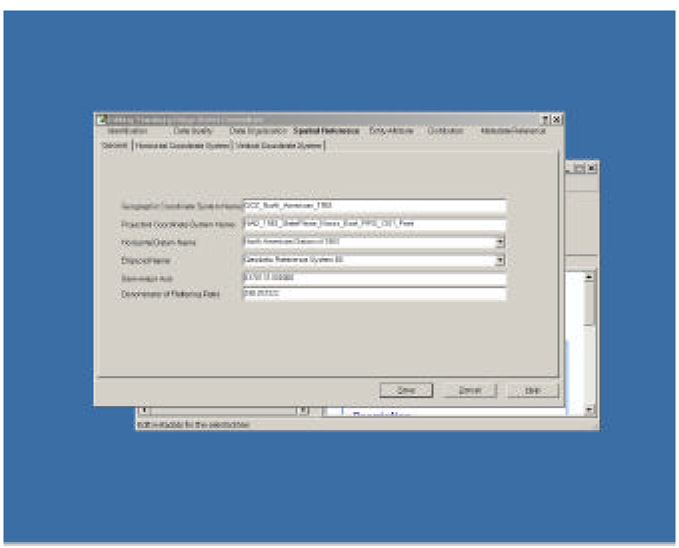
"This program, and most other programs, provide you with the ability to view **metadata** for each geographic file," Dover replied.

“Meta-what?”

“Think of this way,” Dover explained. “Metadata is data about data. By reviewing the metadata for a file, you can find out who created the data, it’s purpose, time period, and when it was last updated, things like that. It usually will also list the fields contained in the file, and provide you with information such as the data type, width of the fields, map **scale**, and other relevant information.

“It also contains the spatial characteristics of the file. This is where you’d find information you wanted, such as the coordinate system. There you would know that your file was in State Plane coordinates. Let’s check the metadata for your street **centerline** file and see if it contains any spatial reference information.”

Dover opened the mapping program’s metadata application in edit mode so he could view metadata related to the Hamburg Ridge street centerline file. He then clicked on the ‘Spatial Reference’ tab in the menu and retrieved a screen that appeared like the following:



Spaulding interjected. “I can see from the ‘Projected Coordinate System Name’ field that the coordinates are in State Plane, like you said. But will the coordinates of the map always be there?"

"Yes, if the program in which the file was created had that functionality," Dover replied. "But I should point out that some metadata are created automatically when new map data are created but other information is only there if the person who created the file put it there."

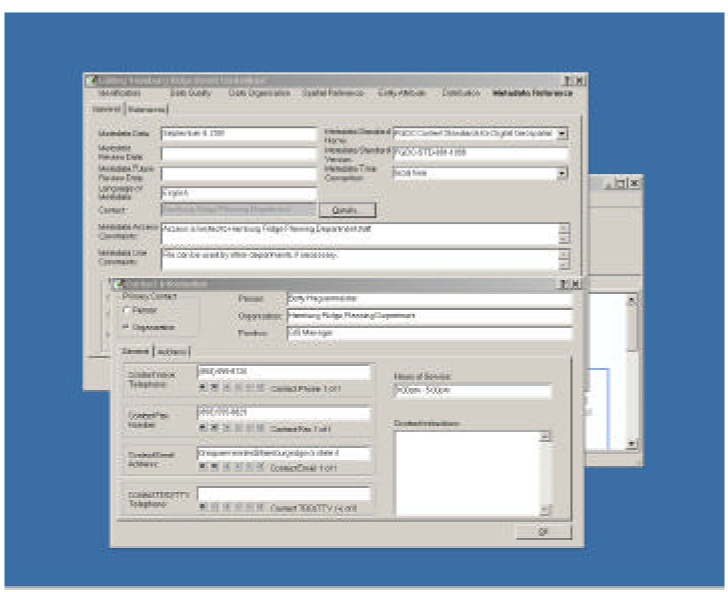
"What if it isn't?"

"Then you should ask the person or department who created it," Dover answered. "In your case, you would ask someone in the city planning department, because that's where you obtained you data."

"That's simple enough," Spaulding said.

"I have an idea," Dover said. "Let's check some other metadata for the street file to see whether it lists any other useful information."

Dover then clicked on the 'Metadata Reference' tab and pulled up a window of general information about the file, including the date the metadata was created, its language, and whether there were any access and usage constraints placed on the street file. Dover then saw the contact information for the person who created the file, and clicked on the 'Details' box to pull up a window that appeared like this one:



"There it is. The contact person is Betty Haguermeister. Now I know exactly who to blame if I encounter problems with the street file," Spaulding joked. "I've got her name, number, e-mail address, and office hours! She can't hide!"

"It's all there," said Dover. "Actually, she did a pretty good job of filling in the metadata. She made it very useful for other users."

For the next few minutes, Dover and Spaulding browsed through the rest of the metadata screens. In the process, Dover explained to Spaulding that there were standards to follow when creating metadata. He advised Spaulding to check into the standards developed by the **Federal Geographic Data Committee (FGDC)** (www.fgdc.gov) before he created any metadata of his own. After they finished viewing the metadata, Dover closed the application.

"What if I have two files of different coordinate systems?" Spaulding asked. Can I use them both on the same map?"

"Yes," Dover replied. "You can use them on the same map but only after converting one to the other. Our program, as well as other GIS programs can handle that. But that stresses the importance of actually *knowing* the coordinate system and **map projection** of any new data that you use."

"What exactly *is* a projection?"

"Literally, a projection is a mathematical transformation of the three-dimensional earth to a two-dimensional surface," Dover answered. "They're used to represent large areas of the Earth's surface. Because of this, all projections introduce some kind of distortion in the map. It's a lot to go into right now, but if you want to learn more about projections, there are lots of geographical texts on the subject. You might also have received a manual on map projections when you purchased your GIS software. Another book you might want to check out is this

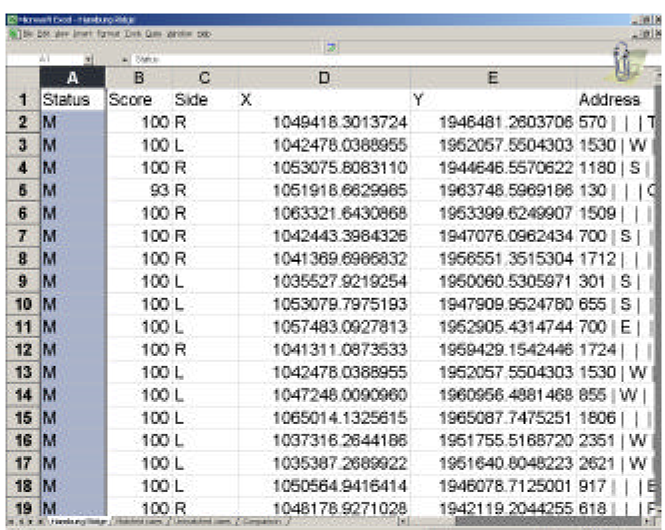
‘Mapping Crime’ book. It contains a good section on projections and coordinate systems. Here, you can borrow mine.”

Dover then handed Spaulding *Mapping Crime: Principle and Practice* by Keith Harries, published by the National Institute of Justice.

Dover then added, “Let’s just say, though, as crime analysts working at municipal police departments, we really don’t have to worry about projections too much, just coordinates. That’s because our jurisdictions are usually small enough that map projections are not a major concern. The main thing to remember is that you just have to make sure you are using maps with compatible projections and coordinate systems. If not, then you have to convert one to the other.

“Okay, getting back to the table here, the next thing is to sort the file by the ‘Status’ field and then copy and paste the associated records into new spreadsheets.”

Before he did that, Dover first created three new spreadsheets, one called ‘Matched’, for matched cases, one called ‘Unmatched’, for unmatched cases, and one called ‘Comparison’ used for comparing the two types of cases by beat. Dover then sorted the file in ascending order, which put all matched cases at the top (represented by the letter ‘M’ in the ‘Status’ field). The spreadsheet now appeared like this:

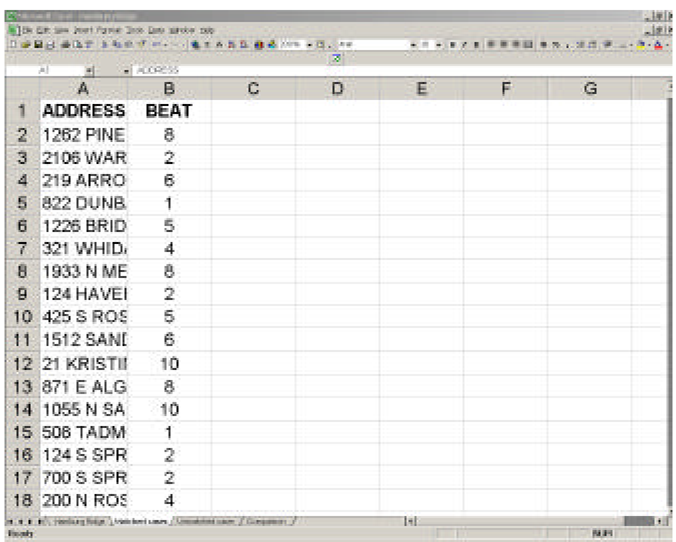

<table>
<tr><th></th><th>A</th><th>B</th><th>C</th><th>D</th><th>E</th><th></th></tr>
<tr><td>1</td><td>Status</td><td>Score</td><td>Side</td><td>X</td><td>Y</td><td>Address</td></tr>
<tr><td>2</td><td>M</td><td>100</td><td>R</td><td>1049418.3013724</td><td>1946481.2803706</td><td>570 | | | T</td></tr>
<tr><td>3</td><td>M</td><td>100</td><td>L</td><td>1042478.0388955</td><td>1952057.5504303</td><td>1530 | W</td></tr>
<tr><td>4</td><td>M</td><td>100</td><td>R</td><td>1053075.8083110</td><td>1944646.5570622</td><td>1180 | S |</td></tr>
<tr><td>5</td><td>M</td><td>93</td><td>R</td><td>1051918.6629985</td><td>1963748.5969186</td><td>130 | | | C</td></tr>
<tr><td>6</td><td>M</td><td>100</td><td>R</td><td>1063321.6430868</td><td>1953399.6249907</td><td>1509 | | |</td></tr>
<tr><td>7</td><td>M</td><td>100</td><td>R</td><td>1042443.3984326</td><td>1947076.0962434</td><td>700 | S |</td></tr>
<tr><td>8</td><td>M</td><td>100</td><td>R</td><td>1041369.6986832</td><td>1956551.3515304</td><td>1712 | | |</td></tr>
<tr><td>9</td><td>M</td><td>100</td><td>L</td><td>1035527.9219254</td><td>1950060.5305971</td><td>301 | S |</td></tr>
<tr><td>10</td><td>M</td><td>100</td><td>L</td><td>1053079.7975193</td><td>1947909.9524780</td><td>655 | S |</td></tr>
<tr><td>11</td><td>M</td><td>100</td><td>L</td><td>1057483.0927813</td><td>1952905.4314744</td><td>700 | E |</td></tr>
<tr><td>12</td><td>M</td><td>100</td><td>R</td><td>1041311.0873533</td><td>1959429.1542446</td><td>1724 | | |</td></tr>
<tr><td>13</td><td>M</td><td>100</td><td>L</td><td>1042478.0388955</td><td>1952057.5504303</td><td>1530 | W</td></tr>
<tr><td>14</td><td>M</td><td>100</td><td>L</td><td>1047248.0090960</td><td>1960956.4881468</td><td>855 | W |</td></tr>
<tr><td>15</td><td>M</td><td>100</td><td>L</td><td>1065014.1325615</td><td>1965087.7475251</td><td>1806 | | |</td></tr>
<tr><td>16</td><td>M</td><td>100</td><td>L</td><td>1037316.2644186</td><td>1951755.5168720</td><td>2351 | W</td></tr>
<tr><td>17</td><td>M</td><td>100</td><td>L</td><td>1035387.2689922</td><td>1951640.8048223</td><td>2621 | W</td></tr>
<tr><td>18</td><td>M</td><td>100</td><td>L</td><td>1050564.9416414</td><td>1946078.7125001</td><td>917 | | | E</td></tr>
<tr><td>19</td><td>M</td><td>100</td><td>R</td><td>1048178.9271028</td><td>1942119.2044255</td><td>618 | | | F</td></tr>
</table>

Dover then copied and pasted the matched cases (with Status = M) into the 'Matched' spreadsheet and the unmatched and tied cases (with Status = U or T) into the 'Unmatched' spreadsheet.

"Remember, we included the tied cases as unmatched because we cannot assume accuracy," Dover said as he finished. "So now each spreadsheet should have only it's respective cases.

"Next, we need to calculate the frequency of cases by police beat. But first let's delete everything we don't need and just keep the address and beat fields. We don't actually need the address field for this exercise but we'll keep it here anyway."

Dover then edited the spreadsheets for matched and unmatched cases to look similar to this:

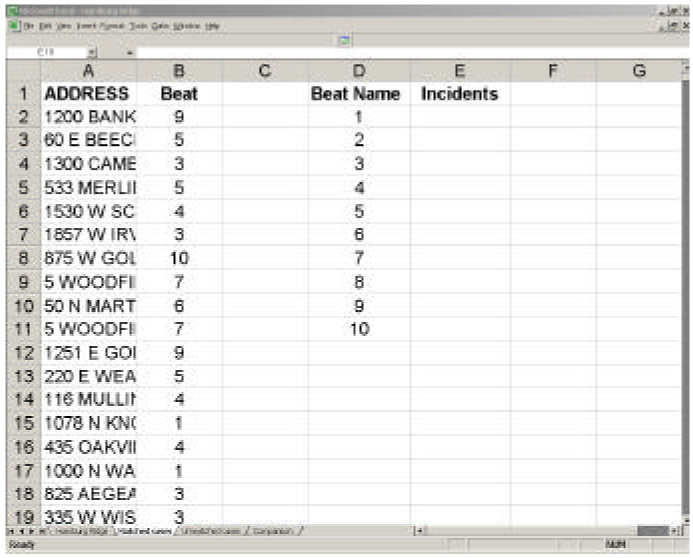


"Now we have to calculate a frequency, or count the number of cases by beat," he said.

"How do we do that? Just sort them and count them manually?" Spaulding asked.

"That's the hard way," Dover said. "The easy way is to let the spreadsheet accomplish the task. Let's do matched cases first."

Dover then created two new fields, one with the beat name and one with the number of incidents by beat. In the 'Beat Name' field he created a list of individual beat na mes. Since Hamburg Ridge had 10 beats, he numbered it from 1…10. The table appeared like this:

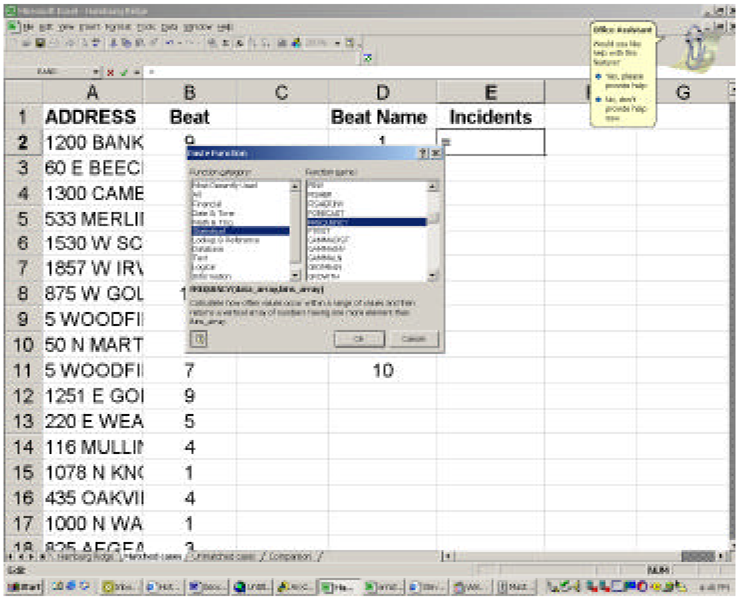


	A	B	C	D	E	F	G
1	ADDRESS	Beat		Beat Name	Incidents		
2	1200 BANK	9		1			
3	60 E BEECI	5		2			
4	1300 CAME	3		3			
5	533 MERLII	5		4			
6	1530 W SC	4		5			
7	1657 W IR\	3		6			
8	875 W GOL	10		7			
9	5 WOODFI	7		8			
10	50 N MART	6		9			
11	5 WOODFI	7		10			
12	1251 E GOI	9					
13	220 E WEA	5					
14	116 MULLII	4					
15	1078 N KN(	1					
16	435 OAKVII	4					
17	1000 N WA	1					
18	825 AEGEA	3					
19	335 W WIS	3					

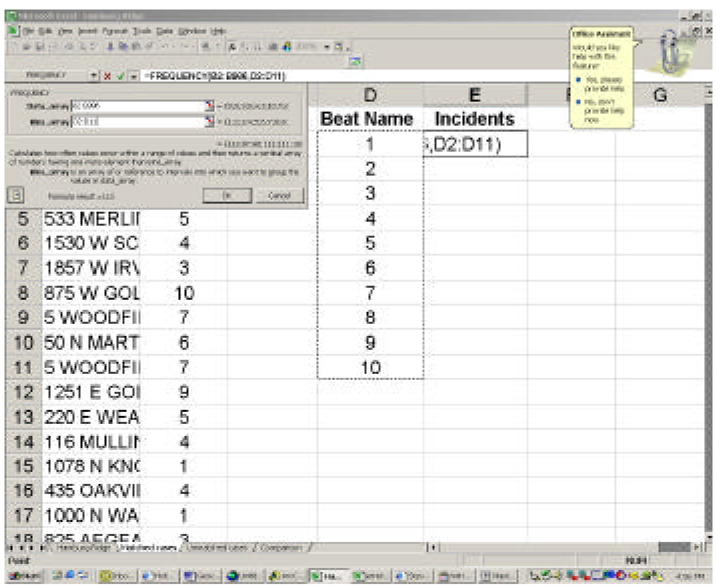
"Now in the 'Incidents' field, we have to calculate the frequency of incidents by beat," he said. "For that, we need a statistical formula."

Dover opened a statistical function in the spreadsheet program by clicking on the function button next to the sigma, '*E'*. It looks like this:

Once the 'fx' button was pressed, the "Paste Function' screen opened (as shown below). Dover then chose the 'Statistical' function from the category column, and the 'FREQUENCY' function from the right column.



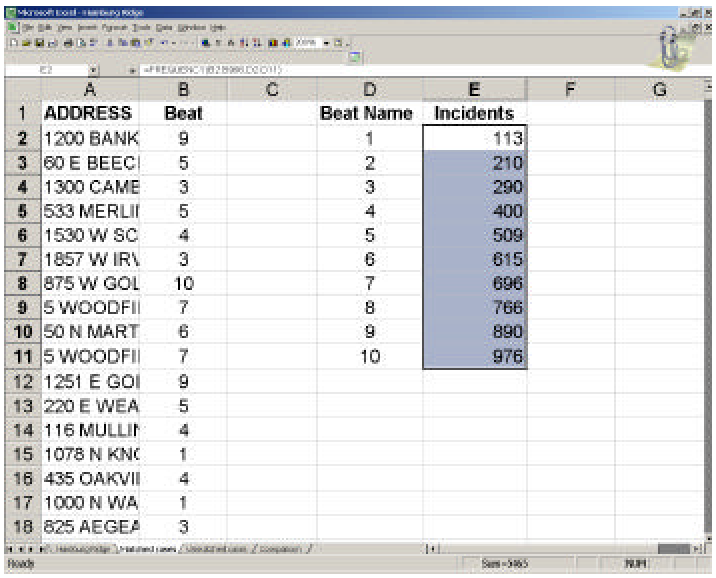
Next, Dover clicked ‘OK’ and the program asked him for the range of data to calculate frequencies (as shown below).



The range of data is simply the cell locations of the data to be arranged. He entered the range into the ‘Data_array’ box. In this situation, the range read B2:B986. Then in the ‘Bins_array’ box he entered the range that included the beat numbers. This range included cells

D2:D11. The formula to calculate a frequency appeared in the incident column across from Beat 1.

Dover copied the formula into the cells across from the rest of the beats to receive the results in the incident field.



	A	B	C	D	E	F	G
1	ADDRESS	Beat		Beat Name	Incidents		
2	1200 BANK	9		1	113		
3	60 E BEECI	5		2	210		
4	1300 CAME	3		3	290		
5	533 MERLII	5		4	400		
6	1530 W SC	4		5	509		
7	1857 W IR\	3		6	615		
8	875 W GOL	10		7	696		
9	5 WOODFII	7		8	766		
10	50 N MART	6		9	890		
11	5 WOODFII	7		10	976		
12	1251 E GOI	9					
13	220 E WEA	5					
14	116 MULLIN	4					
15	1078 N KN(	1					
16	435 OAKVII	4					
17	1000 N WA	1					
18	825 AEGEA	3					

Unfortunately, the program returned the number of events less than or equal to the entry. Thus, the number for Beat 2 includes cases for Beat 1 + Beat 2. To correct this, Dover created a formula to subtract the preceding number of cases from the result in each beat. First he added a new field in Column F called 'True Incidents' that would contain the corrected number of incidents. He then inserted the formula *=E3-E2* in the 'True Incidents' field across from Beat 2.

Dover then copied the formula in to the cells for Beat 3 through 10. For Beat 1, Dover simply copied over the value. The results are in the 'True Incidents' field (as shown below).

	A	B	C	D	E	F
1	ADDRESS	Beat		Beat Name	Incidents	True Incidents
2	1200 BANK	9		1	113	113
3	60 E BEECI	5		2	210	97
4	1300 CAME	3		3	290	80
5	533 MERLII	5		4	400	110
6	1530 W SC	4		5	509	109
7	1857 W IR\	3		6	615	106
8	875 W GOL	10		7	696	81
9	5 WOODFI	7		8	766	70
10	50 N MART	6		9	890	124
11	5 WOODFI	7		10	976	86
12	1251 E GOI	9		Missing	9	
13	220 E WEA	5				
14	116 MULLII	4				
15	1078 N KN(	1				
16	435 OAKVII	4				
17	1000 N WA	1				
18	825 AEGEA	3				
19	335 W WIS	3				

Dover then repeated the same steps above for unmatched cases in a separate spreadsheet.

When Dover finished, he copied and pasted the values of the 'True Incident' field into the spreadsheet he created earlier called 'Comparison.' The table showing the results looked like this:

	A	B	C	D	E	F
1	Matched Cases			Unmatched Cases		
2		Number			Number	
3	Beat 1	113		Beat 1	23	
4	Beat 2	97		Beat 2	29	
5	Beat 3	80		Beat 3	48	
6	Beat 4	110		Beat 4	12	
7	Beat 5	109		Beat 5	29	
8	Beat 6	106		Beat 6	38	
9	Beat 7	81		Beat 7	12	
10	Beat 8	70		Beat 8	21	
11	Beat 9	124		Beat 9	66	
12	Beat 10	86		Beat 10	27	
13	Total	976			305	
14						
15	Missing	9		Missing	9	
16						
17						
18						
19						

“Okay, now we’re getting to the point of this exercise,” Dover said. “We want to find out what percentage of the total each beat represents for both matched and unmatched cases. Then we can compare the differences to see if any beat is disproportionately represented in unmatched cases.”

Dover created a new field for both matched and unmatched cases. In that field he entered the formula *number per beat / total number* for calculating the percent of the total represented by each beat. The formula for matched cases in Beat 1 was:

113/976 = .115 or 11.5 percent (12 percent rounded)

Dover then created a similar formula for the other beats for both matched and unmatched cases. He placed the results side by side for comparison, shown at the bottom of the following table:

Matched Cases	Number	Percent		Unmatched Cases	Number	Percent
Beat 1	113	12%		Beat 1	23	8%
Beat 2	97	10%		Beat 2	29	10%
Beat 3	80	8%		Beat 3	48	16%
Beat 4	110	11%		Beat 4	12	4%
Beat 5	109	11%		Beat 5	29	10%
Beat 6	106	11%		Beat 6	38	12%
Beat 7	81	8%		Beat 7	12	4%
Beat 8	70	7%		Beat 8	21	7%
Beat 9	124	13%		Beat 9	66	22%
Beat 10	86	9%		Beat 10	27	9%
Total	976	100%		Total	305	100%

Comparison	Matched	Unmatched
Beat 1	12%	8%
Beat 2	10%	10%
Beat 3	8%	16%
Beat 4	11%	4%
Beat 5	11%	10%
Beat 6	11%	12%
Beat 7	8%	4%
Beat 8	7%	7%
Beat 9	13%	22%
Beat 10	9%	9%
Total	100%	100%

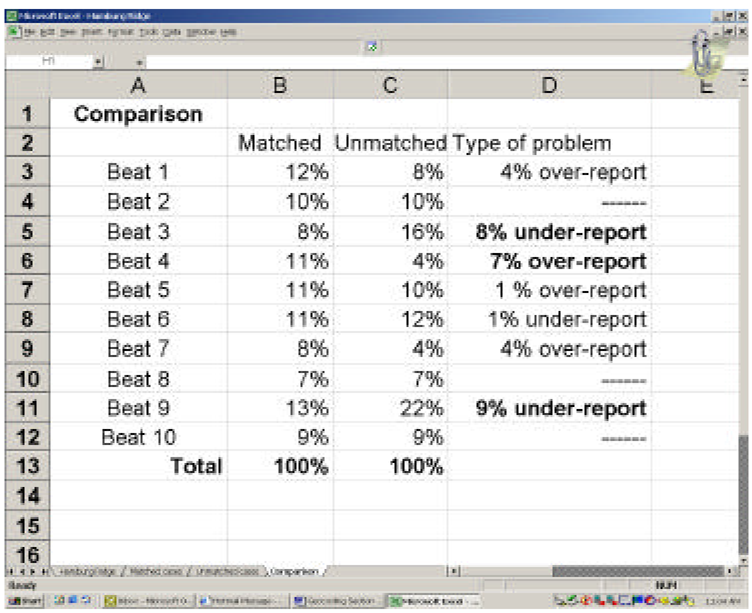
“So that illustrates what you mean by disproportionate,” Spaulding said, edging up in his chair. “Some beats are disproportionately higher or lower for unmatched cases compared to the matched cases. Beat 1 has a disproportionately larger percentage of geocoded cases. Four percent to be exact."

"Precisely."

"That means Beat 1 is over-reported by 4 percent," Spaulding said, beginning to gather the meaning of this.

Dover began to create a new field that categorized each beat by whether it was over-reported or under-reported and by percentage.

"Beats 2, 8, and 10 are the same, while beats 5 and 6 are very similar," Spaulding said. Dover finished the new column and the table and highlighted the beats with the largest difference to reveal this table:



Comparison			
	Matched	Unmatched	Type of problem
Beat 1	12%	8%	4% over-report
Beat 2	10%	10%	-------
Beat 3	8%	16%	**8% under-report**
Beat 4	11%	4%	**7% over-report**
Beat 5	11%	10%	1 % over-report
Beat 6	11%	12%	1% under-report
Beat 7	8%	4%	4% over-report
Beat 8	7%	7%	-------
Beat 9	13%	22%	**9% under-report**
Beat 10	9%	9%	-------
Total	**100%**	**100%**	

"The biggest differences appear in beats 3, 4, and 9," Spaulding concluded.

Spaulding stared at the screen. "I can't figure out why beats 9 and 3 would be *that* under-reported," he said. "Unless there are more aliases being used in those districts that I'm not aware of."

"Do you think there might be any discrepancies in the way data are collected by officers?" Dover asked.

"I can't imagine why there would be, everyone's trained the same way," Spaulding replied. "I mean, how difficult can it be to fill out the correct address?"

"It could also be the street map," Dover said. "Does either of those beats consist of new development or subdivisions? It's possible that the map hasn't been updated in those areas yet."

"We've had some development but I wouldn't say were growing like a boomtown or anything," answered Spaulding.

"It could be the culmination a lot of little errors," Dover said. "Either way, it does appear to be a systematic problem either with the data input or the street map. It also suggests that any analysis conducted using the 76 percent of geocoded cases where the data are aggregated by beat would have to factor these discrepancies."

"Don't worry, I'm not using this for anything at this point," Spaulding said, still searching for answers.

Dover glanced at his watched. It was almost 12 p.m.

"I know I've taken up a lot of your time," Spaulding said. "We could finish up on another day."

"I'll tell you what. I'll show what you could do next to more precisely identify the problem. It shouldn't take more than an hour," Dover said.

"Sounds good."

"The next thing you could do is what I call '**error mapping**,'" Dover said. "You map the geocoded incidents and then compare the distribution to a map of unmatched incidents."

“Wait a second. How can you *map* the incidents that didn’t geocode?” Spaulding asked, amused. “Isn’t that the point? You *can’t* map them.”

“We’re mapping them by manually placing them where they’re *supposed* to go,” replied Dover. “You should be able to get a reasonable approximation by eyeballing it.”

“Why in the heck are we doing that?” asked Spaulding.

“To get a more precise idea of where the problems are located,” Dover replied. “First of all, recording them by beat obscures the relationship of points that are close by, say near the border of two beats but not in the same beat. Second, we already know which beats are more problematic. What we don’t know is in which parts of the beats the problems are located. In other words, whether they are near the outer edges of the beat or whether there are particular streets that are a problem. That kind of thing.”

Spaulding was still skeptical. “So why did we do it the other way if this way is better?”

“Well, in police departments, data are still reported and analyzed by beat, so it’s important to be cognizant of the problems encountered when they are aggregated that way for mapping purposes, especially if you’re getting a low hit rate,” Dover replied. “Also, it’s a lot faster.”

“Yeah, I’d imagine so. Mapping 300-odd incidents, or whatever we had, seems tortuous.”

“You didn’t think geocoding would be easy, did you?” Dover asked, with a chuckle. “You’re right. Doing this type of exercise is painful, but we don’t have to map all of the un-geocoded addresses. We can just take a **random sample** of cases. I can show you how to do that fairly easily with a spreadsheet program.”

“How many cases will we need?” Spaulding asked.

"Obviously the greater the number, the more valid the sample," Dover said. "When I did it, I took a sample of 50 cases. That should be enough for you, too."

Dover pulled out a calculator and keyed in the numbers.

"It works out to be about 15 percent of the remaining 305 cases," Dover added. " I think that will give you a good picture of what is happening."

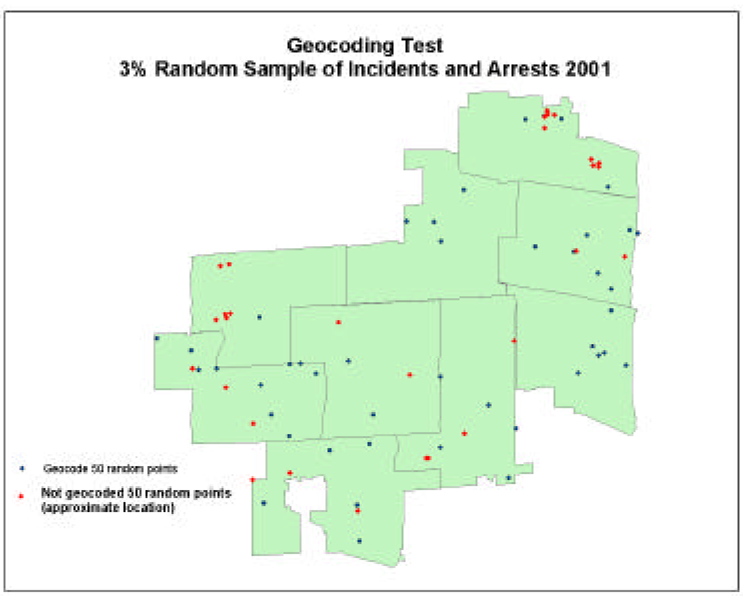
"But won't that only tell me where the problem is again, albeit more precisely?" asked Spaulding.

"Yes. But at the same time, you can identify the type of problem responsible as to why the point didn't geocode…whether it's a data collection or street map problem."

"I'm still a little confused," Spaulding said, shaking his head.

"Maybe I should just show you what I'm talking about," Dover said, reaching for the computer mouse. "Let me show you a map I created when I was doing this for Beaufort."

Dover proceeded to open a map of Beaufort that contained a random sample of 50 matched incidents and a random sample of 50 unmatched incidents (as shown below).



“The blue points are the 50 matched cases and the red points are the 50 unmatched cases that I manually approximated a location for,” explained Dover. “There aren’t exactly 50 dots because in a few cases there was more than one point at an same address.”

“Let me ask you a logistical question. How did you locate an unmatched incident?” Spaulding asked.

Dover explained. “Well, I first located the address in the **attribute table** of the street file. Then I zoomed in on the map where the street was located. If you know your town well that should be no problem. But if you don’t know the streets that well, then I’d suggest using a paper map with a street index. Get the most recent one available. After I zoomed in on the street, I clicked on one of the street segments, noted the address range, and then moved east, west, north, or south based on the street number of my address. For intersections, I just placed the point where the two streets met.”

“How accurate do you have to be?”

“It’s just an exercise so you don’t have to be as precise as if the point were an actual incident used for analysis,” replied Dover. “For this, a few hundred feet or a couple of city blocks is probably fine.”

“Gotcha.”

“The point is to compare the two distributions,” Dover said. “If both distributions were random, then you’d expect their distributions to be similar. But, if you look at the map, the red dots show clusters of unmatched incidents on the outskirts of Beaufort. Of course, I didn’t test for statistical randomness in either distribution but I *could* have if I used a program like *CrimeStat*.”

Dover added, “At this point, I suspected that there were problems with the base map, primarily because the red dots on the outer edges of the map were in areas of town that contained a lot of new development. Beaufort has grown rapidly in the past few years, so I figured the county hadn’t updated the map yet.”

“Was that the case?” Spaulding asked.

“For the most part, yes, but I couldn’t be sure until I identified exactly what type of problem there was for each case. So one by one, as I was mapping each point manually, I categorized the problem in a spreadsheet like this.”

	B	C	D	E	F
1	ADDRESS	BEAT	TYPE OF ERROR	TYPE OF PROBLEM	SOLUTION
2	1116 N KN	1	Missing Address Range	Street Map	Correct Base Map
3	2305 BIRD	1	Incorrect Street Type	Data Collection	Speak w/ officers or data entry
4	2336 ONY	1	No Such Address	Data Collection	Speak w/ officers or data entry
5	520 MANO	1	Missing Address Range	Street Map	Correct Base Map
6	546 MANO	1	Missing Address Range	Street Map	Correct Base Map
7	558 MANO	1	Missing Address Range	Street Map	Correct Base Map
8	1935 NOR	2	Missing Entire Street	Street Map	Correct Base Map
9	2590 W S	2	Outside City	—	Correct Base Map
10	1124 S SP	3	Incorrect Street Range	Street Map	Correct Base Map
11	1124 S SP	3	Incorrect Street Range	Street Map	Correct Base Map
12	1124 S SP	3	Incorrect Street Range	Street Map	Correct Base Map
13	1124 S SP	3	Incorrect Street Range	Street Map	Correct Base Map
14	1651 S WI	3	Missing Address Range	Street Map	Correct Base Map
15	1651 S WI	3	Missing Address Range	Street Map	Correct Base Map
16	1080 W R	4	Incorrect Street Type	Data Collection	Speak w/ officers or data entry
17	318 BITTE	4	Correct - should have matched	Map Software	Calculate Error Rate
18	132 OLIVE	5	Missing Street Segment	Street Map	Correct Base Map
19	145 OLIVE	5	Missing Street Segment	Street Map	Correct Base Map
20	168 OLIVE	5	Missing Street Segment	Street Map	Correct Base Map
21	233 E GRO	5	Misspelled Street Name	Street Map	Correct Base Map
22	8 WATERF	5	Missing North Prefix	Data Collection	Speak w/ officers or data entry
23	1061 PERI	7	Missing Address Range	Street Map	Correct Base Map
24	1114 OLDE	8	Missing Address Range	Street Map	Correct Base Map
25	1120 E AL	8	Incorrect Street Range	Street Map	Correct Base Map

“As you can see, I categorized unmatched incidents by the specific type of error, the general type of problem, and potential solutions.” Dover said.

“It looks like most of your problems were related to the street map you used,” Spaulding said.

“Yes, about 75 percent of our problems were with the base map.”

“What did you do about it?”

"Well the chief and I had a meeting with the county planning department where we showed them our findings," Dover said. "They were a little defensive about it at first, but when they understood that we weren't placing the blame anywhere they relaxed. We just needed the map fixed and we certainly didn't have anyone who could do it. Not only that, I think this kind of thing is better left to a GIS professional trained in this stuff. I don't think they wanted us to touch the map anyway."

"So were they able to fix the problems?" Spaulding asked.

"Yeah. The map has been vastly improved, and it has improved the accuracy and speed of geocoding," Dover said. "The maps that I did, such as the one I just showed you, gave them an idea of where to start. And they basically admitted to being behind in updating some of the new areas on the outskirts of town, which was understandable, given the growth of Beaufort. I also exported the entire list of unmatched cases to a file and they looked into those addresses and the surrounding areas based on that information."

Dover added, "There are still some problems, but I have a good working relationship with our county GIS person. Every so often, I send her a list of unmatched addresses and she fixes the map."

"OK, so what if my problems are related more to data input errors?" Spaulding asked.

"If they're on your end, then that might be a bigger problem to deal with, because it might indicate that your department is not ready to map until you can improve your data collection methods."

"And that's what we have yet to determine," Spaulding said.

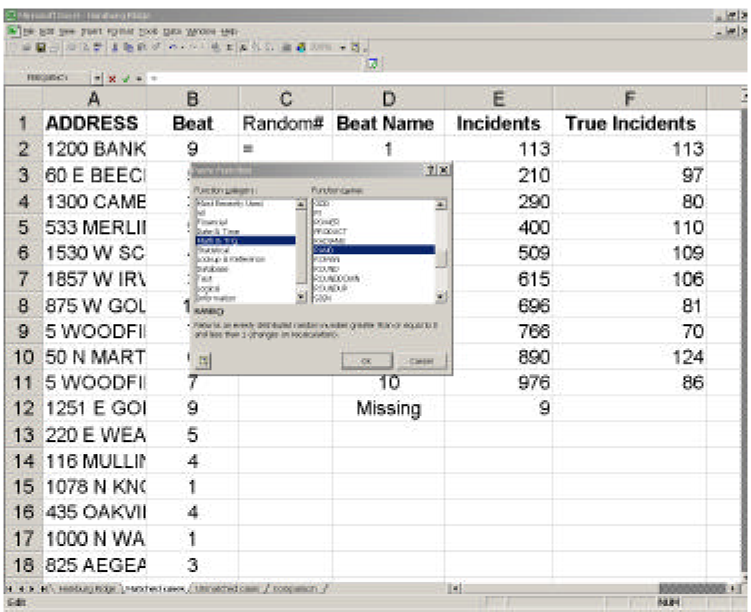
"Yep."

“OK,” Spaulding said. “Do you have a minute show me how to derive a random sample?”

“Sure,” Dover said. “It’s fairly straightforward. First, we have to go back to the original spreadsheet that contained the address and beat data for matched and unmatched cases.”

Dover re-opened the ‘Matched’ worksheet and created a new field to contain random numbers. In the new field, across from the first case, Dover opened a statistical function by clicking on the ‘*fx*’ button and inserted the formula for calculating a random number.

Once the ‘*fx*’ was clicked, the paste screen function opened. Dover then chose the ‘Math & Trig’ function from the category column, and the ‘RAND’ function from the right column (as shown below).

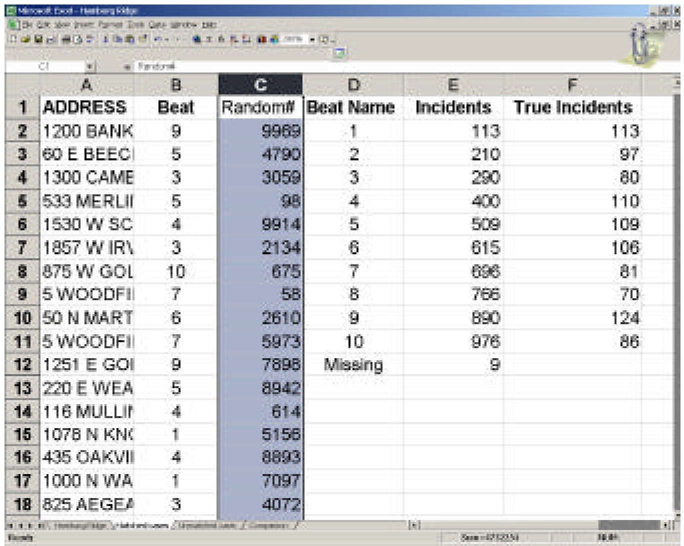


Dover clicked ‘OK’ and edited the formula to look like this:

INT(@RAND()*10000)

He used 10000 because that reduced the chance that he would have a duplicate number out of the 985 unmatched cases.

He clicked ‘OK’ again, and a random number appeared in cell C2. He copied that formula to the rest of cases so each one now contained a random number from 1 to 10000 (as shown below).



	A	B	C	D	E	F
1	ADDRESS	Beat	Random#	Beat Name	Incidents	True Incidents
2	1200 BANK	9	9969	1	113	113
3	60 E BEECI	5	4790	2	210	97
4	1300 CAME	3	3059	3	290	80
5	533 MERLII	5	98	4	400	110
6	1530 W SC	4	9914	5	509	109
7	1857 W IR\	3	2134	6	615	106
8	875 W GOL	10	675	7	696	81
9	5 WOODFII	7	58	8	766	70
10	50 N MART	6	2610	9	890	124
11	5 WOODFII	7	5973	10	976	86
12	1251 E GOI	9	7896	Missing	9	
13	220 E WEA	5	8942			
14	116 MULLII	4	614			
15	1078 N KN(	1	5156			
16	435 OAKVII	4	8893			
17	1000 N WA	1	7097			
18	825 AEGEA	3	4072			

Dover then sorted the entire worksheet by the ‘Random #’ field. He deleted everything except the address and beat fields for the first 50 records.

“Since we don’t need the random numbers any more, we can delete them,” Dover explained. “Then you save the file as a database file, or whatever your mapping program requires, and re-geocode them. Since they’ve already been geocoded correctly once, they should be geocoded correctly the next time. Then you’ll have the 50 matched cases for the map.

“Next, follow the same steps for the unmatched cases. Manually map those and you’re in business. You’ll have a map just like the one I showed you.”

“Great,” Spaulding said. “But, there is one thing that I’m still puzzled by.”

“What’s that?”

"You said that the mapping software can incorrectly geocode addresses, and I saw in your table of unmatched cases that you attributed one case to the map software. How can that be?"

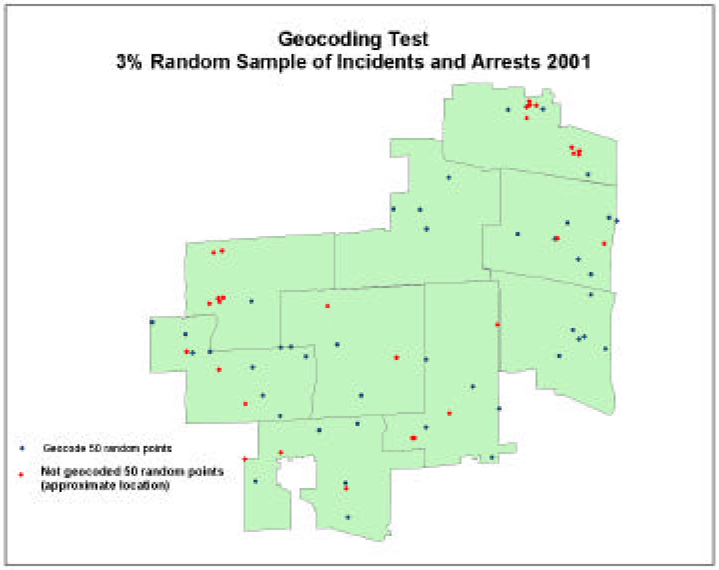
Rookies, Dover thought to himself. "That's a mystery to me, too. Just don't assume that all addresses are matched correctly. You should have an idea of what the **error rate** is."

"How do I do that?" Spaulding asked.

"Easy, but also a little time-consuming," Dover said. "You remember the random sample of 50 correctly geocoded cases?"

"Yeah."

"Well, click those points one by one on the map and then determine whether it was placed close to the right spot," Dover instructed. "Then count the number that aren't in the right spot, divide by 50, and you'll have your error rate." Dover calculated the error rate using the random sample of geocoded points on the map below (shown in blue).



Dover added. “Of course, as with all random samples, the more cases you use, the more representative it is.”

“What you’re saying is that I could go crazy and do 100, or even 200,” replied Spaulding. “So what’s your error rate?”

“About 6 percent,” Dover replied. “We’re still debating about whether to include that and the hit rate on the maps we produce.”

Dover glanced at his watch again and noticed the time was already creeping up on 1 p.m. Spaulding also looked surprised when he saw the time. They were ready to call it quits. Dover could feel the hunger pangs in his stomach, and he was expecting Det. Bowers to show up any minute to go to lunch.

“Well, thanks for the Geocoding 101 class,” Spaulding said. “This has been very eye opening to say the least.”

“I hope I was able to get you started,” Dover said. “That’s one of the good things about going through this process. You begin to understand your data a lot better and eventually become an expert.”

“Definitely…definitely,” Spaulding said while nodding his head in agreement.

“But there is one last thing I should tell you.”

“What’s that?”

“With the type of street files we’re using, essentially most points are placed in the wrong spot on the map anyway,” Dover said.”

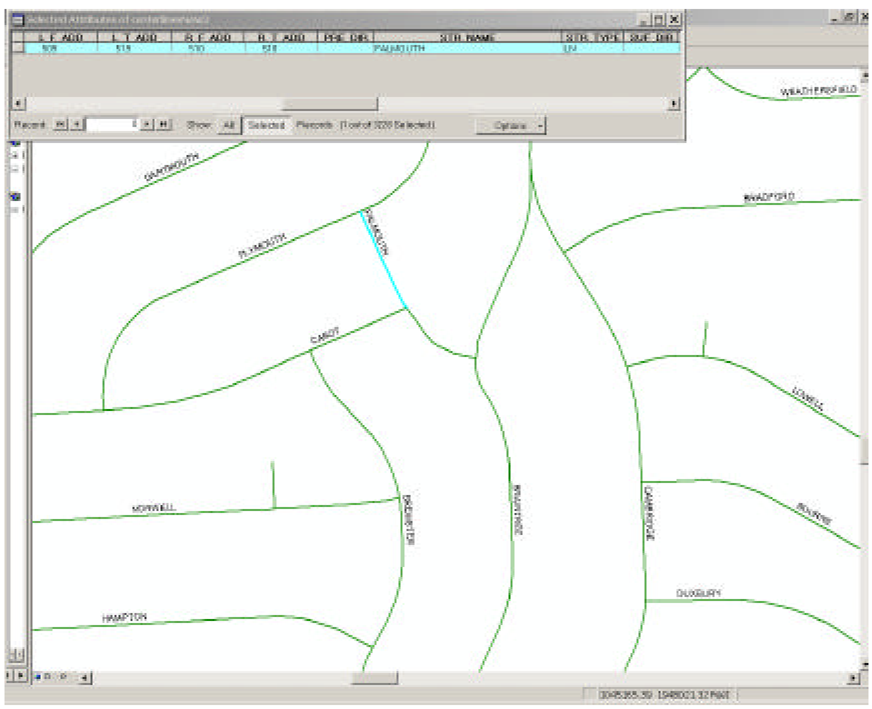
“What?” Spaulding threw up his hands. “We do all of this and then you tell me that most addresses are geocoded to the wrong spot!”

“Saying most points is a little too strong. I should probably explain,” Dover said. “A variety of geographic data types may be used as a reference layer, though the one that we’re using, the Census Bureau’s **TIGER** file, are the most commonly used. The reason they are called centerline files is that they depict the center of the streets by line segments. In other words, they do not depict curbs or alleys and other features that streets contain in reality. You follow me?”

“So far,” said Spaulding, still a little perturbed.

“Let me demonstrate.”

Dover opened a map onto the computer screen and showed an example of street segments in a street centerline file. He then zoomed in on one area and selected one street segment of ‘FALMOUTH LN’ (as shown below).



“You see the ‘L_F_ADD’ field, right? That’s an abbreviation for LEFT_FROM_ADDRESS. ‘L_T_ADD’ means LEFT_TO_ADDRESS. The fields in your map might be abbreviated slightly differently. In other words, it means that the street segment of 'FALMOUTH LN' goes from address 509 to 519 on the left side of the street. Of course then, the right side goes from 510 to 518. You still with me?"

"I think so."

"The street centerline files were designed to show only the relative position of geographic elements," Dover explained. "We know a street doesn't actually look like a line. It has width. It also might have a few more curves than depicted on the map."

"Okay, but how does that relate to the address?" Spaulding asked.

"Let's assume that you had an incident that occurred on 514 FALMOUTH LN," Dover said. "Using a TIGER file, the address is *estimated* along the block face and may not represent the true block face location. In this case, because the number 514 is halfway between the one node at 510 and the other node at 518, the address is estimated at halfway along the street centerline."

"But in reality the address 514 FALMOUTH LN might not be halfway along the street," Spaulding said.

"Precisely. So on the map the point might actually be placed closer to another address."

"Well, that shouldn't matter too much if I were making maps for our entire town, or for one whole beat. It's probably close enough at those scales," Spaulding said.

"Right. It's probably good enough at those scales, but if you are doing analyses for smaller areas that's important to keep in mind."

Dover continued, "Another option, if you have access to it in a spatially enabled format, is to geocode to a **land parcel** map when you're doing an analysis of small areas. Do you know what that is?"

"Yeah. It's a map showing each individual property in the city. I think the city planning department has one," Spaulding replied.

"Yeah, check it out. It should have an address attached to each property," Dover said. "But you could run into similar geocoding issues with that as with a street file. So you have to make sure it's updated regularly and well maintained. Our map is totally messed up."

"Well. I'm definitely not there yet," replied Spaulding, glancing at Det. Bowers as he approached the office door. "I have to work on these other issues first."

Det. Bowers popped his head in the office.

"Well, if it isn't Lewis and Clark, blazing new trails in geocoding. You guys ready for lunch?"

"Want to stick around for lunch before you go?" Dover asked Spaulding.

"Yeah, sure, but on one condition," Spaulding answered.

"What's that?" Dover asked.

"We don't talk about G-E-O-C-O-D-I-N-G!"

Chapter Three – Point Pattern Analysis

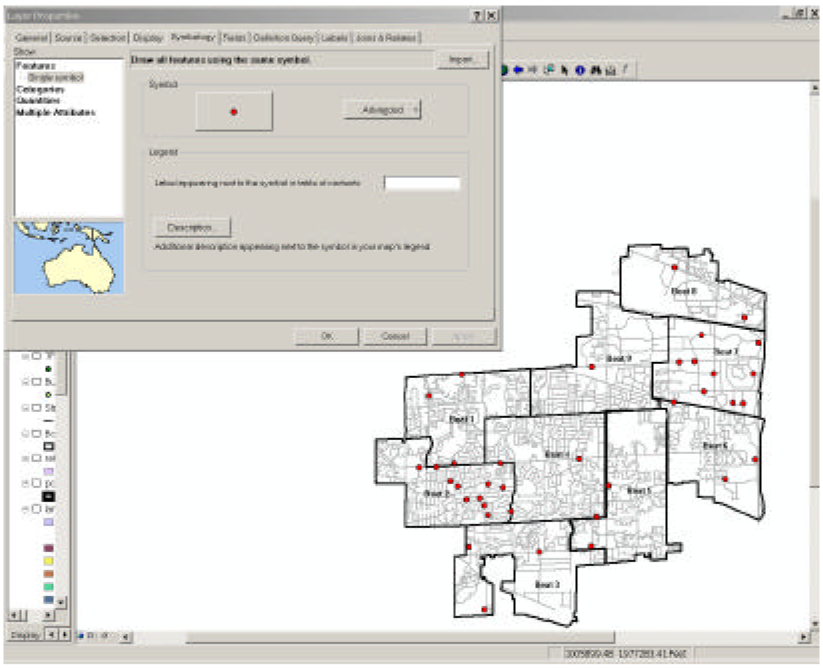
Dover arrived back at his office after lunch with Matt Spaulding knowing that his little detour into geocoding cost him some valuable time – time that he would have to, somehow, make up in order to get something to field officers by the end of the day. It was times like this when he realized how important it was that he ironed out Beaufort's geocoding problems early on. Now at least he could go right into the analysis. He hoped that he stressed that point enough to Matt Spaulding.

Dover had left off at the point where he had geocoded 47 out of 48 vehicle burglaries (98 percent). While that was above the standard set for incident data, he knew that the remaining incident could still be important. With small amounts of data, one point might prove critical in providing the missing link between crimes, especially in analyzing localized crime patterns. He decided that, later, he would manually place the point on the map to see if it was located within a significant pattern of vehicle burglaries.

In beginning his analysis, Dover was looking for the existence of a crime pattern. A **crime pattern** is a set of similar offenses happening in a specific geographical area. That could be a village, a block, or a parking lot.

Dover knew that GIS could greatly assist in identifying and analyzing crime patterns. GIS enables the computerized layering of information to examine the relationship between variables. It also allows for the capturing, storing, updating, manipulating, analyzing, and displaying of all forms of geographically referenced data. It is different than manual pin mapping and computer mapping in that it enables the analyst to view the data behind geographic features, combine various features, manipulate the data and maps, and perform statistical functions.

First, Dover imported the geocoded vehicle burglaries onto a map. To help orient him, he brought in some other geographic data, from his GeoArchive, including a layer of Beaufort streets, and a layer of beat boundaries (as shown below). Because he was simply giving the map context, he did not need any additional layers at this stage.



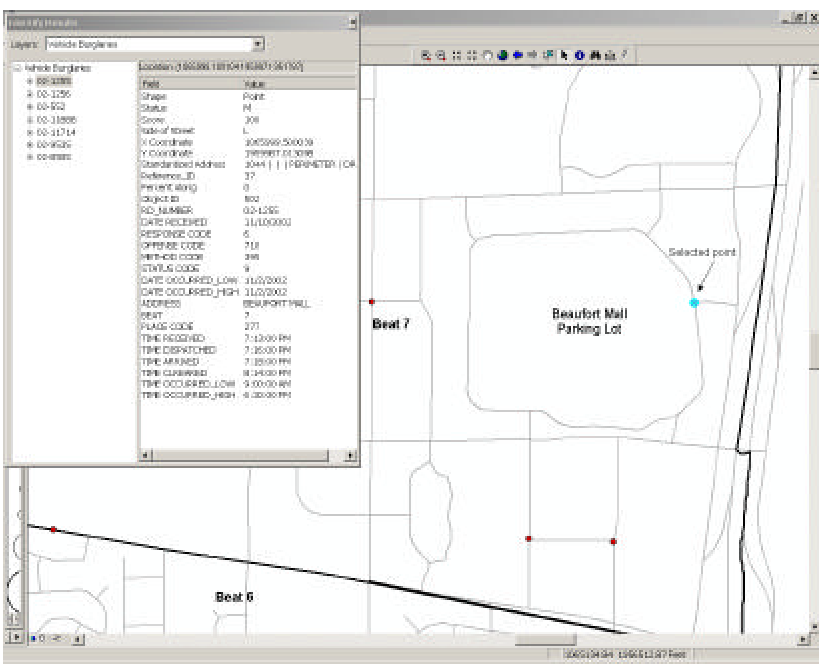
The map showed the three basic types of layers using vector data: points, lines, and polygons. Vehicle burglaries were represented by point symbols, lines represented streets, and polygons represented police beats.

This is called a **single symbol map** because all points are represented by the same symbol, both in color and in size. A **symbol** in cartography is a mark used to represent a geographic feature on a map. Symbols can be realistic depictions of what they represent (trees for a park, airplanes for airports, or a bag of money for thefts) or they can be abstract (points, lines, polygons). The single symbol map is essentially the default setting when a geocoded set of addresses is brought into a map.

From his initial glance at the data, Dover could begin to see the pattern in vehicle burglaries unfold. However, something seemed odd about the map. *It appears there are more vehicle burglaries in Beat 2 than in Beat 7, but I already know that Beat 2 has 13 vehicle burglaries whereas Beat 7 has 17 incidents.* Dover thought. *This must mean that some of the data in Beat 7 is being obscured. Maybe multiple incidents occurred at individual addresses.*

Dover to decided to test this suspicion. He was certain that the Beaufort Mall was one place he would find multiple incidents of vehicle burglaries. He did not know exactly where the mall was located just by looking at the map, but was able to find it by zooming in on a smaller region on the map in the general vicinity of the mall and then by using the 'Identify' button on his toolbar (as shown below).

By clicking on each point with the 'Identify' button, Dover could pull up a window with a list of the **attributes** behind each incident. When he finally found the mall (highlighted in blue on the map), the window looked like this:



The left column showed each individual incident occurring at the mall, represented by its unique record number (RD_NUMBER). The top case, 02-1255, was currently selected. The attributes for that case are shown in the two right columns. One column shows the field name and the other column shows the value for each field. The 'ADDRESS' field shows that the incident occurred at the Beaufort Mall. (Note: In order to geocode these incidents, Dover had created an alias address for the Beaufort Mall, which is shown as 1044 PERIMETER DR in the 'Standardized Address' field.).

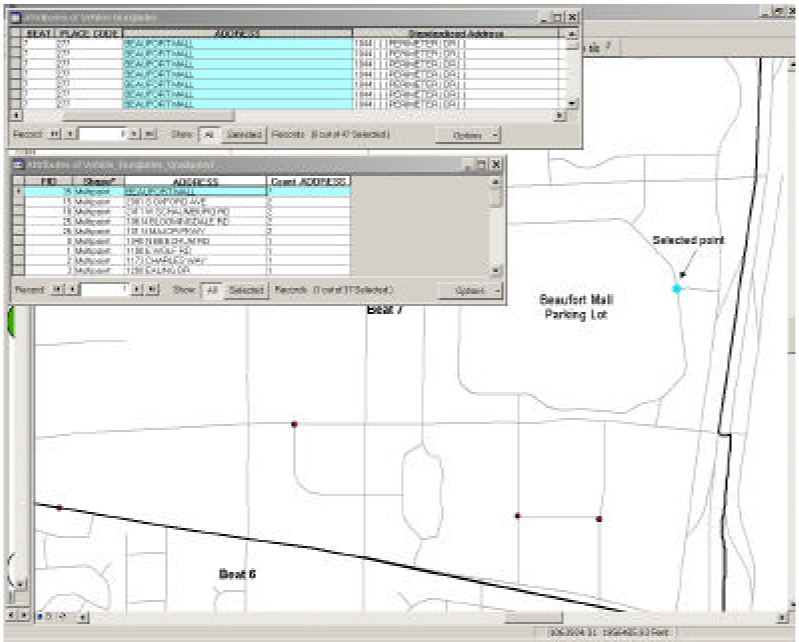
By counting the individual records in the left column, Dover could see that seven vehicle burglaries occurred at the mall. All seven incidents were represented by one point. By selecting the points just south of the mall, he found they also contained multiple incidents that were not apparent just by looking at the map. Dover knew that a major drawback of the single symbol map is that if two incidents have the same address, they are placed exactly on top of one another and cannot be differentiated by looking at the map. Because of this, Dover concluded that a single symbol map was not the most appropriate map to display this type of pattern. He pondered other options.

I know the three basic ways to differentiate between points is through symbol type, color, and size. Differentiating by symbol type is useful when I am dealing with different types of crime on the same map, for example, vehicle burglaries along with vehicle thefts. In that case, I would use a different symbol for each. Since I'm only dealing with one type of crime, it won't be necessary to use different symbols right now. That means symbol color and symbol size are left as my options. I'll experiment with those two and determine which one works best.

The technique used to differentiate by symbol size and color is called graduated mapping. A **graduated symbol map** is a map in which different sized symbols (points or lines) represent different numeric values or a range of values. For example, eight incidents might be represented by a larger symbol than two incidents. Similarly, a **graduated color map** shows each symbol (points, lines, or polygons) using a range of colors to indicate the progression of numeric values. In this map, eight incidents might be represented by a darker shade of red than two incidents. While myriad combinations of symbol colors and sizes are possible in graduated mapping, convention suggests that larger quantities be represented by larger or darker-colored symbols and smaller quantities be represented by smaller or lighter-colored symbols.

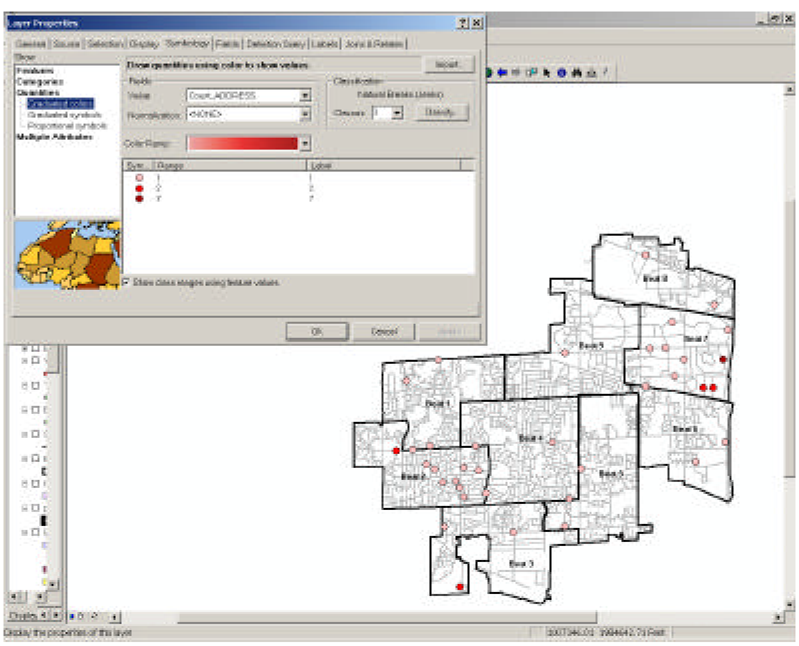
To create a graduated map, Dover first had to summarize, or aggregate, the data by a specific field in the table. Currently, each incident in the vehicle burglary table was listed individually. Because Dover wanted to count the occurrences at each address, he used the 'ADDRESS' field to aggregate the data, although he could have aggregated the data by any variable in the table.

Dover then ran the **geoprocessing** routine in his program to perform the operation to aggregate the data, and opened the new layer's attribute table. As shown below, the attribute table window on top shows the data before it was aggregated, and below that is the data after it was aggregated by address. The 'Count_ADDRESS' field shows the number of incidents per address.

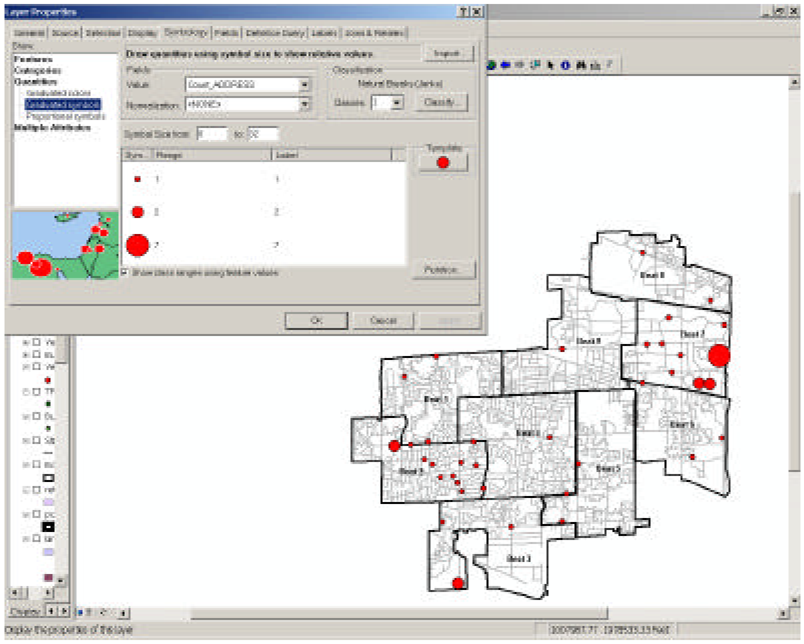


Dover saw two interesting results from this operation. First, there were 37 unique addresses in which the 47 vehicle burglaries occurred in November. Second, seven vehicle burglaries occurred at the Beaufort Mall, while four other addresses contained multiple incidents. The remaining locations had one vehicle burglary apiece.

With this task completed, Dover was ready to experiment with the methods to create a graduated map. He first made a map graduated by color (as shown below).



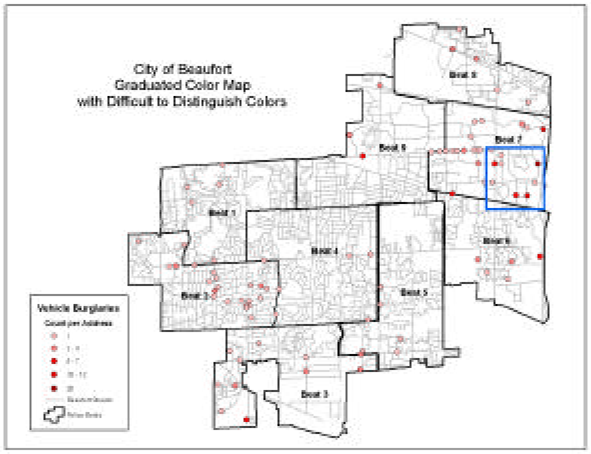
After he printed the map, he created a map graduated by symbol size (as shown below).

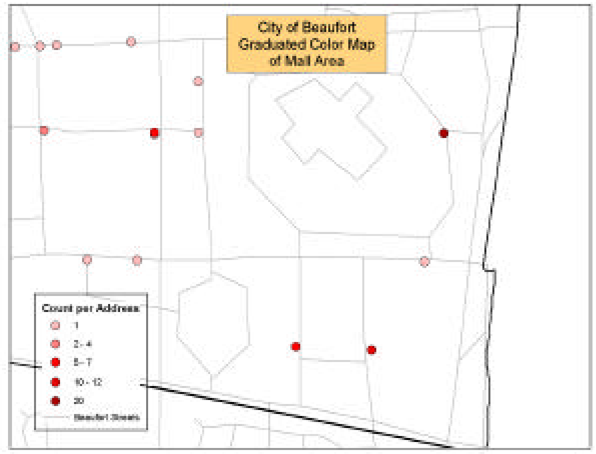


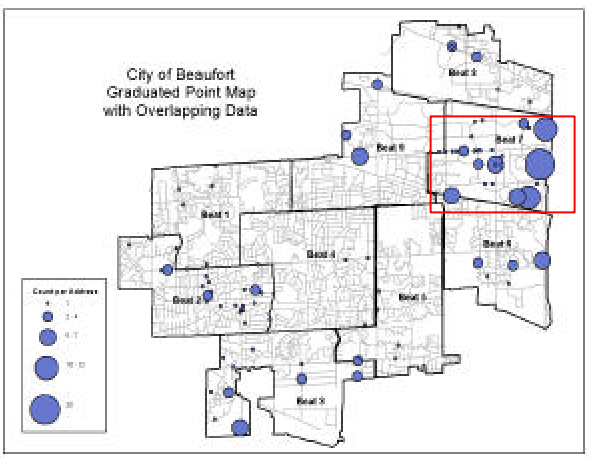
As he looked at the two maps, he compared the advantages and disadvantages of each method. The four maps below show his comparison. The advantage of the graduated color map is that most points are distinguishable from one another. In other words, there is not much overlap between points. However, using large amounts of data at this scale, he imagined the potential difficulty in distinguishing between colors in the middle ranges (as shown below in Map 1, top left). Dover reasoned that given that situation, it would probably be more appropriate to use this type of map for smaller areas (Map 2, top right). In addition, he thought that this map might be very useful in showing nominal data reflecting varying levels of importance, for instance for Priority 1, Priority 2, and Priority 3 calls (not shown).

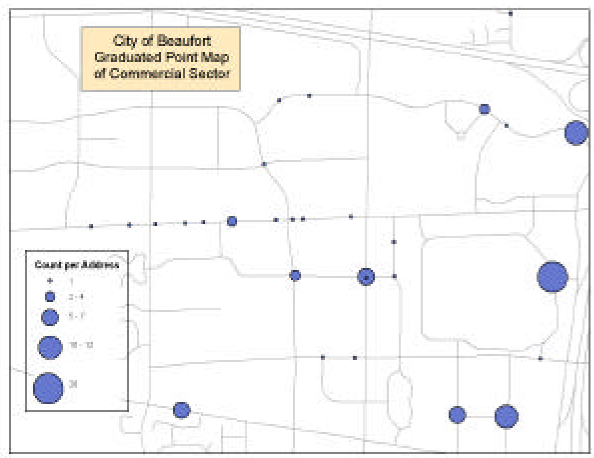
On the other hand, Dover thought the graduated symbol size map was a better method to communicate the overall vehicle burglary pattern. The information on a map should jump out at the viewer. This map certainly did that. But he also realized that, with a substantial number of incidents, this type of map could become cluttered and points could be masked from view (Map

3, bottom left). In this case, similar to the graduated color map, he thought it would be easier to view the map at a larger scale (Map 4, bottom right).









With the graduated symbol map decided upon, Dover next wanted to understand which types of places were being hit. He already knew that the Beaufort Mall was hit most often, but decided to investigate the two points south of the mall that were also hit on a repeated basis (with two or more incidents). After pulling up the attribute data for each point by selecting them with the 'Identify' button, he could easily recognize them by their address as the Enormodome Movie Theater and the Streets of Beaufort shopping annex.

Dover then decided to investigate other locations in the area. After selecting a few of the other locations, Dover found them all to be business establishments. This fact was not ascertained simply by looking at the address, so Dover had to use the ‘Place Code’ variable in the attribute table. The department uses the place code to classify the incident location, such as a street, business parking lot, or residential driveway. He was glad he had decided to include that field in the table before he began geocoding, because now it came in handy. In fact, Dover decided to include as much of the electronic data the department had available, especially the data elements that might be useful for crime analysis, such as location information, date, and time variables.

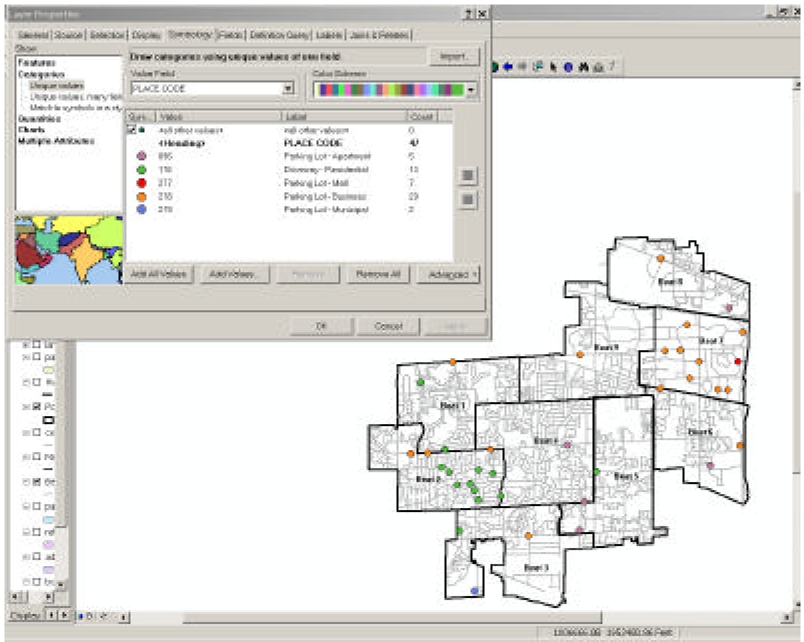
Unfortunately, other incident information was not yet computerized, including data related to Modus Operandi (MO), suspect, and victim information. For that kind of information, he still had to work from the actual incident reports.

On the opposite end of town, Dover decided to investigate the types of locations being hit in the concentration of points in and around Beat 2. After selecting about a dozen points, a different pattern emerged – a vast majority of incidents occurred in residential driveways.

How do I show this pattern? So far, I’ve just been mapping based on quantities of the data, but I know that qualitative aspects of data can also be mapped. I’ve seen maps where areas are mapped by their different categories of land use, such as residential, commercial, and agricultural. Typically, each unique value is symbolized with a different color. That’s exactly the kind of data the department collects in the Place Code field!

In the GIS program Dover was using, the type of map he wanted to create was called a **unique values map**. On a unique values map, you draw features based on the qualitative characteristic of an attribute.

The process used to create a unique values map is similar to the other methods Dover has used, only this time instead of a map based on quantities, he chose the map option based on categories (as shown below).



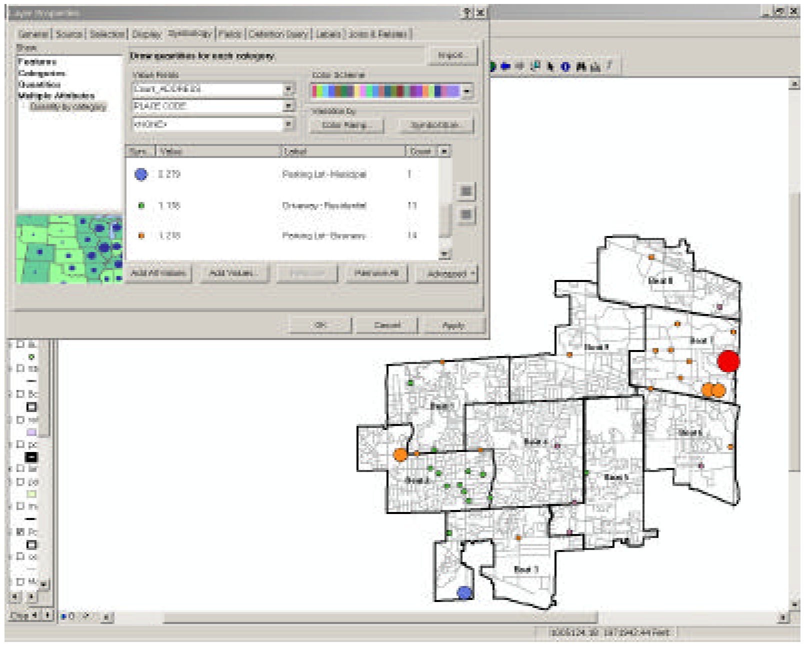
The 'Value' field in the left column shows the code for each type of location. Vehicle burglaries occurred at five different types of locations in the past month. Across from the value codes, in the middle column, appeared the 'Label' field. Dover decided to label these with more descriptive information than simply the codes. Finally, the 'Count' field on the right shows how many incidents occurred at each type of location.

One benefit of the unique values map is that it illustrates how much of one category there is compared to other categories. Dover could see that most vehicle burglaries in November had occurred in the parking lot of Beaufort businesses or the mall (27 of 47 incidents). The residential driveways category contained the second most vehicle burglaries (13 incidents). The least number of vehicle burglaries (two incidents) occurred in municipal parking lots. In fact, only one site, the commuter rail station, comprised all of the vehicle burglaries occurring in municipal parking lots.

Unique value maps are also useful in showing how similar features are distributed – whether they are grouped or dispersed. In this situation, most vehicle burglaries occurring in residential driveways were clustered in the southwestern portion of the city. Similarly, most vehicle burglaries occurring near businesses were also grouped together, but on the opposite end of town in the northeast part of Beaufort. On the other hand, vehicle burglaries occurring at apartment buildings were widely scattered throughout town.

Having created the graduated circle map showing the distribution of vehicle burglaries by quantity, and now the unique value map showing a more qualitative nature of the pattern, Dover was beginning to see more pieces of the puzzle come together. He was also getting a little excited with the variety of mapping options he had at is disposal. Next, he set out to merge the information together on the same map. He reasoned that if it was possible to make those two maps separately, there had to be a way to combine that information together on one map.

His answer would come through the use of multivariate mapping. The maps he created so far showed only one attribute at a time, such as the amount of vehicle burglaries at each address or the type of locations being targeted. On the other hand, a **multivariate map** displays two or more attributes at the same time (as shown below).



Dover selected 'Multiple Attributes' category from the left side of the 'Layer Properties' dialog window. He then selected the 'Quantity by category' option. (It was the only multiple attribute option in his program.) For the 'Value Field' representing the quantity, Dover chose the 'Count_ADDRESS' field. For the category field, Dover selected the 'PLACE CODE.' He then clicked the 'Add All Values' command button, located below the big white list box, which produced a list of multivariate categories to be mapped. Similar to the unique values map, each category was listed under the 'Value' column, only this time the quantity was listed next to the place code, separated by a comma. For example, the case at the top contained a quantity of two vehicle burglaries and a place code of 279, representing a municipal parking lot. As seen by the 'Count' field, there was one location exhibiting this characteristic. (Note: Only three of the six categories are visible in the dialog box.)

At this point, the map gave him a good geographical profile of vehicle burglaries for the past month. Next, he needed a way to summarize this information spatially.

His answer would come through the identification of hot spots. A **hot spot** is a geographic area or an address with an unusually high concentration of criminal incidents. It can consist of one place with a large number of crimes or a concentration of crimes in close proximity to each other. The practical importance of hot spots is in their use for effective resource allocation, alerting the department to problem areas, and targeting intervention strategies.

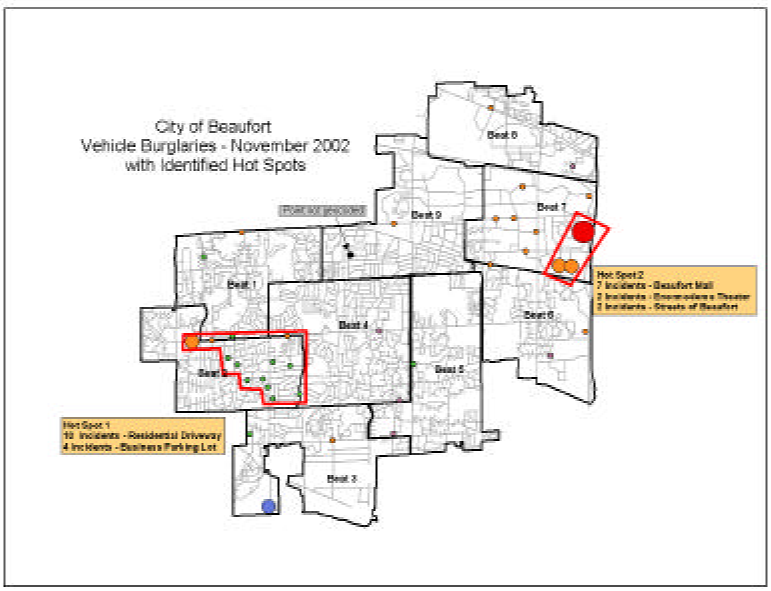
Dover knew there was much debate on hot spots, much of it taking place on NIJ's M.A.P.S. Internet discussion group, among other crime mapping topics and technical discussions. The debate often centered on hot spot definitions, such as how many crimes constitute a hot spot, in how big of an area, and by how close in time. A second major source of debate revolved around the various hot spot methods, from basic to more sophisticated statistical techniques.

Dover learned that determining a hot spot method depends a great deal on the amount and type of data being analyzed, in addition to the type of problem being addressed. Dover also learned that it was best not to leave the judgment and common sense of the crime analyst out of the process.

At this stage, Dover speculated that he would need very few statistical hot spot methods. With the small amount of data he needed to analyze, visual hot spot identification (or eyeballing it), would probably work just fine.

Before determining hot spots, Dover remembered he had to first complete one housekeeping task. He still needed to manually place the one last vehicle burglary incident that was not geocoded. He went back to the original database, jotted down the address of the incident, and then placed a dot on the map at its approximate location. The incident occurred in the western part of Beat 9. (Note: see the black dot in Beat 9 of the map below.) The relative isolation of the point compared to the rest of the vehicle burglaries did not cause Dover any great concern.

Then, upon examination of the map, Dover identified two hot spots (highlighted on the map below). The first hot spot constituted a **cluster** of vehicle burglaries in and around the border of Beat 2. The second one constituted the **repeat address hot spots** in District 7.



By identifying hot spots, Dover knew where to focus his attention. He determined that the hot spot in and around Beat 2 should be the primary focus for a number of reasons, beyond the fact that it contained the most incidents. One factor was the results of his previous analysis. *Based on what I saw before, I know that Beat 2 contains an unusually high number of vehicle burglaries compared to the averages for the year and to a similar period last year. While the addresses did not contain the magnitude of vehicle burglaries, as did some addresses in the eastern part of town, there still seemed to be lot of individual addresses being hit. This is also where citizen complaints have originated.*

His knowledge of overall crime patterns in Beaufort was also important in helping him decide where the hot spots were. While the Beaufort mall has been hit the most of any one location, seven incidents of vehicle burglary at the mall in one month was not a particularly high number compared to the year or to the same month last year. Similarly, two incidents apiece at the Enormodome Movie Theater and Streets of Beaufort shopping annex was not too bad. On the other hand, 14 vehicle burglaries in an area the size of one-half of one beat on the west side of town was alarming, especially given the fact that most of them occurred at residential locations not used to this type of problem.

Once Dover had decided to concentrate on the zone of vehicle burglaries centered on Beat 2, he zoomed in on that part of the map and prepared to analyze that area in greater detail. At this stage, Dover realized that a review of the incident reports was necessary to understand whether any cases in the hot spot were related by MO and other factors, but also felt that he had developed a good geographical profile of vehicle burglaries so far.

Based on my point pattern analysis, I now know the magnitude of the problem, the types of places being hit, and where I need to focus my attention. More importantly, by identifying the hot spots, I also know which incident reports to pull. Instead of beginning the process by analyzing all 48 vehicle burglary reports and then looking for patterns, by reversing the process and looking for patterns first, I have been able to save myself a lot of time by eliminating many irrelevant cases.

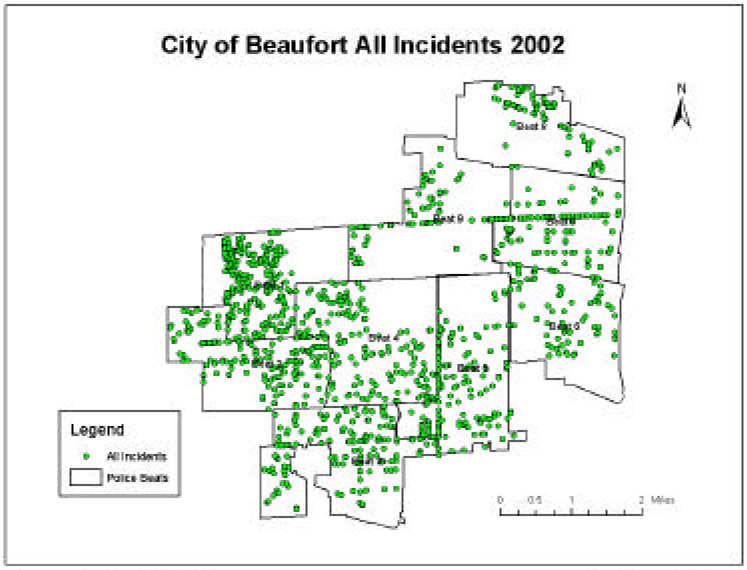
Before going down to the records department to pull the 14 incident reports, Dover decided it was a good time to print a few more maps on the plotter for the meeting with the mayor's office. *No reason the computer needs to be idle while I'm gone*, he thought.

He printed three incident-based hot spot maps. He thought they would clearly show the case for the department to create a new beat out of the area around the Beaufort Mall. While the choropleth map will show that Beat 7 contained 20 percent of all calls for service, these maps will show specifically where crime had ballooned within that beat. He was hoping the maps would knock the socks off the mayor.

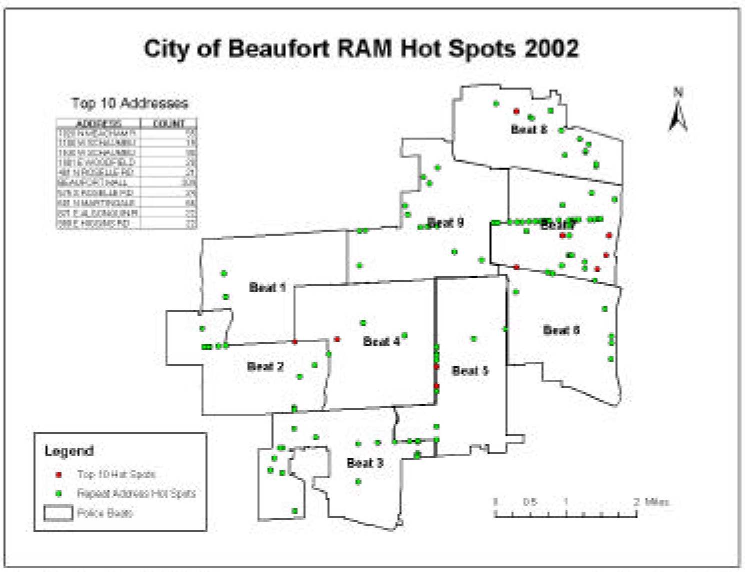
The first two maps showed a comparison between all incidents for the year to hot spots derived using the **Repeat Address Mapping (RAM)** method – defined as the top 10 percent of addresses with the most incidents. It uses a ***minimum plotting density*** (or breakpoint), above which a place is identified as a hot spot. They are derived by:

- Sorting a list of places according to the number of crimes so that the place with the most crimes is at the bottom of the list and the place with the fewest is at the top.
- Dividing the list into 10 equal sections, with the top group containing the fewest crimes.
- Designating addresses within the bottom section as hot spots.

The RAM method has no complex formulas behind it, so it is straightforward and easy to use, and it is helpful in focusing attention on the most frequent locations of activity (as shown below). (The full sized version of the second map is shown in the Appendix.)



City of Beaufort, Crime Analysis Unit Date: December 03, 2002

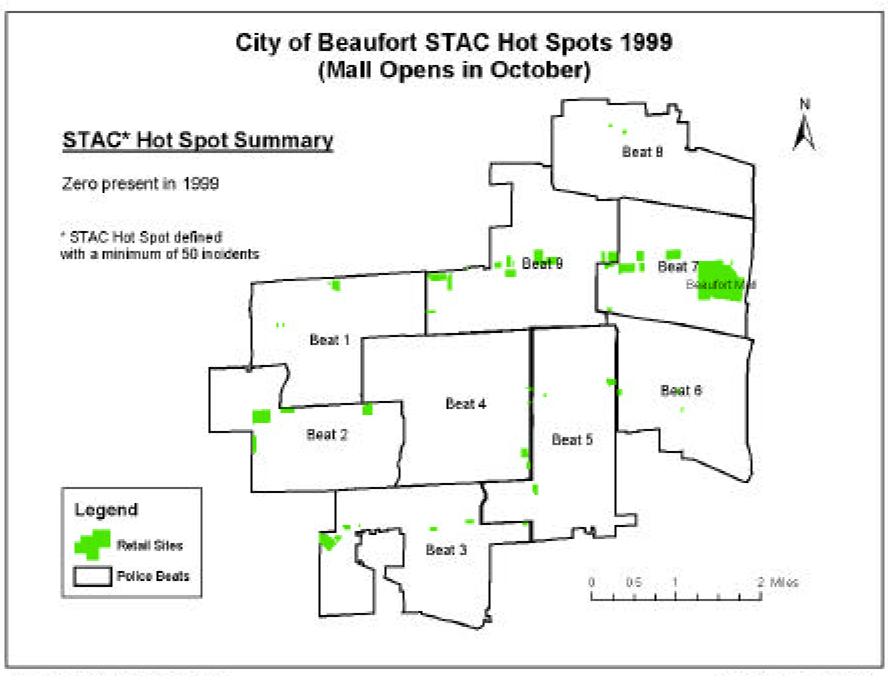


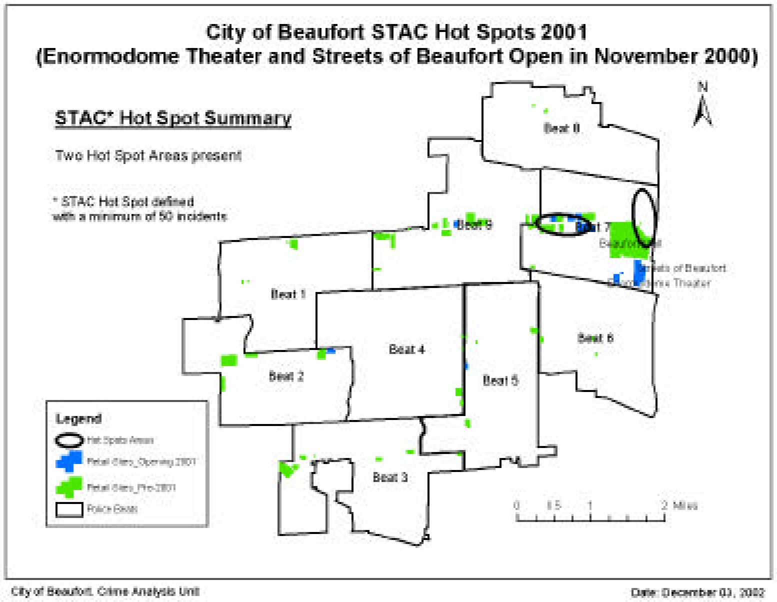
City of Beaufort, Crime Analysis Unit Date: December 03, 2002

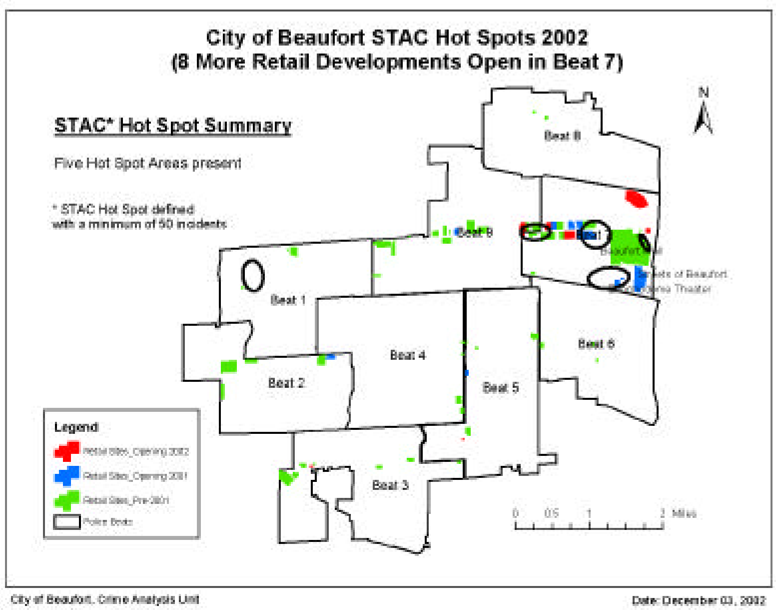
In addition to RAM hot spots, the above map shows the top 10 individual addresses for incidents (in red), because sometimes it's important to show the "worst of the worst." Accompanying the map is a table listing the count of incidents at the top 10 addresses. It was telling that four of the top 10 addresses are located in Beat 7, with the two highest being the Beaufort Mall and the Streets of Beaufort shopping annex.

The next three maps Dover opened up on his screen and printed showed hot spots using the **Spatial and Temporal Analysis of Crime (STAC)** method, developed by the Illinois Criminal Justice Information Authority (now available in *CrimeStat*). The STAC method defines hot spot *areas*, as opposed to individual addresses, by using a statistically based ellipse (or oval). Among its strengths, STAC is good at showing the shift in hot spots over time.

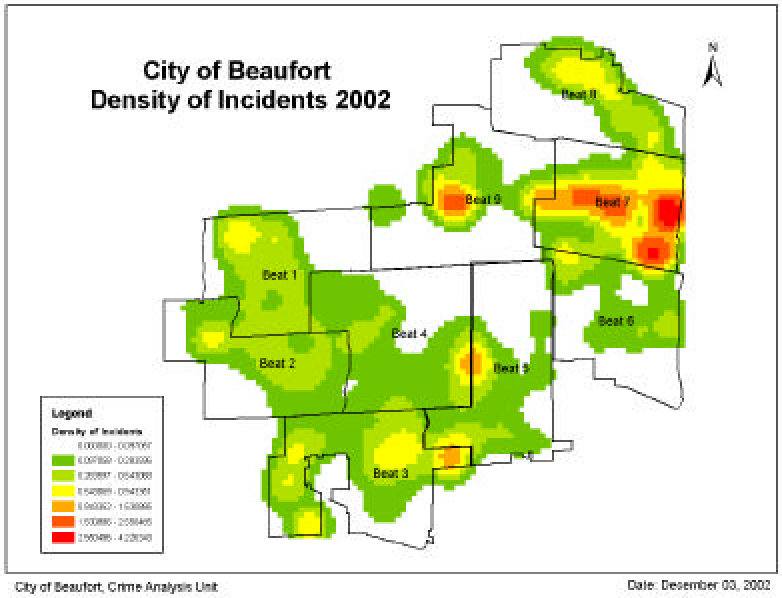
The STAC program requires that the user define a set of parameters, such as the search area, search radius, and the minimum number of incidents, on which to base a hot spot area search. When doing comparisons, it is important that these parameters are consistent from one hot spot search to the next. For the sequence of the three maps shown below, Dover defined the search area as the entire town of Beaufort, the search radius at 1,750 feet, and the minimum number of incidents at 50. Dover was hoping these maps would demonstrate how hot spots have emerged in the commercial sector of town, as the mall and other developments appeared in Beaufort over the past three years. (A full sized version of the third map is in the Appendix.)







The final map showed the spatial density of incidents for the past year using a **grid cell analysis** method called **kernel density estimate** (as shown below). (It is also available in *CrimeStat*.) It basically showed a high density of incidents occurring in the small area around the mall, a definite indication that something needed to be done to better manage crime in that area. (A full sized version is in the Appendix.)



Looking at the maps again, Dover was reminded of the necessity of sometimes using advanced methods to determine hot spots. While visual interpretation is quick and intuitive, it also has its limitations. One problem is encountered when dealing with repeat locations (more than one crime mapped at the same address). These situations could result in points overlapping or being stacked on top of one another, thereby effecting cluster perceptions. A second problem is created by significant amounts of data being mapped, making the map appear cluttered and difficult to interpret. A third problem is that visual perceptions vary by individual, so what is considered a hot spot to one person might not be considered a hot spot by another. A fourth problem is that visual interpretation requires that the analyst have a good contextual knowledge of the area and the problem being analyzed. In Dover's situation, he was able to rule out the apparent hot spot near the mall, because he knew that the amount of incidents present in that area was not out of the ordinary. He would not have known that without prior knowledge of crime patterns in his town, or without having a general definition of a hot spot beforehand.

While it is difficult to determine the threshold from which to switch from visual interpretation to some statistical method, Dover follows one rule of thumb – if he cannot visually determine hot spots within a matter of seconds when looking at the map, then a statistical technique might be necessary. Dover also uses a variety of hot spot methods as crosschecks against each other. If two or more methods find the same hot spot, then the hot spot probably has more validity. Finally, Dover never lets the results overrule common sense. For instance, Dover knows that many methods produce hot spots irrespective of artificial boundaries (police jurisdictions) and natural boundaries (lakes and rivers). So he knows to factor that into his analysis in order to avoid misinterpretations by himself and others.

Chapter Four – Mapping a Crime Series

Through the process of point pattern analysis, Dover had answered many of the "where" questions related to the incidents. Most of his concern centered on 14 vehicle burglaries in and around the eastern part of Beat 2. Now he hoped the incident reports would give specific information on the "what," "when," and "how" questions that needed to be answered.

At least I can begin by collating and analyzing those 14 cases that make up my primary hot spot, instead of having to scan through all 48 cases for the month, Dover thought.

The process would have been even easier if all the incident information had been available in a computerized format. But, other than basic data elements related to the date and time of occurrence, most of the other incident data were not yet in place.

A few years ago, the department had re-vamped the incident report to make it more useful for crime analysis. One area of change included the expanded MO and suspect information categories. The new incident report was designed for compatibility with the Federal Bureau of Investigation's National Incident Based Reporting System (NIBRS) format, and contains a series of questions in checkbox format. While the department has computerized some of the information, the transition has been slow. Chief Meer decided to wait until the reporting formats were in place before he would seek to automate the department's entire record management system.

Dover pulled the 14 cases from the files and carried them back to his office. Because it was two days into December, Dover also checked those days for incidents. After a quick search, he found that so far there were no December vehicle burglaries within the geographic area of concern.

A useful way to collate and organize data from incident reports is by creating an **information matrix form**. It helps provide a uniform way to organize and transfer information from the incident reports pertinent to each case. Dover had used it on many occasions in the past so he already had it saved on his computer in spreadsheet format. It included data pertaining to the offense, offender, victim, property, and additional information taken from the narrative section of the offense report (as shown below).

Crime Analysis Information Matrix					
Data Element	*Crime 1*	*Crime 2*	*Crime 3*	*Crime 4*	*Crime 5*
UCR Code					
Date					
Time					
Location					
Attempt/Complete					
Method of Entry					
Method of Exit					
Ransacked/Mischief					
Property Description					
Property Removed					
Type Property Loss					
Amount of Property Loss					
Value of Property					
Bias Motivation					
Weapons Used					
Tools Used					
Suspected Drug Quantity					
Type of Target					
Type of Victim					
Age of Victim					
Race of Victim					
Sex of Victim					
Ethnicity of Victim					
Type of Victim Injury					
V/O Relationship					
Resident Status					
Age of Suspect					
Sex of Suspect					
Race of Suspect					
Ethnicity of Suspect					
Height					
Weight					
Hair					
Eyes					
Complexion					
Facial Hair					
Glasses					
Car Year					
Car Make					
Car Model					
Color					
License Number					

The information matrix helped him decide which information he would enter into his personal computer for further analysis. His goal was to compare incident reports containing different data elements, that would ultimately point toward a similar offender or group of offenders based on common characteristics. Without this form or a way to organize the data, the incident reports would merely contain disjointed pieces of information, making it difficult to identify possible connections between incidents.

What Dover was looking for was the existence of a **crime series**. A crime series is a crime pattern that appears to be done by either the same person or group of persons. The discovery of a crime series is useful to the analyst because it allows him to create an offender profile, forecast future crime incidents based on MO information, and create specific investigation and patrol strategies. Generally, crime series or patterns that are observable are also obvious and thus discovered quickly. In many cases, only an analysis of one calendar month is necessary.

The incident information that can lead to a crime being classified as part of a pattern or series includes geographical factors, time factors, property loss descriptions, target descriptions, specific MO factors, suspect information, and physical evidence descriptors. It is also important to remember that specific crime types will require different data elements to establish the existence of a pattern or series. For instance, in sex crimes it may be important to know the victim/suspect relationship.

Dover began by examining the incident reports for information that might suggest a specific pattern. He figured he could examine modal categories (most frequent) in the information matrices for patterns by examining the dates, times, types of vehicles targeted, property loss/target information, method of entry, tool or weapon used, and suspect and witness information. He hoped that, when combined with the mapped locations, this would provide enough information to begin alerting patrol officers to where and when future crimes may occur.

By examining the modal categories, Dover determined that eight of the 14 incidents of vehicle burglaries seemed to be highly related. The type of property stolen and the method of entry were the tell-tale connection between them. In seven of the eight incidents, expensive stereo equipment or CD players were stolen, and in almost all cases the passenger side window was smashed.

In the one case where nothing was stolen, an attempt to steal the stereo was evident due to the amount of damage to the console. Based on that case, Dover also determined what kind of pry tool was used, as a piece of one was taken into evidence after it was found inside one of the automobiles. Apparently it had chipped off as the offender attempted to pry out a particularly stubborn stereo.

The thief also tended to target older model vehicles, probably because they lacked a security system. The types of vehicles ran the gamut of makes and models, but they all lacked an alarm or other security device.

The victims' reports were similar. They had parked their cars in the driveway because they intended to go back out later that night or because their families owned more vehicles than could fit into the garage. They preferred to park the oldest vehicle outside in the driveway.

As far as Dover could tell, the information was leading to the conclusion that a crime series was in progress, given the type of property stolen, method of entry, pry tools used, type of locations targeted, coupled with the close geographic proximity of the eight locations.

After Dover created the information matrix with each of the 14 cases, he created a summary of the information showing the most relevant information in a separate table (as shown below). He then highlighted (in blue) each case he identified as part of the crime series.

Matrix Analyzed								
Pattern Vs. Series								
Location	Dates	Times	Target	Entry	Tool/Weapon	Suspect	Other MO	Reference
2203 W	11/01-11/1	800-1530	CD's, change	unknown/stealth				1
621 Aub	11/09-11/10	1915-645	Stereo	unknown/stealth	pry tool			2
535 S Sp	11/09-11/10	1930-730	Coins	unsecured vehicle				3
2411 W	11/12-11/12	1330-1415	Cell phone, check bk.	unsecured vehicle				4
2411 W	11/12-11/12	1330-1330	cell phone	unknown/stealth				5
1524 W	11/15-11/15	1900-2200	Stereo, CD Player (aiwa)	smash window	pry tool			6
1624 W	11/16-11/17	2000-800	CD Player (sony)	smash window	pry tool			7
128 Lyn	11/20-11/20	1800-2300	CD Player (sony)	unsecured vehicle	pry tool			8
Carver L	11/22-11/22	800-2045	Spare tire	no entry				9
1309 W	11/22-11/23	2130-1000	Stereo	smash window	pry tool			10
426 Cab	11/25-/11/25	2215	Digital Car Radio	smash window	screwdriver/pry tool	Dark coat, backpack		11
1917 Wh	11/27-11/27	1800-600	CD Player (pioneer), 10 CD's	unsecured vehicle	pry tool			12
1932 Ark	11/30-11/30	1900-2345	ATTEMPT	smash window	pry tool		pc. Wonder Bar found	13
604 S Br	11/30-11/30	1315-1730	$1 in change	unknown/stealth	pry tool			14

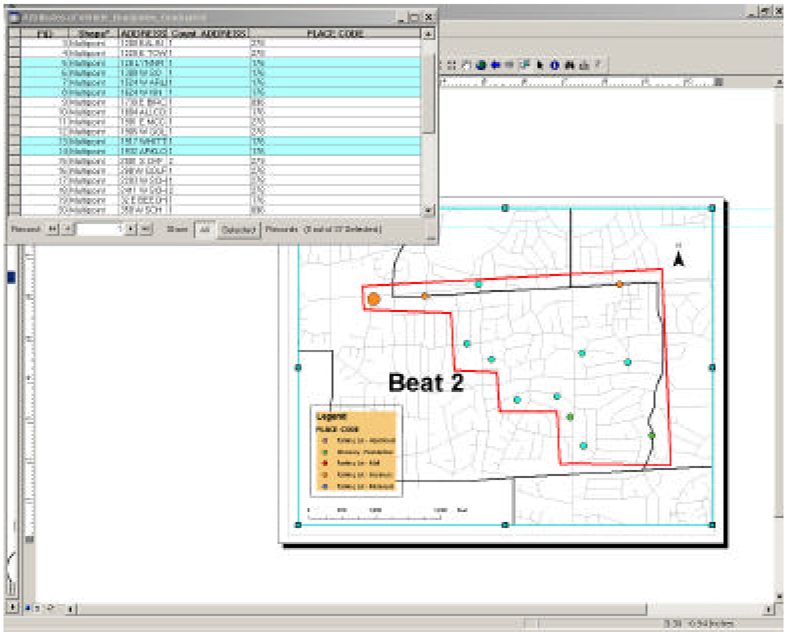
Next, he created a separate table containing only the eight cases that made up the series:

Martrix Final								
Crime Series								
Location	Dates	Times	Target	Entry	Tool/Weapon	Suspect	Other MO	Reference
621 Aubu	11/09-11/10	1915-645	Stereo	unknown/stealth	pry tool			2
1524 W A	11/15-11/15	1900-2200	Stereo, CD Player (aiwa)	smash window	pry tool			6
1624 W K	11/16-11/17	2000-800	CD Player (sony)	smash window	pry tool			7
128 Lynn	11/20-11/20	1800-2300	CD Player (sony)	unsecured vehicle	pry tool			8
1309 W S	11/22-11/23	2130-1000	Stereo	smash window	pry tool			10
426 Cabl	11/25-/11/25	2215	Digital Car Radio	smash window	screwdriver/pry tool	Dark coat, backpack		11
1917 Whi	11/27-11/27	1800-600	CD Player (pioneer), 10 CD's	unsecured vehicle	pry tool			12
1932 Arkl	11/30-11/30	1900-2345	ATTEMPT	smash window	pry tool		pc Wonder Bar found	13

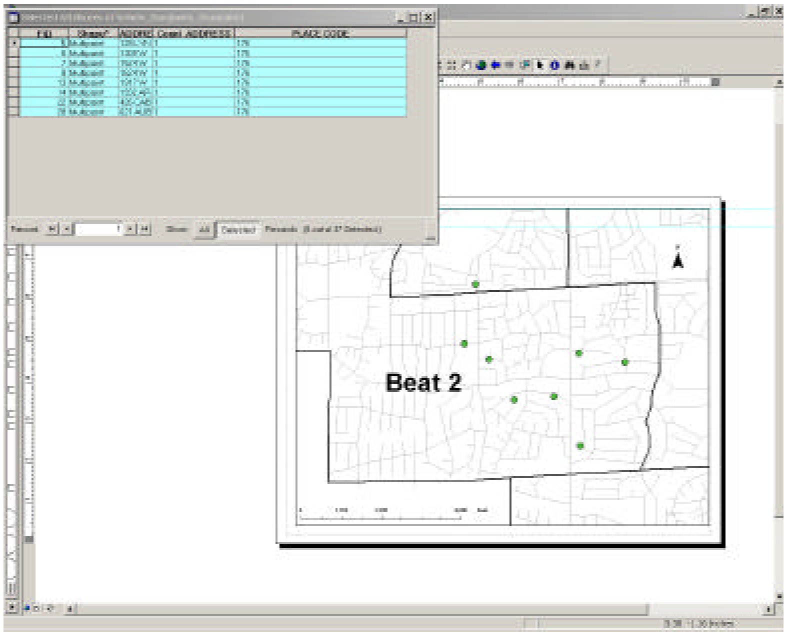
In the one case where a suspect was identified, the witness reported seeing only the suspect from behind fleeing the scene. The suspect appeared to be a male of average height and weight, but a determination of race, or any other identifying information was not possible. The suspect was observed wearing a dark winter coat with a hood over his head, either as part of the coat or part of a hooded sweatshirt underneath his coat, and was carrying a backpack.

The data also indicated that the thief committed eight vehicle burglaries over a 21-day period, beginning with the first hit on Nov. 9 or 10 and hitting most recently on Nov. 30. The data also indicated that the thief preferred to operate at night or early in the morning. Most incidents occurred on the weekend.

Next, Dover went to the map and selected the eight cases from his original data set. As he selected each point on the map, the record was also selected in the table (as shown below).



From the selected set, Dover created a new map layer containing only the identified series (as shown below). This is what he would use for the rest of his analysis. The map indicated that all vehicle burglaries occurred at residential locations (symbolized by the color green, representing the location code "residential driveway").



Using mapping and incident reports, Dover pinpointed a possible pattern of related incidents, and identified the types of property being stolen. The true test would be to try and predict the next location, time, day, and date the perpetrator would strike again, and then place officers there waiting to intercept. This process is called **forecasting**.

Dover began by trying to predict the next *date of occurrence*. Since forecasting an individual date that the next crime will occur with complete accuracy is almost impossible, he created thresholds within which to work. The thresholds would give him an idea when he could expect the next crimes to occur. Within one **standard deviation**, he could be 68 percent sure that his predicted date was accurate within the limits he set for himself.

Dover created a worksheet that contained the date of occurrence of each vehicle burglary in the series, and the number of days from the last occurrence. He then calculated the average number of days between hits, and used this information to predict when the next crime was likely to occur. By converting these thresholds into dates, he could predict (within 68 percent confidence) the earliest and latest dates the next vehicle might be burglarized. These data are shown in the furthest and most recent hit day cells in the table (as shown below). The closest and furthest hit dates are the predicted times for the next vehicle burglary (for one standard deviation).

Crime Analysis Data Collation Matrix

Date Predictions

Crime Number	Month	Date	Days Between Hits
1	11	9	
2	11	15	6
3	11	16	1
4	11	20	4
5	11	22	2
6	11	25	2
7	11	27	2
8	11	30	3
		Sum	20
		Mean	3
		STD	1.68
	Furthest Hit Day		4.68
	Most Recent Hit Day		1.32
	Closest Hit Date		1-Dec
	Furthest Hit Date		5-Dec

The date predictions table above shows the number of crimes, the month of occurrence (in numerical order 1=January, 2=February, etc.), the date of occurrence, and the number of days between crimes. The calculations give the average number of days between crimes and the amount of time that varied above and below the average (in other words, the average is 3 days, give or take 1.68 days). The furthest hit day (the longest time from the last hit) is the mean and standard deviation added together (4.68), the most recent hit day (the closest time from the last hit) is the standard deviation subtracted from the mean (1.32).

The last crime occurred Nov. 30 (Crime Number 8). Adding 4.68 days (rounded to 5 days) gave Dover the furthest hit date of Dec. 5. Carrying this calculation forward for two standard deviations (to be 95 percent confident in the prediction) produced a furthest date of Dec. 6. Three standard deviations (to be 99 percent confident in the prediction) produced a furthest hit date of Dec. 8. By adding the most recent hit day to Nov. 30, Dover found that the next crime could occur as soon as Dec. 1, which was yesterday. By checking the reports for that day he already knew that no crime had occurred but realized that this prediction gave urgency to his analysis because the offender could strike at any time.

The next step would be the calculation of the next *time of occurrence*. This process would be a little tricky because Dover was not working with exact times. In only one incident was an exact time known as a result of a witness stumbling upon the offender fleeing the scene. In all other cases, Dover was dealing with time ranges.

In Part 1 of the process, Dover created a table with six columns (as shown below). The first five columns included the crime number, start date, end date, start time, and end time. (Note: the start and end times are formatted in military time.) In the sixth column, Dover included the full hour range in which the incident occurred, rounding up if the time range began or ended after half past the hour, and rounding down (or truncating) if the time range began or ended before half-past the hour. For example, the actual time range for the first crime was 1915-0645. After conversion to the full hour range it was 1900-0700.

Crime Analysis Data Collation Matrix					
Time Predictions					
Part 1					
Crime Number	**Start Date**	**End Date**	**Start Time**	**End Time**	**Full Hour Range**
1	9	10	1915	0645	1900-0700
2	15	15	1900	1000	1900-1000
3	16	17	2200	0900	2200-0900
4	20	20	1800	2300	1800-2300
5	22	23	1930	2200	1900-2200
6	25	25	2215	2215	2215
7	27	28	1800	0600	1800-0600
8	30	30	1900	2345	1900-0000

In Step 2 of the process, Dover basically had to assign a value to each possible hour that the crime occurred. Because each crime could consist of a different time range, the value assigned to each hour of that range was dependant on the total number of hours between the start and end time.

He started by creating a new table with five columns (as shown below). For the first two columns, he simply copied and pasted the crime number and full hour range fields over into the new table. He then added three additional columns for the number of hours, standard value, and fractional time values.

Crime Analysis Data Collation Matrix				
Time Predictions				
Part 2				
Crime Number	Full Hour Range	Number of Hours	Standard Value	Fractional Values
1	1900-0700	12	1	0.08
2	1900-1000	15	1	0.07
3	2200-0900	11	1	0.09
4	1800-2300	5	1	0.20
5	1900-2200	3	1	0.33
6	2215	0	1	1.00
7	1800-0600	12	1	0.08
8	1900-0000	5	1	0.20

For the ‘Number of Hours’ field, Dover counted the number of hours in his time range. For example, in crime number 1, there are 12 hours between 1900 hours (military time equivalent for 7 p.m.) and 0700 hours (military time equivalent for 7 a.m.), thus he entered a 12 for that record. For the ‘Standard Value’ column, Dover gave each crime a value of 1. Then, to compute the ‘Fractional Values,’ he used the formula *standard value / number of hours*. He then rounded the value to two decimal places.

The value in the ‘Fractional Values’ column now represented the proportional likelihood of the crime occurring for each hour in the range. Looking at the value as a percentage, for crime number 1, a value of 0.08 meant there was an 8 percent chance that the vehicle burglary occurred in each of the 12 hours between 1900-0700.

Step 3 involved creating a matrix that includes the hours of the day (formatted in military time) across the top and the crime number in a column along the side. After creating the matrix, Dover then entered the fractional values for each crime by hour, beginning with the first hour of the range and ending with the last hour (as shown below).

Crime Analysis Data Collation Matrix

Time Predictions

Part 3	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300
Crime Number	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
1	0.08	0.08	0.08	0.08	0.08	0.08	0.08													0.08	0.08	0.08	0.08	0.08
2	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07										0.07	0.07	0.07	0.07	0.07
3	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09														0.09	0.09
4																			0.20	0.20	0.20	0.20	0.20	
5																				0.33	0.33	0.33		
6																							1.00	
7	0.08	0.08	0.08	0.08	0.08	0.08													0.08	0.08	0.08	0.08	0.08	0.08
8																				0.20	0.20	0.20	0.20	0.20

In step 4, Dover calculated the time predictions from the information in the matrix. The results are presented in the table below under Part 4.

Crime Analysis Data Collation Matrix

Time Predictions

Part 3	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300
Crime Number	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
1	0.08	0.08	0.08	0.08	0.08	0.08	0.08													0.08	0.08	0.08	0.08	0.08
2	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07										0.07	0.07	0.07	0.07	0.07
3	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09														0.09	0.09
4																			0.20	0.20	0.20	0.20	0.20	
5																				0.33	0.33	0.33		
6																							1.00	
7	0.08	0.08	0.08	0.08	0.08	0.08													0.08	0.08	0.08	0.08	0.08	0.08
8																				0.20	0.20	0.20	0.20	0.20
Part 4																								
Total by Hour	0.32	0.32	0.32	0.32	0.32	0.32	0.24	0.16	0.16	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.96	0.96	0.96	1.72	0.52
Divide by 8	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.02	0.02	0.01	0	0	0	0	0	0	0	0	0.04	0.12	0.12	0.12	0.22	0.07
Convert to %	4%	4%	4%	4%	4%	4%	3%	2%	2%	1%	0%	0%	0%	0%	0%	0%	0%	0%	4%	12%	12%	12%	22%	7%
65% chance between 1900-2400																								
93% chance between 1800-0600																								

While the table above looks complicated, the calculations are straightforward. First, Dover summed each column to get a total per hour using the 'SUM' function in his spreadsheet. It looked like this:

Σ

Next, he divided each total by 8 because that was the number of crimes in the series. Finally, he converted that decimal number into a percentage.

Based on his calculations there was a 65 percent chance that the next vehicle burglary would occur in the five-hour span between 1900-2400 hours, and a 93 percent chance that it would occur between 1800-0600 hours.

The next forecasting method would entail predicting the next *location of occurrence* of a vehicle burglary. In this analysis technique there are two events taking place – working with the map consisting of the identified series and the creation of an analysis spreadsheet. This holds the data and helps facilitate the calculation of statistical techniques.

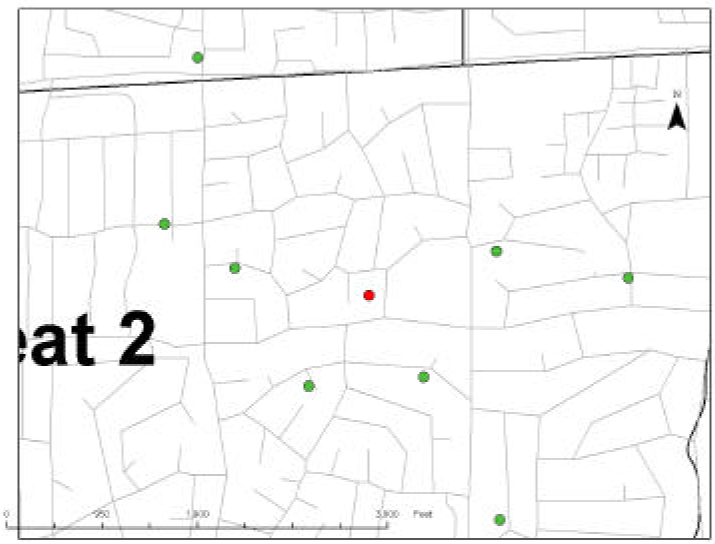
In the past, Dover often visually examined crime maps for hot spots. If he determined one was a crime series, he used common sense to determine where more incidents may occur. He eventually realized he could apply basic geographical statistics to this **spatial forecasting**. He devised a method called **Standard Distance Around Mean Center Point (**or **STAMP).**

The first main step in the STAMP process is to calculate a **mean center** from the x- and y-coordinates for the points that comprised his vehicle burglary crime series. The mean center is the simplest measure of the center of a spatial distribution. It is analogous to the mean of a set of data, and is calculated in a similar way. It can be determined by calculating the mean of the x-coordinates and the mean of the y-coordinates.

Since the mapping program Dover was using automatically added the x and y coordinates to the attribute table for him, all Dover had to do was export the coordinates to his spreadsheet program. He then calculated the mean for the x- and y-coordinates by using the 'AVERAGE' function in his spreadsheet program. The resulting x-y coordinate pair was the mean center point (as shown in blue in the table below). (Note: coordinates are in the State Plane.)

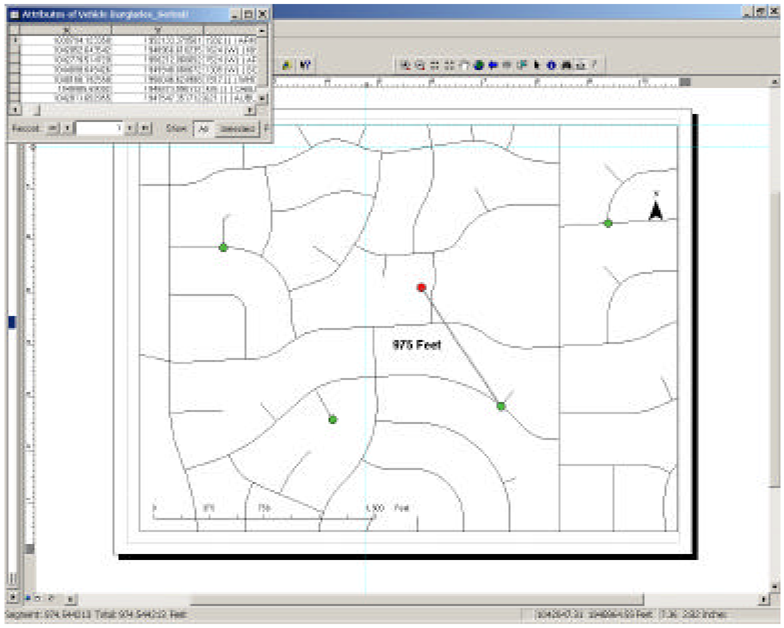
Vehicle Burglaries			
Mean Center Point			
Crime Number	Address	Xcoord	Ycoord
1	1932 Arklo	1039794.123	1952133.380
2	1624 W Ki	1042052.643	1948966.610
3	1524 W A	1042779.515	1950212.961
4	1309 W S	1044098.649	1949948.089
5	1917 Whit	1040166.193	1950046.625
6	426 Cable	1040905.690	1948873.998
7	621 Aubur	1042811.653	1947547.352
8	128 Lynnfi	1039466.363	1950485.961
		1041509.354	**1949776.872**

After calculating the mean center point, Dover geocoded that point and plotted it on the map. The point is shown in red on the map below.



The mean center is analogous to the center of gravity of a spatial distribution of points if each point is given equal weight. *While I'll mainly be using the mean center for statistical forecasting, this location also could act as a central meeting point for coordinating surveillance activities surrounding these vehicle burglaries. Later, I'll have to translate this point to a specific address for our patrol officers.*

Dover next measured and recorded the distances between the mean center point and each of the eight incidents. Measuring the distances between points can be done in the mapping software by manually drawing a line between the mean center point and each incident (as shown below).



After measuring each distance, Dover updated the corresponding table with those distances and calculated a **mean distance**. Like all means, the mean distance is derived by either using the 'AVERAGE' function in the spreadsheet, or summing the column and then dividing by the count of crimes. The table below shows the results of Dover's calculations. The mean distance was 1,871 feet.

Vehicle Burglaries				
Mean Center Point				***Mean Distance***
Crime Number	Address	Xcoord	Ycoord	Distance(ft.)
1	1932 Arkld	1039794.123	1952133.380	2,901
2	1624 W Ki	1042052.643	1948966.610	975
3	1524 W A	1042779.515	1950212.961	1,335
4	1309 W S	1044098.649	1949948.089	2,580
5	1917 Whit	1040166.193	1950046.625	1,373
6	426 Cable	1040905.690	1948873.998	1,065
7	621 Aubur	1042811.653	1947547.352	2,570
8	128 Lynnfi	1039466.363	1950485.961	2,172
		1041509.354	1949776.872	**1,871**

Using this information, Dover was ready to calculate the **standard distance** (or **standard distance deviation**). The standard distance provides the most concise description of the spread of points around the mean center. The results are shown in the following table:

Vehicle Burglaries									
Mean Center Point				*Mean Distance*		*Confidence Intervals*	*Standard Distance*		
									Difference
Crime Number	Address	Xcoord	Ycoord	Distance(ft.)			Mean	Difference	Squared
1	1932 Arklo	1039794.123	1952133.380	2,901			1,871	1,030	1,060,900
2	1624 W Ki	1042052.643	1948966.610	975			1,871	-896	802,816
3	1524 W A	1042779.515	1950212.961	1,335			1,871	-536	287,296
4	1309 W S	1044098.649	1949948.089	2,580			1,871	709	502,681
5	1917 Whit	1040186.193	1950046.625	1,373			1,871	-498	248,004
6	426 Cable	1040905.690	1948873.998	1,065			1,871	-806	649,636
7	621 Aubur	1042811.653	1947547.352	2,570			1,871	699	488,601
8	128 Lynnfi	1039466.363	1950485.961	2,172			1,871	301	90,601
	MEAN	1041509.354	1949776.872	1,871	MEAN			Total	4,130,535.000
								Variance	516,316.875
								Standard Distance	719

To calculate the standard distance Dover:

- Wrote the mean distance (1,871 ft.) two columns to the right of each measured distance, forming a second column called 'Mean.'
- Subtracted the mean distance from each measured distance, and wrote these results in a third column to the right of the second called 'Difference.' For example, for crime number 1, the formula read: 2,901 – 1,871 = 1,030.
- Squared (a value multiplied by itself) each value in the 'Difference' column and marked these values in a fourth column called 'Difference Squared.'
- Summed the squared differences to get a total (4,130,535.000).
- Divided the total of squared differences by the number of incidents to get the **variance**.
- Computed the square root of the variance to get the standard distance. The 'SQRT' function in his spreadsheet program performed this task.

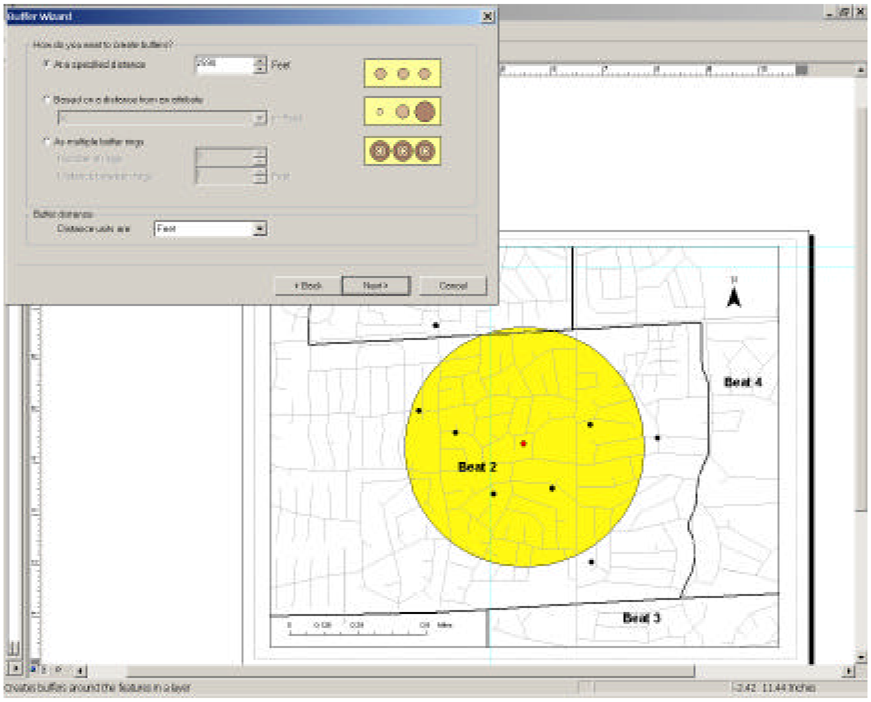
The results of the calculations produced a standard distance of 719 feet.

With the mean and standard distance computed, Dover was able to calculate confidence intervals. The confidence intervals would determine how large of a ring, or **buffer,** to plot around the mean center point on his map.

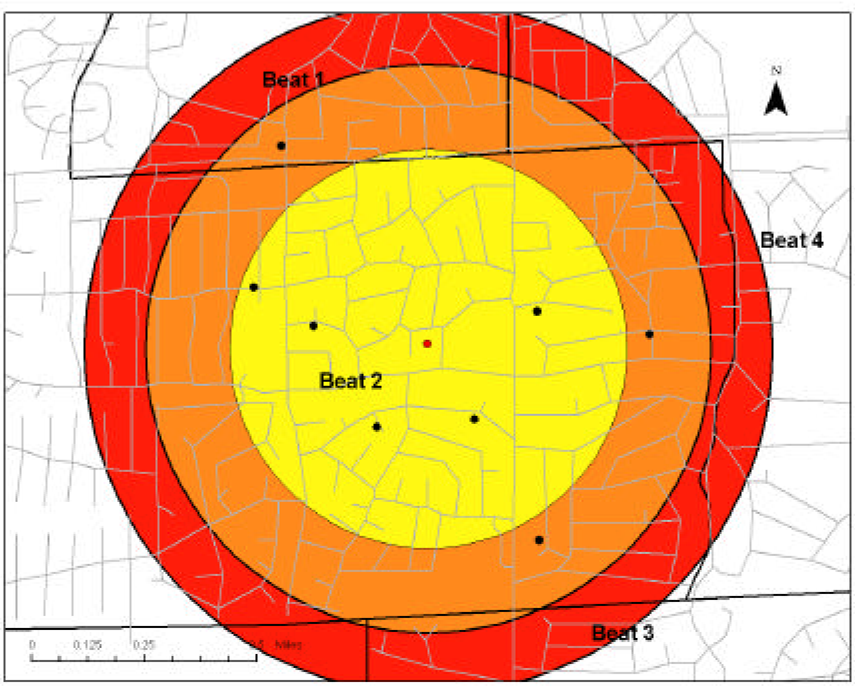
Using the mean distance and standard distance, Dover calculated three levels of **confidence intervals**. He added one standard distance unit to the mean distance, two standard distance units (the standard distance multiplied by two) to the mean distance, and three standard distance units (the standard distance multiplied by three) to the mean distance. The results are shown below in the column called 'Confidence Intervals.'

Vehicle Burglaries									
Mean Center Point				*Mean Distance*		*Confidence Intervals*	*Standard Distance*		
rime Numb	Address	Xcoord	Ycoord	Distance(ft.)			Mean	Difference	Difference Squared
1	1932 Arklo	1039794.123	1952133.380	2,901			1,871	1,030	1,060,900
2	1624 W Ki	1042052.643	1948966.610	975			1,871	-896	802,816
3	1524 W Ai	1042779.515	1950212.961	1,335			1,871	-536	287,296
4	1309 W S	1044098.649	1949948.089	2,580			1,871	709	502,681
5	1917 Whit	1040166.193	1950046.625	1,373			1,871	-498	248,004
6	426 Cable	1040905.690	1948873.998	1,065			1,871	-806	649,636
7	621 Aubur	1042811.653	1947547.352	2,570			1,871	699	488,601
8	128 Lynnfi	1039466.363	1950485.961	2,172			1,871	301	90,601
	MEAN	1041509.354	1949776.872	1,871	MEAN			Total	4,130,535.000
				719	STDistance1	2,590		Variance	516,316.875
				1,438	STDistance2	3,309		Standard	719
				2,157	STDistance3	4,028		Distance	

In the final step, Dover plotted three standard distance buffers around the mean center point. He used the buffer function in his mapping software and then entered the three confidence interval values separately. The process for calculating the first buffer is illustrated here:



Dover completed the STAMP process by calculating the second and third buffers (as shown below).



The resulting map showed the original incidents, mean center point, and three concentric zones. The yellow zone covers a likely area (63 percent confidence interval) where the next incident may occur; the yellow and orange zones cover a very likely area (98 percent confidence interval) where the next incident may occur; the yellow, orange, and red zones cover an extremely likely area (approximately 99 percent confidence interval) where the next incident may occur. ((Note: confidence intervals for standard distance deviations (two-dimensional space) are slightly different than confidence intervals for standard deviations (one-dimensional space)). It has been theorized that criminals tend to have comfort zones, usually committing crimes in areas where they have familiarity because they live, work, socialize, or pass through frequently. Based on this, we can also predict with similar levels of certainty that an offender will be found within the same buffers.

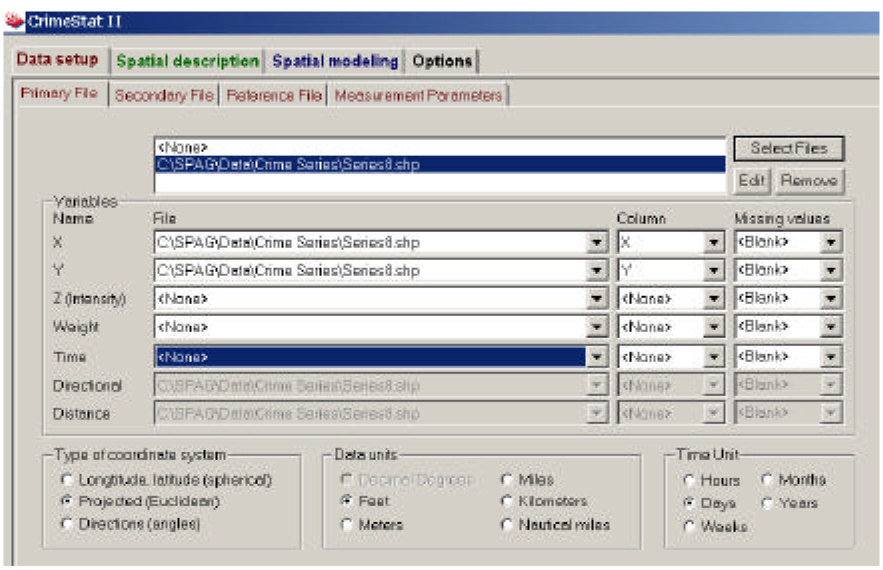
Dover knew that this map was trying to tell him something, but he was unsure of what. *The standard distance rings show the dispersion in terms of a circle about the mean center. From the map, it is apparent that the dispersion is greater in the northwest-southeast direction. However, the shapes of the rings don't really reflect that directional slant.* He thought about it a few more minutes and the answer hit him.

I've got it! I'll need to use an ellipse! The problem with the circular shape of the standard distance buffers is that they take no account of the fact that the spread about the mean center may be different in different directions. Circles work fine if the points are spread evenly in all directions, but that wasn't the case here.

The ellipse shape Dover was looking for was more specifically known as a **standard deviational ellipse**. As the name implies, it is a measure that summarizes dispersion in a point pattern in terms of an ellipse (or oval) rather than a circle. The ellipse is centered on the mean center, with its long axis in the direction of maximum dispersion and its short axis in the direction of minimum dispersion.

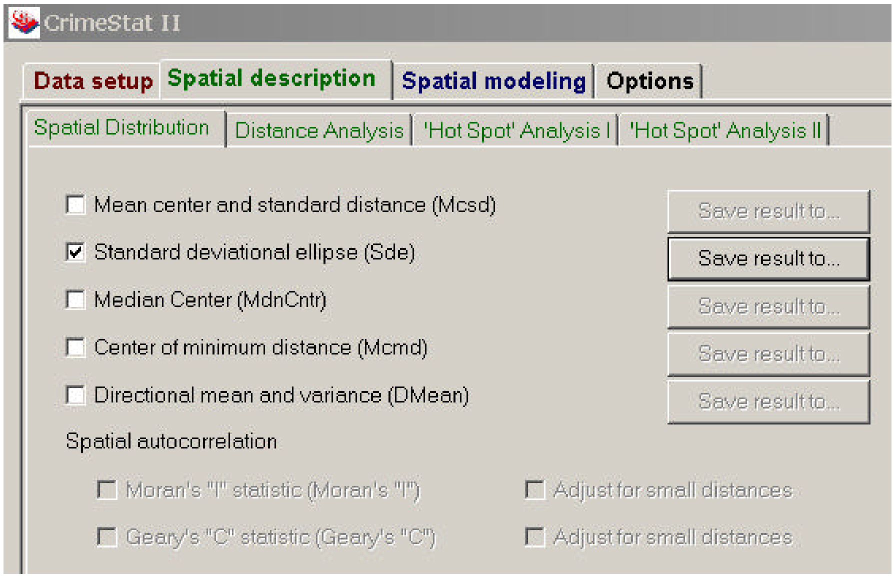
Dover knew that calculating an ellipse using his GIS program for the dispersion in vehicle burglaries was not possible. The GIS program allowed him to create an ellipse with the drawing tool, but there was no statistical validity to it. On the other hand, a standard deviational ellipse could be calculated with the *CrimeStat* program. He had already downloaded it free of charge from NIJ's M.A.P.S. website when he used it to conduct hot spot analysis for the beat re-mapping project. It was user-friendly and contained many spatial statistical routines, and appeared to be compatible with a variety of database and mapping formats.

Dover opened up *CrimeStat* to calculate a standard deviational ellipse based on the vehicle burglaries. The first step involved setting up the data and files to be used (as shown below).

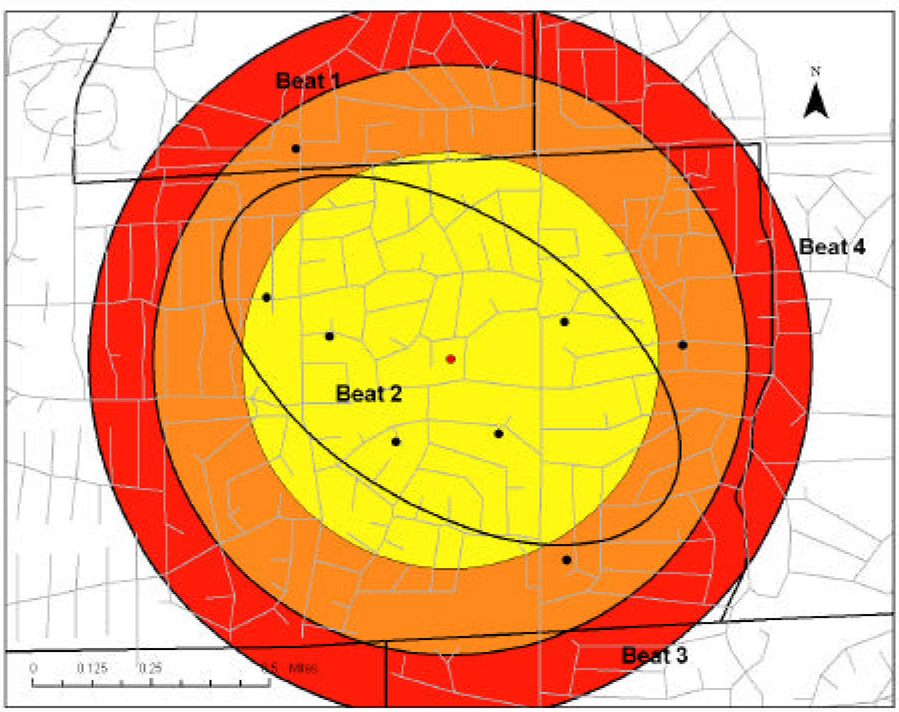


Dover selected the file he was using, the corresponding 'X' and 'Y' fields, and the type of coordinate system. Since he was using State Plane coordinates, he selected the 'Projected' option in the box in the lower left hand corner.

After the data and file setup, Dover chose the 'Standard deviational ellipse (Sde)' statistical routine (as shown below).



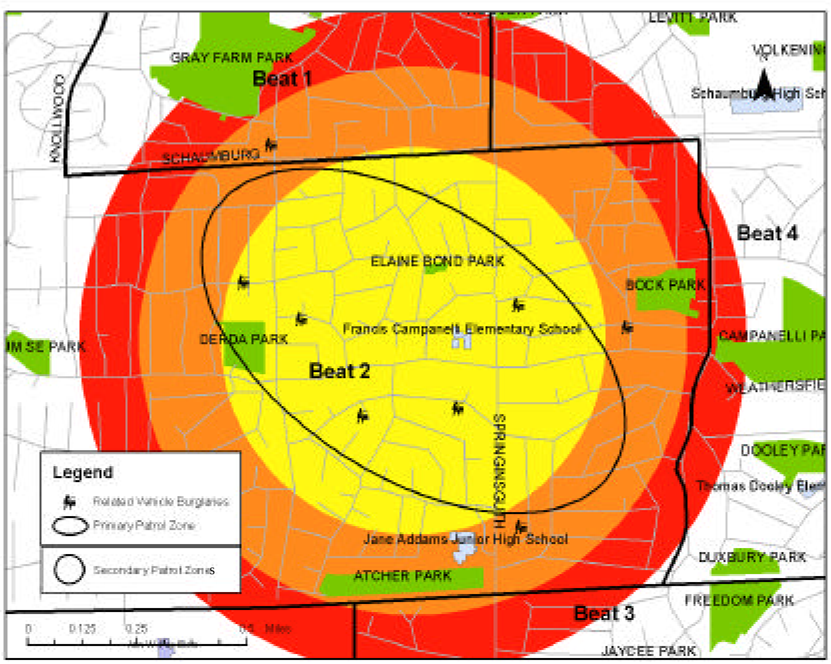
Dover then computed the ellipse, saved it, and opened the ellipse file onto his map (as shown below.)



As Dover analyzed the map, he knew the ellipse was a much better way to represent this pattern. He would designate the area inside the ellipse as the *primary patrol zone*; the remaining area he defined as *secondary patrol zones*.

Next, Dover wanted to give the map more meaning by bringing in more geographic layers, such as parks, schools, and streets, and major streets labels. Since this map was intended for use by police officers, landmark information would be important to help them orient themselves while canvassing the area on patrol.

The new map indicated that the most likely location for additional vehicle burglaries in the Dec. 1 to Dec. 5 time period, between the hours of 7 p.m. and 12 a.m., was in a residential area centered on Francis Campenelli Elementary School. The school could be the central meeting point for officers.



Dover had little time to waste. According to his calculations, the thief was poised to strike very soon.

If I can provide officers with the future time, date, and location of the next crime, Chief Meer will probably be very happy. But, if I can also figure out what types of response techniques he can use to mobilize resources and manpower, the chief will be ecstatic!

Chapter Five – Reporting and Response Techniques

It was early afternoon of the next day. No new reports of vehicle burglaries had occurred in the predicted area the night before. No perpetrators had been caught.

As Dover finished the last of his response plans, he leaned back in his chair and looked over his printouts, reports, tables, and maps to recap what he had done. *I've analyzed almost everything that could be analyzed,* he thought. *The department has little physical evidence, no fingerprints, and little suspect information. This means that what I have found through my analysis is all that we know about these crimes.*

To summarize the information, Dover devised a number of reporting and response plans that covered many facets of the investigative process. He had two goals in mind. One was to create a directed response plan. The second goal was to provide information that could assist in investigations.

To meet the first goal, Dover created a directed patrol plan that consisted of two parts. The first step required creating a **crime pattern summary**. The purpose of the crime pattern summary was to provide detailed information to the chief and patrol supervisors so they could make decisions about how to handle the problem. It would include information on the nature of the problem, suspect descriptions, property information, modus operandi information, and eyewitness statements. It also included information related to the dates, times, and locations of past incidents, in addition to forecasted dates, times, and locations. This was essentially information taken from incident reports, the information matrix, and the analysis phase. The two-page crime pattern summary is shown below: (A full sized version is in the Appendix.)

Beaufort Police Department
Internal Memorandum

To: All Patrol Supervisors
From: Officer William Dover, Crime Analyst
Re: Directed Patrol Plan

SCOPE OF PROBLEM
Eight vehicle burglaries occurred over a three-week time span between November 9-30, 2002 in a residential area centered in the eastern portion of Beat 2, including one incident in Beat 1. The crime analysis unit has determined that these vehicle burglaries constitute the same offender or offenders. In an effort to apprehend these individual(s), we are calling for patrols that are specifically focused on the data contained within this memorandum.

ENTRY METHOD
Entries were gained by smashing the front passenger window or opening unsecured vehicles. In one case, an unknown/stealth method was used.

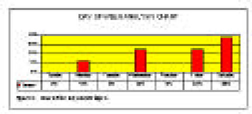
TYPE OF TARGETS
Property taken includes stereos, CD players and car radios. In one case, an attempt was made but nothing was taken. There was no apparent preference in makes and models as a variety of different vehicles have been hit although older vehicles without security devices seem to be preferred.

BURGLARY TOOLS
A pry tool was used to remove the equipment from the vehicles. It is suspected that the tool of choice is a Stanley Wonder Bar. A chip from one was taken into evidence on 11/30.

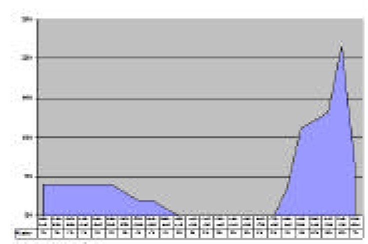
SUSPECT
One witness reported an apparent male suspect of average height fleeing the scene wearing a dark, waist-length outer coat, a hooded sweatshirt underneath, and carrying a backpack. No other identifying information was given. No other physical or forensic evidence found, other than piece of burglary tool.

DATES
The date range is 11/09/2002 through 11/30/2002. The minimum number of days between hits (DBH) is one, and the maximum DBH is five. The mean (average) is 3.0. **More incidents are likely before 12/05, very likely before 12/06, and extremely likely before 12/08.**

DAYS OF THE WEEK
Figure 2 shows the days of the week the incidents occurred (using the first day for incidents that occurred in an overnight time range). These are likely days they will continue to occur. There is a **65% peak on Friday-Saturday and a 25% peak on Wednesday.**



TIMES
The full possible time range is 1800-1000 hours. Figure 1 shows when the incidents occurred within each hour of the day. It is therefore likely they will continue to occur in these hours. **The most significant peak is 1900-2400 at 65%, with 2200-2300 at 22%.**



LOCATION
Two methods were used to analyze location. The first is a self-developed method called Standard Distance Around Mean Center Point (STAMP). The second used the Standard Deviational Ellipse function available in CrimeStat 2.0. Figure 3 is a map showing the related vehicle burglary incidents. The three concentric rings are the STAMP results, which indicate the **chance of further incidents within the yellow zone is high; within the yellow and orange zones is very high; and within the yellow, orange, and red zones is extremely high.** The ellipse (oval) shows the results of CrimeStat 2.0. It indicates the **chance of further incidents within the ellipse is high.** Special attention should be directed to the areas covered by both results. Also, it has been theorized that criminals act in an area they frequent for other reasons (such as a residence, school, job site, or socializing) so **it is likely the offenders will be found within these same areas.**

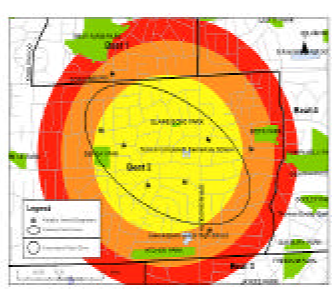
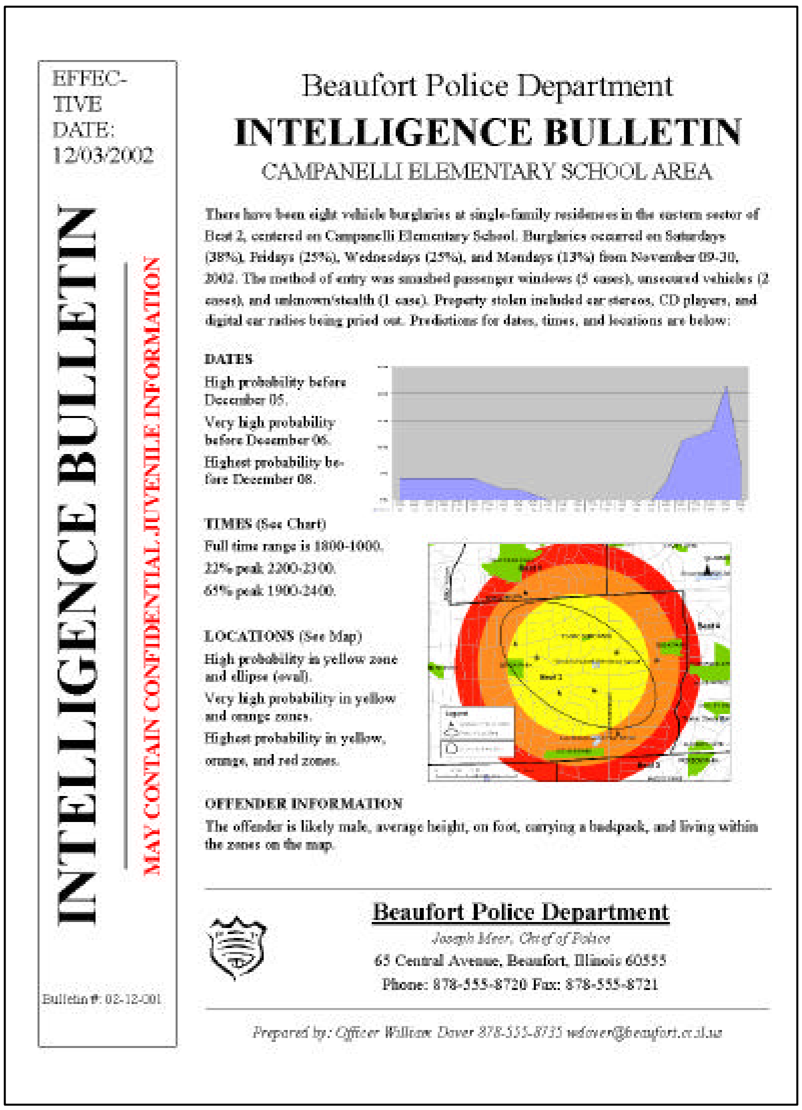


Figure 3: Spatial Analysis Results

Based on this information, Chief Meer was persuaded to deploy an extra patrol car during the predicted dates and times, and in the predicted area. The first night for the increased patrol would be tonight.

The second part of the directed patrol plan involved creating a one-page ***Intelligence Bulletin*** for police officers. The bulletin was basically a more condensed version of the crime pattern summary, and utilized the predictive intelligence information and a brief description of the nature of the problem and suspect information, when available (as shown below). (A full sized version is in the Appendix.)


EFFEC-
TIVE
DATE:
12/03/2002

INTELLIGENCE BULLETIN

MAY CONTAIN CONFIDENTIAL JUVENILE INFORMATION

Bulletin #: 02-12-001

Beaufort Police Department

INTELLIGENCE BULLETIN

CAMPANELLI ELEMENTARY SCHOOL AREA

There have been eight vehicle burglaries at single-family residences in the eastern sector of Beat 2, centered on Campanelli Elementary School. Burglaries occurred on Saturdays (38%), Fridays (25%), Wednesdays (25%), and Mondays (13%) from November 09-30, 2002. The method of entry was smashed passenger windows (5 cases), unsecured vehicles (2 cases), and unknown/stealth (1 case). Property stolen included car stereos, CD players, and digital car radios being pried out. Predictions for dates, times, and locations are below:

DATES
High probability before December 05.
Very high probability before December 06.
Highest probability before December 08.

TIMES (See Chart)
Full time range is 1800-1000.
22% peak 2200-2300.
65% peak 1900-2400.

LOCATIONS (See Map)
High probability in yellow zone and ellipse (oval).
Very high probability in yellow and orange zones.
Highest probability in yellow, orange, and red zones.

OFFENDER INFORMATION
The offender is likely male, average height, on foot, carrying a backpack, and living within the zones on the map.

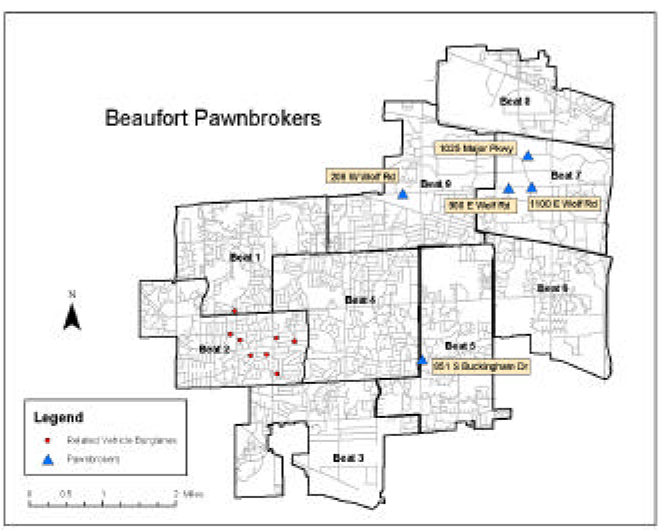
Beaufort Police Department
Joseph Meer, Chief of Police
65 Central Avenue, Beaufort, Illinois 60555
Phone: 878-555-8720 Fax: 878-555-8721

Prepared by: Officer William Dover 878-555-8735 wdover@beaufort.ci.il.us

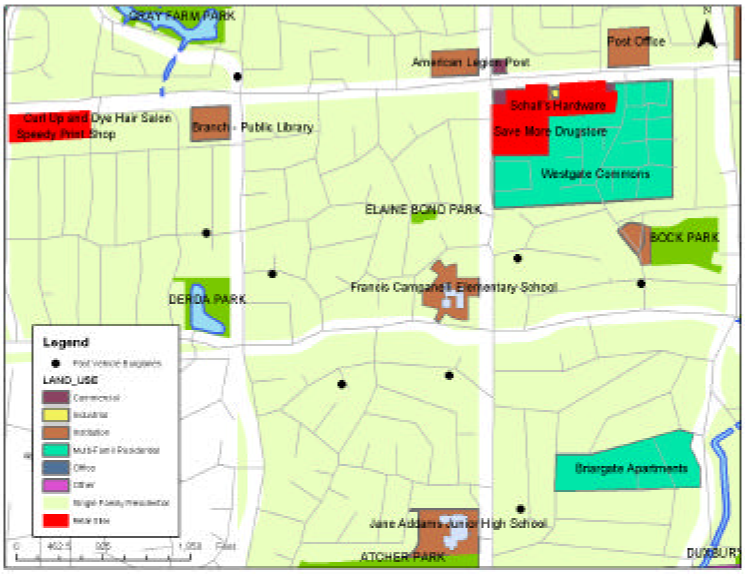
The *Intelligence Bulletin* is designed for officers to carry with them on the beat and refer to as needed. It tells them where and when to patrol, and for whom to look. It also encourages patrol officers to be proactive, rather than reactive, to specific crime problems.

Dover placed the *Intelligence Bulletin* in the mailboxes of officers in the beats and shift of concern. In addition, he posted it in the briefing room so that all officers would be made aware of the analysis, in case they had additional information that could be helpful.

After completing the directed response plan before he went home the night before, Dover spent the better part of the morning investigating ways to support detectives with mapped information – he liked to refer to this process as **spatial intelligence gathering.** It involved the analysis and evaluation of a variety of spatial data to determine its usefulness for investigations. Of course, depending on the situation and crime problem, some data would be more useful than others. For example, because of the quantity and different types of equipment being stolen, the offender was likely stealing the property for re-sale. So Dover provided Detective Bowers with a map of pawnshops in Beaufort (as shown below). By providing a map of pawnshops in town, along with the address of each shop, Bowers could conduct follow-up investigations to see if any of the stolen merchandise matched what pawnbrokers were selling. If so, Bowers could then question management regarding the identity of the individual who sold it to them.



Similarly, maps that bring together diverse pieces of information in a coherent way could also help in investigations. By bringing in a combination of layers, such as the plotted crime series locations, land use map of the area, and a map of retail establishments, Dover was able to improve his knowledge of the area and to speculate about the nature of the offender's relationship to the area (as shown below).



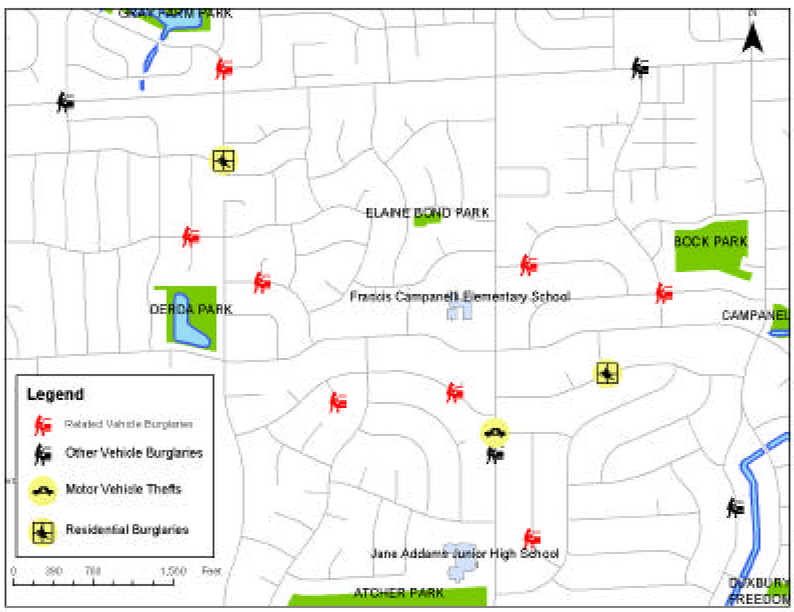
The land use layer was useful because it showed the general nature of the area, whether it was residential, commercial, agricultural, or something else. While Dover already knew the criminal targeted residential locations, he was looking for clues as to whether the offender lived, worked, socialized, or attended school in the area.

Dover quickly eliminated the possibility that the offender socialized in the area, because there were not any adult gathering places in the zone of concern, such as bars or taverns. He also ruled out that the offender worked in the area. While there were a few employment centers in the general vicinity, primarily retail establishments, their hours of operation were not consistent with the offender's active time period. Finally, Dover doubted that the offender attended school in the area, as the only two schools were an elementary school and a junior high school. Given the level of sophistication of the crimes, he reasoned that it was unlikely a juvenile offender committed them. As a result of eliminating these possibilities, Dover theorized that the offender probably lived in the area.

By following this spatial intelligence gathering process, Dover was also able to evaluate the usefulness of other potentially significant information. He mapped recent arrests for vehicle burglaries occurring in the area on the assumption that past behavior was the best predictor of future behavior (as shown below). Checking the arrest reports for these cases might elicit potential suspects involved in the recent crime spree based on modus operandi patterns or descriptions of offenders.

After reviewing reports for the two arrests in the area, Dover determined the offenders in those cases followed different MO’s than the current thief. Those cases involved local heroin addicts stealing change and loose items from vehicles to support their habit. Therefore, past arrest data was eliminated as a potential source of intelligence information in this situation.

Dover also thought it was important to map other crimes occurring in the general vicinity of the vehicle burglary pattern, particularly closely related crimes such as vehicle thefts and residential burglaries (as shown below). In a process similar to analyzing arrest reports, an examination of recent incident reports might provide a link between crimes, suggesting larger crime patterns of which officers should be aware. In addition, this information could assist with case clearances in the event that an offender is caught.



After an analysis of the actual incident reports (for the incidents in the above map: four other cases of vehicle burglaries, two residential burglaries, and one motor vehicle theft), Dover determined that these other crimes were also isolated incidents. Dover followed this spatial intelligence gathering process until he was satisfied that an exhaustive analysis of the most pertinent spatial data had been performed.

Dover was completing the last of his reporting and response objectives, which included an email to broadcast the information to other crime analysts via the Crime Analysts of Illinois (CAI) Association website. The site feature has a secure "Members Only" area where crime analysts can share information and receive advice from each other. The members' mailing list is a true e-mail discussion list. Members can send messages that are then forwarded to all other CAI members. The CAI also maintains an online searchable database of crime bulletins that helps facilitate information sharing.

When Dover broadcasted the information to the group, by posting the *Intelligence Bulletin* on the website, he also sent a special alert to a crime analyst in Crystal Stream, because the town bordered the area in Beaufort where the vehicle burglaries occurred. In fact, a small portion of the town was included in the forecasted geographic area for the next incident. The response Dover received indicated that Crystal Stream had not experienced any vehicle burglaries in that area of town recently. This confirmed that the pattern was a localized crime problem confined to Beaufort.

Dover was in the process of sending an email reply to the Crystal Stream crime analyst, thanking her for her help. At that moment his phone rang. It was Det. Bowers.

"Hey Dover! I'm out here in the field driving around town with your little pawnshop map and just wanted to call and thank you for sending me on a wild goose chase," he said sarcastically. "None of these leads have panned out."

"Seriously?" Dover asked rather dejectedly.

"No. I'm just messing with you," Det. Bowers replied with a chuckle.

"Why do I ever take you seriously?" Dover asked.

"You want me to answer that?"

"Not really."

"Actually, it looks like we have a suspect," said Det. Bowers. "The owner of one of the pawn shops remembers a Caucasian male, early 20s, bringing in a car stereo and a CD player just a few days ago. The CD player matched the description of one of the items stolen. It was a Pioneer. He said the guy was wearing a dark hooded sweatshirt underneath a dark coat and carrying a backpack, just as the witness described. He also described the guy as being about 5'10'', 170-180 pounds with medium length brown hair, dark eyes, a fair complexion, and no facial hair. He also had no visible marks or scars."

"OK, got it," said Dover. "So which pawn shop was it?

"One of the ones by the mall, 1100 E. Wolf Road," Det. Bowers said. "In fact, the owner told me that he remembered the guy because he also purchased a used Wonder Bar in his store a few weeks ago. Probably that very Wonder Bar that we have a piece of. When the owner asked him why he was selling the equipment, the guy stated that he pried them from his own vehicle because he needed extra cash to purchase gifts for the holidays.

"That's not all. Apparently he likes to dump them off in pairs, one CD player and one stereo at a time, probably not trying to raise too much suspicion," Det. Bowers said. "I checked the other two pawn shops you mapped out in the area and, after browsing around in each of the stores, saw a CD player and stereo that matched the description of the stolen equipment. But in both of those shops, no one remembers who sold them the equipment. I got the feeling they didn't ask many questions."

"That's six of the eight items stolen right there," Dover said. "So what should we do, stake out the pawn shops?"

"No. I doubt if he's stupid enough to go to the same shops twice, especially because he was pretty systematic in the way he sold the equipment in the first place," Det. Bowers said. "But at least now we have a good description of the suspect and a possible witness if we need one."

"Cool. I'll update the analysis and get the suspect information to the second shift field officers before they head out later today," Dover said.

"Fantastic. You also want to tell the chief?" Det. Bowers asked.

"Yeah, don't worry about it. I'll tell him," Dover said. "I have to go talk to him about some other stuff anyway. Thanks, Detective."

After Dover hung up the phone, he pounded his fist against the desk. "Yes!" he exclaimed. He was ecstatic that intelligence information he provided Det. Bowers paid off.

He decided to quickly update the *Intelligence Bulletin* with the new suspect description. The *Intelligence Bulletin* was a fluid document that required updating as circumstances demanded. He inserted the following text on the form and clearly indicated that the information was new:

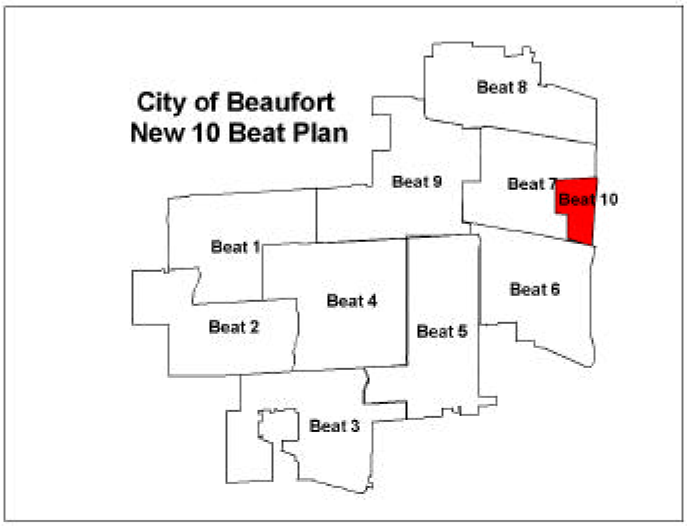
> ***UPDATED SUSPECT INFORMATION*** Effective Date: 12/03/2002
> M/W 5'10'' tall, 170-180 pounds, early 20s, medium length brown hair, dark eyes, fair complexion, and no facial hair. He also had no visible marks or scars."

It was imperative to disseminate the new *Intelligence Bulletin* to relevant patrol personnel and replace the old *Intelligence Bulletin* posted in the briefing room. Dover was also eager to inform Chief Meer of the recent developments. But seeing that he still had about 50 minutes before the second shift roll call, Dover decided to finish the final map for tomorrow's meeting with the mayor.

The last map related to the department's new beat proposal. The need to modify the old structure was driven by recent business growth over the last few years. Development of the

Beaufort Mall, Enormodome Movie Theater, Streets of Beaufort shopping annex, and many other businesses drove up crime in the area, particularly property crimes such as retail theft, vehicle burglaries, and motor vehicle theft. This created an imbalance in the number of service calls and crime incidents handled in Beat 7 compared to the rest of the beats.

To make more efficient use of department resources, the department developed a plan to create a new patrol beat consisting of the area surrounding the Beaufort Mall (as shown below).



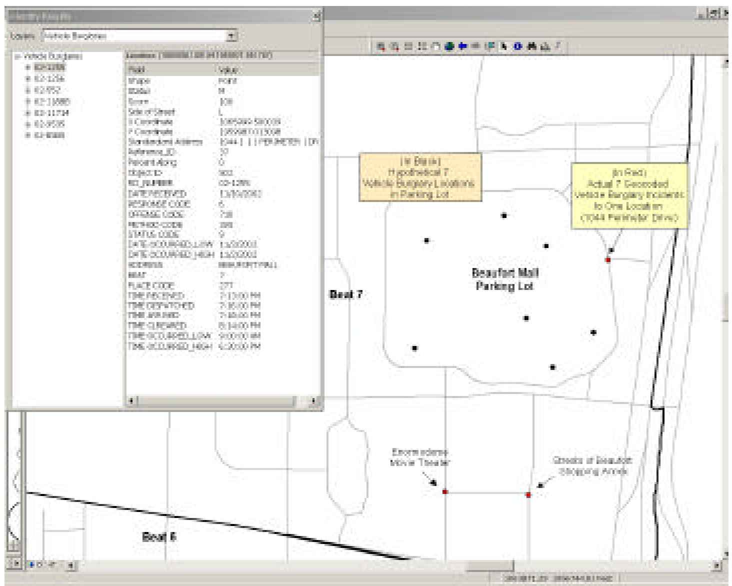
GIS was instrumental in developing the new beat plan. After mapping calls-for-service data for the past year, Dover experimented with a number of different border configurations until he finally devised a plan that accomplished the dual goal of making call volumes more equal between beats, while maintaining patrol unit cohesiveness. Maintaining cohesiveness was a big factor for patrol supervisors of beats that would be potentially affected by the re-alignment. For example, the Beat 6 supervisor argued against modifying the northern border of his beat because it would have sliced up a cohesive residential community. Similarly, Chief Meer wanted the Beaufort Mall, Enormodome Movie Theater, and Streets of Beaufort shopping annex to be included in the same beat because they were similar type of places – all three were large retail and entertainment complexes with expansive parking lots.

Based on those considerations, the borders of the new beat were drawn (as shown below).

Creating the new beat distributed crime more evenly across all patrol units. Given the old nine beat alignment, the larger-sized Beat 7 accounted for nearly 19.9 percent of Beaufort calls for service. Implementing the new 10 beat plan divided that total into two beats, with the adjusted Beat 7 accounting for 9.0 percent of total calls and the new Beat 10 consisting of 10.9 percent of the total (as shown below).

City of Beaufort Beat Plan Comparisons				
	Old Beats		New Beats	
	CFS	Percent of Total	CFS	Percent of Total
Beat 1	1,180	7.9%	1,180	7.9%
Beat 2	1,405	9.4%	1,405	9.4%
Beat 3	1,360	9.1%	1,360	9.1%
Beat 4	1,599	10.7%	1,599	10.7%
Beat 5	1,464	9.8%	1,464	9.8%
Beat 6	1,972	13.2%	1,972	13.2%
Beat 7	**2,974**	**19.9%**	**1,340**	**9.0%**
Beat 8	1,434	9.6%	1,434	9.6%
Beat 9	1,554	10.4%	1,554	10.4%
Beat 10	**0**	**0.0%**	**1,634**	**10.9%**
Totals	14,942	100.0%	14,942	100.0%

After determining its boundaries, the department foresaw the difficulty in analyzing crime within this new beat. Crime events occurring in parking lots presented a challenge to the department because incidents were traditionally aggregated to the address of the nearby business. However, using a conventional street address is meaningless in conveying locational precision for an area the size of the Beaufort Mall parking lot. In reality, crime incidents are scattered all around the lot (as shown below).



To map crime occurring in large parking lots, Dover outlined two alternatives to Chief Meer. Both options involved the use of **Global Positioning System (GPS)**. GPS is a constellation of 24 satellites developed by the U. S. Department of Defense that orbit the earth at an elevation of approximately 20,000 kilometers. These transmit signals that allow the calculation of any location on the earth using a GPS receiver. Depending on the equipment and environmental conditions, accuracy of GPS points can be anywhere from 10-15 meters to a few centimeters.

The first potential solution involved having a member of the county planning department, the gatekeepers of the GIS data, use a GPS hand-held device to collect coordinate points for each of the parking lot lampposts. Each parking lot had regularly spaced lampposts with numbers listed on the pole that could, in essence, be used as reference points for crime locations, like an address (see picture below). The coordinates can then be integrated into the GIS system and converted to the appropriate coordinate system in order to create a new map layer of parking lot poles.

Of course, new data collection procedures would have to be implemented whereby officers would capture the lamppost data on an incident or arrest report. Geocoding would then involve matching the pole number entered into the crime database to its corresponding mapped location, similar to address matching.

A second option was to have officers patrolling the new beat carry GPS hand-held receivers. From the scene of a crime, the actual location of the event can be pinpointed with the device and then later in the office can integrated into the GIS system, eliminating the need for geocoding altogether.

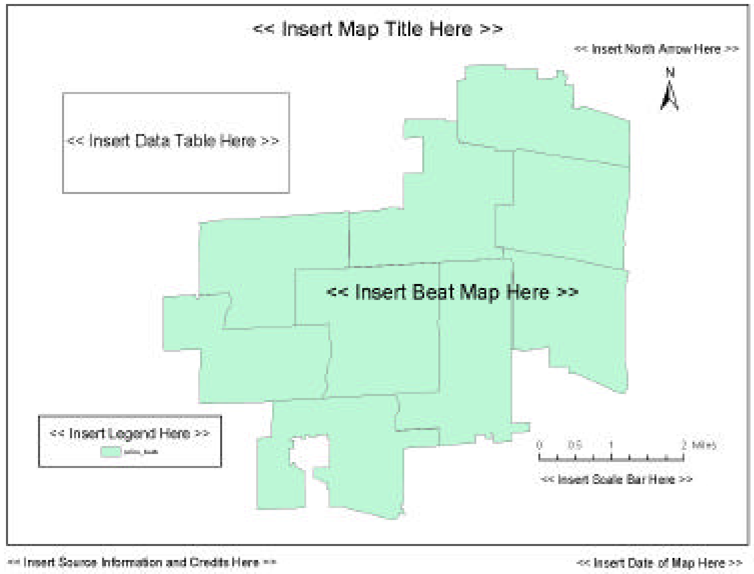
Both methods would facilitate crime analysis of parking lot crime. For instance, more precise mapping of auto theft patterns at the Beaufort Mall could reveal areas of the mall lot that are more susceptible to crime, due possibly to poor lighting or the proximity of access points to the expressway. Having officers carry GPS hand-held devices could have the added benefit of mapping crimes inside the mall, whether in particular stores or in public places.

When presented with the two options, Chief Meer decided the best choice was to create the map layer of lampposts. While the chief could see the wealth of possibilities posed by GPS, he preferred to wait for the technology to gain greater legitimacy within the law enforcement community before using it as an analytical tool.

Next, Dover was faced with the difficult task of deciding how to coherently place the beat re-mapping information and crime analysis strategy on a map for tomorrow's presentation for the mayor. The purpose of the map was three-fold:

- To show call volume allocated to reflect the new beat structure.
- To show the boundaries of the new beat.
- To illustrate the strategy to create a map of parking lot lampposts.

Dover pondered his options and reviewed the material again. He determined the best strategy was to start from the City of Beaufort **map template** he created and to modify the document as needed. A map template is a generic document that guides the organization of various components of a map. Dover found it particularly useful to work from a template for maps that are done on a regular basis, because it helped to standardize and speed up the map production process and develop consistency from map to map. Dover used a template for citywide maps as well as maps of individual beats. The citywide beat map template is shown below:



A template should include the design elements that are needed on most crime analysis maps, including:

Titles, sub-titles, or captions.

Legend. Lists and explains the colors, symbols, line patterns, shadings, and annotations used on the map.

Scale. Used to measure distance on the map, marked like a ruler in units proportional to the map's scale.

North arrow. A map symbol that points north, thereby showing how the map is oriented.

Source information and credits. Includes such items as data sources, map author, and date the map was created.

Neatlines and borders. Usually drawn around a map to enclose the legend, scale, title, geographic features, and other information pertinent to the map.

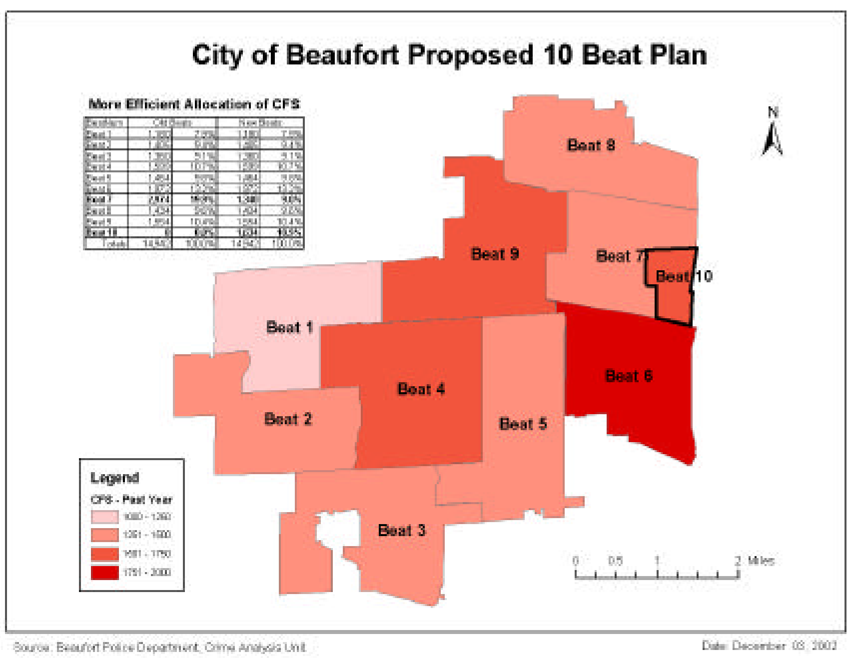
Labels. Text placed next to a feature on a map to describe or identify it.

Symbols. A mark used to represent a geographic feature on a map.

Disclaimers (optional). Information generally referring to limitations or cautions of the information on the map, such as “For Police Use Only” or “95 Percent Geocoded.”

Each design element is intended to make the map more informative. Decisions on what items to include on a map should be based on the purpose of the map, the intended audience of the map, and the medium in which it will be presented. For example, including source information would probably be more important to maps intended for groups outside the police department than it would be if distributed to internal personnel. Moreover, maps used in presentations to mass audiences with varying levels of map exposure might require all of these design elements, while maps shared between other crime analysts could be less inclusive.

Working from his template of Beaufort, Dover created the following map:



This map accomplished only one of his goals. *Okay, this only shows the map of the new 10 beat plan, but how do I show the boundaries of the new beat? I know that’s the first question the mayor will ask.*

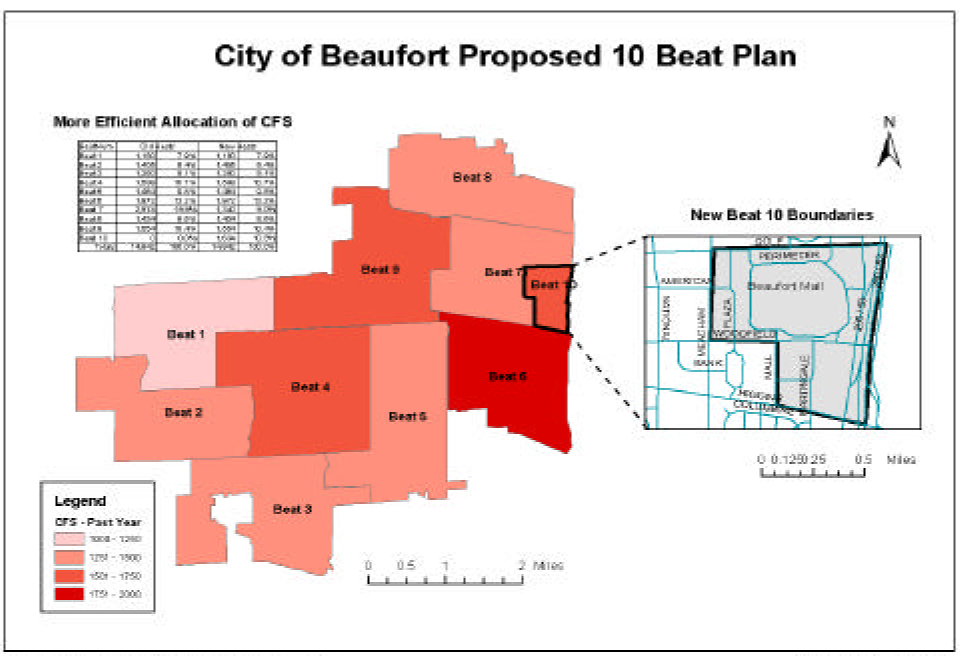
Dover sat back in his chair and pondered his options. *I guess I could always make a separate map or place the map at the bottom.* He quickly disregarded those possibilities. *I wish there was a way to place the new beat map and the map of the boundaries side by side. But how do I do that?*

Becoming frustrated, he was beginning to wonder if that cartography class he took at the community college was all a waste of time. Instead of panicking he told himself to relax and just think for a minute. After a few more minutes and a walk to the water fountain, the answer finally came to him based on his training.

Wake the kids and phone the neighbors, I think I've got it! If I want to place an enlarged view of the new beat next to the citywide map, I could use an ***inset map****!*

An inset map is a small map set within a larger map. It is useful for showing an area that does not fit neatly into the main map, or a detail of part of a map at a larger scale, or the context of the area covered by the map at a smaller scale.

After creating the inset map, the map document now looked like the following:



Source: Beaufort Police Department, Crime Analysis Unit

Date: December 03, 2002

Officer Dover felt pretty good. He figured out a way to show a detailed map of the street boundaries of the new beat in tandem with the overall city beat plan. The map was now beginning to take shape.

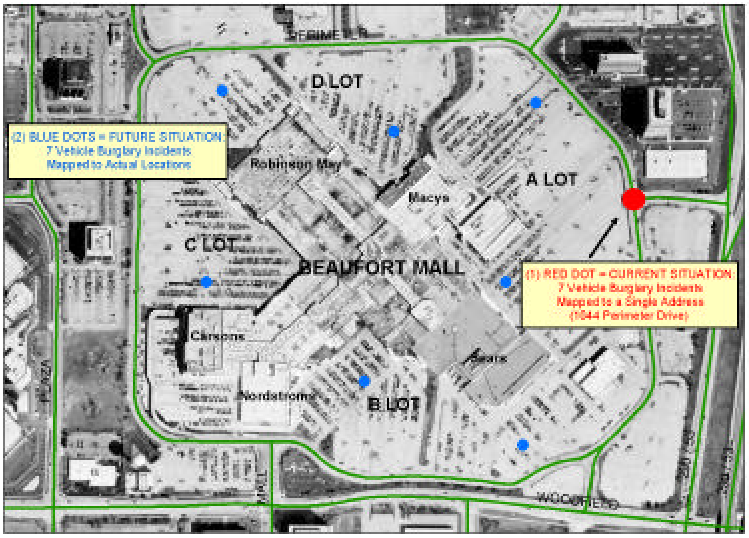
The next step is to find a way to illustrate our strategy of creating a map of the lampposts.

Dover thought the best way to show this was with a series of images and pictures of the mall area. He had taken a number of digital photographs of the mall parking lot, and the latest versions of most GIS software supported picture integration. However, because pictures and photographs were not items traditionally displayed with maps, Dover was unsure how the audience would view it. Running it by the chief first would be a good test.

After scanning through the digital pictures stored in his computer, Dover designed the following sequence of pictures and a map that he hoped would effectively tell that story.

He wanted the first picture to simply show the sheer expanse of the parking lot:

This would lead to the middle illustration consisting of an **orthophoto** of the mall area overlaid with the actual and theoretical locations of crime incidents at the mall. An orthophoto (also known as a **digital orthophoto**) is an aerial photograph of an area that is turned into a digital map. It has many potential uses for law enforcement. It can be overlaid with other mapped data to provide vivid pictures of crime scenes used for court, add a sense of realism to crime analysis maps, and used to map routes for emergency evacuation plans, among other things. Dover hoped that it would illustrate how the department's crime analysis capabilities were hampered by crime being reported to a single business address, when in reality crime is occurring all over the lot (as shown below).

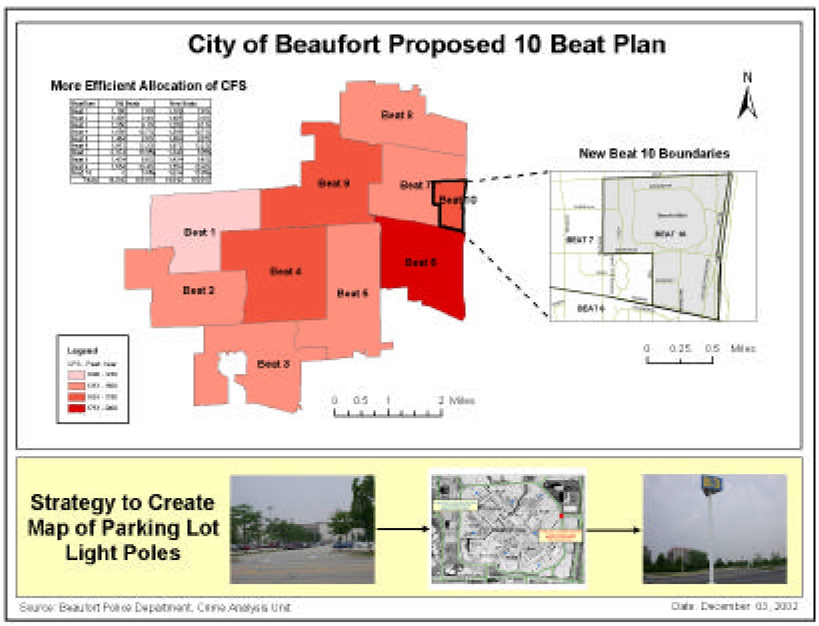


The red dot shows the current situation – all crimes are mapped to a single address. The blue dots show a hypothetical pattern based on mapping to parking lot lampposts.

This would finally lead into the third illustration showing an example of a light pole marker and an explanation of how mapping the poles could ultimately enhance the crime analysis process in the future (as shown below).

Photographs are usually not as self-explanatory as maps, because of the their lack of symbolization and labeling. Therefore, Dover would have been hesitant to use them if the map was intended as a stand-alone document.

After playing around with the arrangement of the layout, Dover decided to place the sequence of photos at the bottom of the map document. He also placed a neatline around them to illustrate that they were grouped together. The neatline is a handy way to segment the map document into different sections. Another way is through the use of color differentiation. Dover used a slightly darker background color for the neatline box to indicate contrast between the top and bottom sections of the map (as shown below). (A full sized version is in the Appendix).



"That's not a bad map, if I do say so myself," Dover said. *It shows everything I want to show, the new calls for service allocation, the new beat boundaries, and the strategy to create a map of parking lot poles. At the same time, while it does present a lot of information, the map doesn't appear to be too cluttered or confusing. And the arrangement's not too bad either, given* *the asymmetrical shape of Beaufort. All items are placed in an organized and well-balanced manner. Adding the dashed lines, arrows, and neatlines also helps provide visual cues to draw the viewer's attention from one item to the next.*

Dover glanced at the time on his computer screen and was jolted back to reality. He had little time to waste. He still had to show this map and the updated *Intelligence Bulletin* to Chief Meer, and then get over to the briefing room before the second shift meeting.

After printing the map, Dover jumped up from his desk, grabbed the copies of the *Intelligence Bulletin* off the printer, walked over to the plotter and picked up the new beat map, unrolled it briefly to make sure it looked okay, and then made his way down the hallway to Chief Meer's office.

He approached the chief's office and rapped on the door.

"Chief, you busy?" Dover asked.

"No. What's up?"

"First, we have some good news," Dover said stepping into the office. "I got a call from Det. Bowers. He checked out some of the pawnbrokers in town. Apparently, many of the stolen items are popping up on the east side at two shops on Wolf Road and one on Major Parkway. The owner of one of them ID'd the suspect. Here's the updated suspect information." Dover handed Chief Meer the updated *Intelligence Bulletin*.

Chief Meer read it over and handed it back to Dover. "Great," he said. "Make sure you get that to the troops before they head out this afternoon."

"Yes, sir." Dover replied. "The briefing room is my next stop."

"Good. I also want you to hang around for the meeting in case the patrol guys have any questions. Using predictive information is a new concept to many of the officers around here."

"No problem, Chief."

"Anything else?" Chief Meer asked.

"Here's the last of the maps for tomorrow's meeting," Dover said. "I just finished it."

Dover unrolled the map and draped it across the chief's desk. "It's basically our beat re-mapping plan and crime analysis strategy all in one. The map shows calls for service more efficiently distributed across 10 beats versus our old nine beat plan. To the left of the map is a table comparing specific call numbers between the new and old plan. And to the right of the map is basically a detailed blowup of the newly proposed Beat 10.

"I also put pictures of the mall parking lot at the bottom to illustrate the second part of our strategy to start collecting data for crimes in the parking lot by using the lampposts as address markers."

"I like the pictures because it illustrates the challenge of analyzing crimes occurring at the mall by *not* having a map of lamppost locations," Chief Meer said. "Have you already asked the planning department about doing the map for us?"

"Yeah. They said no problem," replied Dover.

"Good. Then I can tell the mayor that they're already on board," declared Chief Meer. "Plan on attending the meeting tomorrow in case we get technical questions."

"Already cleared my schedule," responded Dover.

"Good. It looks like we're ready."

Dover then rolled up the map and headed for the door.

"By the way Dover, great work this week!"

"No problem Chief," Dover said. "See you tomorrow."

As he proceeded down the hallway, Dover had an extra hop in his step. Chief Meer was not too liberal when it came to handing out compliments. He expected a job well done because the citizens of Beaufort demanded it. He always said if you wanted positive reinforcement, you were in the wrong business. But getting a compliment every so often did not hurt.

Dover went to the briefing room with the updated bulletins in hand. He replaced the old *Intelligence Bulletin* on the bulletin board with the new one. He then waited for the second shift daily briefing to start. Officers were beginning to filter in.

At that moment, Dover felt both physically exhausted and mentally wired, just like he felt after pulling an all-nighter in college. He was definitely running on fumes. A jumble of thoughts ran through his mind. *What if I'm wrong in my predictions? What if we don't catch the criminal with one of my response plans? What if this all was a waste of time?*

Dover knew that the odds were against the offender getting away with his crimes for much longer. It was nearly impossible for this offender to continue to burglarize vehicles without leaving more physical or forensic evidence, and the more times he committed a crime, the more likely he would leave information behind for Dover to use. Regardless of what happened during his first predicted time frame or his fourth, Dover knew this guy was going to be arrested. But all he could do now was wait.

Chapter Six – Evaluation and Assessment

The next day the department presented the new beat map to the mayor's office. By all accounts, the meeting was a success. The mayor agreed to back the new plan and to do whatever she could to sell it to mall area businesses. Everyone also seemed quite impressed with the maps.

Meanwhile, Dover anxiously awaited word that an offender had been caught for the series of vehicle burglaries.

Time passed slowly within the department. The night of Dec. 4 came and went with no arrest, incident, or even a report of suspicious activity in the predicted zone.

The same thing happened on Dec. 5.

Then at 11:30 p.m. on the night of Dec. 6, while at home going through the job section of the local newspaper, Dover got the call from Det. Bowers. A white male, age 25 had been arrested stealing stereo equipment from a 1998 Acura Integra. Bowers had just finished questioning the offender and figured Dover would want to hear the good news.

According to the detective, two undercover officers assigned to patrol the area spotted the suspect hastily fleeing from a residential driveway while zipping up his backpack. As they approached the premises, they noticed that the passenger side window of an automobile was smashed in, so they sped up and apprehended the suspect about four doors down from the scene of the crime. Found in his backpack was a Sony CD player and a Stanley Wonder Bar. They had their man.

The offender's name was Donald Joseph Tauber. He had recently moved to the southwest side of Beaufort and had a history of vehicle burglaries and theft. In fact, he was on probation. He was 5'11", 165 pounds, with short brown hair. When he was arrested, he was wearing a black, hooded sweatshirt and a dark green, medium length winter coat.

Dover felt vindicated. The offender profile was right on target and Det. Bowers said that the *Intelligence Bulletin* he developed had been useful in planning the directed patrols and assigning undercover officers.

The detective also noted that the offender originally denied involvement in any previous burglaries. But when the detective pointed out the similarities with the other crimes and fit the broken piece of the Wonder Bar (in front of the offender) with the missing segment found on the one in the offenders backpack, the guy knew he was sunk. He finally admitted to all eight of the vehicle burglaries in the area.

It turned out the guy was recently hired on as holiday help for a store in the Beaufort Mall. He worked part-time on Mondays, Wednesday, Fridays, and Saturdays from 3 p.m. to 9 p.m. He would steal the items on his way home from work. He would take the bus back from the mall and get off at various stops close to his apartment. While walking home he would either scope out future targets or burglarize targets that looked inviting. After stealing the stereo equipment, he would then sell it to various pawnshops for cash. The fact that a few pawnshops were located close to the mall made it easy for him to dump the stolen property before he started his shift at work.

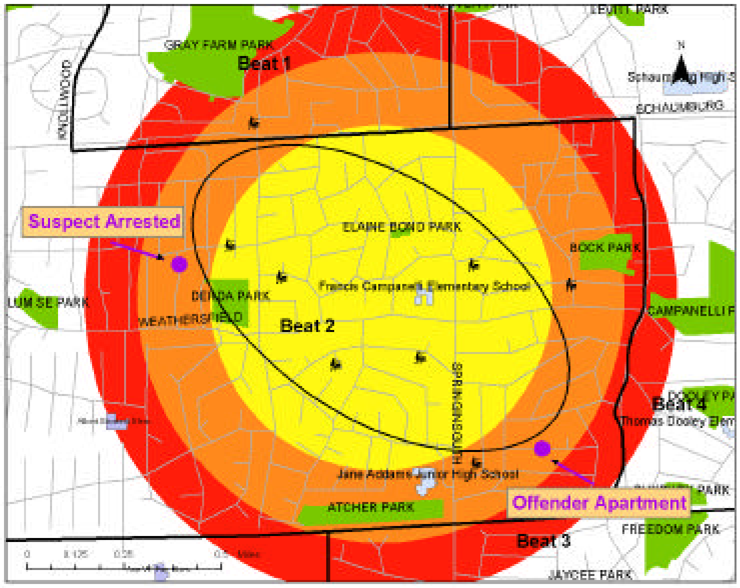
Tauber said that he never counted on the department developing specific tactical plans based on an analysis of his past crimes. He figured that by making sure there were no witnesses and by wearing gloves so as not to leave any fingerprints behind, there was little chance he would be caught. He also thought the plan worked perfectly until he discovered that a piece of his pry bar was missing two days earlier. He was planning to buy a new one, but was arrested before he did.

Dover spent much of the weekend regaling family and friends with stories of his crime analysis prowess. He felt a renewed sense of pride and purpose in his job as crime analyst of the Beaufort Police Department. He was actually excited about going back to work on Monday.

When he did arrive Monday morning, waiting for him was a copy of the arrest report with a note that said, "Good job, Sporto! Let's do lunch." It was from Det. Bowers. Throughout the morning other staff members came to his desk to offer accolades on a job well done. While Dover knew that his contribution to this arrest was huge, he managed to deflect praise away from himself to the officers and detectives that actually implemented the directed patrol plan.

When he was finally able to get back to work, the first order of business was to conduct an assessment of the accuracy of his predictions. He compared the predictions listed on the *Intelligence Bulletin* to the specifics from the arrest report. The date analysis predicted that more incidents were likely before Dec. 5, very likely before Dec. 6, and extremely likely before Dec. 8. **The apprehension was made on Dec. 6**. For the days of the week, the analysis showed the peak days were Saturday (37.5 percent), Friday (25 percent), and Wednesday (25 percent). **The offender was caught on Friday**. The time analysis showed the most significant peak was between 1900-2400 at 65 percent. The 2200-2300 hour was the single highest at 22 percent. **The arrest was made at approximately 2145 hours**.

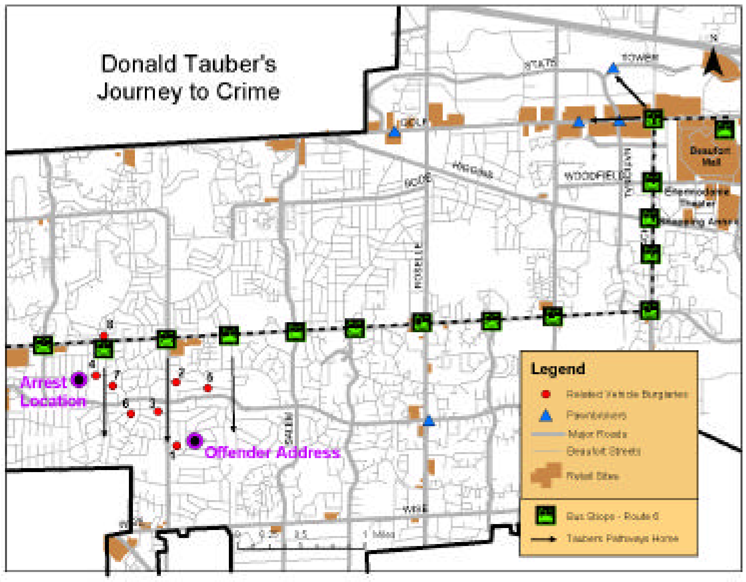
Two methods were used to analyze location. The first method was STAMP. The second used the standard deviational ellipse function of *CrimeStat*. The map below shows the locations of the eight original vehicle burglaries, the arrest location, the offender's residence, and the spatial forecasting zones.



The STAMP method is shown by the three circular rings, which indicated the chance of further incidents within the yellow zone was high; within the yellow and orange rings was very high; and within the yellow, orange, and red rings was extremely high. The ellipse (oval) shows the result of *CrimeStat*, which indicated the chance of further incidents within the ellipse was high. **The apprehension was made within the orange zone of the STAMP predicted area** (left of center).

When conducting his analysis, Dover postulated that the offender lived in the area where the vehicle burglaries occurred based on the elimination of other likely scenarios, such as the offender working, going to school, or socializing in the area. This theory was based on a detailed analysis of the land use characteristics of the area. It turned out that the offender also lived within the orange STAMP zone, in the southeast part of the predicted area.

In order to understand Donald Tauber's criminal **activity space** better, Dover decided to map out the key elements of his calculated crime spree (as shown below). (A full sized version is in the Appendix.)



Tauber's journey to crime began on his way home from work at the Beaufort mall. **Routine activity theory** suggests that crime opportunities appear in the activities of everyday life. The routine patterns of work, shopping, socializing, and leisure affect the convergence in time and place of would-be offenders, suitable targets, and the absence of guardians. Many crimes occur while an offender is traveling from one activity to another. This was the case with Donald Tauber.

After Tauber got off work at 9 p.m., he would take the No. 6 bus home. When he first began his criminal activity in Beaufort, he used the most direct route from the bus stop to his apartment. However, he was afraid that burglarizing vehicles along the same path for too long would be too risky, because people would be on the lookout for suspicious activity. Thus, he began to get off at different stops to vary his pattern.

Selecting shops to pawn off his merchandise was also based on the convenience of his routine activities. He sold off six of the eight stolen items at pawnshops near the mall on the way to work. The remaining items, one stereo and one CD player, he kept for himself for when he had his own car.

Dover always got a laugh out of reading offender statements on arrests reports. *Criminals always think they can outsmart the police,* he marveled silently. *Why is it that it's always the ones that think they have the best plans that are the ones to get caught? It must be that every time they get away with a crime it bolsters their courage. But criminals like Tauber fail to realize one point, that every new crime they commit, because of the patterns left behind, brings them one step closer to an inevitable arrest.*

As a final step in the evaluation process, Dover documented what was learned to improve problem-solving activities in the future. The following conclusions were based on his assessment of the accuracy of crime forecasting, the review of the arrest report, and the mapping of Tauber's journey to crime:

1) **Crime forecasting was accurate**. While crime forecasting is not perfect, in this case it was accurate enough to produce favorable results. This apprehension was made by investigation, analysis, and planning, and not by chance.

2) **Detective and police officer initiative was the key**. Analysis only works if action is taken. Detectives and police officers spent many hours investigating, planning, and conducting surveillance, which ultimately led to the capture of the offender.

3) **Investigating new statistical methods is necessary.** In an evaluation, a crime analyst takes an accounting of what he or she *knows* about a given crime problem. An honest appraisal of what he or she *does not know* is also important to improve the problem-solving process.

Part of the evaluation Dover conducted involved, in essence, an after-the-fact **journey-to- crime** analysis. Journey-to-crime analysis is aimed at estimating the distance that serial offenders will travel to commit a crime, and by implication, the likely location from which they started their trip. It is essentially a statistical approach to estimating the residential whereabouts of an offender given a pattern of related offenses.

Dover lacked an understanding of how to use journey-to-crime measurements, but realized that they could have proved useful in this case or for similar cases where its important to zero in on the residence of the offender (geographic profiling). To learn more about this methodology, he decided to examine the various journey-to-crime statistics available in *CrimeStat* the first chance he got.

4) Acquiring additional data is necessary. After Donald Tauber was arrested, Dover learned he had a rap sheet a mile long. He had an extensive criminal history of vehicle burglaries and theft. In fact, he was serving two years probation for a string of vehicle burglaries he committed in other jurisdictions.

Knowing the residential locations of recent probationers and parolees living near a crime scene could assist in investigations. Many police departments are beginning to overlay that type of information on maps of crime patterns. In this situation, layering the residential locations of recent probationers and parolees with a history of vehicle burglaries on a map with the eight vehicle burglaries could have revealed a cluster of activity near certain probationer residences. That type of information might help victims and witnesses identify the offender from a group of suspects selected according to geographic proximity. Would it have assisted in nabbing Tauber earlier? Dover did not know. But it could have. Because of this, Dover decided to make acquiring recent probationer/parolee data from the Department of Corrections a priority.

5) Implementing daily mapping of Part I crimes is required to create a proactive crime analysis unit. Throughout the process of solving these burglaries, Dover felt like he was playing catch-up. While simply responding to citizen complaints once the crime was committed was acceptable, Dover thought the process made the department appear reactionary, and slow to respond. The goal of the crime analysis unit should be not only to react to crime problems when they happen but also to stop crime dead in its tracks.

In the past, Dover had gone through incident reports for the more serious types of offenses (Part I crimes) looking for modus operandi patterns. But he had been tied up with the beat re-mapping project so long he had sort of gotten away from that practice. With the added mapping dimension, Dover could also look at the spatial patterns of crime as they occur from day to day. He hoped that this would lead to a more proactive crime analysis unit down the road.

One month passed and vehicle burglaries decreased in the southwestern part of Beaufort. The arrest of Donald Tauber brought incidents back down to average levels.

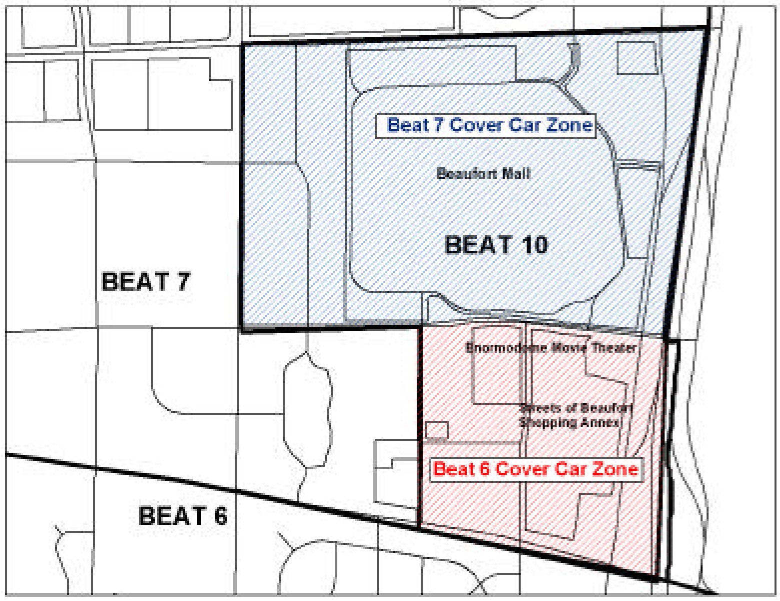
In the months that followed, Dover also carried out many of his own recommendations. He started getting probation/parolee data from the Department of Corrections on a monthly basis, and began mapping Part I crimes daily. Those strategies paid dividends. Mapping crime daily enabled Dover to recognize developing hot spots and serial crime patterns much earlier than in the past. When significant crime patterns did appear, Dover used data on recent probationers/parolees to provide detectives with a list of suspects for questioning. In one case, a witness identified a suspect living near an area that had suffered a rash of burglaries to commercial establishments. The suspect was brought in for questioning and then arrested. Something similar occurred in a case of residential burglaries.

So mapping and GIS became a vital spoke in the crime analysis wheel for the Beaufort Police Department. Dover was happy that the crime analysis unit was taken seriously again. Chief Meer was happy that the department's time and investment in mapping had paid off.

As far as the beat re-mapping plan was concerned, the mayor got the business community on board, just as she said she would. The new beat plan was implemented Jan. 1, 2003. One patrol car was assigned to the new Beat 10. The department informally referred to it as the "parking lot beat" given its essential composition of major retail establishments. Because of its composition, most of the dispatched calls were vehicle-related, including thefts, burglaries, traffic accidents, or moving violations.

The new beat plan did not come off without a hitch. A few months into it, the department realized they had one major problem. Because mall area businesses agreed to get tougher on offenders, it resulted in more arrests. Of course, this meant more trips to the station, in the center of town, leaving a patrol void at the mall when other calls came in for Beat 10. This problem was compounded by traffic congestion near the mall, especially during the evening rush hour when mall traffic combined with commuter traffic to cause major logjams. Beat 10 officers would get caught in that traffic and would not be able to get back in a timely fashion, causing response times and complaints from business managers to shoot up.

The department debated over whether to put a sub-station at the mall to eliminate the necessity of officers going back and forth to headquarters, but business owners were decidedly against that idea. They argued that having that much police presence might give shoppers the perception that the mall was not safe, which would be bad for business. As an alternative, the department decided to employ the use of two "cover cars." The plan involved patrol units from the two adjacent beats covering for the Beat 10 patrol car when it was out of the area; the Beat 7 patrol unit would cover the northern part of Beat 10, and the Beat 6 patrol car would cover the southern part (as shown below).

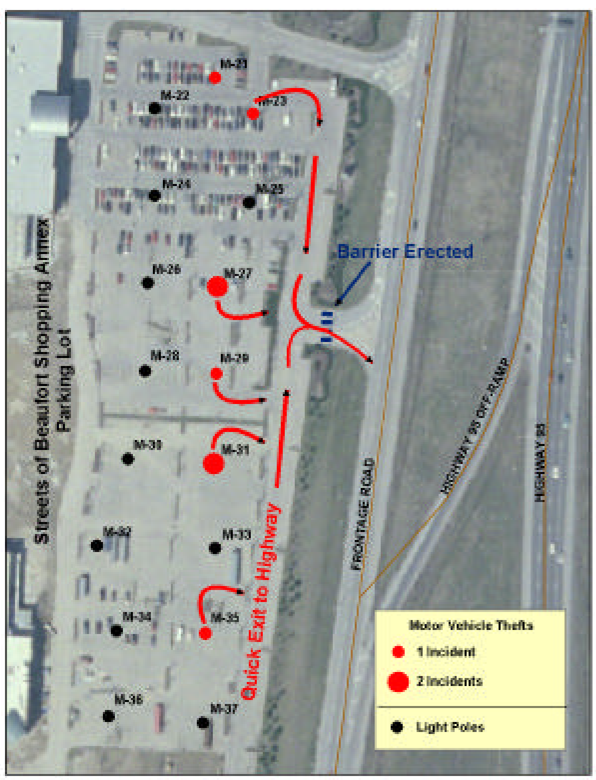


The strategy worked well. As soon as the Beat 10 patrol car was able to get back to its beat, the cover cars resumed normal patrols.

Another successful aspect of the new beat plan was the strategy to create a map of parking lot lampposts for the purposes of crime analysis. The county planning department provided a map, and Dover used the light pole numbering system to geocode crimes occurring at specific locations within the parking lots of the Beaufort Mall, Enormodome Movie Theater, and the Streets of Beaufort shopping annex.

Dover used his new crime analysis capabilities to the fullest. One example in particular demonstrated the usefulness of the new system. While mapping crimes that happened in each lot, he noticed a number of motor vehicle thefts were in the back lot of the Streets of Beaufort shopping annex. Because of the different types of vehicles being stolen and different methods used to steal the vehicles, Dover did not suspect that the same offender or group of offenders had committed the crimes. However, he suspected that particular section of the lot became a hot spot for motor vehicle thefts for another reason, namely its close proximity to the highway. A car thief could exit from the back entrance of the parking lot to Frontage Road, which could then quickly lead to the on-ramp for Highway 95.

Meeting with management of the shopping mall, Dover learned that the back exit was developed as a benefit to customers. Management did not anticipate that car thieves could derive the same benefit from quick and easy freeway access. After Dover showed them the map of theft occurrences in relation to highway access points (as shown below), they decided to erect a barrier where that the old entrance/exit used to be. The map illustrates the problem and solution. It shows the Streets of Beaufort parking lot, the mapped lampposts, the mapped motor vehicle thefts, the proximity to Highway 95, and the barrier erected to close the exit.



This section of the parking lot ceased to be a problem after Dover's analysis and the resulting preventative measures were taken. Other analyses Dover performed showed similarly successful outcomes. He pinpointed other portions of area parking lots that were more conducive to crime due to poor lighting or because they were obscured from view. He even identified and stopped a number of serial crime patterns in the mall parking lot.

Being able to map crimes that in the past were recorded without any meaningful locations attached to them opened a new avenue for crime analysis for the Beaufort Police Department.

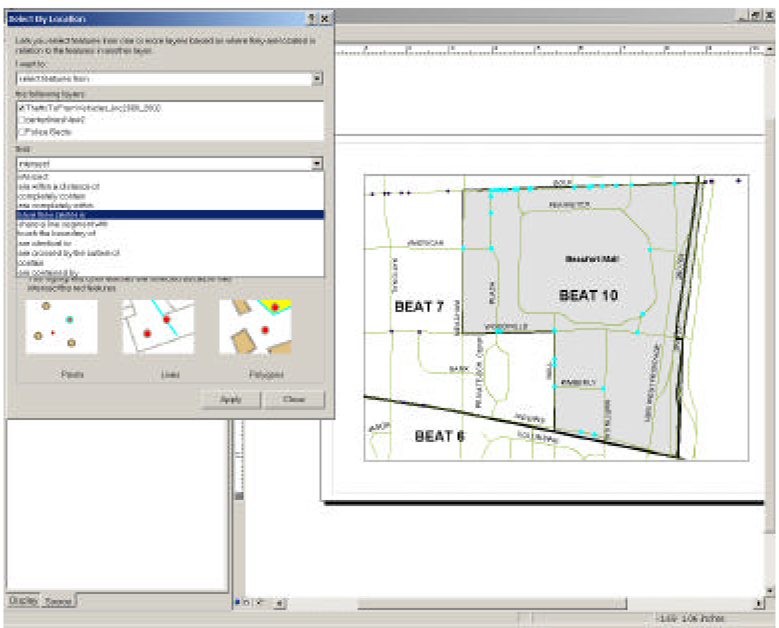
It was now early November. Ten months had passed since the new beat plan was implemented. Chief Meer called Dover into his office.

"Dover, I want you to do an analysis of the new beat plan," the chief said. "As you know, the primary purpose of adding the new beat was to equalize workloads, but I think it is also important to determine whether or not it had any effect on crime. I'd like you to give me an idea of what our current year numbers look like for Beat 10 compared to last year. Just look at thefts to and from vehicles, because those are the types of crimes most affected by our exterior patrols. Get it to me by the end of the day. Dismissed."

Dover headed back to his office, and got started. Basically, the chief was asking for an evaluation of past data.

Before he could perform the evaluation, Dover realized had one slight problem. He was able to acquire monthly data for the current year for Beat 10 by querying the crime database. But how would he get data for Beat 10 for last year, when the beat had not existed? The answer was simple. His GIS program would acquire the data as *if* the beat *did* exist. It required a series of steps.

First, Dover geocoded and plotted the incidents for last year. Next, he brought in the beat map and selected Beat 10. Finally, he performed a **spatial query**. A spatial query enables map features to be queried based on their location on the map or their location relative to other features. In a GIS program, there are typically a variety of methods to select features in one layer based on their location relative to other features in the same layer or other layers. Three examples in the program Dover was using included selecting features that “intersect,” “are within a distance of,” or “are completely within” other features. Because Dover wanted to select all the thefts to and from vehicles occurring within Beat 10, he chose the most appropriate option (as shown below).



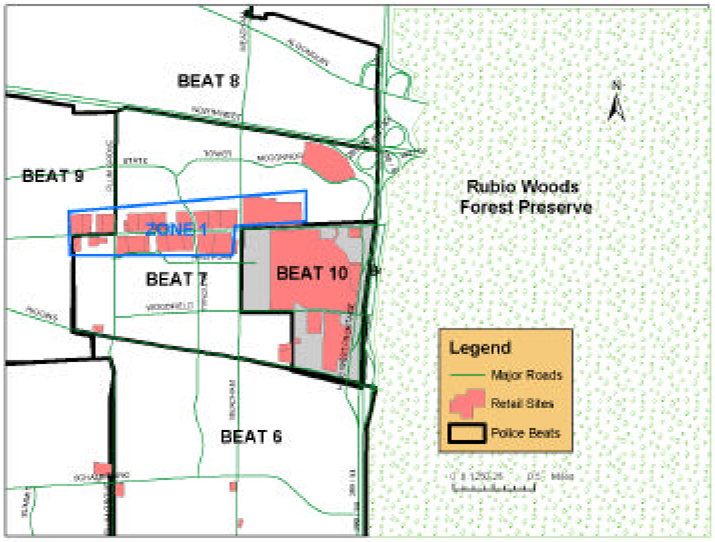
GIS enables a crime analyst to perform a variety of spatial queries that are helpful to their work. For instance, suppose Dover wanted to know how many drug arrests occurred within 1,000 feet of a school. He could answer that question – along with ones like it – by using a spatial query. GIS also allows an analyst to combine a spatial query with a **tabular query** to build more complex searches. A tabular query enables features to be selected based on attributes of the data, such as by date or time. If Dover wanted to determine which types of crimes would be affected by enhanced alley lighting in a crime-ridden part of town, he could select all offenses occurring within alleys (spatial query) and then refine the selection by pinpointing crimes that occurred at night (tabular query).

Once Dover got the data and summarized it by year, he compared the crime numbers. Based on his calculations, it appeared that there would be a reduction in vehicle-related crimes during the current year (141 incidents) compared to the year prior (177 incidents). In fact, there was a 20 percent decrease.

This result pleased Dover, but it left him with one nagging question. What if crime was just shifted to other parts of town?

Dover was looking for the effects of **spatial displacement**. Spatial displacement occurs when a criminal searches for a new area or region in which to operate. **Crime displacement** can take other forms as well. Temporal displacement occurs when a criminal substitutes another time of the day, week, or season to victimize the same site or area. Tactical displacement occurs when the criminal substitutes different modus operandi. Target displacement occurs when the criminal searches for an easier target in the same area. Displacement by type of crime occurs when the criminal substitutes a different type of crime instead of a crime targeted by a crack-down or community intervention.

Dover perceived the greatest threat in this situation as that of spatial displacement. For example, there was the threat that criminals who were deterred from committing a motor vehicle theft or burglary in Beat 10 would find other suitable targets nearby, particularly in the commercial corridor west of the mall. The area consisted of a two-mile long strip mall. Dover believed that if spatial displacement of vehicle-related crimes occurred, it would most likely be found in Zone 1 (as shown below).



To determine whether spatial displacement had occurred, Dover compared thefts to and from vehicles in three mutually exclusive areas: Zone 1, the remaining area of Beat 7, and Beat 6 (see the above map). He was not worried about displacement to the east of the mall, because that consisted of unincorporated land occupied by a forest preserve.

After mapping the incidents and summarizing the data, Dover found no substantial difference in vehicle-related crimes in any of the three measurement areas. In fact, all three showed a slight reduction in thefts to and from vehicles (as shown below).

Spatial Displacement Analysis

	Before Period Jan-Oct 2002	After Period Jan-Oct 2003	% change
Beat 10	177	141	-20.3%
Zone 1	78	76	-2.6%
Rest of Beat 7	22	21	-4.5%
Beat 6	35	34	-2.9%

Data on the movement patterns of criminals was necessary to analyze crime displacement most effectively. If criminals who offended in Beat 10 decided to offend in Zone 1 instead, then it could be said that crime was not deterred but displaced. Conversely, if there were no evidence that criminals who offended in Beat 10 either re-offended in Beat 10 or in other areas, then it probably could be said that spatial displacement did not occur. This type of analysis required an examination of arrest data.

Dover would look into that aspect of spatial displacement, but first he wanted to tell Chief Meer the good news. Creating the new beat not only helped to equalize workloads but also seemed to have a secondary benefit – reducing crime in Beat 10 without noticeable spatial displacement. Dover also wanted to believe that the enhanced crime analysis afforded him by having a map of the parking lot lampposts also had some positive impact on the strategy's success.

Dover walked down to the chief's office, and rapped on the door.

"Chief, you busy?"

"No, Dover, come on in," the chief replied. "You're just the person I'm looking for."

Uh, oh, what did I do now, was Dover's first thought. But then he figured it must be about the results of his analysis, so he started to explain.

"I did the analysis regarding Beat 10. Based on what I found, this year shows about a 20 percent decrease in incidents. A second piece of good news is that crime in the surrounding beats also went down slightly, so it appears that crime wasn't displaced to those areas. But, I still have a little more work to do before I can be completely sure."

"Oh, yeah, right," the chief said with surprise, as if he had forgotten about it. "That's great news, Dover! Thanks for the update. Give me a report after you finish it.

"I wanted to see you about something else. I found out something very interesting about you at the chief's meeting today." The chief glanced at the sheet of paper he was holding in his hand.

Dover started to panic.

"Let me ask you something," the chief said. "Do you like working here?"

"Yes, sir," Dover replied, with a puzzled look.

"You sure?" Chief Meer asked. "Maybe being the crime analyst of Beaufort is not challenging enough for you anymore."

"No, sir. I mean yes, sir," Dover stammered.

"Or maybe now that you have the mapping program, you've solved all of our crimes, so are looking for other work?"

"Uhhhm, no, sir."

"So you haven't done any moonlighting lately?" Chief Meer again asked.

"Moonlighting? No, sir, definitely not!"

"Then what's this?" the chief asked, handing Dover the sheet of paper.

Glancing at the document, Dover saw that it was a newspaper article from the *Hamburg Ridge Gazette.* The headline read, "Crime Analysts Solve Regional Crime Spree." It talked about how crime analysts from several police departments collaborated to analyze and solve a pattern of commercial burglaries that had occurred at gas stations and tobacco stores. The offenders were operating across five different jurisdictions.

Dover immediately recognized the information, but was shocked to see it in the newspaper. He worked on it with members of the Crime Analysts of Illinois Association. Case information was exchanged via the CAI's website. Matt Spaulding did the analysis, summarized it, and then sent it back to the group. The team effort resulted in the arrest of an offender. The article even mentioned Dover's STAMP spatial forecasting method.

"You never told us you were famous!" Chief Meer said with a smile.

"I didn't know it myself," Dover said. Dover figured since the article was from the Hamburg Ridge paper that it must have been Spaulding who notified the press. Ever since Spaulding worked out Hamburg Ridge's geocoding problems, he had been downright enthusiastic about the types of analyses mapping has afforded him. *What a publicity hound*, Dover thought.

"Well, it made quite a splash at the meeting," the chief said. "We were all in agreement that we wanted to see more of this kind of collaboration."

"Yeah, doing **regional crime analysis** is the main goal."

"Good, because we have your next case," the chief said. "Apparently, like us, many other departments are currently having problems with identity theft."

Oh man, Dover thought as he sat down. *This could be a long night*.

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Additional Resources

Recognized as one of the most important and popular innovations in American policing in the past decade, the U.S. Department of Justice's Office of Community Oriented Policing Services (COPS) began supporting crime mapping efforts by funding crime mapping software and hardware through the COPS MORE grant program.

With the assistance of COPS funding, the Police Foundation established the Crime Mapping Laboratory which provides technical assistance to law enforcement agencies that have received COPS funding to develop or expand upon existing mapping capabilities. Each year, eight training courses are conducted at the Police Foundation's headquarters in Washington, DC, and are offered at no charge. All travel and lodging expenses are the responsibility of course participants. In addition, onsite training and technical assistance can be provided for a fee. The following are a list of downloadable crime analysis and mapping publications available through the COPS office and the Police Foundation.

- *User's Guide to Mapping Software, 4th Edition*
- *Introductory Guide to Crime Analysis and Mapping*
- *Address Based Geocoding: Final Report*
- *Geocoding in Law Enforcement, Final Reports*
- *Guidelines to Implement and Evaluate Crime Analysis and Mapping*
- *Integrating Community Policing and Computer Mapping*
- *Manual of Crime Analysis Map Production*
- *Crime Analysis and Crime Mapping Information Clearinghouse*
- *Overcoming the Barriers: Crime Mapping in the 21st Century*
- *Frequently Asked Questions of Crime Analysis and Mapping*

The National Institute of Justice (NIJ) also recognized the benefits of geographic information systems (GIS) technology and established the Mapping and Analysis for Public Safety (MAPS) program, formerly known as the Crime Mapping Research Center. NIJ-funded training and resources include the Crime Mapping and Analysis Program (CMAP), conducted in Denver, Colorado which currently offers a free one week introductory course as well as courses in more advanced applications. For course schedules and other information, contact CMAP staff at (800) 416-8086 or by e-mail at cmap@du.edu. The following is a list of downloadable crime analysis and mapping publications available through MAPS.

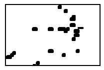
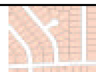
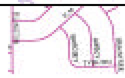
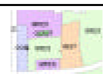
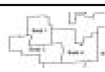
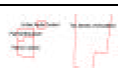
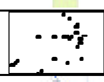
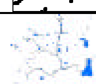
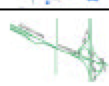
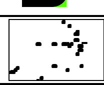
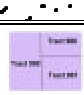
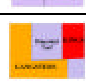
- *The Use of Computerized Crime Mapping by Law Enforcement*
- *Use of Computerized Mapping in Crime Control and Prevention Programs*
- *Mapping the Path to Problem Solving*
- *Mapping Out Crime: Providing 21st Century Tools for Safe Communities*
- *Strategic Approaches to Community Safety Initiative (SACSI): Enhancing the Analytic Capacity of a Local Problem-Solving Effort*
- *Measurement and Analysis of Crime and Justice*
- Mapping Crime: Principle and Practice
- Crime Mapping and Data Confidentiality

Appendix

Crime Mapping Needs Assessment: Technology

Hardware:	Start-up	Optional
Personal computer	X	
Laptop		X
Projector		X
Laser printer	X	
Color printer	X	
Plotter printer		X
Scanner		X
Server space (for storing large amounts of data)		X
Global Positioning System (GPS) hand-held device		X
Software:		
Word processing	X	
Spreadsheet	X	
Statistical (CrimeStat, SPSS, SAS)		X
Desktop GIS	X	
Base map (street map)	X	
Database manager		X
Presentation		X
Graphics		X
Internet and email		X
Records management system		X
Adobe Acrobat		X
Training courses:		
Mapping software -- Introduction class*	X	
-- Intermediate class		X
-- Advanced class		X
Technical writing (local college)		X
Introduction to cartography (local college)		X
Data or crime analysis for police agencies	X	
Miscellaneous:		
Travel to one mapping-related conference per year		X

* Some government and commercially sponsored courses are tailored to crime mapping.

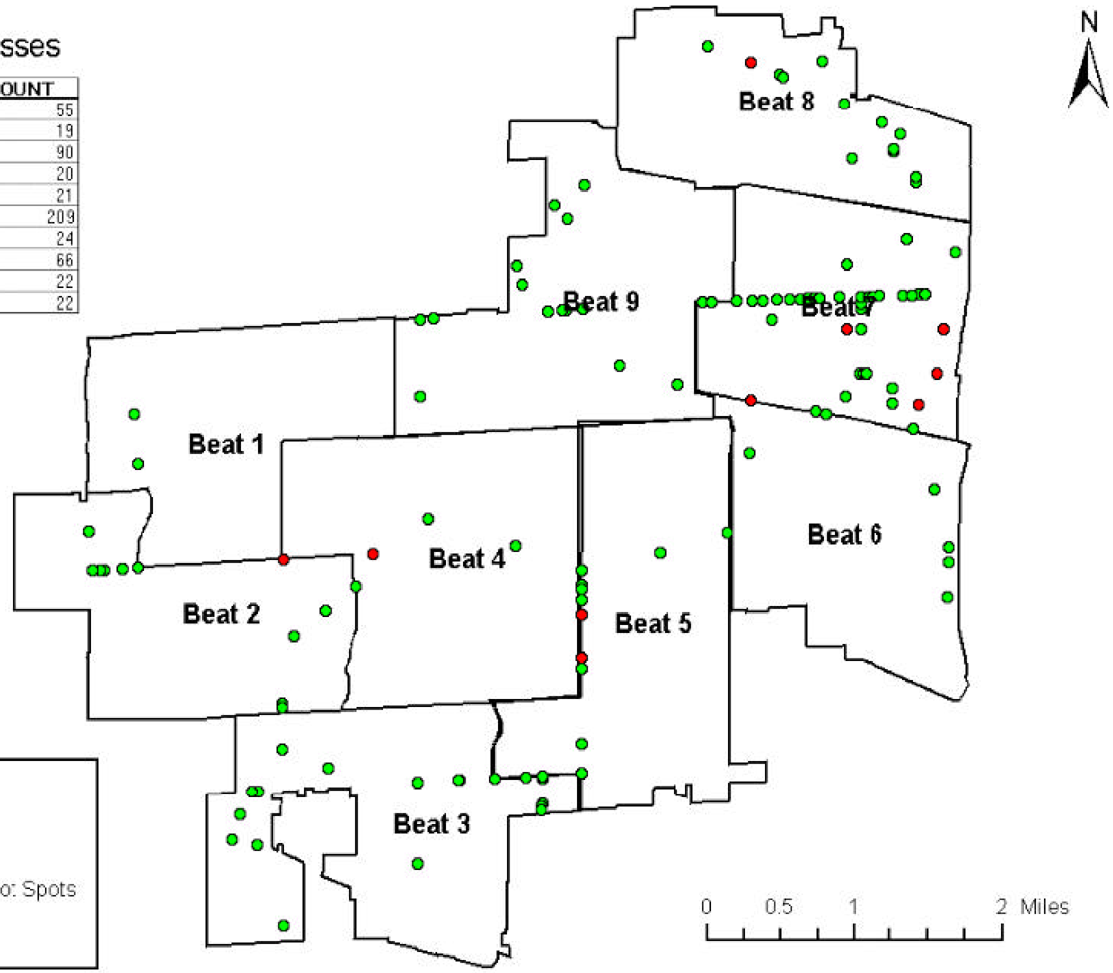
TYPE OF LAYER	IMAGE	TYPE OF DATA	POTENTIAL USES
Crime Points*		Point	Crime locations, point pattern analysis (hot spots)
Buildings		Polygon	Megan's Law - sex offender location analysis
Land Parcels		Polygon	Alternative layer for geocoding in small areas
Parking Lots		Polygon	Analysis of vehicle-related crime
Street Centerlines*		Line	Geocoding, Geo-reference
Land Use		Polygon	Burglaries by type of land use, Understanding nature of crime areas
Parks		Polygon	Juvenile-related crime, Geo-reference
ATM Locations		Point	Proximity to robberies
Police Beats		Polygon	Reporting jurisdictions, Resource allocation
Retail Sites		Polygon	Retail thefts, Identity thefts, Vehicle-related crime
High Schools		Polygon	Narcotics violations, Juvenile crime, Emergency response plans, Geo-reference
Elementary Schools/Day Care		Polygon	Megan's Law analysis, Geo-reference
Digital Orthophoto		Raster	Emergency response plans, Real-world visualization
Churches		Polygon	Hate crime locations
Known Offenders		Point	Sex offenders, Parolees/probationers
Water		Polygon	Geo-reference
Expressways/High-ways		Line	Proximity to drug buys, Motor vehicle thefts
Municipalities*		Polygon	Home-town boundary, Regional crime analysis
Public Transportation	£	Point	Proximity to crimes
Taverns		Point	DUI's, Liquor law violations, Disorderly conducts
Census Data		Polygon	Population, Demographics, Community policing, Geo-reference
Street Gang Turf Boundaries		Polygon	Turf violence, Proximity to gang crimes

* Minimum required for basic pin mapping

City of Beaufort RAM Hot Spots 2002

Top 10 Addresses

ADDRESS	COUNT
1020 N MEACHAM R	55
1100 W SCHAUMBU	19
1530 W SCHAUMBU	90
1901 E WOODFIELD	20
401 N ROSELLE RD	21
BEAUFORT MALL	209
575 S ROSELLE RD	24
601 N MARTINGALE	66
871 E ALGONQUIN R	22
900 E HIGGINS RD	22

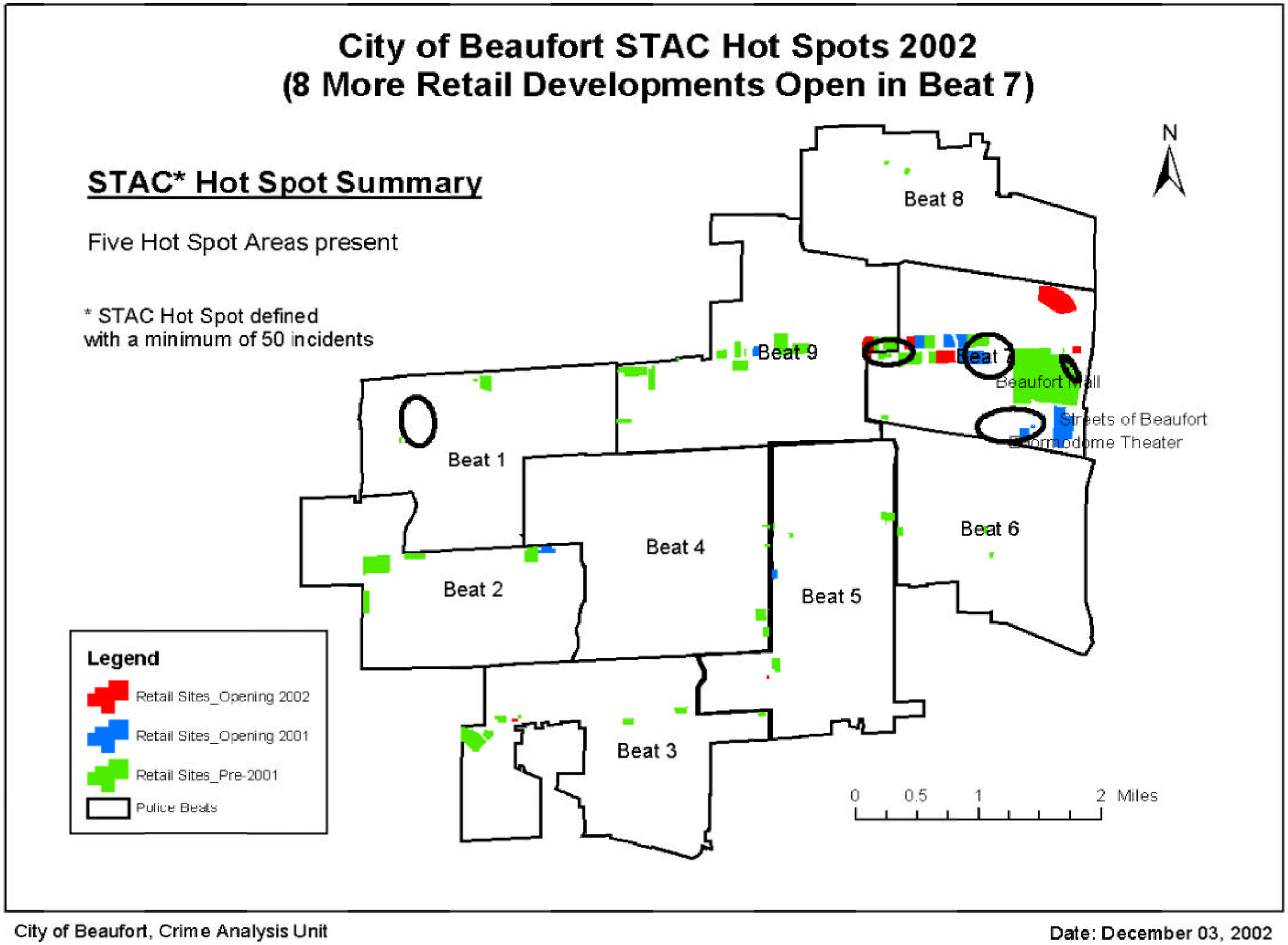


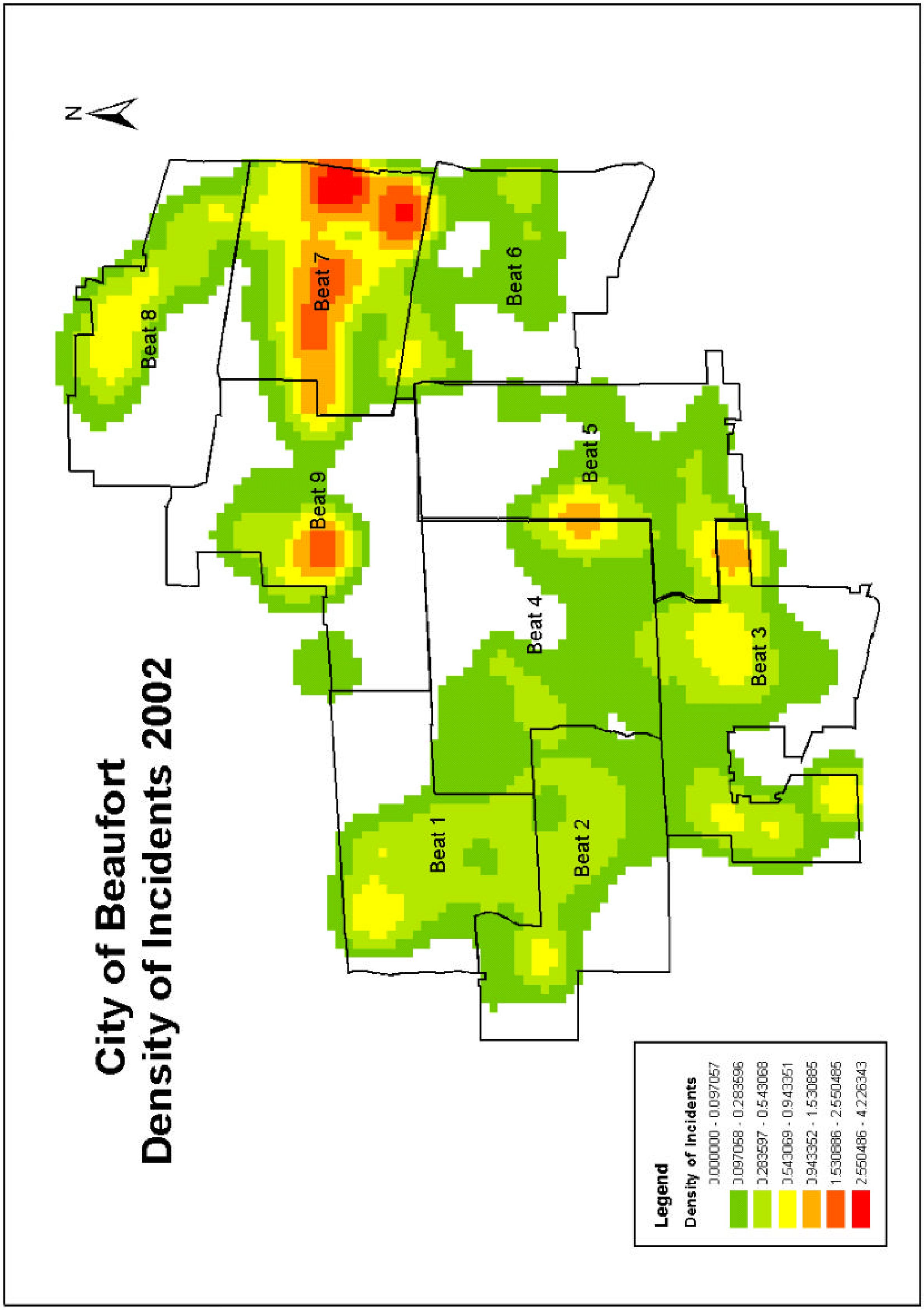
Legend

- Top 10 Hot Spots
- Repeat Address Ho: Spots
- Police Beats

City of Beaufort, Crime Analysis Unit

Date: December 03, 2002


City of Beaufort STAC Hot Spots 2002
(8 More Retail Developments Open in Beat 7)
STAC* Hot Spot Summary
Five Hot Spot Areas present
* STAC Hot Spot defined
with a minimum of 50 incidents
N
Beat 8
Beat 9
Beat 7
Beaufort Mall
Streets of Beaufort
Theater
Beat 1
Beat 4
Beat 6
Beat 2
Beat 5
Beat 3
Legend
Retail Sites_Opening 2002
Retail Sites_Opening 2001
Retail Sites_Pre-2001
Police Beats
0 0.5 1 2 Miles
City of Beaufort, Crime Analysis Unit
Date: December 03, 2002



Date: December 03, 2002

City of Beaufort, Crime Analysis Unit

Beaufort Police Department
Internal Memorandum

To: All Patrol Supervisors
From: Officer William Dover, Crime Analyst
Re: Directed Patrol Plan

SCOPE OF PROBLEM
Eight vehicle burglaries occurred over a three-week time span between November 9-30, 2002 in a residential area centered in the eastern portion of Beat 2, including one incident in Beat 1. The crime analysis unit has determined that these vehicle burglaries constitute the same offender or offenders. In an effort to apprehend these individual(s), we are calling for patrols that are specifically focused on the data contained within this memorandum.

ENTRY METHOD
Entries were gained by smashing the front passenger window or opening unsecured vehicles. In one case, an unknown/stealth method was used.

TYPE OF TARGETS
Property taken includes stereos, CD players and car radios. In one case, an attempt was made but nothing was taken. There was no apparent preference in makes and models as a variety of different vehicles have been hit although older vehicles without security devices seem to be preferred.

BURGLARY TOOLS
A pry tool was used to remove the equipment from the vehicles. It is suspected that the tool of choice is a Stanley Wonder Bar. A chip from one was taken into evidence on 11/30.

SUSPECT
One witness reported an apparent male suspect of average height fleeing the scene wearing a dark, waist-length outer coat, a hooded sweatshirt underneath, and carrying a backpack. No other identifying information was given. No other physical or forensic evidence found, other than piece of burglary tool.

DATES
The date range is 11/09/2002 through 11/30/2002. The minimum number of days between hits (DBH) is one, and the maximum DBH is five. The mean (average) is 3.0. **More incidents are likely before 12/05, very likely before 12/06, and extremely likely before 12/08.**

DAYS OF THE WEEK
Figure 2 shows the days of the week the incidents occurred (using the first day for incidents that occurred in an overnight time range). These are likely days they will continue to occur. There is a **63% peak on Friday-Saturday and a 25% peak on Wednesday.**

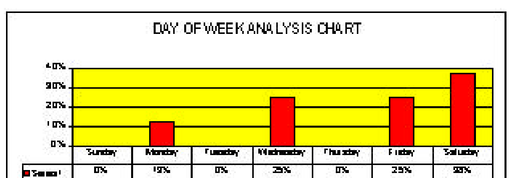


Figure 2: Hour of the day percentage

Page 1

TIMES
The full possible time range is 1800-1000 hours. Figure 1 shows when the incidents occurred within each hour of the day. It is therefore likely they will continue to occur in those hours. **The most significant peak is 1900-2400 at 65%, with 2200-2300 at 22%.**

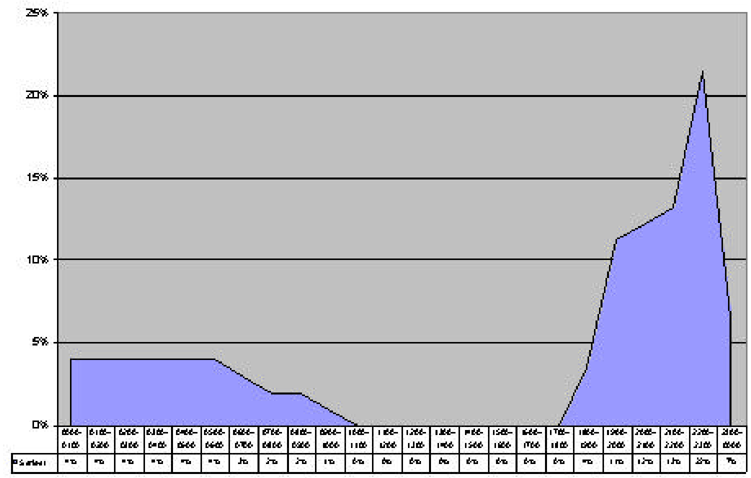


Figure 1: Hour of day percentages

LOCATION
Two methods were used to analyze location. The first is a self-developed method called Standard Distance Around Mean Center Point (STAMP). The second used the Standard Deviational Ellipse function available in CrimeStat 2.0. Figure 3 is a map showing the related vehicle burglary incidents. The three concentric rings are the STAMP results, which indicate the **chance of further incidents within the yellow zone is high; within the yellow and orange zones is very high; and within the yellow, orange, and red zones is extremely high.** The ellipse (oval) shows the results of CrimeStat 2.0. It indicates the **chance of further incidents within the ellipse is high.** Special attention should be directed to the areas covered by both results. Also, it has been theorized that criminals act in an area they frequent for other reasons (such as a residence, school, job site, or socializing) so **it is likely the offenders will be found within these same areas.**

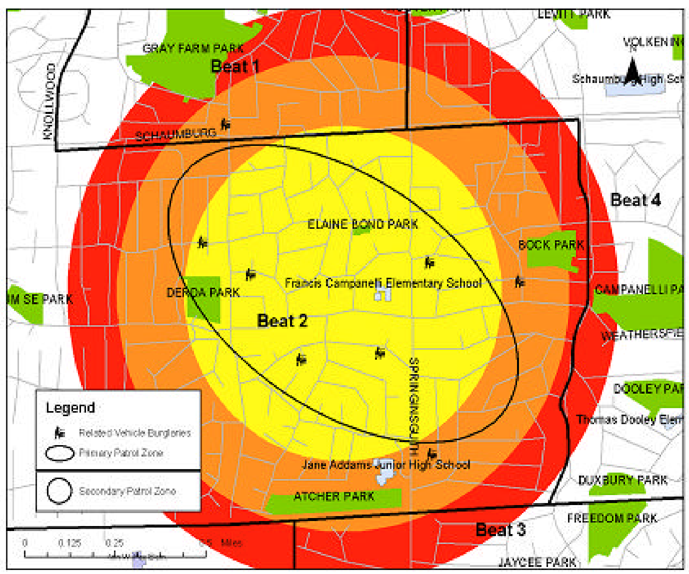


Figure 3: Spatial Analysis Results

Page 2

EFFECTIVE DATE: 12/03/2002

INTELLIGENCE BULLETIN

MAY CONTAIN CONFIDENTIAL JUVENILE INFORMATION

Beaufort Police Department

INTELLIGENCE BULLETIN

CAMPANELLI ELEMENTARY SCHOOL AREA

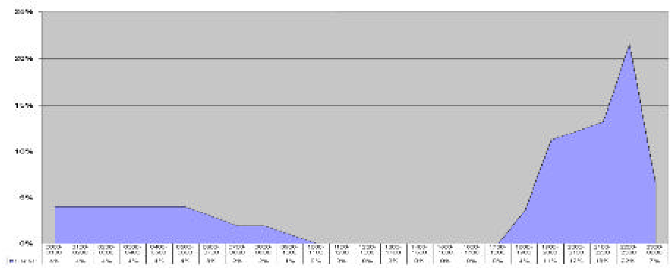
There have been eight vehicle burglaries at single-family residences in the eastern sector of Beat 2, centered on Campanelli Elementary School. Burglaries occurred on Saturdays (38%), Fridays (25%), Wednesdays (25%), and Mondays (13%) from November 09-30, 2002. The method of entry was smashed passenger windows (5 cases), unsecured vehicles (2 cases), and unknown/stealth (1 case). Property stolen included car stereos, CD players, and digital car radios being pried out. Predictions for dates, times, and locations are below:

DATES

High probability before December 05.

Very high probability before December 06.

Highest probability before December 08.



TIMES (See Chart)

Full time range is 1800-1000.

22% peak 2200-2300.

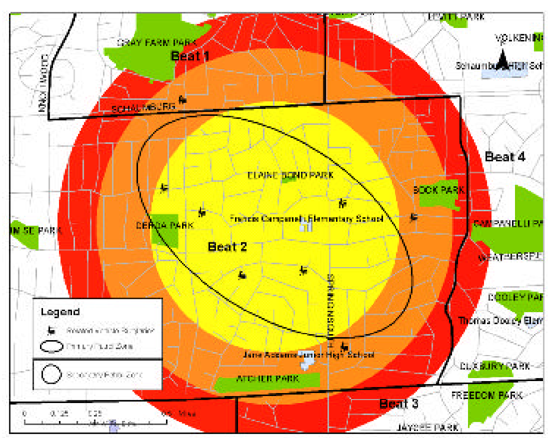
65% peak 1900-2400.

LOCATIONS (See Map)

High probability in yellow zone and ellipse (oval).

Very high probability in yellow and orange zones.

Highest probability in yellow, orange, and red zones.



OFFENDER INFORMATION

The offender is likely male, average height, on foot, carrying a backpack, and living within the zones on the map.

Beaufort Police Department

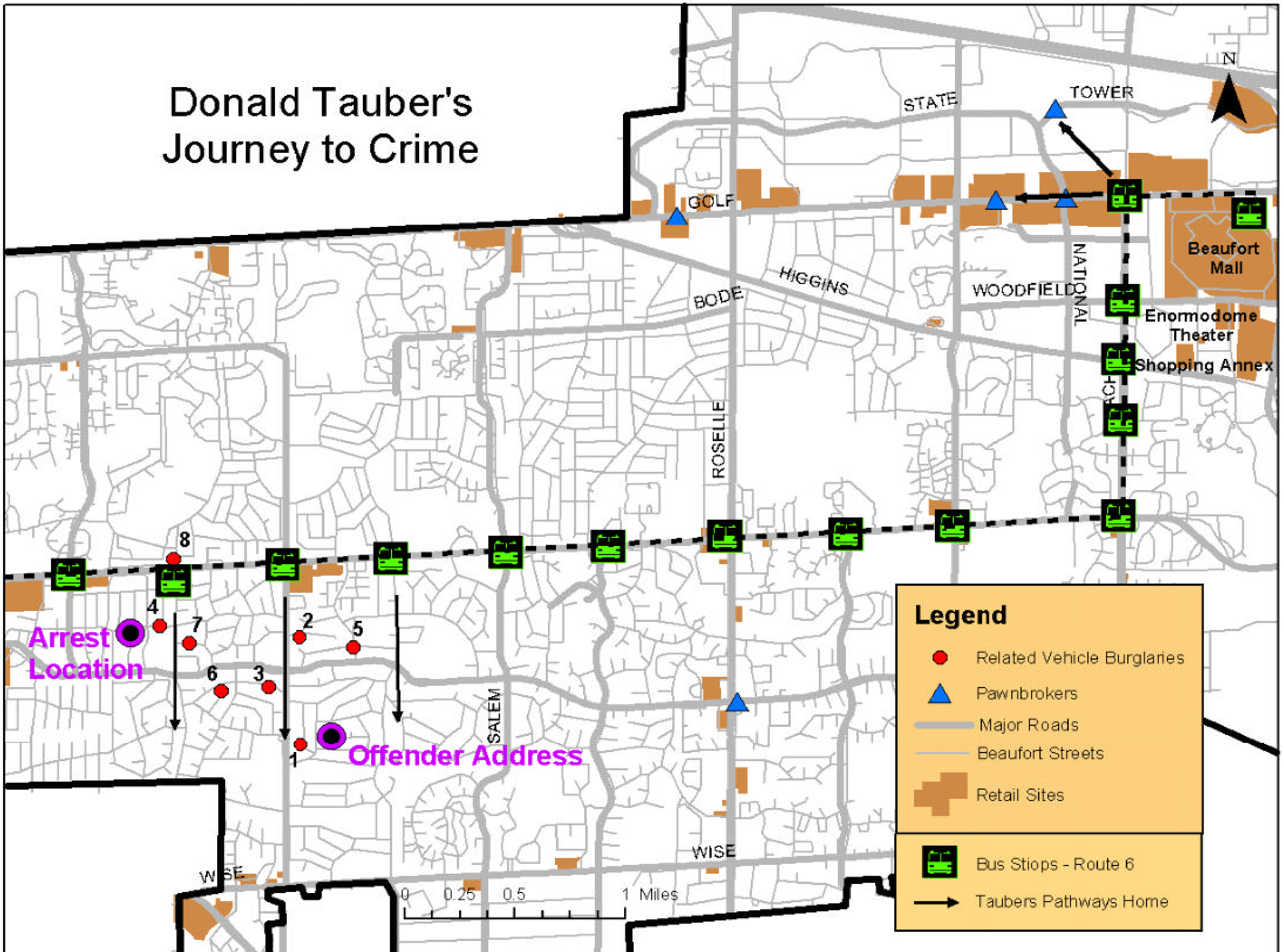
Joseph Meer, Chief of Police

65 Central Avenue, Beaufort, Illinois 60555

Phone: 878-555-8720 Fax: 878-555-8721

Bulletin #: 02-12-001

Prepared by: Officer William Dover 878-555-8735 wdover@beaufort.ci.il.us


Donald Tauber's
Journey to Crime
Arrest Location
Offender Address
1
2
3
4
5
6
7
8
GOLF
STATE
TOWER
HIGGINS
BODE
WOODFIELD
NATIONAL
ROSELLE
SALEM
WISE
Beaufort Mall
Enormodome Theater
Shopping Annex
N
0
0.25
0.5
1 Miles
Legend
Related Vehicle Burglaries
Pawnbrokers
Major Roads
Beaufort Streets
Retail Sites
Bus Stiops - Route 6
Taubers Pathways Home

Key Terms

Activity Space – The area in which the offender customarily moves about and that is familiar to him or her (Brantingham and Brantingham, 1984**).**

Address Geocoding (see geocoding)

Alias – In database management systems and on computer networks, an alternative name for someone or something.

Attribute Table – A table containing descriptive attributes for a set of geographic features, usually arranged so that each row represents a feature and each column represents one attribute. Each cell in a column stores the value of that column's attribute for that row's feature.

Attribute – Information about a geographic feature in a GIS, generally stored in a table and linked to the feature by a unique identifier.

Batch Matching – Initial attempt at automatic geocoding of street addresses. This process is a one-time affair. Then, it becomes necessary to deal with the "misses."

Buffer – A type of proximity analysis where areas or zones of a given distance are generated around selected map objects. Buffers are user-defined or can be generated for a set of objects based on those objects' attribute values. The resulting buffer zones form region objects representing the area that is within the specified buffer distance from the object.

Cartography – The science of map-making. In GIS it is also the graphic presentation and visual interpretation of data.

Centerlines – A line digitized along the center of a linear geographic feature, such as a street, that at a larger scale would be represented by a polygon. A TIGER file is generally referred to as a street centerline file (see TIGER).

Choropleth Map – Map that shows discrete distributions for particular areas such as beats, precincts, districts, counties, or census tracts.

Classification – Grouping items into categories.

Cluster – A pattern in which points are clumped together with substantial empty areas.

Concatenate – To join two or more character strings together, end-to-end. For example to combine the strings "123", "S.", "Main", and "St" into the single string "123 S. Main St.". Address strings have to be concatenated before geocoding.

Confidence Interval – A range of values constructed around a point estimate (usually the mean) that makes it possible to state that an interval contains the desired value between the upper and lower limits.

Coordinate System – (1) Provide the x-y reference system to describe locations in two-dimensional space. Latitude-longitude is a universal coordinate system but as long as determining x and y is consistent and from a fixed point (s), any system will work. (2) In cartography, coordinate systems are closely related to projections. You create a coordinate system by supplying values for the parameters of a projection.

Crime Analysts of Illinois Association – Organization to enhance effectiveness and overall knowledge in the fields of crime and intelligence analysis. It provides practical educational opportunities and training to create a network for the standardization of analytical techniques—through which to bring a more safe and effective community.

Crime Displacement – Crime displacement can take many forms. Temporal displacement occurs when a criminal substitutes another time of the day, week, or season to victimize the same site or area. Tactical displacement occurs when the criminal substitutes different modus operandi. Target displacement occurs when the criminal searches for an easier target in the same area. Displacement by type of crime occurs when the criminal substitutes a different type of crime instead of a crime targeted by a crack-down or community intervention. Spatial displacement occurs when a criminal searches for a new area or region in which to operate.

Crime Pattern – The occurrence of similar offenses in a defined geographic area.

Crime Pattern Summary – Detailed information taken from incident reports, the information matrix, and the analysis phase about a specific crime pattern. Used to develop a directed patrol plan. It includes information on the nature of the problem, suspect descriptions, property information, modus operandi information, and eyewitness statements. It also includes information related to the dates, times, and locations of past incidents, in addition to forecasted dates, times, and locations.

Crime Series – A crime pattern committed by a single person or set of persons.

CrimeStat – A stand-alone spatial statistics program for the analysis of crime incident locations that can interface with most Windows-based desktop GIS programs. The purpose is to provide supplemental statistical tools as an extension to GIS-based software to aid law enforcement agencies and criminal justice researchers in their crime mapping efforts.

Date Prediction Analysis – The forecasted date of a future crime based on when the past crimes occurred.

Equal Count (Quantile) Classification – Each group contains the same number of members.

Equal Interval (Equal Range) Classification – Divides the range of attribute values of a set of geographical features by the number of classes. Classes break at equal intervals, regardless of how many members they contain.

Error Mapping – Comparing the random distribution of matched cases to unmatched cases for the purpose of determining if there are systematic errors by location.

Error Rate – Taken from a random sample of geocoded addresses, it is the percentage of addresses "grossly" mis-located by the GIS program.

Federal Geographic Data Committee (FGDC) – Developed metadata standards. Coordinates development of the National Spatial Data Infrastructure (NSDI).

Forecasting – A statistical analysis method that attempts to predict the next crime instance in a crime series or pattern for the purpose of police interception.

GeoArchive – An information foundation for community policing: a GIS that contains address-based data from law enforcement and community sources and is set up so that it can be updated, maintained, mapped and analyzed at the neighborhood level.

Geocoding (geocode) – (1) The assignment of x- and y- coordinates, to tabular data such as street addresses, so that they can be displayed as points on a map; (2) the x- and y-coordinates that correspond to a given address; (3) the assignment of an event, incident or map feature to an area, such as a census tract or a police department.

Geoprocessing – GIS operations such as geographic feature overlay, coverage selection and analysis, topology processing, and data conversion.

Geographic Information Systems (GIS) – An organized collection of computer hardware and software designed to efficiently create, manipulate, analyze, and display all types of geographically or spatially referenced data. A GIS allows complex spatial operations that are difficult to do otherwise.

Global Positioning System (GPS) – A constellation of twenty-four satellites, developed by the U.S. Department of Defense, that orbit the earth at an altitude of 20,200 kilometers. These satellites transmit signals that allow a GPS receiver anywhere on earth to calculate its own location. The Global Positioning System is used in navigation, mapping, surveying, and other applications where precise positioning is necessary.

Graduated Color Map – A map that uses a range of colors to indicate a progression of numeric values. For example, differences in calls for service density could be represented by increasing the saturation of a single color.

Graduated Symbol Map – A type of thematic map that shows symbols in a variety of sizes to indicate which objects have higher or lower numerical values.

Greenwich Mean Time (GMT) – The mean solar time on the 0 degree meridian (longitude) at Greenwich, England, reckoned from midnight. Greenwich mean time is the basis for standard time worldwide.

Grid – Equally sized square cells arranged in rows and columns. Each cell contains a value for the feature it covers (see raster).

Grid Cell Analysis – A grid is superimposed over a map. Points within cells, or within a designated radius from the centers of the cells, are assigned to the cells.

Hit Rate – The percentage of all addresses that are capable of being geocoded.

Hot Spot – Is a geographic area or an address with an unusually high concentration of criminal incidents. It can consist of one place with a large number of crimes or a concentration of crimes in close proximity to each other. If high crime rates are clustered, it may indicate a hot spot (see also hot spot area).

Hot Spot Area – The hot spot area search routine in STAC searches for the densest cluster(s) of points regardless of arbitrary boundaries and defines them by a standard deviational ellipse. Hot Spot Areas turn point data into area data (see STAC, standard deviational ellipse).

Information Matrix Form – A spreadsheet form that captures data elements for each crime in a crime series or crime pattern in a uniform fashion. These data elements generally include information on the offense, the suspect, the victim, and the property/crime scene.

Inset Map – A small map set within a larger map. An inset map might show an area that does not fit neatly into the main map, or a detail of part of the map at a larger scale, or the context of the area covered by the map at a smaller scale.

Intelligence Bulletin – A document describing a crime or crime series in terms of the scope of the problem, modus operandi, and temporal (time) and spatial aspects. It may also offer forecasted dates, days, times, and locations likely for further incidents; possible offender location; behavioral analysis; and other solutions or suggested investigative actions.

Journey-to-Crime Estimate – Aimed at estimating the distance that serial offenders will travel to commit a crime, and by implication, the likely location from which they started their trip. It is essentially a statistical approach to estimating the residential whereabouts of an offender given a pattern of related offenses.

Kernel Density Estimate – A single-variable kernel density estimation routine for producing a surface or contour estimate of the density of incidents (e.g., burglaries) and a dual-variable kernel density estimation routine for comparing the density of incidents to the density of an underlying baseline (e.g., burglaries relative to the number of households). This technique is available in CrimeStat.

Label – Text placed next to a feature on a map to describe or identify it.

Land Parcel – An area of land for which rights of ownership and use can be bought.

Land Use – The classification of land according to how it is used; for example, agricultural, industrial, residential, urban, rural, or commercial. Natural features of the land such as forest, pastureland, brushland, and bodies of water are also often classified in this manner.

Latitude-Longitude – The most commonly used spherical reference system for locating positions on the earth. Latitude and latitude are angles measured from the equator and the prime meridian to locations on the earth's surface. Latitude measures angles in a north-south direction; longitude measures angles in the east-west direction.

Layer – Basic building block of maps. A map typically consists of several superimposed layers (e.g., a layer of street data superimposed over a layer of police beat boundaries). When a table appears in a window, it occupies a layer in that window. Typically, each map layer corresponds to one open table.

Legend – The reference area on a map that lists and explains the colors, symbols, line patterns, shadings, and annotation use on the map, and often includes the map's scale, origin, and projection.

Line – A shape having length and direction but no area, connecting at least two x,y coordinates.

Map Projection – A mathematical model that transforms the locations of features on the earth's surface to locations on a two-dimensional surface, such as a paper map. Since a map is an attempt to represent a spherical object (the earth) on a flat surface, all projections have some degree of distortion. A map projection can preserve area, distance, shape or direction but only a globe can preserve all of these attributes.

Map Template – A generic map document used to arrange the appropriate map design elements, such as the map, legend, scale bar, north arrow, etc.

Match Score – The score derived from matches on each component of the address. If all components of an address are correct – street name, direction, street type – the address will receive a perfect score.

Mean – The arithmetic average of a set of data in which the values of all observations are added together and divided by the number of observations.

Mean Center – The point representing the center of spatial distribution. It is analogous to the mean of a set of data, and is calculated in a very similar way. It is calculated by summing the x- and y-coordinates individually and dividing by the total number of points.

Mean Distance – The average distance between the mean center and a set of points.

Median – The outcome that divides an ordered distribution of data exactly into halves.

Metadata – Information about a data set. Metadata for geographical data may include the source of the data; its creation date and format; its projection, scale, resolution, and accuracy; and its reliability with regard to some standard (see Federal Geographic Data Committee).

Minimum Match Score – When geocoding, the lowest user-defined score with which an address will be considered a match. For example, with a minimum match score of 80, only those addresses matched equal to above that score will be geocoded.

Minimum Plotting Density (MPD) – Minimum number of events (e.g., incidents) at a place that the analyst needs to find to consider a place a hot spot.

Mode – The single category among all categories in a distribution with the largest number or highest percentage of observations.

Multivariate Map – Map showing more than one variable at a time.

Natural Breaks Classification – A data classification method that uses a statistical formula called Jenk's optimization to find patterns in the data by minimizing the sum of the variance within each class.

Neatline – A border drawn around a map to enclose the legend, scale, title, geographic features, and any other information pertinent to the map.

North Arrow – A map symbol that points north, thereby showing how the map is oriented.

Orthophoto (also digital orthophoto**)** – A perspective aerial photograph from which distortions owing to camera tilt and ground relief have been removed. An orthophotograph has the same scale throughout and can be used as a map.

Percent Change – An arithmetic method of determining how much change has occurred between two numbers over time.

Percent of Total – An arithmetic method determining the proportion of a total.

Plotter – A device that draws an image onto paper or transparencies, either with colored pens or by drawing an image of electrostatically charged dots and fusing it onto the paper with toner. A flatbed plotter holds the paper still and draws along its x- and y-axes, a drum plotter draws along one axis and rolls the paper over a cylinder along the other axis, and a pinch roller draws along one axis and moves the paper back and forth on the other axis over small rollers.

Point – A map object defined by a single x-y coordinate pair.

Random Sample – A method in which the choice of individuals for inclusion in the sample is left entirely to chance.

Raster – A type of computerized picture consisting of row after row of tiny dots. Raster images are sometimes known as bitmaps. Aerial photographs and satellite imagery are common types of raster data found in a GIS.

Rates Per Population – An arithmetic method of standardizing different values by a common population for analysis and comparison.

Regional Crime Analysis – The sharing and integration of data and information among police departments to prevent crime occurring across jurisdictional boundaries.

Repeat Address Mapping (RAM) – A method developed Eck, Gersh, and Taylor (1997) aimed at identifying the places in a data set that account for the highest proportion of crime and then plotting only those incidents on a map. The authors suggest beginning with the top 10 percent of places as a "convenient number." The goal is to determine the *minimum plotting density* (MPD), defined as the minimum number of events (e.g., incidents) at a place that the analyst needs to find to consider a place a hot spot. For example, if the MPD were five incidents, then only those places with five incidents or more would be plotted on the map.

Repeat Address Hot Spot – A place with at least two crimes, and consistently containing more crimes relative to other places.

Routine Activity Theory – Suggests that crime opportunities appear in the activities of everyday life. The routine patterns of work, shopping, socializing, and leisure affect the convergence in time and place of would-be offenders, suitable targets, and the absence of guardians. Many crimes occur while an offender is traveling from one activity to another.

Scale – The ratio or relationship between a distance or area on a map and the corresponding distance or area on the ground.

Scale Bar – A map element that graphically depicts the map scale (e.g., 0—1—2 miles).

Single Symbol Map – Map showing all points with the same symbol, both in color and size.

Spatial and Temporal Analysis of Crime (STAC) – Spatial statistic used for analyzing the distribution of events on a map. Hot spot areas are represented by an ellipse. STAC was developed by the Illinois Criminal Justice Information Authority and is available in CrimeStat.

Spatial Displacement – Occurs when a criminal searches for a new area or region in which to operate.

Spatial Forecasting – An analysis technique which results in a forecasted location of a future crime based on either the similarity of crimes or the occurrence of multiple crimes in a defined geographic area.

Spatial Intelligence Gathering (SIG) – The process of mapping and evaluating available spatial data to determine the potential usefulness for analyzing a given crime problem.

Spatial Query – Selecting geographic features by where they are in relation to each other. For example, features can be selected if they fall inside, are adjacent to, or lie within a specified distance of other features.

Standard Deviation – The spread or dispersion of a set of scores around some central value, generally the mean. The standard deviation is used to determine the normal limits around the mean and is useful in performing forecasting and prediction analysis.

Standard Deviational Ellipse – By rotating the original reference axes (from which the measurements for mean center and standard distance were made), an ellipse whose major and minor axes are drawn to represent the magnitude of the minimum and maximum dispersion of a set of points from the mean center.

Standard Distance (see standard distance deviation)

Standard Distance Around Mean Center Point (STAMP) – A method of analyzing mapped crime locations to determine a geographical mean center point, then plotting three buffers (circles) around this point, representing an increasing likelihood of areas for further crimes and offender location.

Standard Distance Deviation – The spatial equivalent of standard deviation. It provides the most concise description of the spread of points around the mean center.

State Plane Coordinate System – A group of planar coordinate systems that divides the United States into more than 130 zones by superimposing a rectangular grid over the latitude/longitude graticule. Each zone has its own map projection and parameters. In effect, this system assumes that the individual states are flat, so they can be described by plane geometry rather than a spherical grid.

Symbol – A small, relatively simple shape (e.g., square, circle, star, push-pin) used to graphically represent a point object (e.g., a residential burglary)

Tabular Query – Selecting items in a table based on descriptive information, such as date and time of occurrence of a crime.

TIGER (Topologically Integrated Geographic Encoding and Referencing) – Digitized street map data created by the U.S. Census Bureau for the 1990 Census, for all the streets in every county in the United States.

Time Prediction Analysis – The forecasted time of a future crime based on the temporal patterning of past crimes.

Unique Values Map – Features are drawn based on the qualitative characteristic of an attribute.

Universal Transverse Mercator (UTM) – A commonly used projected coordinate system that divides the globe into sixty zones.

Variance – The total amount of disagreement between numbers, calculated as the mean of the squares of the deviations from the mean value of a range of data.

Vector – A data structure used to represent linear geographic features. Features are made of ordered lists of x-y coordinates and represented by points, lines, or polygons; points connect to become lines, and lines connect to become polygons. Attributes are associated with each feature (as opposed to a raster data structure, which associates attributes with grid cells).

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