

Full Length Research Paper

The use of remote sensing in the protection and management of archaeological sites: A case study of the Anastasian wall

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Approximately 30 km from the center of Istanbul, is a Byzantine or Late Roman period wall, constructed and reconstructed from approximately 500 - 600 C.E. by a variety of Byzantine emperors. The majority of the wall was constructed apparently during the reign of Anastasias (491 - 515 C.E.), hence the name 'Anastasian Wall'. It was approximately 50 km long stretching from the Black Sea to the Marmara Sea. The present wall corridor consists of earthen mounds, stone walls, towers and ancillary buildings. However, this unique cultural monument is being threatened by modern farming, road construction, increasing exurban and suburban development, mining and forestry. Although a significant portion is no longer visible, approximately 20 km is still evident-making it an impressive historic architectural structure. It is crucial that the wall is more extensively documented for future study and as a basis for more extensive protective actions (that is, creation of a national historic park.) Through the combined application of Geographic Information System (GIS), Remote Sensing and GPS, the authors were able to create a geographic database of the wall, identifying where there were: visible structures, structures beneath the surface or underwater; and areas which need further on-site investigation. The study demonstrates that spatial technologies have an integral role in the documentation of archaeological sites, greatly augmenting and in some cases surpassing traditional surveying and mapping techniques used in archeology. This paper will discuss the different methods used here to determine the location of the wall and suggest a management plan for this area.

Key words: Spatial technologies, archeology, Anastasian wall, Byzantine history geography, cultural resources management.

INTRODUCTION

The increasing interoperability and usability of spatial technologies (GIS, Remote Sensing and GPS) and the availability of moderate (30 m) and high-resolution (<1 m) images has enabled new archaeological sites to be discovered and additional findings within existing sites. With the availability of infrared bands on recent IKONOS images and infrared and thermal bands on Landsat TM images, the ability to discern archaeological sites has been greatly improved. Although the use of spatial tech-

nologies is becoming more prevalent in archaeological prospecting, many archaeologists and others who study historic sites are only now realizing the potential of spatial technologies to assist them in their research.

The use of spatial technologies is becoming an essential element in archaeological prospecting. Satellite images can be used to detect sites and then create a base map using a GIS that can be used in the field for reference (Clark et al., 1998; Aminzadeh and Samani, 2006). The use of remote sensing images and related software can allow for the ability to discern the overall patterns of the site and understand its context with the surrounding vegetation, topography and other features

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(Carla et al., 1995; Capra et al., 2002; Masini and Lasaponara, 2007). Loose soil and material that is buried beneath the surface, which is often indicative of archaeological elements can be detected using visible and infrared bands in satellite images (Ben-Dor et al., 1999; Elbaz, 1997; Ustin et al., 1999). The use of Digital Elevation Models (DEM) has proved useful in the location of archaeological sites, since these sites have a direct relationship to the topography (Carmichael, 1990; Krist and Brown, 1994; Alexakis et al., 2009). Overall, the use of spatial technologies is becoming an integral part of archeology; not only because of their spatial database function, but also due to their ability to open up new ways of analysis.

This study applied Remote Sensing, GIS and GPS technologies to study the Anastasian Wall in Thrace (Trakya), Turkey. The Anastasian Wall was constructed about 500 C.E. by a variety of Byzantine emperors. However, the majority of the wall was constructed or reconstructed apparently during the reign of Anastasias 491-515 C.E. (Williams and Friell, 1998). It was approximately 50 kilometers long, ranking it as one of the longest walls in ancient times, but is relatively unknown as compared to the Great Wall of China or Hadrian's Wall. The wall consists of earthen mounds, stone/rubble walls, towers and ancillary buildings. It is being destroyed due to farming, suburban/exurban development, mining, road building and forestry. It is crucial that the wall is further documented for future archaeological investigations and for the basis for protective measures. The study demonstrates that spatial technologies have a crucial role in the documentation of archaeological sites, greatly augmenting and in some cases surpassing traditional surveying and mapping techniques used in archeology.

This is a unique and significant historic area. There are only two only cases similar to it: Hadrian's Wall (U.K.) and The Great Wall of China. However, while China and the U.K. have protected and promoted their historic walls, the Anastasian Wall is only protected by Turkish Law as a historical monument. This is insufficient to protect it from: looting by those seeking artifacts; mining; agriculture; and housing and industrial development. By a twist of fate, a large portion of the wall has been protected by being in a military zone during the Cold War and its isolation. It has been stated by some archaeologists that it is better preserved than Hadrian's Wall in the U.K. However, the increasing development pressures may destroy the wall much more rapidly than over 1,500 years of weathering and deterioration due to vegetation. The accurate documentation is merely the first step leading to a multiple of actions leading to its protection. The Anastasian Wall has the possibility to be utilized as a tourist attraction, open air museum and a green/ recreation belt for greater Istanbul. The assembly of the necessary elements to create a planning environment that would result in the accomplishment of these goals is not an easy task requiring the cooperation of multiple actors

(private and public) across different scales for a long period of time (Healey, 2006).

BACKGROUND

History of Anastasian wall

The primary purpose of the wall, which stretched for approximately 50 km from the Black Sea to the Marmara Sea in Thrace, was for defense against invading tribes. Most sources attribute the walls to the Late Roman/Early Byzantine Emperor Anastasias who appears to have constructed or reconstructed the wall about 500 A.C.E. thus the name of Anastasian Wall. However, there is some evidence that a portion was built early by his predecessor Zeno (Williams and Friell, 1998).

Beginning at approximately 5th Century, the western portion of the Roman Empire was facing increasing pressures from hostile groups (Huns, Bulgars, Vandals, etc.) and was beginning a slow decline into what would be later called the Middle Ages or Feudal period-which was a period of almost continual warfare among a pageant of a changing group of nations. Previously, the Empire had been able to maintain a semblance of its former form by making treaties, bribery or incorporating the tribes into the Empire. The western portion of the Roman Empire by this period was significantly weakened, while the eastern portion was still prospering. The term Byzantine Empire was coined later by historians for the eastern portion of the Roman Empire. The Emperors of the eastern portion of the existing Roman Empire perceived themselves as continuing the legacy of the Roman Empire and protectors of the 'true Christian faith'. Even before Constantine the Great established Byzantium as his new capital, later to be renamed and dedicated by him as "Constantinople" (Constantinople in English)/Nova Roma, Rome had ceased to be the functional capital of the Roman Empire. Rome's wealth was steadily declining due to several raids led by a variety of Germanic tribes. However, Constantinople was increasing its wealth and by the 5th Century was the wealthiest city in the Western and Central Asian regions representing a great prize for raiding groups (Williams and Friell, 1998).

Theodosius had built a wall around Constantinople in 400 A.C.E. which had effectively defended the city. Anastasias who was a prudent emperor perceived that another wall would provide additional protection becoming the first line of defense against the tribes who wished to attack and raid Constantinople. In the past, the Bulgars had often raided the towns in Thrace and by the late 5th Century, their activity was increasing. Their interest was not territory, but loot. About 500 A.C.E., Anastasias started the construction of a set of walls stretching from the Marmara to the Black Sea. It was later reconstructed by Justinian. Both emperors also encouraged the construction of city walls of cities in the vicinity



Figure 1. Portion of wall in northern section.

of the wall (that is Selymbria-modern day Silivri). However, after about 700 A.D., it ceased to be manned because of the cost of maintaining and supplying troops along the wall, and a decreased threat from the West (Williams and Friell, 1998).

Archaeological surveys

Until recently, the wall was not well documented. The first major archaeological exploration of the wall was begun by the Archeology Department of the University of Newcastle led by James Crow in the late 1990s. The wall was followed and mapped by the Newcastle team from its beginnings at the Marmara to the Black Sea (University of Newcastle 2005). This was done by following the visible portions of the wall and documenting its location with a GPS portable station including some of the major forts. The best well preserved portions of the wall are found in the center and the northern sections. In these sections, one can see portions of regularly hewn blocks amid ivy and other vegetation that grows along or on the walls (Figure 1). The southern section exists as mounds (Figure 2) due to either being either plowed over or taken for building materials for buildings in the surrounding villages or for other structures. Pieces of the wall can easily be found in some of the structures in the villages located near the wall. At various places along the wall, there is evidence of other structures such as fort complexes. The evidence of underwater dock structures at the southern end has been documented by James Crow and his team (University of Newcastle 2005). Despite, significant portions of the wall being destroyed or covered by mounds, the visible remains are still impressive.



Figure 2. Mound wall portion in southern section.

Spatial technologies and archeology

The use of spatial technologies has been found to be a tremendous tool for archaeologists (Wiseman and El-Baz, 2007; Montufo, 1997; Capra et al., 2002). The combined tools of Geographic Information Systems (GIS), Remote Sensing and Global Positioning Systems have been able to document archaeological sites much better than previous methods. Remote Sensing, which includes images taken from satellites and aircraft, has helped to discover many sites that were previously hidden. Other Remote Sensing instruments such as Side-looking Airborne Radar (SLAR) Light Detection and Ranging (LIDAR) and Ground Penetrating Radar are also proving to be invaluable.

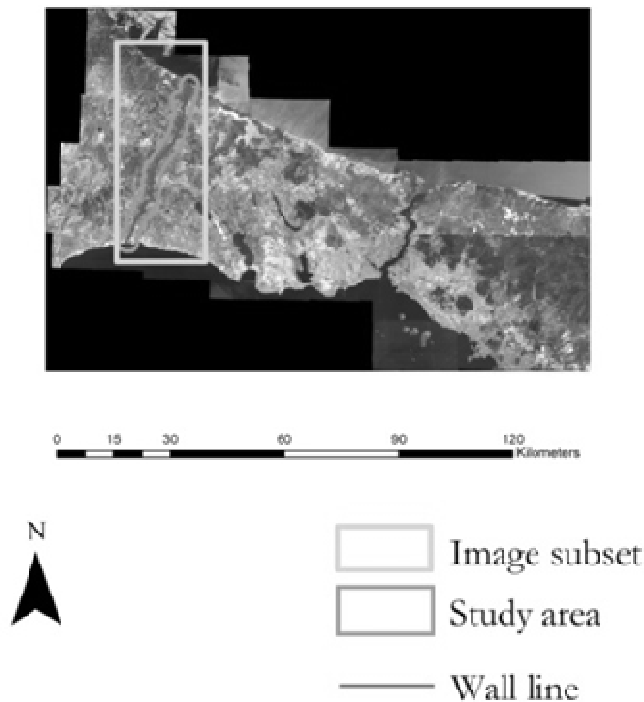


Figure 3. Study area (IKONOS pan-sharpened Istanbul-2006 image with 1 m resolution).

able tools for archaeologists (Faintich, 2003; Fietcher and Evans, 2003; Kucukkaya, 2004). High resolution images have revealed greater detail than was gained via lower resolution satellite images. Spatial technologies have enabled an increased awareness of archaeologists so that many are beginning to view archaeological sites not as isolated places with artifacts, but part of a historic physical and human geographical context. The use of GIS supports additional analysis capability. Using a vector GIS can clarify the spatial relationships of building, artifacts and topography within archaeological sites, once they are delineated via image processing. The use of GPS to survey sites and record other information and their integration with Remote Sensing and GIS systems provides additional information. Other analytical methodologies tied to spatial technologies such as fractal analysis are creating a more robust toolbox for archaeological investigations (Brown, Witschey and Liebovitch, 2005).

Pertaining to the Anastasian Wall, orthophotos were used by Crow and Ricci (1997) to initially to see elements of the wall from the visible spectrum and later to investigate the pattern of agricultural plots as to their orientation around the wall in its lower section. McAdams and Kocaman (2008) used the visible and the infrared portion of IKONOS images to explore its potential in the middle portion of the wall where there is heavy vegetation covering the wall. The authors of this paper used a 1 meter resolution Digital Elevation Model (DEM) of the Istanbul area to further enhance the Remote Sensing

images. The DEM of Istanbul is created by Water and Sewage System Administration of Istanbul (ISKI) by using 1/5000 scale maps. Paper maps were scanned, geo-referenced, and digitized by using ArcGIS software for creating DEM of Istanbul. As will be discussed later in this paper, the combination of images and a DEM proved to be valuable to further delineate the wall area.

STUDY AREA AND METHODS OF ANALYSIS

Study area

The study area is located approximately 30 km from Istanbul with its boundaries being defined by a buffer of 2 km on either side of the wall line (Figure 3). The subset image was cut approximately to be the presumed area of the wall before delineating the wall corridor. This area is approximately 24 km wide and 60 kilometers long, an area of approximately 1,340 sq km. The wall line is approximately 50 km long. The concentration was mainly on the wall and related structures.

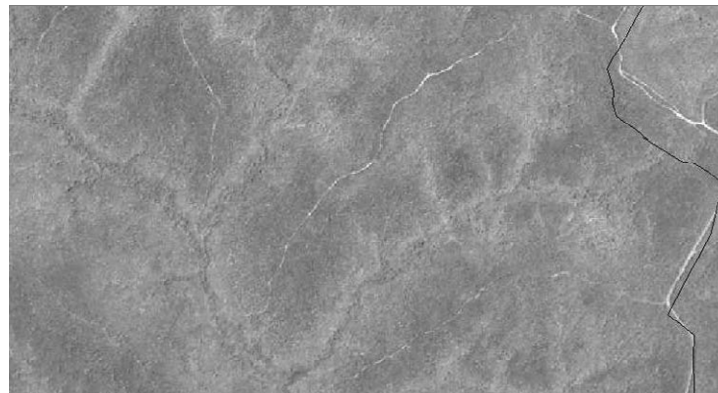
Methods of analysis

Initially, the general location of the wall was determined by first consulting a map developed from GPS surveying by the University of New Castle (University of Newcastle 2005). In the analysis conducted by the authors in an earlier study (McAdams and Kocaman, 2008), a vector file showing Anastasian Wall, was created by digitizing using IKONOS images from March, 2006 and September, 2007 as background. The image from 2007 included an infrared band. In the visible bands of both images, the wall was clearly seen in the middle portions. The infrared bands confirmed that this area was primarily overlaid with heavy vegetation. In numerous visits to the wall by the authors and in consultation with Franziska Zimmer, an environmental biologist at Fatih University who visited with us on several occasions and was familiar with the vegetation, it was determined that the major of the wall which was above ground was covered with ivy and Linden trees. In the area of ditches, there is found various kinds of brush vegetation, which often made it difficult to inspect the wall. As previously mentioned, the southern portion of the wall had been either destroyed or plowed under. This study was focused on isolating the signatures, which had thick vegetation, and determining areas of crop distress and soil markings related to moisture content using infrared and thermal bands (Figure 4).

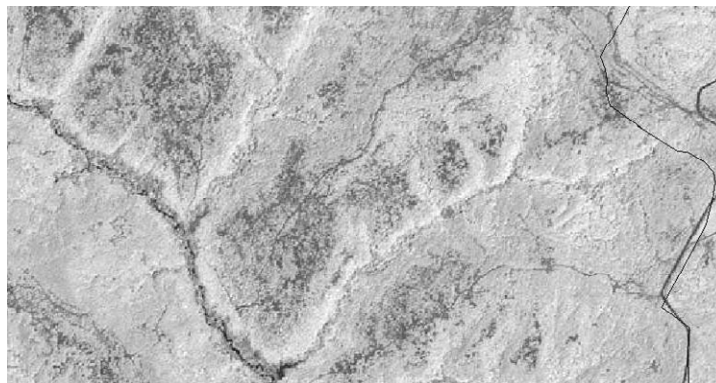
In the first study by the authors (McAdams et al., 2009), the line of the wall was determined with the visible bands of an IKONOS image. In the present study, the shape file overlaid a DEM of the area and a more recent IKONOS image. The wall follows the topography and therefore the line was better estimated in places when it was unclear by using the DEM. To better isolate the areas of the wall where there was thick vegetation, supervised classification was performed using all the bands of the IKONOS images. In the southern area of the study area, the area was analyzed using the infrared band from the IKONOS image and the thermal bands from the Landsat image.

RESULTS

By using false color images, enhancement techniques and unsupervised classification, most of the locations of the wall were identified. In the middle portion of the wall, in these areas, it was clear where the wall is located in



Green Band:
Stressed
vegetation is
represented by
dark colors and it
is not clear as
much as in NIR
band.



NIR (Near
Infrared) Band:
Stressed
vegetation is
represented by
dark colors and it
is much clearer
than in green band.

Figure 4. Comparison of visible (green) and NIR (Near Infrared) bands in representing vegetation stress.

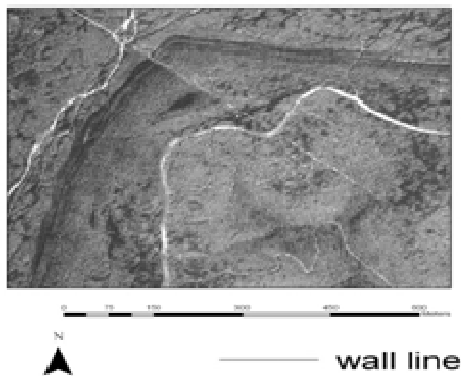


Figure 5. Section of Middle Portion (visible bands; blue, green, and red).

this area via visible inspection of the images. Classification of the images reveals further details about the vegetation that is located on or near the wall and where there are exposed sections. In some cases, other structures such as forts and unidentified buildings can also be identified through classification methods. Given the page

constraints for this article, it is impossible to display all the sections of the wall via visible and classified images or give detailed analysis of the findings. The next paragraphs will briefly examine some of the findings of selected areas of the wall to serve as an example of the use of remote sensing in investigating the wall.

Figure 5 shows a section of the middle portion of the wall. The wall is identified by dark linear patterns. Other similar lineal marks in the center of the image that could be a fort associated with the wall. When the image was classified using unsupervised classification, the wall area appeared as a lineal unit of classes associated with vegetation. The lineal patterns are areas of dense vegetation, mainly brush-as noted when the authors visited the sites of the wall.

In the southern end of the wall, there were evidences of mounds or disturbed soil that indicated the presence of the wall. Evidences of this on the image are difficult to discern as bare plowed soil can also give the impression of the location of the wall. The most well preserved area of the wall was found in the center and northern area. With the use of images with infrared bands other attributes of the wall are such as vegetation, roads and bare soil can be discerned (see Figure 6). Before doing a de-

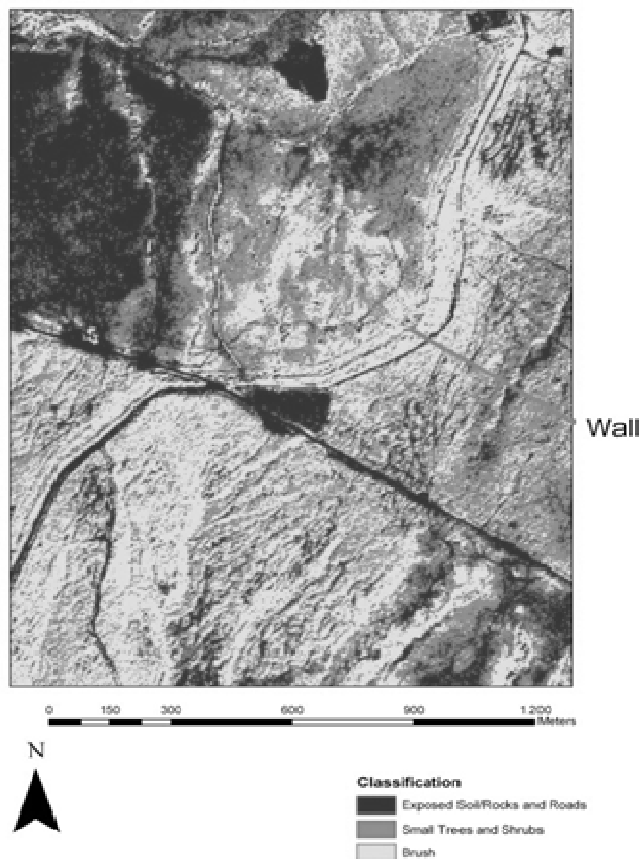


Figure 6. Section of middle portion (Near Infrared Band).

detailed inspection of the area, it was presumed that the exposed wall would emit signatures (reflection values) similar to exposed ground or concrete. However, this was not the case since due to the top of the wall being completely covered with vegetation.

Because the middle and upper portion of the wall is covered with a combination of trees, ivy and other vegetation, infrared can clearly delineate the wall. However, the vegetation is similar to other types in the area and therefore can not be separated easily for supervised classification.

The use of a DEM (Figure 7) greatly assisted in better locating the wall. While the upper sections were fairly distinguishable by visible and infrared bands, there were some uncertainties in some areas, particularly in the lower portion of the wall. Since the wall follows the ridges in the area, the correct path was determined by using the DEM in relation with known portions of the wall. The combination of visible, infrared and DEM raster images resulted in the area of the wall being located with a degree of accuracy that could be used as a guide for preserving and protecting the entire length of the wall. Given the conditions of the area surrounding the wall, it is extremely difficult to survey the wall, even in known areas due to the vegetation.

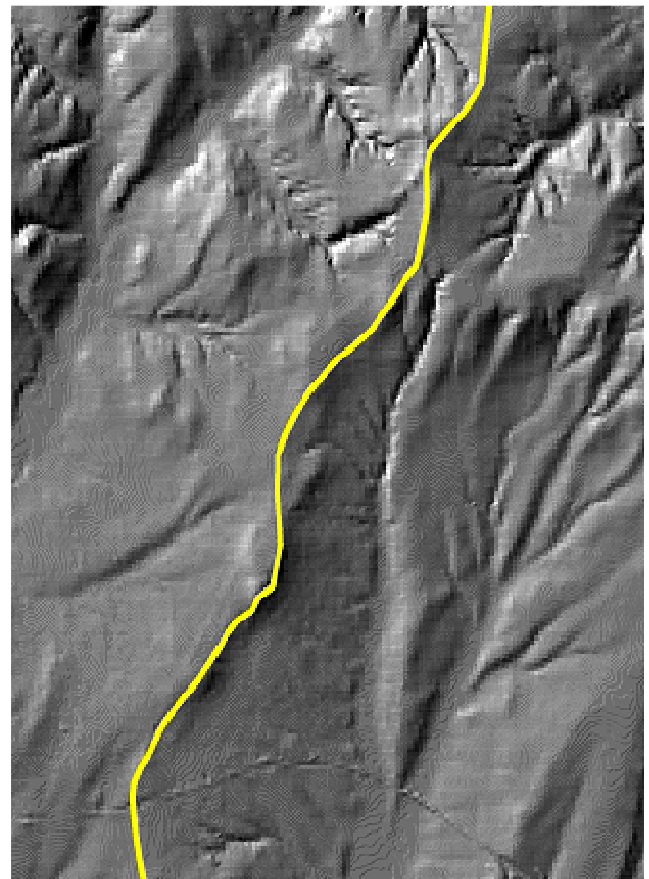


Figure 7. DEM of portion of wall with wall line.

The use of spatial technologies in the case of the Anastasian Wall clearly shows that they are useful tools in determining the location of archaeological sites. While there are some cases, where there is a clear knowledge of the location of archaeological sites in the Istanbul area, there are many cases where the areas are not clearly discerned using ground inspection or difficult to determine due to terrain and vegetation. There are also many sites, which have only been documented in a very minor manner, but need further inspection. For example, there is known pre-historic site and Byzantine sites around Büyükçekmece Lake, which have been only been identified in a cursory manner. The combined use of visual inspection and spatial technologies could help to locate and ensure that they are protected from further damage.

RECOMMENDATIONS FOR PRESERVATION OF ANASTASIAN WALL

The Anastasian Wall is an important part of the history of Istanbul. It represents a period where the Western Roman Empire was in a state of decline, while the Eastern Roman Empire was solidifying and ascending. While Rome was still recognized as having an important place

in divided Roman Empire during the 6th century A.D., it had been relegated to the Goths. Constantinople, later to be called Istanbul, was seen as the capital of the Roman Empire without any rivals. While the Theodosian Walls were already in place by the time of the construction of the Anastasian Wall, the threats at this time to the hinterland of Constantinople, which was important to the functioning of the city, was during this time under constant threat from the Bulgars. The rulers of the Eastern Roman Empire thought that this was a necessary outer defense to protect the richest city in Europe.

The Anastasian Wall stands along with other ancient long walls such as the Great Wall of China and Hadrian's Wall as worthy of being preserved and protected. While it is noteworthy that the wall has special designation by Turkish Law, there are no significant efforts to preserve, protect or restore it by any level of government in Turkey or internationally. Looters are visiting the site and digging around the wall in search of treasure. Mining, industrial, agriculture and residential activities pose a constant threat to the lower part of the wall. The vegetation around the wall is slowly destroying it. This monument which predates many other historic sites stands a good chance of being severely compromised in the near future if there is not a substantial preservation effort. It will be relegated to be among the many victims of modern development which will quietly dissolve into being a footnote in history books.

However, this archaeological site could become an asset to the Istanbul area on multiple levels:

- (1) It could provide a rediscovery of a portion of Istanbul's history which has been ignored by the global community.
- (2) Be a touristic site similar to Hadrian's Wall and the Great Wall of China, which could provide additional jobs and opportunities for the residents of greater Istanbul.
- (3) Create a green belt around Istanbul including the preservation of agriculture and traditional village life.
- (4) Open up a large recreational area for the residents of Istanbul.
- (5) Be a part of a development plan for greater Istanbul that would encourage the preservation of open space, historic sites and the environment while still accommodating the needs of industrial, residential and commercial needs of the city.
- (6) Serve as an example for redevelopment for other areas of Istanbul.

The identification of the wall area is a simple task when compared to the effort that will be necessary to ensure that this irreplaceable monument will be properly preserved and developed. The following would be a recommended path that could lead to a new future for the Anastasian Wall:

- (1) Further documentation of the wall using GPS, GIS and LIDAR to better define the area including other

structures and related historic settlements around the wall.

- (2) Additional archaeological digs to obtain more information on the details of the wall and surrounding villages; and integration within a GIS.
- (3) Extensive collection of historical documents related to the wall area and its context.
- (4) Additional security forces to ensure that treasure hunters are discouraged from looting.
- (5) Establishment of a protection buffer, a moratorium on development and monitoring of any harmful activity until an official development plan can be developed.
- (6) Awareness creation by a committed core group composed of representatives from non-profit organizations, academia, key industrial leaders and government officials through media and other efforts on a national and intentional scale.
- (7) Establishment of a protected park area under Turkish Law according to standards of the European Union and recognition as a U.N.E.S.C.O. Protected Site.
- (8) Creation of a working group composed of local citizens, leaders of business and industry, and all levels of government to create a "vision" and implementable strategic plan for the Anastasian Wall.
- (9) Implementation of the Plan developed by the above working group with appropriate funding structures and implementing regulations to enable a sufficient amount of money and park operation authority for the preservation and redevelopment of the area.
- (10) Promotion by appropriate bodies (national and international).
- (11) Monitoring by the Greater Istanbul Government, the Republic of Turkey and appropriate international organizations and creation of an ongoing funding/operating organization for the wall area.

While the preservation of such a historic monument is a laudable goal that none, but a few, could oppose; the route to the realization of this goal is not an easy one. The documentation of the Anastasian Wall is just one minor step to bring about its preservation, restoration and viability into the Istanbul area. There are multiple forces that would oppose the limiting of development and redirection of their plans to exploit this very valuable land. The outlook for this area is not promising given the rate and the structure of the development in the last twenty years without a strategic planning environment focusing on the proper development of the Anastasian Wall. Many areas in Istanbul have been turned into faceless suburbs of which formerly were very livable environments because of the lack of planning. If we fatalistically resign ourselves to a dystopia, this is what will be allocated to this area. If we dream of utopia where there will be no conflict and this area will be developed as an idealistic historic/cultural park with "shiny happy people (R.E.M. 1991)", we are delusional. However, if we strive for something better (somewhere between dystopia and utopia),

this is realistic, but still not an easy road. It is my hope that citizens and governments (nationally and internationally) will have the vision to pursue an alternative that may lead to a new urban strategic environment for the protection of historical monuments in the Istanbul metropolitan area founded on Istanbul's long tradition of inclusion and cooperation.

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