GIS Litigation Support Applications in the Courtroom

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ABSTRACT

GIS as a technology has proven to have many different applications in various fields of study. One tangible application of GIS is in the courtroom, as support in either the defense or prosecution of parties under the law. Two case studies in this paper will be examined to demonstrate the applicability of GIS applications as litigation support. One study focuses on the use of three-dimensional GIS tools to quantify illegal dumping amounts on a property and prosecuting the responsible offending party. The second case study shows an approach to integrating a soil erosion and transport model into GIS to assist in the defense of a county government from a litigation suit filed by residents impacted by excessive sedimentation.

Development of GIS tools for litigation support, as examined in this study, display how GIS technology can be successfully implemented to assist parties in litigation, ultimately enabling them to determine the truth.

INTRODUCTION

With the advent of newer GIS technologies, tools have been developed to help model and quantify changes in the environment. These changes, when quantified, can be very powerful evidence in a court of law. In this paper two cases are examined in this paper that employed GIS technology to quantify environmental impacts to assist in identifying responsible parties, and in effect allocate responsibility.

The first case involved a county government that was alleged by a group of residents to have caused adverse impacts to surface water due to land disturbing activities. Residents claimed the County was the primary source of excessive sedimentation in trout streams and lakes located on and near their properties, and demanded that the County fix the problem to restore natural conditions. In this case study, GIS techniques in conjunction with satellite imagery and aerial photography were applied to determine the County’s relative contribution to sedimentation in a small North Georgia watershed.

The second case involved a small business owner that was charged by a real estate company for illegal waste disposal on their undeveloped property. Brown and Caldwell provided litigation support to the real estate company and used GIS methods to substantiate criminal charges against the small business owner, and further to file suit against the waste owners to recoup the cost of cleanup.

A CASE OF DEFENSE: GIS USED TO IDENTIFY SEDIMENT SOURCES IN THE BLUE RIDGE MOUNTAINS

Introduction

Residential growth in the North Georgia Mountains and throughout the remainder of the Blue Ridge Mountains region of the Southeast during the past decade has brought with it an increase in

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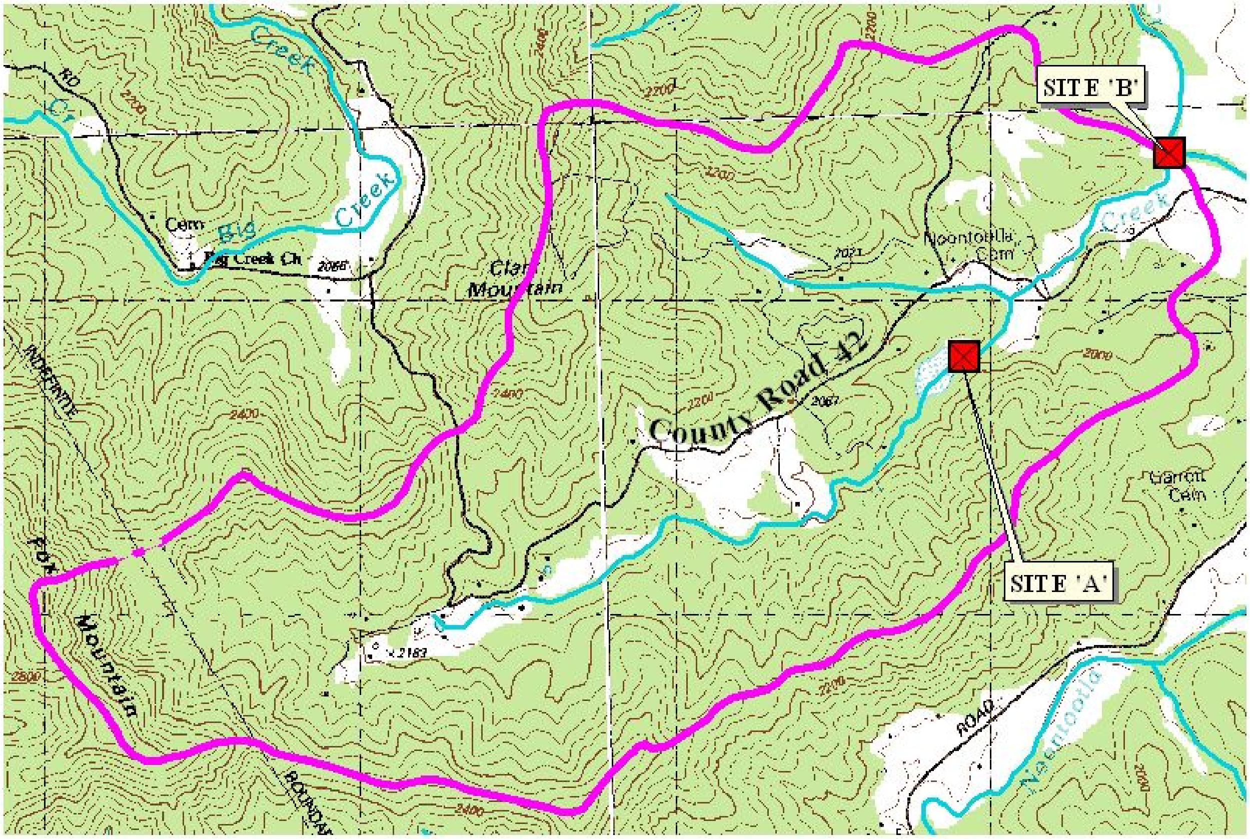
awareness of environmental issues for the long-time residents. In some areas, the impact of development has inspired residents to initiate various preservation efforts to reduce sediment loading to local streams. The challenge in taking action to reduce impacts on the streams is to properly identify the sediment sources and accurately assess their contributions to sedimentation so that necessary preventative measures can be implemented.

The study area in question was a small, narrow watershed located in the North Georgia Blue Ridge Mountains (Figure 1.). Prior to 2000, all of the roads in the watershed were gravel, including the county road (CR 42) that runs through the watershed. The County began widening and paving CR 42 in the summer of 1999; at the same time additional land disturbance activities conducted by others began to occur. Shortly thereafter residents began to observe sediment accumulation in the stream and in a privately owned impoundment. The residents filed suit against the County, claiming that it was the CR 42 road work that induced this problem, which continued into the summer of 2002.

In concert with the County’s legal counsel, Brown and Caldwell used GIS tools to examine historic sources of sediment and their rate of transport to and sedimentation in streams during the period in question. The objective was to demonstrate that the County was in fact a de minimus contributor to the overall sedimentation and that the resident group’s lawsuit was misdirected.

Figure 1. Study Watershed Map



The RUSLE Model: Input Derivation

The Revised Universal Soil Loss Equation (RUSLE) was integrated into ArcView GIS to model the sediment production in the study area. The RUSLE was then further integrated into a surface flow model using Spatial Analyst techniques to model the delivery of the eroded sediments to the stream. The RUSLE was chosen for this study because of its general acceptance in the hydrologic scientific world, and its ease of use. The RUSLE estimates soil erosion by assigning values to six different factors which influence soil erosion in the environment. The Equation can be calculated as follows:

$A = RKLSCP$ where:

A is the estimated tons of soil loss expressed in tons/acre/year
R is the Rainfall Erosivity Factor
K is the Soil Erodibility Factor
L is the Slope Length Factor
S is the Slope Steepness Factor
C is the Cover-Management Factor
P is the Support Practice Factor
(Renard et al., 1997)

The K and R Factors are dimensional and expressed in terms of tons/acre/year. The L,S,C, and P factors are dimensionless. The output of the model, the A, can be mapped using GIS. Different conditions in the same study area can easily be modeled using GIS by altering the input factors to reflect existing conditions.

The input factors for the RUSLE model for the study watershed were represented in GIS using grid themes. The original Digital Elevation Models (DEMs) were represented by a continuous Surface of 30 meter grid cells, resized to 10 meter grid cells to better represent the areas of interest in the study watershed. All of the factor layers were represented in 10 meter grids, and all model runs were calculated using these input grids.

In order to save time and effort calculating the R factor using the RUSLE's complicated equation, the R factor was interpolated from a map supplied by the U.S. Department of Agriculture (USDA) RUSLE guidelines document (Renard et al. 1997). The interpolated R factor value was determined to be 260 tons/acre/year. This value was applied uniformly across a GIS grid of 10 meter grid cells.

The soil erodibility factor (K) was derived from the Natural Resources Conservation Service (NRCS) soil survey for this study area. Within the Soil Survey, the K Factor is provided for each soil type based upon depth of the soil. For the purposes of this study, the K factor value for topmost layer of each soil type was used. The soil map of the study watershed was digitized, and corresponding K factor values were assigned and then converted to a 10 meter grid cell layer.

The slope length (L) and slope steepness (S) factors represent the effect of topography on erosion. Usually when used in the RUSLE the L and S factors are combined for ease in calculation. This combined factor is termed the LS, or Slope length/gradient factor. The LS factor was represented in this study using the outputs from a series of GIS scripts authored by Hickey et al.(1994) and modified by Van Remortel and Hamilton (2002). This series of scripts, when run, calculates the LS factors based upon the source elevation grid, and applies the LS factor value to an output 10 meter grid cell grid for use in the RUSLE model.

The cover-management (C) factor is the factor which was most readily changed to represent the different areas of land cover disturbances in the study watershed. A total of nine different dates of satellite imagery and aerial photography were acquired in order to derive the C Factor layer for each different model run corresponding to a different date. The information on the imagery used in this study can be seen in Table 1. A C factor value corresponding to specific land use/land cover types was then assigned to each land use type for each date and then the layers were converted into a series of nine grids, each corresponding to a specific date. This methodology allows the RUSLE model to output different numbers from different dates, and any disturbances in the watershed can be seen to affect the output of the GIS RUSLE model.

Table 1. Digital Imagery Information Table, Study Watershed

Image Date	Image Type	Image Band	Image Source	Image Resolution
January, 1994	Aerial Photograph	Visible	Georgia GIS Clearinghouse	1 meter
November 26, 1998	Satellite Image	Panchromatic	SPOT Image Corp.	10 meter
September 10, 1999	Satellite Image	MultiSpectral	LANDSAT (NASA)	15 meter
April 7, 2000	Satellite Image	Panchromatic	SPOT Image Corp.	10 meter
July 10, 2000	Satellite Image	MultiSpectral	LANDSAT (NASA)	15 meter
March 27, 2001	Satellite Image	Panchromatic	SPOT Image Corp.	10 meter
August 14, 2001	Satellite Image	MultiSpectral	LANDSAT (NASA)	15 meter
March 10, 2002	Satellite Image	MultiSpectral	LANDSAT (NASA)	15 meter
August 1, 2002	Satellite Image	MultiSpectral	LANDSAT (NASA)	15 meter
April 14, 2003	Satellite Image	MultiSpectral	LANDSAT (NASA)	15 meter

The study watershed was identified as having six major land use types: forest, pasture, residential, clear cut, road, and water. Each category was then assigned a C Value factor derived from various source tables in different documents related to the RUSLE. Forest C factor values were assigned the value assigned to the closed canopy forest designation in a table found in the T. Del M. Lopez et al. (1998) document. Pasture C values were derived from the same table, using the value assigned to the pasture classification. Residential C values were derived from the T. Del M. Lopez (1998) table classification of Less Dense Urban. Clear cut areas were assigned C values from the Toy and Foster (1998) Table 5-3 value for the ‘Cut – Scalped surface (some roots remain from weeds)’ classification.

The C value designation for the roads in the study watershed required a higher level of detail in representing the land cover types within the 10 meter area defined as the roadway. Within this 10 meters of roadway, it was assumed that 75% of the area would be actual road surface, and the remaining 25% would consist of a grassy shoulder (for paved and gravel road designations) and a bare soil ditch bottom running parallel to the roadway on either side. For the gravel road land cover type, the road surface was assigned a value for 90% gravel cover (Table 5-2, Toy and Foster (1998)), with the grassy shoulder assigned a C value for pasture as defined in Table 3 from T. Del M. Lopez (1998), and the ditch bottoms assigned a value for bare dirt from Table 3, T. Del M. Lopez et al. (1998). Furthermore, the C Values of the road were assigned three different values dependent upon the state of the roads at various times during the examined time period: one for gravel or unpaved, one for road under construction, and another value for paved road.

After the calculation of all the C values for the existing land covers in each of the nine different dates, they were then converted into 10 meter grid cell layers for use in the GIS model.

The P factor was used in the model to represent management practices employed in the study area during the study time frame. Specifically two different instances of sediment control practices were implemented in the study watershed. The first consisted of two sediment ponds installed by the County adjacent to CR 42 and near a tributary to the study creek, and the second consisted of a sediment pond installed on one private property intended to catch sediment from the land disturbances occurring at that site. The P factor in this model is represented as a ratio expressing the effectiveness of the management practice installed. In this case, a series of sediment ponds were installed and rated at 80% sediment removal efficiency.

Model Calculations

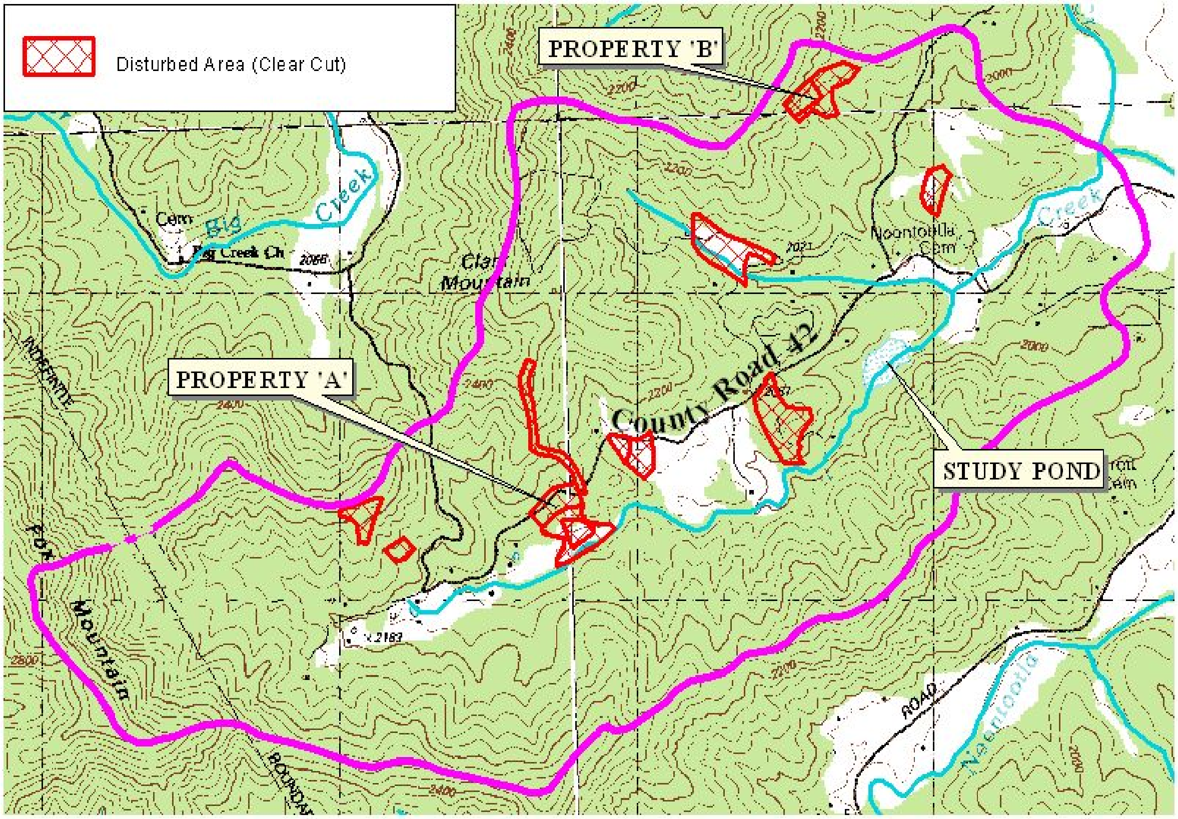
Using the grid layers representing each of the factors of the RUSLE model, the potential erosion was then calculated using ArcView 3.3 software Spatial Analyst techniques. The input layers were spatially multiplied together to result in a final output grid containing potential erosion estimates per 10 meter grid cell in the study watershed. After the output grids were created for each of the nine dates used in this study, a hydrologic modeling tool was then used in ArcView 3.3 to determine erosion accumulation patterns based on the topography of the watershed. Using the outputs from this tool, accumulated potential soil erosion estimates could be determined upstream from any point in the watershed. For purposes of this study, the potential erosion upstream from two specific locations was used: at the outfall of the pond downstream from one private property A (Figure 1, Site A), and at the mouth of the study creek (Figure 1, Site B).

The nine different dates were represented in nine different model runs to estimate the effect of various land disturbance practices and road construction activities in the Study Watershed from 1998-2003. Specifically, CR 42 was considered to be gravel prior to June 1999, being widened between June and August 1999, gravel between August 1999 and September 2000, and paved from September 2000 to the present. The road was assigned appropriate C values during the changes. All other land cover characteristics for each date were derived and represented as existing conditions using satellite imagery (Table 1). The model outputs enabled estimates of soil erosion accumulation at any point in the watershed, as well as being able to estimate erosion production potential from specific areas.

Model Results

After completing the nine different model runs representing nine different dates during the study watershed’s history, the resulting erosion accumulation estimates values were analyzed to delineate specific sediment source locations. Significant source activities were identified in the watershed during this 5-year period, including significant clear cutting, residential construction and agricultural activity changes, along with the County’s paving of CR 42. The model results show that the impact of other activities in the watershed contributed up to five times more sediment to the study stream than all County activities combined. Various areas in the watershed that were impacted during the study time period, as well as private properties (Properties A and B) of concern can be seen in Figure 2.

Figure 2. Impacted areas of study area



Erosion estimate values from the RUSLE model output were measured and spatially analyzed to get values in tons per year for specific areas in the watershed. Properties ‘A’ and ‘B’ were known to have extensive land cover modification. The estimated sediment production rate from their activities was measured versus the County’s sediment production rate from their modifications in the watershed. For the purposes of this comparison, the potential erosion upstream from ‘Site A’ and ‘Site B’ were examined.

The study found that more than 90 % of the sediment production originated from other land disturbance activities over the five year duration of the study. In examining the potential contributions of CR 42 to the sediment loading of the watershed, it was shown that CR 42 does not contribute more than 5 percent of the potential sediment contribution rate to the study pond, except for one date when it was 8 percent. Furthermore, CR 42 did not contribute more than 4 percent of the potential sediment contribution rate to the entire Study Watershed, except for one date when it was 6.3 percent.

Some private properties in the Study Watershed (Properties ‘A’ and ‘B’) were shown to have contributed extensive sedimentation to the stream during the study time period due to land cover changing activities, specifically road and vacation home construction. The model results show that the Property ‘A’ land disturbance areas contributed more than 12 percent of the potential sediment contribution rate to the Study Pond, and even exceeded 15 percent for one date. The model results also show that the Property ‘A’ land disturbance areas contributed more than 8 percent of the potential sediment contribution rate to the entire Study Watershed for three of the nine dates, and even reached 10 percent for one date. The model results show that the Property

‘B’ land disturbance area contributed almost 11 percent of the potential sediment contribution rate to the entire Study Watershed for one of the dates.
In terms of the total potential sediment estimated to be delivered to the Study Pond during the study time period for land disturbance activities, Property ‘A’ was calculated to have contributed almost 85 percent and CR 42 only contributed 10 percent. CR 42 contributed less than 7 percent of total sediment to the mouth of the watershed, while Property ‘A’ contributed 60 percent and Property ‘B’ 23 percent with the remainder coming from other land disturbances in the watershed.

Conclusion

In conclusion, the RUSLE model integrated into a GIS proved to be invaluable to the County in winning the legal defense of the lawsuit filed against them. The model results, based upon real-world data and scientifically accepted modeling techniques, allowed the County to show the plaintiffs that they were only responsible for a de minimus portion of the sediment contribution to the study stream. In fact, because the County paved CR 42, it in effect *reduced* sediment contribution from the road after the year 2000. As a result, the plaintiffs in this case dropped their suit against the County, and decided to pursue other responsible parties within their watershed.

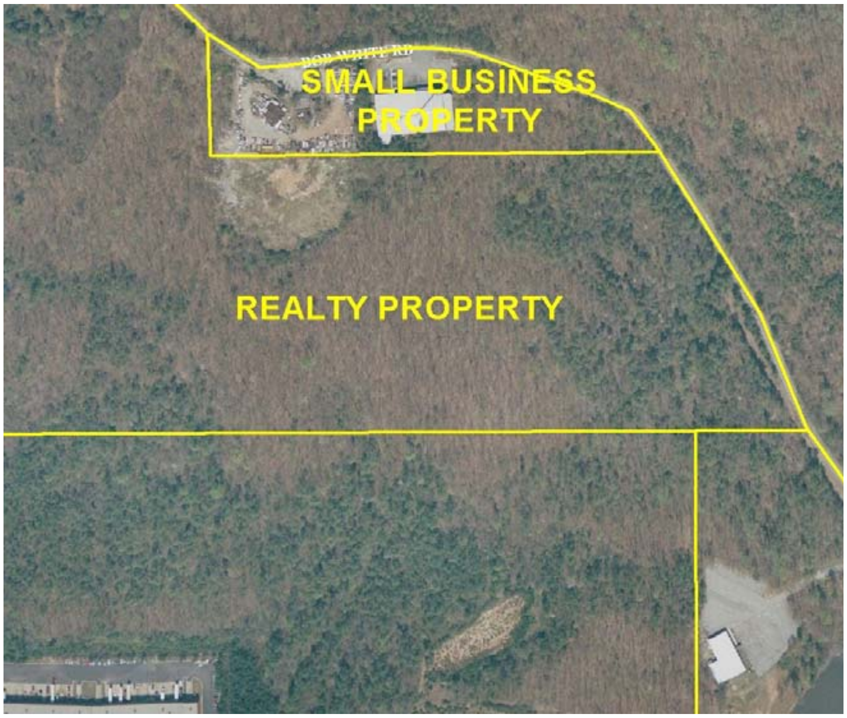
A CASE OF PROSECUTION: GIS USED TO DELINEATE ILLEGAL WASTE DISPOSAL

Introduction

In an area west of Atlanta, Georgia, a real estate property owner performed a survey of their property during 2001 in order to plan an office park development. During the survey, they noticed that one portion of the property was being used for dumping by a neighboring small business owner. The portion of the property in question was heavily wooded, so the dumping had escaped notice for several years, with some activity on the property starting as early as 1988. Approximately three acres of the study property were impacted by the neighboring small business owner, and the real estate property owner decided to pursue a combination of criminal charges against the scrap yard owner in combination with a law suit against the owners of the waste to pay for the cleanup. Figure 3 shows the study site property boundaries, with the small business property easily identified as the smaller northern ‘wedge’ of property surrounded on the south and west by the realty company property.

The determination was made by the prosecuting party at the recommendation of Brown and Caldwell, the prosecuting attorney decided to employ GIS technology and techniques to quantify any evidence that they had against the responsible party to ensure a conviction. The GIS technology proved to be powerful court room evidence as it clearly refuted the defendant’s story and helped secure a conviction. Furthermore, GIS techniques were used to calculate waste volumes in support of cost estimates for removal of the illegally dumped debris. This cost estimate was used to specify a dollar amount in the lawsuit filed against the responsible parties.

Figure 3. Realty Property Site Boundaries



Aerial Photo Interpretation

A detailed investigation of the dump site was performed by the real estate company by trying to establish the history of activities that had occurred at the site in question on their property. The investigation began by acquiring seven aerial photos in digital format from seven different years dating from 1988 (Table 2.). These photos were delivered in raw scanned digital format and using ArcInfo Registration and Transform routines, the photos were layered in the GIS.

Table 2. Digital Aerial Photography Information, Illegal Dump Site

Image Date	Image Band	Image Resolution
March, 1988	Visible, Black and White (B&W)	1 meter
April, 1990	Visible, B&W	1 meter
May, 1992	Visible, B&W	1 meter
April, 1996	Visible, B&W	1 meter
April, 1997	Visible, B&W	1 meter
October, 1998	Visible, True Color	1 meter
April, 1999	Visible, B&W	1 meter

The Aerial photos in GIS were used for various means, including putting together a visual timeline of all the events that occurred on the study property, and impacted area delineation. The aerials told a story about the history of the site starting in April of 1988. The April 1988 photograph (Figure 4) shows that the study property (the property boundary is represented by a yellow line) was cleared of trees and used to stage motor vehicles, a presumably unauthorized practice that was soon discontinued as shown in the April 1990 photograph. The green line on the April 1990 photograph (Figure 5) shows the area impacted by this activity, which was estimated to be 3 acres. The impacted area was depicted on each subsequent photograph as a means of reference. Vegetation on the property appears to continuously recover and flourish through the April 1997 photograph (Figure 6), after which time it appears as if the area was once again either cleared of vegetation or covered with fill material. The fill activity is shown in the October 1998 photograph (Figure 7) and the approximate area of impact, estimated at 2.25 acres, is outlined in red.

Figure 4. 1988 Site Activity

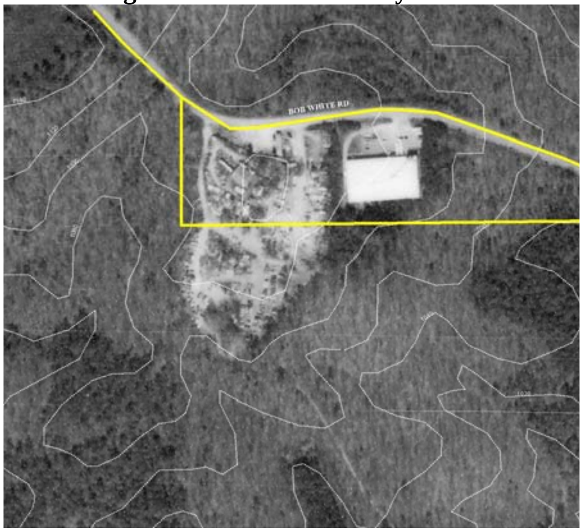


Figure 5. Lack of Activity – 1990

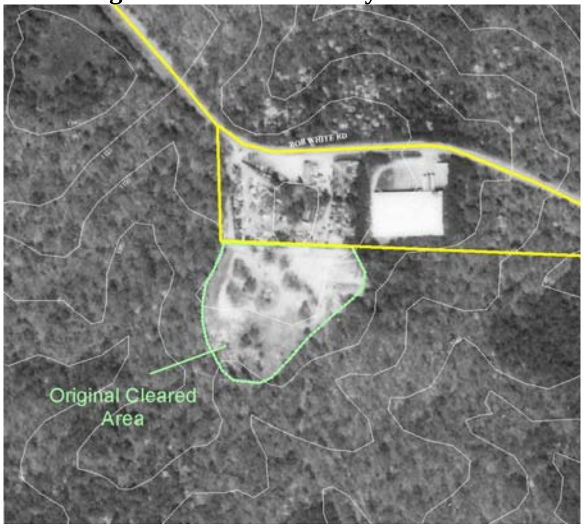
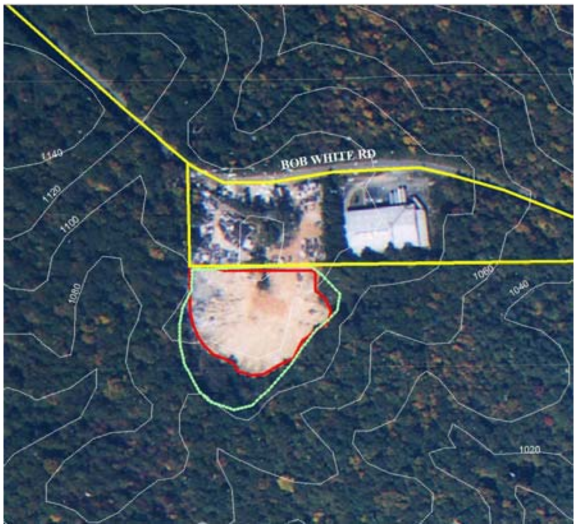


Figure 6. 1997 Site Vegetative Regrowth

Figure 7. Illegal Waste Disposal Activity, 1998



The Aerial Photo delineation alone proved to be indispensable in showing the history of what had occurred at the site. It is graphically obvious that some trespassing and illegal dumping activities had occurred on the realty company's property. These photographs were mosaicked onto a poster board for use as a visual aid in the courtroom during the criminal case against the small business owner.

Dump Site Delineation

With the history of impacts on the site already established using aerial photography interpretation techniques; the extent, volume, and depth of materials within the dump site were examined in more detail using GIS. The goal was to quantify the amount of debris that was dumped on the realty property illegally. This would be used to estimate how much to be removed and at what cost. The quantified amount of materials dumped was also used to further bolster the graphical evidence against the small business owner in court. Field verification and sampling cores were taken at the dump site to determine what types of materials were buried and at what locations for further cost estimation.

To calculate total volume of debris dumped on the realty property, a topographic differential analysis was performed using ArcView Spatial Analyst. The site was originally surveyed for elevation contours in 1990, and surveyed later in 1999. Using these two different surveyed elevations, differences in the elevations could easily be calculated in Spatial Analyst to determine total volume of debris change since 1990. Both sets of elevation contour lines were converted into 5 foot grid cell DEMs to represent each date’s elevation surface (Figures 8 and 9).

Figure 8. 1990 Elevation DEM

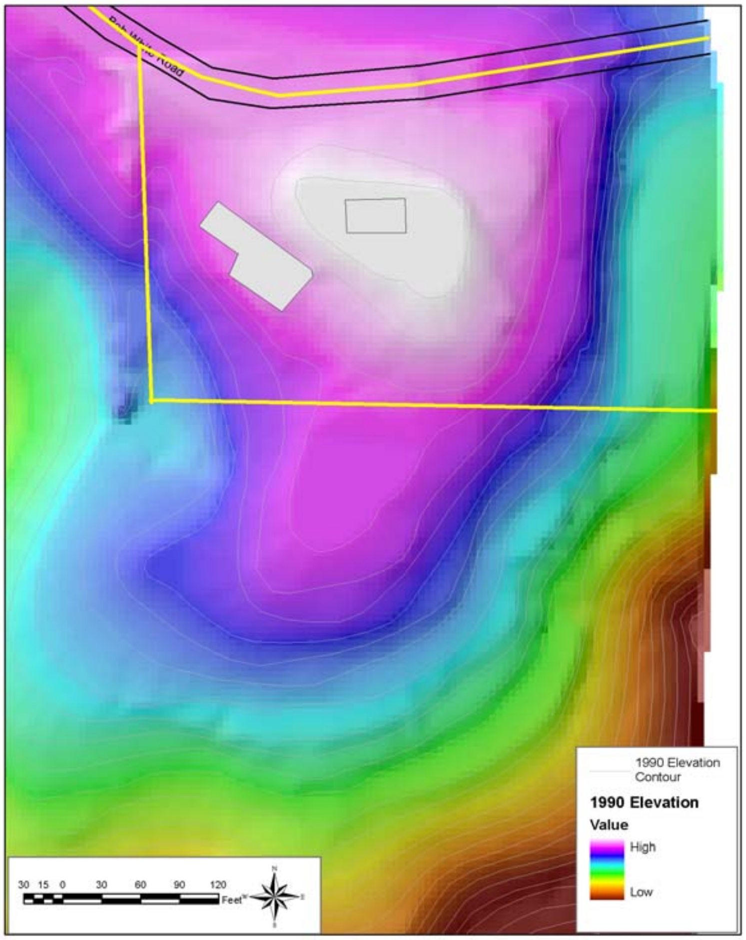
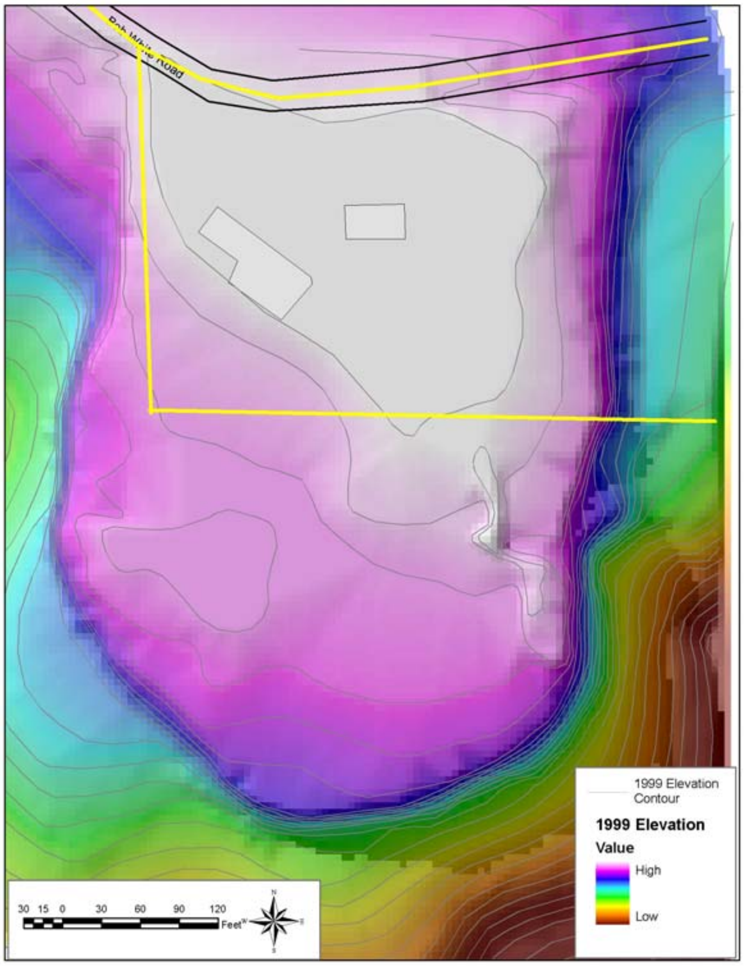


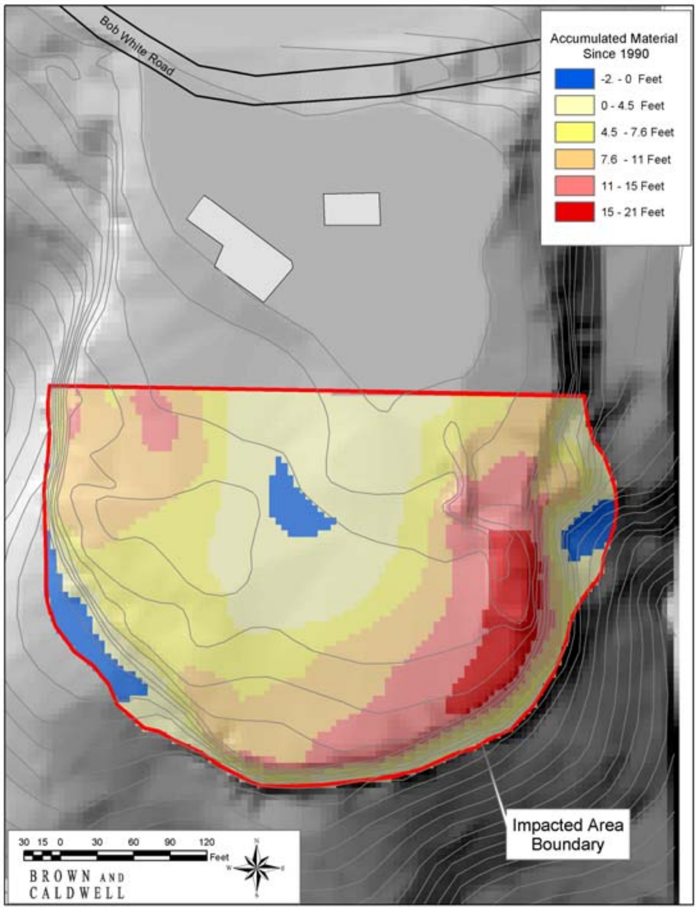
Figure 9. 1999 Elevation DEM



In order to convert the contour line features into a continuous surface, a script was run in ArcView 3.3 to convert the lines into points containing x,y, and z coordinates. These points were then converted into a continuous surface using the TOPOGRID function of ArcInfo. The1990 DEM was then spatially subtracted from the 1999 DEM using the map calculator tool of Spatial Analyst. A new grid resulted showing the difference between the two elevation surfaces: the depth grid (Figure 10). The areas of greatest filling (or depth of) with construction debris can clearly be identified by the dark red areas in Figure 10. The blue areas indicate locations where some soil erosion has occurred or some dirt may have been excavated for use to cover the waste materials.

A calculation was performed using Spatial Analyst to derive the total volume of waste and fill material within the identified impacted area on the property site. There was a total amount of approximately 34,000 cubic yards of construction materials dumped on the realty property calculated by the GIS. This amount was used to estimate total removal costs of debris from the site, and the realty company filed suit for this amount against the small business owner and all other owners of the waste.

Figure 10. Depth Grid Map



Conclusion

The use of GIS to verify the extent, volume, and duration of illegal waste disposal and trespassing provided prosecutors with invaluable evidence that helped secure both civil and criminal damages. The evidence presented during the jury trial included historical aerial photography overlayed with GIS interpretations of temporal data that revealed area and volume impacts. The GIS results showed that the small business owner did indeed trespass on the realty company's property starting in 1988, and then illegally disposed of at least 34,000 cubic yards of construction debris on the property in 1997. During the presentation of this evidence during trial, it was obvious that the GIS results had a significant impact on the outcome of the case because it represented quantifiable, concrete evidence to the jury. The visual interpretation of the aerial photos alone greatly aided in juror comprehension and understanding of information that may have been difficult to interpret. The lawsuit filed by the real estate company proved to be successful in a later series of litigations, with the cost based from GIS calculations being what was awarded.

CONCLUSION

The presented case studies in this paper highlight the applicability of GIS technology in supporting litigation in the courtroom. The visual nature of GIS proves to hold some substantial weight as evidence in court, as the maps and graphics produced exemplify the age old adage ‘a picture is worth a thousand words’. The evidence is further legitimized in the eyes of a jury and judge in the courtroom because the actual methodologies used to model and calculate the results are specifically explained as having a basis in science.

GIS is a great tool to use for litigation support, but one must be wary of the limitations in its use. As with any evidence presented in our legal system, one must ensure that the results from GIS analysis will stand up under examination in the court of law. Data and methodology validation requires that every process and data source used in the calculations of any evidence be well documented, and accuracy verified. Further, quality control must be performed on any outgoing data produced by GIS models. If documented and data checked properly, GIS applications in litigation support can make the difference in any court case.

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