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Emily Diane Risinger

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Master's Professional Report:**

**Defining GeoDesign and the Emergent Role of
The Sustainable Sites Initiative (SITES^{TM}) for
Integrative Project Management**

**APPROVED BY
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Defining GeoDesign and the Emergent Role of The Sustainable Sites Initiative (SITES™) for Integrative Project Management

by

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Master's Professional Report

Presented to the Faculty of the Graduate School of

The University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

Master of Science in Community and Regional Planning

The University of Texas at Austin

August 2012

Dedication

To my family, BG, and ’12 CReePs for your patience, humor and enduring support—“Yes we can. Ten year plan!”.

Acknowledgements

I would have been unable to complete this Master's Professional Report without the guidance and steadfast encouragement of Dr. Ming-Chun Lee. I am deeply grateful for his commitment, and invaluable thoughts regarding the challenges associated with teaching the newly emergent field of GeoDesign.

I would also like to extend a special thanks to Dr. Nancy Kwallek, for serving as a continual mentor regarding all things design, and Professor Stephen Ross, for inspiring students to reach beyond the standard definitions of sustainability propagated by the status quo.

Additional thanks to the entire team of Design Workshop, for sharing invaluable insights about the day-to-day realities and opportunities associated with remaining committed to the research based metrics approach in professional practice.

Abstract

Defining GeoDesign and the Emergent Role of The Sustainable Sites Initiative (SITESTM) for Integrative Project Management

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The University of Texas at Austin, 2012

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This report is a discussion of the multifarious applications of the modern day geographic information system and how the universal merit of the technology across disciplines has led to the emergence of GeoDesign. The purpose of this Master's Professional Report was to retrace the core conceptual framework and landmark events occurring in the evolution GIS technology, and how these factors have led to recent creation of new performance based rating systems and evidence-based design techniques. The Sustainable Sites Initiative (SITES^{TM}), a new performance based rating system that has emerged in response to the call for increased knowledge and best practices lacking in LEED, is discussed; along with integrated project management. This professional report was intended to be an exploratory discussion of the larger theoretical implications fueling the shift towards mandating greater standards for sustainable design. It offers some ideas for how we should continue evolving GeoDesign moving into the next century; and outlines the importance of all new rating systems needing to acknowledge the growing importance of GeoDesign and ever advancing imagery technologies in understanding complex system processes in the future.

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Introduction

Computer technology has played a significant role in our ability to create advanced design processes. It is now largely acknowledged that working with others to plan and design for a multitude of physical, economic and social constraints early on in the site development process is the common ‘best practice’ approach for ensuring ‘sustainability’ throughout a projects lifecycle.

This report focuses on the emergent role of GeoDesign in various professions and how it is redefining the ways in which things are being done. Additionally, this report focuses on the newest ‘green’ rating system, SITES^{TM} and how the two indicate a fundamental shift in our approach to design in the 22nd Century.

Chapter 1 explores the core conceptual framework, individuals and events predicating the initial day geographic information system and the evolution of the technology through today. Chapter 2 defines the term ‘GeoDesign’ and the ways in which the basic anatomical make-up of GIS determine its application. Chapter 3 is a discussion of the universal merits of GIS technology and the GeoDesign process, and how this has led to various applications across disciplines in both the hard and soft sciences. Chapter 3 also delineates key differences between the geographic information systems and computer-aided design approaches to modeling. Chapter 4 delves into the ways in which GeoDesign has been bridging the gaps between disciplines, paving the way for more collaborative and integrative design processes. Chapter 5 introduces the newest ‘green’ rating system (SITES^{TM}) and how this was a result of larger theoretical shifts towards research-based, or evidence-based design, made possible through advances in computer technology. Chapter 6 outlines the appropriateness of GeoDesign for SITES^{TM}, and whether or not GeoDesign may be an art, rather than a tool or science.

Chapter 1: Putting the 'Geo' in GeoDesign

1.1—Defining Geographic Information System (GIS)

Before we can delve into GeoDesign, we must define and discuss the technology making it possible—the geographic information system. Geographic refers to anything that involves some aspect of location—meaning it is on or near Earth's surface and can pinpointed using latitudinal/longitudinal coordinates. Information means raw tabular data—such as numbers, text, symbols—but can also refer to imagery derived from aerial photographs, satellites orbiting in space or digital maps. System refers to computer programs or technology. Thus, a geographic information system, commonly referred to as GIS, is any "computer system capable of capturing, storing, analyzing, and displaying geographically referenced information; that is, data identified according to location".[1] For many practitioners, a geographic information system also includes "the procedures, operating personnel, and spatial data" that go into "any system used to create digital representations of various aspects of the geographic world by storing, manipulating and presenting geographical information" provided by datasets.[2,3] Although the acronym for geographic information systems is sometimes used interchangeably with geographical information science or geospatial information studies, in this report GIS refers to any computer software or system created to merge "cartography, statistical analysis, and database technology" for decision making or resource management purposes.[4]

1. USGS Eastern Region PSC 4, Geographic Information Systems, U.S. Geological Survey, February 22, 2007, http://egsc.usgs.gov/isb/pubs/gis_poster/index.html (accessed July 7, 2012).
2. Paul A. Longley, Michael F. Goodchild, David J. Maguire and David W. Rhind, Geographical Information Systems and Science (Chichester, West Sussex: John Wiley & Sons, 2005).
3. Geographic Information System, Wikimedia Foundation Incorporated, http://en.wikipedia.org/wiki/Geographic_information_system (accessed June 25, 2012).
4. Ibid.

1.2—Core Conceptual Framework

1.2.1—Primitive Geometry

At the most fundamental level, individuals performing GeoDesign or spatial analyses of any kind are concerned with what happens where—as all problems we seek to solve or better understand on Earth have locational factors embedded. Whether it is finding the best soil for growing plants, pinpointing an area to safeguard endangered species, or finding new ways to market a business using the geographic spread of customers filtered by socioeconomic attributes, being able to link differing types of data to where it occurs on the globe is crucial to decision making processes.

Enter the geometric primitive: G = f (x, y, z, t, F)—a simple model allowing us to convert raw data into maps using geometry. Under this model all things are viewed as a function of x, y, z coordinates that reference the phenomena's particular place on earth, the time at which it occurs (t), and natural or man-made features (F) that can be represented as a point, line, line segment, or polygon on a map. While there are much more complex iterations for data analysis that can be derived from the primitive, the core conceptual framework of GIS is that we are able to map anything as long as we know where it happens (x,y,z), when it happens (t), and what it is (F). This basic principle has proven infinitely useful in that even as "places change continually, as people move, climate changes, cities expand, and a myriad of social and physical processes affect virtually every spot on the Earth's surface" we will still be able to map the world around us.[5]

5. Michael J. de Smith, Michael F. Goodchild and Paul A. Longley, Geospatial Analysis: A Comprehensive Guide to Principles, Techniques and Software Tools (Leicester: Matador).

1.2.2—Overlay Mapping Technique

At its simplest, geographic information systems are merely tools for visual communication—they produce maps. However, the real merit of GIS comes into play when analyses require one or more layers to be joined together physically in a process known as map overlay (seen in Illustration 1 below). GIS processing can be conceptualized as a stack of floating maps that are geographically registered making information for any location readily accessible.[6]

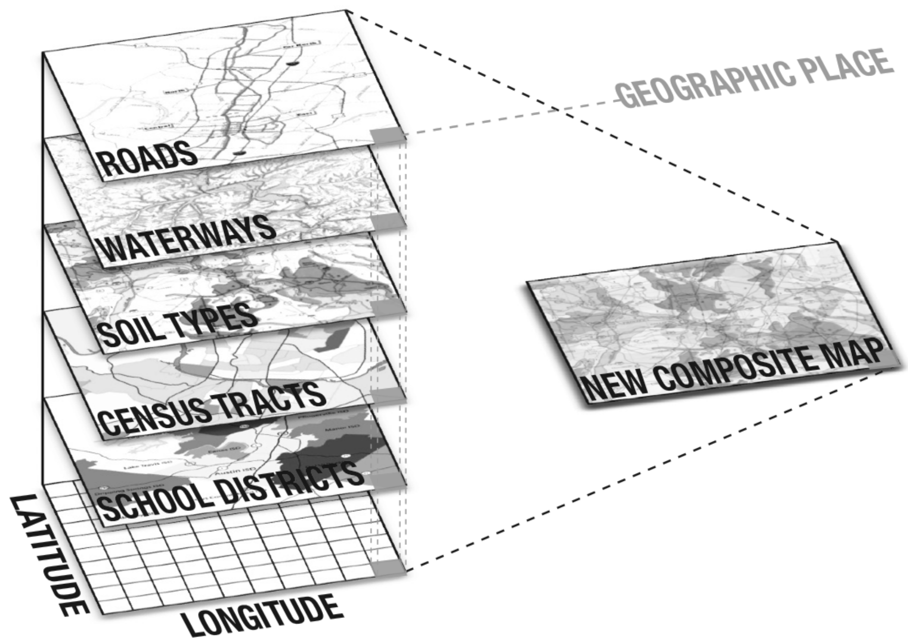

Illustration 1: Conceptualization of GIS processing and overlay mapping.[7]

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6. Joseph K. Berry, "GIS TECHNOLOGY IN ENVIRONMENTAL MANAGEMENT: a Brief History, Trends and Probable Future," in Handbook of Global Environmental Policy and Administration, ed. Dennis L. Soden and Brent Steel (Postfach, Basel: Marcel Dekker, 1999).
7. Kenneth E. Foote and Margaret Lynch, Geographic Information Systems as an Integrating Technology: Context, Concepts, and Definitions, The University of Texas at Austin, 1995, http://www.colorado.edu/geography/gcraft/notes/intro/intro_f.html (accessed June 28, 2012).

In the overlay mapping, GIS integrates different data layers; allowing us to look for more in-depth patterns and relationships. GIS treats each thematic map (such as roads, waterways, soil types, etc.) as a 'layer'. Each layer is carefully overlaid onto others "so that every location is precisely matched to its corresponding locations on all the other maps".[8] The bottom layer shown in Illustration 1 above is the most important, in that it "represents the grid of a locational reference system (such as latitude and longitude) to which all the maps have been precisely registered".[9]

The opportunities provided by overlay mapping techniques are seemingly endless, as they can be applied in many differing research efforts and contexts. For example, to analyze the impact of urban sprawl on the ecological performance of place an overlay could integrate data on slope, plant species, soil types, watersheds, and land use. Additional queries could then be performed to locate pollution sources, predict future ecologically at-risk areas, or to plan for increased vehicular traffic in the area. The composite maps created from the overlay process are invaluable problem solving tools—in that they illustrate the combination of all factors involved.

1.3—Precursors to Modern Geographic Information Systems (GIS)

GIS originated out of a singular purpose: overlaying different varieties of information to reveal patterns or processes that point towards some 'truth' about reality. Although we oftentimes associate GIS with complex computer software, the technique of overlaying maps and graphic representations of geographic information as a problem-solving approach has been in use for centuries.

8. Ibid.
9. Ibid.

Many cite Charles Picquet's color gradient map of Paris' cholera districts or John Snow's map using points to represent cholera deaths in London during in the 1850s (seen in Figure 1)[10] as the first instances of cartographical overlays, however, the origin of GIS extends back to the American Revolution. In the late 1700s, militaries began overlaying maps to illustrate patterns of enemy troop movements as a form of strategizing new battle techniques.[11] During the early 1900s, aerial photographs taken from kites, hot air balloons and airplanes gained popularity for property mapping and inventories being conducted by the U.S. Census Bureau. The U.S. Army was also using aerial imagery for military intelligence operations and assessing damage caused by natural disasters across the nation. In the 1920s photogrammetry, or taking of measurements of earth's surface using photographs emerged, marking a significant advance in technology for all fields that used or related to geography.

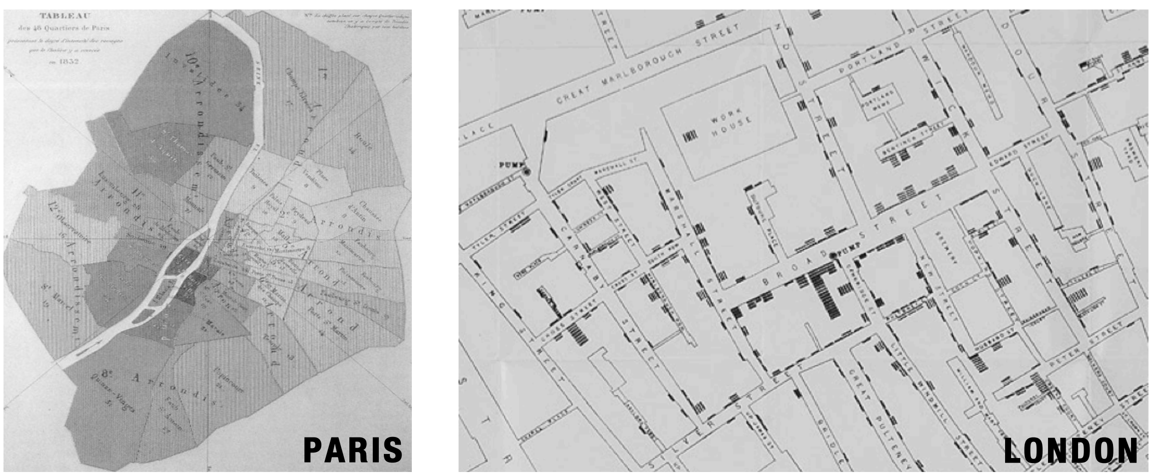

Figure 1: 1850s cholera maps.

10. Mid-1850s cholera maps demonstrating the gradient overlay and point techniques that would later serve as the foundation of modern day GIS. Charles Picquet map of the cholera epidemic in Paris, France is seen on the left. John Snow's map of London, England's cholera deaths is seen on the right. Source: Snow and Kudick.
11. Paul A. Longley, Michael F. Goodchild, David J. Maguire and David W. Rhind, Geographical Information Systems and Science, 16-24.

1.3.1—Jacqueline Tyrwhitte: 'Mother' of GIS and Urban Design

Ian McHarg is often credited as the first author to discuss GIS techniques; but this is a fallacy. The first textbook discussing "the manual map overlay method as an approach to land planning" was actually written by a woman named Jacqueline Tyrwhitte nearly twenty years prior. Although rarely acknowledged for pioneering the GIS movement, Tyrwhitte "exerted significant influence on post-war reconstruction" by conducting research, publishing texts and educating ex-soldiers during the 1950s, 1960s and 1970s about using transparent thematic map overlays to complete nationwide urban redevelopment "based on co-operation and… harmony with nature".[12] Despite being largely unaccredited for being the founding 'mother' of the GIS movement and modern urban design, Tyrwhitte's textbook *Town & Country Planning* paved the way for many of the mapping "methods popularized by Ian McHarg two decades later, and adapted in computerized Geographic Information Systems (GIS)" to the current day.[13]

1.3.2—Ian McHarg: Founding 'Father' of Modern GIS

Although Jacqueline Tyrwhitte's work preceded Ian McHarg's, he is widely heralded as the "father of the GIS movement".[14] His landmark text *Design with Nature* (1969) was the first to describe the concepts ultimately comprising modern-day GIS. McHarg's work on the interplay of "natural and cultural systems has become the dominant visualization technology of our time" while his arguments regarding the merit of designing with nature not only changed 20th and 21st century design and planning, but also influenced fields as diverse as geography and engineering, forestry and environmental ethics, soils science and ecology.[15] Most importantly,

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12. Ellen Shoshkes, "Jaqueline Tyrwhitt: A Founding Mother of Modern Urban Design," Planning Perspectives (Taylor & Francis Group, LLC) 21, no. 2 (2006): 179-197.
13. Ibid.
14. Shannon McElvaney, Designing Geography Part I - Reframing an Old Idea, November 2011, 2011, http://engagingcities.com/article/designing-geography-part-i-reframing-old-idea (accessed June 15, 2012).
15. Frederick Steiner, "Healing the earth: the relevance of Ian McHarg's work for the future," Philosphy & Geography (Carfax Publishing Company) 7, no. 1 (February 2004): 141-149.

however, was McHarg's pioneering work using overlay analysis that would have a "fundamental influence on the up-and-coming field of environmental planning" and solidify many of the core concepts emerging in the young field of GIS.[16]

1.4—Other Landmarks in the Evolution of GIS

1.4.1—CanadaGIS and SYMAP

In 1963, Canada was the first country to put forth effort on the federal level to identify national resources and existing/potential land uses with CanadaGIS (CGIS)—still in operation today. CGIS set the precedent for many other nations who, after the 1960s would also began to employ computer technology and cartography to manage their land supply and national resources. Meanwhile, the U.S.'s Harvard University developed the first general purpose, vector based computer mapping software called SYMAP in 1964, and the first raster based geographic information system in 1966. SYMAP became the dominant mapping product used globally for many years thanks to its innovative vector based technology consisting of a collection of objects—points, lines, and areas—in planar coordinate space that could be attached to thematic values such surface temperature, land use, soil type, census tracts or postal codes. Additionally, SYMAP marked the first time "maps of various sizes could be produced with different symbolism, legends, titles and so forth" which would "set the standard basic functions that any subsequent cartographic display program…had to provide" (seen in Figure 2).[17,18]

16. Shannon McElvaney, Designing Geography Part I - Reframing an Old Idea.
17. Nick Chrisman, Charting the Unknown: How computer mapping at Harvard became GIS, The Department of Computer Science at Duke University, 2004, http://www.cs.duke.edu/brd/Historical/hlcg/HarvardBLAD_screen.pdf (accessed July 1, 2012).
18. Ibid.

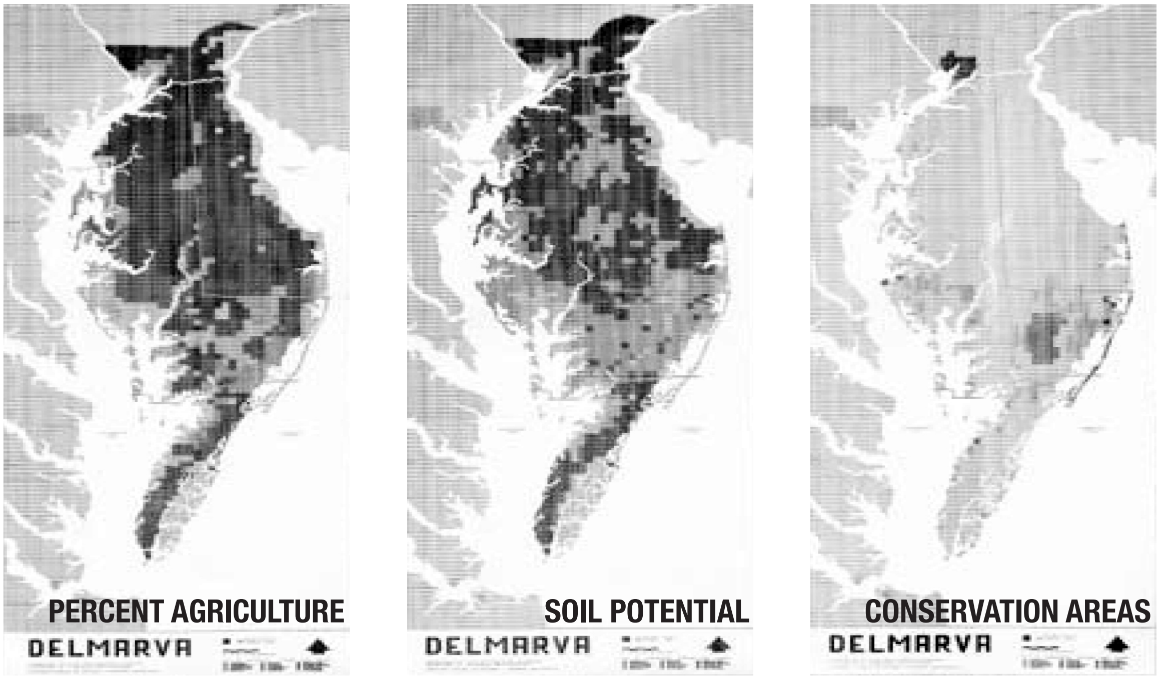

Figure 2: 1960s SYMAP documents.

1.4.2—The Environmental Science Research Institute (Esri)

Prior to the 1960s, researchers, natural resource industries and governing entities were struggling with being unable to access various types of data. The financial burden associated with the equipment and personnel necessary to run geographic information systems remained high, ensuring GIS users remained largely in the public sector (i.e. government, educational and military) through the 1970s.

But wheels were in motion for GIS technologies to become more widely available to the private sector moving out of the 20th century. In 1969, Jack and Laura Dangermond founded the Environmental Systems Research Institute, Inc. (Esri)—a research firm interested in organizing and analyzing "geographic information to help land planners and land resource managers make well-informed environmental decisions".[19] The Dangermonds' Esri, which

19. Environmental Systems Research Institute, Inc., History Up Close, http://www.esri.com/about-esri/about/history-more.html (accessed July 1, 2012).

started as a small business operating out of their home in Redlands, California, would go on to become the forerunner in GIS software manufacturing and distribution. From inception the couple began “developing relationships with like-minded companies in Germany, Japan, Australia, and Canada” allowing them to become the leader and “foundation of today's large international network of [GIS software] distributors”.[20] Their efforts in creating a global GIS community paved the way for the successful transitioning of GIS software applications into the mainstream.

1.4.3—Remote Sensing, The Internet and Access to Public Data

The 1970s marked the U.S.’s initial large-scale federal GIS effort with the creation of a process for assigning addresses recorded on Census Bureau surveys to geographical locations across the country. The U.S. Department of Defense’s Landsat I, the first of many satellites enabling the remote sensing of earth from space, was launched in 1972. The 1970s also marked Ray Tomlinson’s creation of email and a paradigm shift in societal thinking; as many “came to the realization that the future of computers wasn’t in computing itself, but in the storage, retrieval and searching of information that, at the time, was only contained in libraries”.[21] Global conferences put on by the International Geographical Union’s Commission on Geographical Data Sensing and Processing (established 1968) “undertook an evaluation of the handling of digital spatial data” and published a landmark report citing the duplicate efforts and the ineffective use of resources and a real need for greater data sharing and cooperation amongst agencies at all levels—though it would take until the mid-1990s to successfully make progress in this regard.[22] Geolibraries, such as the Alexandria Digital Library or the U.S.

20. Ibid.
21. Cameron Chapman, The History of the Internet in a Nutshell, November 15, 2009, http://sixrevisions.com/resources/the-history-of-the-internet-in-a-nutshell/ (accessed June 29, 2012).
22. J.T. Coppock and D.W. Rhind, The History of GIS, Vol. 1, in Geographical Information Systems: Principles and Applications, 21-43.

Geospatial One-Stop, now provide public access to millions of maps using simple online search platforms.

The emergence of the Internet and computers capable of producing more complex graphics during the 1980s paved the way for geographic information systems to really take root in the private sector. The transition of GIS from desktop computers (which only serve small subsets of the population) to web-based platforms meant thousands of users could benefit from it. Additionally, the 1980s signified an important paradigm shift, in which GIS was pressed to evolve more towards analysis rather than basic map overlays and cartographical productions. In 1982, Esri released ARC/INFO, the first ever GIS software package available for commercial purchase. In 1985, NASA's global positioning system (GPS) made it possible to "determine the position of an object quickly and cheaply" for the first time in U.S. history.[23] The 1980s also suffered from a severe economic recession brought on by Reagan era federal policy which forced the price of computing hardware low enough that "forestry companies and natural-resource agencies, driven by the need to keep track of vast timber resources", finally had the ability to purchase geographic information systems.[24]

Free, online-based mapping resources (such as Mapquest) debuted in the early 1990s– signifying another important era for GIS. As computers became less and less expensive, GIS finally became a viable technology for use by everyone. During the 1990s, GIS is also pushed to become an important part of decision-making processes for state and municipal planning. By the year 2000, an unprecedented number of individuals had incorporated the regular use of GIS into their daily routines.

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23. Michael Kennedy, The Global Positioning System and GIS: An Introduction (New York, NY: Taylor & Francis, 2002).
24. Paul A. Longley, Michael F. Goodchild, David J. Maguire and David W. Rhind, Geographical Information Systems and Science, 2005.

Chapter 2: The Foundation of GeoDesign in GIS Modeling

2.1—Basic Anatomy of the Modern Geographic Information System

Today, modern geographic information systems consist of six key components (seen in Illustration 2 below). The first, and most important, is people. These are the scientists, environmentalists, academics, governmental employees, etc… that work together to build and use a GIS. Performing GIS requires a group of people with various complimentary skills and/or differing knowledge levels regarding geographic data, computers, and data management.

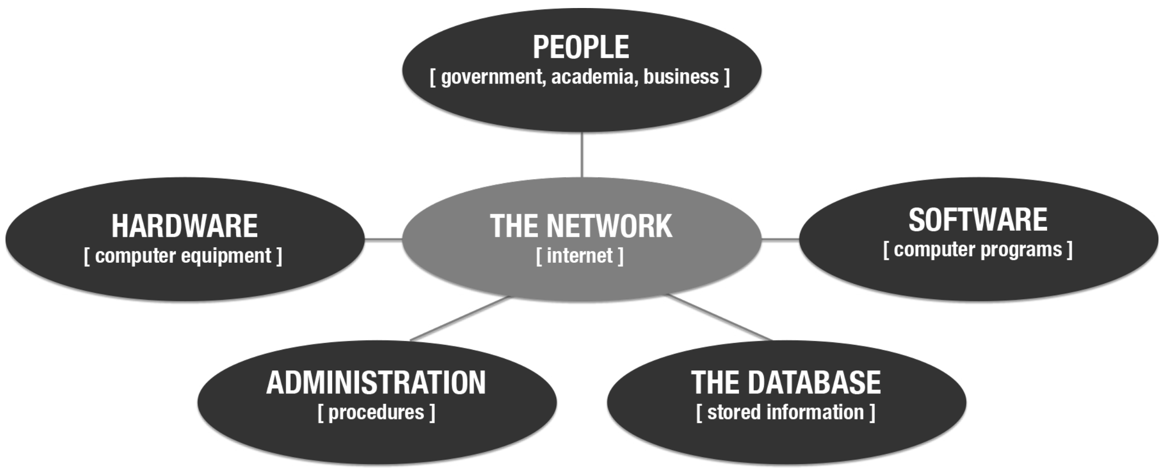

Illustration 2: Basic anatomy of modern day GIS.[25]

The second component is the network. In GIS, the network is the platform through which geographic data and GIS knowledge is shared amongst users. This can be either an internal network (intranet), or an external network (the Internet). The Internet is oftentimes the most cost and time effective way to link together co-workers, students, and business departments. While some companies have remained on stand-alone networks, "the development of themed geographic networks, such as the US Geospatial One-Stop […] one of

25. Ibid.

24 federal e-government initiatives to improve the coordination of" various local, state, and federal initiatives has drawn many public and private sector GIS users to the free information resources available on the world-wide web.

The third and fourth component of modern day GIS, computer hardware and software, go hand in hand. Computer hardware such laptops and handheld GPS devices, along with software, such as ArcGIS and Google Maps, allow us to produce cartographic maps and perform spatial analyses. The fifth component of GIS, the database, is used to organize and model geographic information data in different forms. Spatial database management systems (SDBMS), established in the late 1980's, proved critical in the advancement of GIS technologies throughout the turn of the century.

Databases are crucial to modern day GIS because it is in these that "identification numbers are assigned to each geographic feature, such as a timber harvest unit or wildlife management parcel […which enable a user] to point to any location on a map and instantly retrieve information about that location".[26] Two important data models arose from advances in SDBMS: raster and vector data models. A raster data model creates "an imaginary reference grid over a project area, then stores resource information for each cell in the grid" while a vector data model more "closely mimics the manual drafting process by representing map features as a set of lines which, in turn, are stored as a series of X,Y coordinates.[27] In subsequent chapters we will discuss the advantages / disadvantages of raster and vector, but for now it suffices to say that both have exponentially increased our capacity to problem solve and represent "overall strengths of a GIS approach" to understanding real-world phenomena.[28]

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26. Joseph K. Berry, "GIS TECHNOLOGY IN ENVIRONMENTAL MANAGEMENT: a Brief History, Trends and Probable Future", 1999.
27. Ibid.
28. Ibid.

The sixth component comprising modern day GIS is management. Management is the organizational rules or procedures that guide how individuals use data and geographic information systems. GIS management varies depending on the context in which it is being used. For example, the protocols a governmental employee must adhere to when producing maps via GIS will be different than students at a university researching thesis topics. However, despite the differing uses GIS is being employed for, all users of GIS must establish hierarchical frameworks to ensure control points are maintained, data remains intact, and project budgets are met.

2.2—The Evolving Definition of GeoDesign

2.2.1—The 'S' Controversy: GIS—System or Science?

The introduction of the term geographic information science (GIScience) by Michael Goodchild in 1992 spurred widespread debate regarding the definition of GIS.[29] The definition of GIS since Goodchild's GIScience hit the Internet has been evolving. This is in large part due to widespread debate about the definition and implications of the technology that make GeoDesign possible—GIS. Namely, the controversy stems from opposing schools of thought regarding the 'S' in the acronym GIS, and whether or not the 'S' should stand for 'system' or 'science'. A review of literature surrounding the topic suggests there are generally three commonly held positions on the issue.

2.2.2—GIS as a Tool

These first is (1) GIS is computer software designed to perform specific functions, therefore it can only be deemed as a tool in our toolbox, or technique, used to perform research—despite the fact that human interactions with GIS software and digital geographic

29. Michael F. Goodchild, "Geographic information systems and science: today and tomorrow," Annals of GIS (Taylor & Francis) 15, no. 1 (2009): 3-9.

data thereof may be used to advance scientific purposes. Under this school of though, GIS is viewed as a technique for performing scientific research, but not a science in and of itself. For example, remote sensing is heavily utilized to do scientific research, but are not ‘sciences’ in their own right.[30]

2.2.3—GIS as Science

The second is (2) GIS is a science and a legitimate research specialty that should be explored. However, for GIS to become a science, it will need “move away from the technology towards the fundamental aspects of modeling spatial phenomena” and divorce itself from other scientific disciplines. In other words, the “theoretical knowledge that forms the design of a model [in GIS] is science” (1997). Determining ways to avoid generating “erroneous spatial data”, or studying “spatial data uncertainty and error, data lineage, and how GIS is adopted” by other disciplines elevate it to “the application of a spatial science to earthbound objects” (1997). Under this viewpoint, doing GIS is the same as doing geography. It is, under this view, a science.

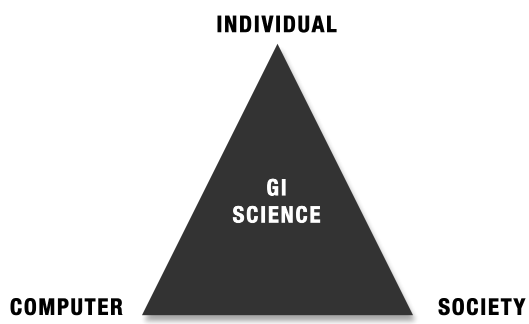

Illustration 3: Goodchild’s Geographic Information Science (GIScience).[31]

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30. Daw J. Wright, Michael F. Goodchild and James D. Proctor, "GIS: Tool or Science? Demystifying the Persistent Ambiguity of GIS as "Tool" Versus "Science", Annals of the Association of American Geographers (Taylor & Francis) 87, no. 2 (June 1997): 346-362.
31. Paul A. Longley, Michael F. Goodchild, David J. Maguire and David W. Rhind, Geographical Information Systems and Science, 2005.

According to Michael F. Goodchild, GIScience is comprised of three concepts—the individual, the computer and society. Illustration 3 above represents the ways in which these three concepts form the vertices of a triangle, with GIScience at the core. Under this ideology, GIScience research about individuals is dominated by “cognitive science, with its concern for understanding of spatial concepts, learning and reasoning about geographic data, and interaction with the computer”.[32] GIScience research regarding the “computer is dominated by issues of representation, the adaptation of new technologies, computation, and visualization” and GIScience “research about society addresses issues of impacts and societal context”.[33]

2.2.4—The Gray Area in Between

However, the lines between GIS as a tool become blurred in that, like science, it is a problem solving activity. This brings us to the third view on the GIS as a tool or science debate: (3) GIS is a scientific method in which researchers can “identify and understand the problems they will eventually attempt to solve”.[34] Under this school of thought, GIS transcends the status of merely being a ‘tool’ (i.e. computer program), to being a methodical approach for proving theorems. It still does not qualify as a *science* because it is a component part of the *scientific process*. The term *science*—often associated with acts in which the discovery of new, provable facts occurs—is where the boundary between GIS as a tool versus GIS as a science will continue to remain fuzzy.

2.3—GeoDesign Defined

Most disciplines agree that GIS and the emergent field of GeoDesign are an unprecedented advancement in our ability to create ‘sustainable’ environments and to manage

32. Ibid.
33. Ibid.
34. Ibid.

our resources more wisely. So what exactly is GeoDesign? GeoDesign is "a design and planning method which tightly couples the creation of design proposals with impact simulations informed by geographic context".[35] This is the most basic definition, however. Many also define GeoDesign as:

> A set of techniques and enabling technologies for planning built and natural environments in an integrated process, including project conceptualization, analysis, design specification, stakeholder participation and collaboration, design creation, simulation, and evaluation (among other stages). Nascent GeoDesign technology extends geographic information systems so that in addition to analyzing existing environments and geodata, users can synthesize new environments and modify geodata.[36]

So how does one go about performing GeoDesign? One of the first steps involved geodesigning is to figure out what to include or exclude in some geographic model of reality. Also, how do we make geographic models of reality? Typically, most designers use an iteration of Peuquet's levels of data abstraction. To clarify, Peuquet essentially argues that in order to create maps using GIS one must go through four levels of abstraction in order to convey geographic phenomena in map formats.

2.3.1—Level 1: Mapping Reality

The first level of Peuquet's data abstraction process is mapping reality; reality being defined as "the phenomenon as it actually exists, including all aspects which may or may not be

35. Michael Flaxman, "Fundamental Principles of GeoDesign," in 2010 GeoDesign Summit (Environmental Systems Research Institute, Inc., 2010).
36. Carla Wheeler, "Designing GeoDesign," in ArcWatch: Your e-Magazine for GIS News, Views, and Insights (Environmental Systems Research Institute, Inc., 2010).

perceived by individuals".[37] This is the 'existing conditions' portion of the process, in which the aim is to minimize bias due to human perception. During this phase one is attempting to show, with as little abstraction as possible, what actually exists.

2.3.2—Level 2: Data Modeling

The second level involved in abstracting data to create maps is to narrow down all of the information that is available to a data model. Before going into the definition of the data model, it is important to reiterate a fundamental difference between data and information. Data are facts and figures gathered about a certain phenomena. Examples of data could be name, age, address, date, size, color, etc. Information is data that has been processed out of its raw state to a form meaningful for decision-making. Note too, "although data are ingredients of information, not all data make useful information".[38] Data "not properly collected and organized are a burden rather than an asset to an information user" while some items deemed to be "useful information for one person may not be useful to another person".[39] Generally, information is only useful when:

> It is relevant (to its intended purposes and with appropriate level of required detail); reliable, accurate and verifiable (by independent means); up-to-date and timely (depending on purposes); [and] complete (in terms of attribute, spatial and temporal coverage).[40]

The data model, then, is best understood as "an abstraction of the real world which incorporates only those properties thought to be relevant to the application or applications at

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37. Keith Clark, "Lecture 4: Spatial Data Properties and Spatial Data Sampling," Geography 176B Technical Issues in GIS, Department of Geography, January 16, 1997, http://www.geog.ucsb.edu/~kclarke/G176B/Lecture4.html (accessed July 1, 2012).
38. Albert K. Yeung, NCGIA Core Curriculum in Geographic Information Science, National Center for Geographic Information and Analysis, 1998, http://www.ncgia.ucsb.edu/giscc/units/u051/u051.html (accessed July 1, 2012).
39. Ibid.
40. Ibid.

hand […that is] usually a human conceptualization of reality”.[41] In other words, it specifies what components will be included in the analysis based on how they relate to the phenomena at hand.

At the data modeling level of abstraction, it is important to consider the differing natures of data and information and the implications thereof for conveying messages, both quantitatively and visually. This is a pivotal point in map production in which decisions regarding the inclusion of elements, structures, or entities becomes crucial for suitably representing the system under examination. There are four common data model typologies used by geographic information systems to represent real world phenomena via data abstraction: 1) raster, 2) vector, 3) computer-aided design (CAD) and 4) object-oriented.

2.3.2.1—Raster Data Models

The raster data model, also known as the continuous field data model, represents geographic landscapes as a rectangular matrix of square cells (seen in Illustration 4 below). It divides space into uniformly shaped cells, or matrix of pixels, organized into rows and columns. Each cell contains a value (0, 1, 2, 3, etc…) that represents information—such as color, temperature, address, or elevation—that can later be used to run spatial analysis queries. Oftentimes, rasters are “digital aerial photographs, imagery from satellites, digital pictures, or even scanned maps”.[42]

41. Keith Clark, "Lecture 4: Spatial Data Properties and Spatial Data Sampling," Geography 176B Technical Issues in GIS.
42. Environmental Systems Research Institute, Inc., ArcGIS 9.2 Desktop Help, September 22, 2008, http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?TopicName=What_is_raster_data? (accessed July 1, 2012).

Illustration 4: Conceptualization of raster data model.

The raster data model approach has some advantages as well as disadvantages for map creation and GeoDesign initiatives. It does not provide precise locational information (i.e. exact latitude/longitude coordinates). Instead of an absolute location, points existing within landscapes are represented as single grid cells, or single numbers representing an attribute for each grid cell location.

While the coarser resolution of the raster data model reduces the amount of time it takes to produce maps, it also means a loss of information. Rasters also tend to be less graphically appealing. However, raster data models offer far more advantages then disadvantages. For one, the output for large datasets under the raster data model is quicker because the math required to create maps is less complex.

Computers run on binary—they only use numbers with the base of 2. Data are stored in the form of ‘switches’ that have only two possible states: ‘on’ or ‘off’. Under a computer’s binary code, ‘on’ is triggered by the number ‘1’; ‘off’ is triggered by the number ‘0’. So, under the raster data model things are either ‘on’ or ‘off’. A grid cell is either occupied with an object (filled in), or not (left blank). Illustration 5 below shows how the raster data model and binary code works in practice.

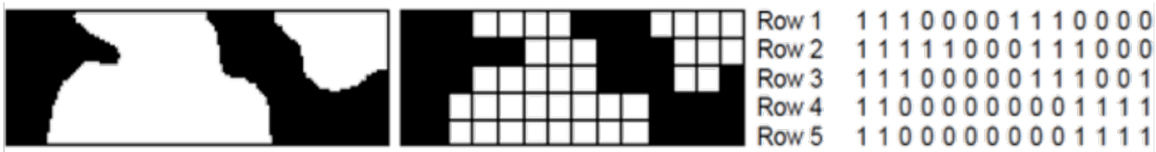

Illustration 5: Binary code under the Raster Data Model.[43]

In raster, the time it takes a computer to process data is far less than the vector data model (discussed below), in which the algorithms used in map output are far more complex. In addition to speedier process times for large quantities of data, the raster data model also excels at overlaying maps. Out of all the data models, the primitive grid structure serving as the basis of raster analyses ensure it is the best data model to use when multiple variables need to be layered and analyzed quickly.

Additionally, the raster data model is best suited to handle heterogeneous data. This is important to note, in that oftentimes in reality data is not homogenous and there are many different ways to measure/classify/record varying phenomena. It also allows us to weight data layers by importance—which is an invaluable tool for land suitability analyses.

2.3.2.2—Vector Data Models

The vector data model, also known as the discrete object data model, represents geographic landscapes with points, lines and polygons tied to precise X and Y coordinates. Unlike the raster data model, which explicitly quantifies the landscape using a grid, the vector model uses geometry to mimic reality more closely. Space is not assumed to be continuous, and each object is considered as a separate entity (i.e. not tied to any 'grid' matrix that connects all things in space).

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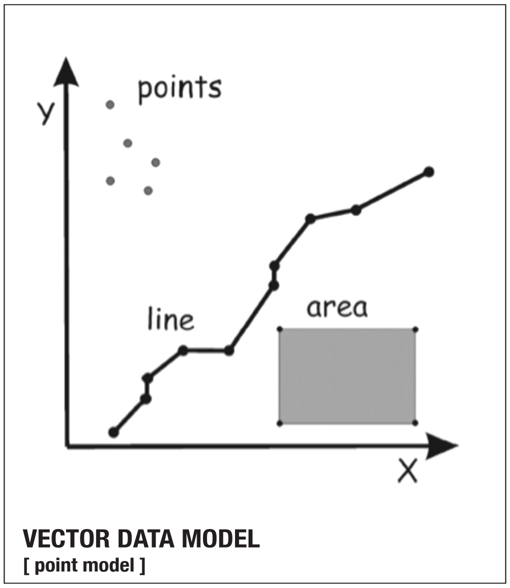
43. N. Trodd, Spatial Data Models and Spatial Data Structures, 2005, http://www.gisknowledge.net/topic/methods_in_gis/trodd_spatial_data_models_and_spatial_data_structures_05.pdf (accessed 2012, 1-July).

When using the vector data model, points have an X coordinate. Lines are two X coordinates (or points) connected. Polygons have numerous X coordinates, but are always closed forms (i.e. the first X coordinate is the same as the last X coordinate). How this works can be seen in Illustration 6 below.[44]



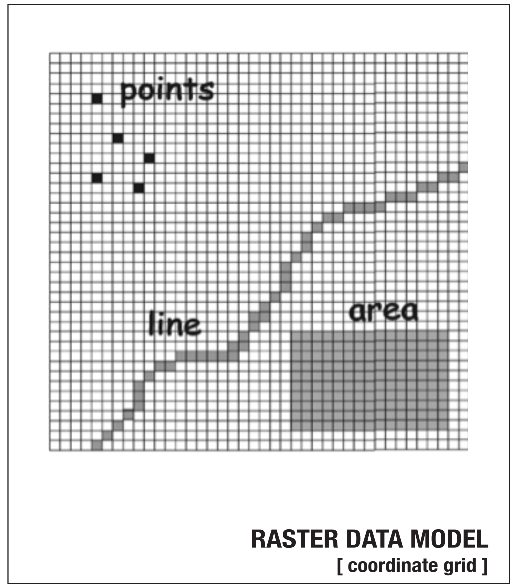


Illustration 6: Vector data model versus raster data model.

One major advantage of the vector data model is a much more precise representation of real-world phenomena. For example, a river "will be represented using a line of appropriate thickness—rather than a series of contiguous inappropriately shaped cells (as with the raster [data] model).[45] When concerned about visually communicating with audiences through maps, the vector data model is a good choice—the finer quality imagery produced under vector often

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44. Stefan Leyk, Class 4203/5203 GIS & Modeling, The University of Colorado Boulder, 2008, http://www.colorado.edu/geography/class_homepages/geog_4203_s08/class3_tesselRaster.pdf (accessed July 1, 2012).
45. N. Trodd, Spatial Data Models and Spatial Data Structures, 2005, http://www.gisknowledge.net/topic/methods_in_gis/trodd_spatial_data_models_and_spatial_data_structures_05.pdf (accessed 2012 1-July).

yield output more easily understood by general audiences (versus raster, in which every feature of the landscape is pixilated or generalized into the shape of a square).

When raster maps are zoomed in to closer resolutions, things appear pixilated, or as a series of blocks. Roads and creeks become jagged rows of squares. This does not occur in vector, because the images on screen are drawn to a much greater precision. Illustration 7 below, depicts the difference in close resolution maps between the raster and vector data models. Creeks and roads remain smooth and sinuous, as they would in reality. Therefore, one can zoom in very close to the earth's surface and still see accurate depictions of what exists.

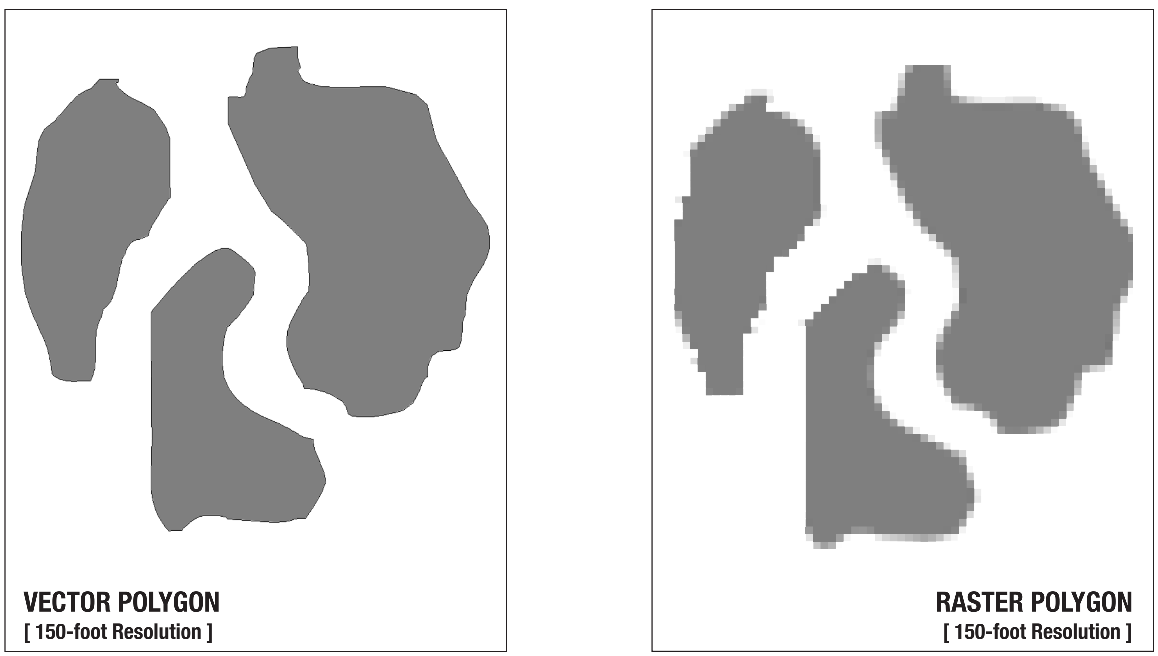

Illustration 7: Vector versus raster image quality at high resolution.

The finely tuned drawings of aspects within the landscape using the vector model also means a more compact data structure and that topology can be represented; topology being a set of rules telling the computer how objects relate to each other. Vector also has greater locational accuracy, making it efficient for homogenous, small data quantities in which the computer only has to perform a limited number of algorithms. The downfall of the vector data model is that these algorithms very complex; making overlay mapping and analysis computationally difficult. Furthermore, in vector there can be no spatial analysis within units (polygons), because the data comprising the polygon is considered homogenous—devoid of some larger context; not connected or related to anything else.

This has led to the vector model being referred to commonly as the spaghetti model, because the computer has not been given any information in its data that allows it to assess that polygon 1 is attached to polygon 2, which is attached to polygon 3, so on and so forth. The computer does not view things in the landscape as part of an overall grid (as in raster); so there are no inherent relationships between objects. In vector, “spatial linkages are only inferred in the viewer’s mind when the lines are displayed on the screen and are not contained explicitly within [the] data file”.[46] This is why things included in vector maps are considered to be discrete objects—as there is nothing in the data model that allows it to do anything more than display features. The X-Y coordinates with which it draws things are very accurate, yet there is no relationships between entities displayed on screen.

2.3.3—Level 3: Data Structure

The third level in Peuquet’s data abstraction theory is to figure out an appropriate data structure or “representation of the data model often expressed in terms of diagrams, lists and arrays designed to reflect the recording of the data in computer code”.[47] The big question at hand while determining a data structure, is what approach is best suited to display things best?

46. Ibid.
47. Keith Clark, "Lecture 4: Spatial Data Properties and Spatial Data Sampling," Geography 176B Technical Issues in GIS.

Determining a data structure is a higher level of data abstraction than information organization because it involves the creation of appropriate databases and files the computer will use in order to display the raster and vector data models on screen. In other words, the data structure is concerned not with digital representation the landscape, it is concerned with the organization of information.

Oftentimes the nature of data being used and desired outcome will steer data structure in GIS, but there is also a component of human perception that needs to be taken into consideration when designing database models. For example, each person's perception of geographic space will vary based on how they view spatial concepts and their relationships to each other. Perception of geographic space will also always be informed by personal experiences and general societal context. All of these variables will also affect how different people go about solving problems, interpret questions, or process data—and therefore should help determine the data structure. Determining how to structure data lays the foundation for the next level of data abstraction: file structure.

2.3.4—Level 4: File Structure

The final level of data abstraction, determining a file structure, is the natural follow-up to determining a data structure. File structure is how people will store the represented data in computer hardware. In other words, this is when you consider the "particular set of instructions and information (data structure) […] the computer [will] require to reconstruct the spatial data model in digital form (level 3 abstraction)".[48,49] Raster and vector data models are the software implementation side of GIS (i.e. the result of specific computer programs), while file structure

48. Spatial Data Models and Spatial Data Structures, http://www.gisknowledge.net/topic/methods_in_gis/trodd_spatial_data_models_and_spatial_data_structures_05.pdf (accessed July 1, 2012).
49. Ibid.

has to do with the hardware side of a geographic information system. File structure involves the physical storage of the data on some specific computer hardware, such as hard drives, local hard-disks, CD-roms, USB flash drives, or a network.

2.4—Other Elements of the GeoDesign Process

In addition to the levels of data abstraction discussed above, there are also three other important components usually are included in the GeoDesign process. The first is ***sketching***, or "the concept of drawing potential designs or plans, usually with approximate parameters and few details" in the preliminary stages of a project.[50] This often occurs when designers or project managers are just trying to get a feel for how components of a design may interact with various portions of a selected site, or with other design components. Seasoned designers can sometimes do this in their heads, but other professionals benefit from putting initial thoughts and program scenarios quickly down on paper during the early stages of design development. The great thing about sketching within a GeoDesign platform, is that ideas therein are instantaneously available to other design team members via the internet or an internal network, or in community planning scenarios, the public—which provides a great opportunity for conversation, brainstorming across discipline boundaries and general feedback.

The second is ***cost estimation***. Models created using GIS can provide designers with estimates as to "how various systems (environmental, economic, etc.) will respond to the plans suggested by the sketches. These models provide information on both impacts (like costs or water consumption) and change (like population growth rates or development patterns)" which are instrumental for the beginning stages of making a case for the inclusion of different program elements into final designs for preferred scenarios.[51]

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50. Environmental Systems Research Institute, "Changing Geography by Design: Selected Readings in GeoDesign," (Environmental Systems Research Institute) October 2010.
51. Ibid.

Finally, the third and most important benefit of GeoDesign is ***iteration***. Iteration is when project team members "sketch an idea, find out its implications, make adjustments and try again, often many times within a single work session" and throughout the schematic design process.[52] This is perhaps the greatest advantage of incorporating GeoDesign into a project; as the liberty to try numerous alternatives has merit far beyond simple constraints regarding project timelines and speed. Quickly iterating ideas promotes teamwork, inventiveness, and increased understanding of complex systems and interrelated processes.

Chapter 3: Factors Leading to GeoDesign's Cross-Disciplinary Utilization

3.1—The Universal Merit of GIS

GIS' widespread utilization amongst various disciplines can be attributed to one simple fact: it helps us manage what we know by making it easier for us to store, organize, access, and manipulate large data sets. This allows us to solve increasingly complex problems across a variety of disciplines. The debate surrounding GIS as a problem-solving tool or a science has not hindered its popularity and its emergent role in many disciplines though. GIS has proven itself to be a time and cost effective mechanism for "developing a true understanding of our complex and dynamic earth", as well as for creating frameworks in which we are able "to take many different pieces of past and future data from a variety of sources and merge them in a single system".[53] As such, GIS has evolved from its primitive beginnings to become "a sophisticated technological tool […] in widespread use by planners, engineers, and scientists to

52. Ibid.
53. Jack Dangermond, GIS: Designing Our Future, Environmental Systems Research Institute, 2009, http://www.esri.com/news/arcnews/summer09articles/gis-designing-our-future.html (accessed June 1, 2012).

display and analyze all forms of location-referenced data about the health, status, and history of our planet”.[54]

Geographic information systems have become vital to soft and hard science disciplines alike because, as mentioned, all fields deal with phenomena having some form of locational importance. It is no surprise then that the hard sciences—i.e. natural or physical sciences such as botany, biology, or geology—benefit greatly from advances in GIS, and will likely remain reliant on the technology well into the future. GIS has similarly affected the softer sciences, such as psychology, sociology, and anthropology, as they too involve investigating criteria difficult to quantify.

3.1.1—GeoDesign in the ‘Hard’ Sciences

Environmental sciences have a long history of using GIS for a wide range of applications. Scientists utilize GIS for water-quality, air pollution, forest cover, and climate change analyses. In more recent years, GIS has been emerging as an invaluable tool in modeling natural hazards such as land slides, earthquakes, and flooding. It has also been used in many different contexts to monitor and/or predict patterns of soil erosion, species extinction, and phenomena occurring in environmentally sensitive zones.

Geographic information systems and GeoDesign have taken root amongst the engineering disciplines as well. Engineers use GIS technologies for generating, managing, exploring, and visualizing all types of geographic phenomena. Today’s engineering firms are often faced with increasingly complex projects that require global data sharing and management. Civil engineers, in particular, have benefited from implementing GIS throughout their project life cycle—allowing them increased multidisciplinary collaboration.

54. Ibid.

3.1.2—GeoDesign in the 'Soft' Sciences

GIS has also transformed the design disciplines, including architecture, landscape architecture, urban design, community planning, and historic preservation. The merit and positive impacts of these systems also extend beyond private sector endeavors. GIS has become increasingly important to many public sector entities, such as non-profit organizations, universities, and government agencies. Environmental scientists and ecologists have established a legacy of quantitatively expressing systems that has spilled over to many professions from civil engineering to real estate development.

3.1.2.1—Computer Aided Design (CAD) versus GIS

For individuals outside the design disciplines it may be hard to distinguish between Computer-Aided Design (CAD) (formerly Computer-Aided Drafting (CAD)) and GeoDesign using GIS, but they should not be confused. CAD and GIS technologies have evolved, in a more or less parallel fashion over the last few decades; becoming increasingly available across multiple platforms and to a growing number of users. They are also both frequently used by professionals in architecture, interior design, engineering, urban planning, product manufacturing, general construction, land surveying and aeronautical design just to name a few. Yet, CAD is mainly used in the architectural design of buildings, structures, or products. GeoDesign and GIS are concerned with designing buildings, structures, or products "in and around the environment".[55]

CAD models are just as the name suggests—a computer tool created to automate the traditional hand drafting technique in order increase worker productivity and decrease business costs. CAD models are best understood as 'read only'—as the software excels in design and rendering construction graphics, not cartographical production, database management of

55. Ibid.

information, or spatial analysis. If you want to use it in a geographic information system, it has to be converted to a GIS operable format—such as a shapefile.

Similar to raster and vector described in Chapter 2, computer-aided design models are file based digital representations of existing objects, only entities within CAD models do not have unique identifiers—which means you cannot assign other attributes to an object, such as temperature, soil type, place name, etc. In CAD, a line is just a line, a polygon just a polygon, so on and so forth. The lines and polygons are the information, whereas in GIS the lines and polygons are just representations of data hidden in tables behind the scenes.

There are no relationships between items stored in the CAD data model, as its sole function is to create imagery based on local drawing coordinates. Unlike GIS, whose features are stored as points, lines, and polygons and then linked to tables of information, CAD programs are designed for the simple storage/reproduction of graphics, and do not reference subsidiary information about objects in a database other than X-Y coordinates.

Spatial analysis capabilities are extremely limited in CAD, as CAD software was created to put out graphics, not analyses. The main dilemma with importing CAD models into geographic information systems is that they equate to spaghetti, as the information contained in CAD models are translated by computers as spatial rather than geographic. They are not linked to any point on earth's surface. Similarly, because individual objects have no unique ID assigned to them, no information on spatial relationships is stored (i.e. no topology, no knowledge regarding shortest path between objects, etc). Table 4A below illustrates six basic types of questions that GIS can answer but CAD cannot.

BASIC QUERIES IN GIS	TYPE OF ANALYSIS
Where is ______?	Mapping
Where is change occurring?	Temporal
What relationships exist?	Spatial
Where is best location for ______?	Suitability
What is affecting what?	System
What if ______?	Simulation

Table 1: Basic GIS queries.

The questions included in Table 4A above are important to consider. CAD is primarily used to document conditions prior to or after construction—but it lacks capabilities to provide much needed guidance for the phases and questions in between. The graphic portrayals of change occurring in geographic space produced by GIS are crucial to plan making and policy-making initiatives.

CAD lacks the functions needed to perform basic queries about where change is occurring and what is affecting what, as it has traditionally not included database linkages. While "storing digital data in multiple 'layers'" is a component of CAD, "what's unique about GIS, and important about map overlay, is its ability to generate a new data layer as a product of existing layers" to answer questions about suitability.[56] GIS' ability to combine differing variables from multiple datasets to create whole new datasets that point designers to the best location for change is one of the most heralded components of the technology. CAD models do not answer the important question of what if?

3.1.2.2—The Interdependent Nature(s) of CAD and GIS

Over the years, however, CAD has become more and more 'GIS' friendly, while GIS programs have built in more 'CAD' like drafting tools. The primary software production

56. David DiBiase, The Nature of Geographic Information, ed. Jim Sloan and Ryan Baxter, Pennsylvania State University, 2009, https://www.e-education.psu.edu/natureofgeoinfo/print/book/export/html/1771 (accessed July 1, 2012).

companies for both CAD and GIS have been working to blur the boundaries between the two software approaches to design. CAD has been developed to have more database linkage capabilities. For example:

> ArcGIS for AutoCAD, a free downloadable tool that offers seamless interoperability between AutoCAD and the ArcGIS platform, is used widely today. ArcGIS for AutoCAD users are provided with quick and easy access, within the AutoCAD environment, to enterprise GIS data published by ArcGIS Server. This tool lets designers include the results of GIS analysis in AutoCAD designs, as well as create, manipulate, and define how CAD data is organized and attributed as GIS content.

CAD combined with GIS has the potential to evolve into an awesome pairing for land-use analyses and integration into mainstream civil engineering practices. But there are still many challenges in bridging the gaps between software programs, and how advanced this will become remains to be seen. CAD's origination of including digital features with fixed characteristics is sure to be a constraint. In the meantime, GIS will remain the main analytical tool used by policy makers and members of the soft sciences. CAD will remain a line-based tool for designing structures that will be built in the future.

Until greater advances occur in linking the two software technologies, the design disciplines will likely continue to adhere to the following mode of operation. A firm hired to build a project on a parcel of land will hire a civil engineering firm as a sub-consultant. The engineering firm will solicit an accurate land survey of the property from a licensed professional and produce base maps using the information provided therein. The contractor, as part of the deliverables outlined in their contract will forward the land survey to the design firm. Once the design firm has real-time, accurate parcel boundaries and features from the land survey drawings, they will proceed to import the information into AutoCAD.

While this may seem less efficient than pulling parcel boundaries from aerial imagery, the benefit of using freshly surveyed drawings is increased accuracy. Engineers' drawings are based on precise latitudinal and longitudinal coordinates; whereas city website data or aerial photographs may be up to ten years old (depending on the municipality). This offers much more exact data and bases for the design firm to model alternatives with. Once the design firm has imported the property map into AutoCAD, they then proceed with importing the CAD file into GIS and modeling design alternatives using other parameters—such as traffic flow, soil type, zoning, tree canopy, etc.

This is just one example of how individuals in design disciplines utilize CAD and GIS interchangeably. It is likely that this will continue to be the status quo for the foreseeable future, until improvements and better linkages between software programs have been made. GIS will remain the preferred tool for quickly sketching up design alternatives and gaining a greater understanding of how things interact with the landscape from the building envelope out, while CAD will remain the preferred tool for designing structures.

The following chapters explore some factors contributing to the interdisciplinary nature of computer technologies and project management. GIS and CAD users are "separated by job description or some arbitrary division based on real or perceived software limitations", but this may prove to be an unsustainable tradition undermining a much needed, larger shift towards holistic design processes and collaborations across disciplines.[57] Currently, GIS is *the* technique for resource planning, mapping and analyses, while CAD is simply a design tool for engineers and architects. Going into the future it will be important to test these limits, and further explore how we may blur these boundaries with GeoDesign moving into the future.

57. Environmental Systems Research Institute, Inc., "Geodesign: A New Approach to Planning and Design" (January 2012), 8.

Chapter 4: Bridging the Gaps between Hard and Soft Sciences

4.1—Integrated Project Management

Over the years, our built environments have become more and more complex. New technologies, materials, and systems have been developed. Building codes and industry regulations are becoming increasingly rigorous; calling for enhanced performance from buildings and building industry professionals. In today's market, successfully producing design projects requires a multifaceted team of project managers, designers, staff, contractors, subcontractors, consultants, and suppliers, not to mention financial advisors, corporate lawyers, and information technology specialists (seen in Illustration 8 below). Last, but certainly not least projects must always include input from the client, community stakeholders, public officials, etc.

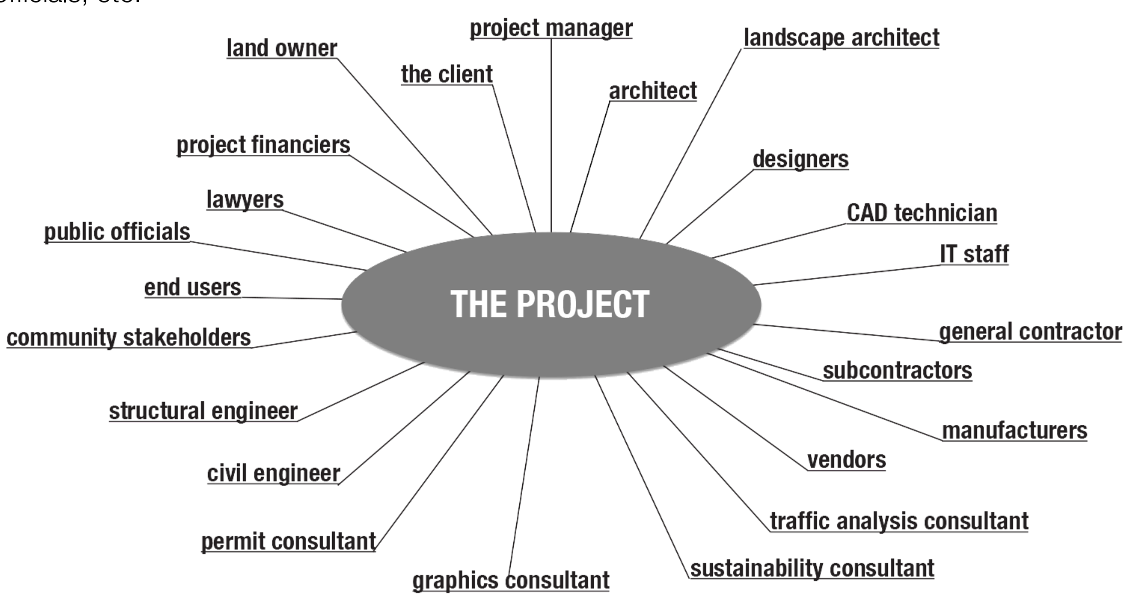

Illustration 8: Potential project members.

Firms now include hundreds, and sometimes thousands, of employees operating from multiple offices across the country. As one would image, the cost of keeping up with all the moving parts necessary to run a modern day design firm is high, and as firms grow in size, they require increasingly sophisticated management techniques and marketing campaigns to keep the business profitable.

Integrated project management (also referred to as *integrated project delivery*, or *integrated practice* in various design industries) is an approach to planning, design, and construction that attempts to pull from the expertise of all team members and stakeholders as early as possible, and as often as possible, throughout the multiple phases of a project in order to produce the highest quality product. Integrated project management started to emerge following the 1970s, when design and construction communities were forced to find new solutions to the challenge of delivering consistent, high-quality results with predictable outcomes in the midst of changing technologies and environments.

The goal behind integrated project management is to capitalize on the expertise of all team members involved, so that the client receives a final product in which the highest levels possible of cooperation, collaboration, quality and efficiency were maintained from genesis to completion. It is about figuring out how to add as much value as possible to a project or product—for the client, for the firm, and for the end-users of a project.

The way a design firm delivers a product or design to a client is often determined by the relationships and responsibilities of project team members; how they delegate and share information regarding schedules, costs, or scope of service; and how each of these apply to the successive phases of a project. In the design professions—such as architecture, landscape architecture, urban design, etc—integrated project delivery often consists of five phases: 1) conceptual design; 2) criteria design; 3) detailed development; 4) construction documents and bidding; 5) construction and project close out. Table 4A on the following page outlines these phases in more detail.

PHASE 1: PROGRAMMING & CONCEPTUAL DESIGN
Design firm works with client to identify needs for the project
Firm develops program (i.e. things to be included in design, preliminary budget)
Firm presents program to client for approval
Once program is approved, firm prepares conceptual, basic, preliminary designs
Firm presents concepts to client for approval
PHASE 2: SCHEMATIC DESIGN
Firm begins formalizing designs and prepares the following documents for client:
Schematic drawings, plots, images, renderings, models, written descriptions
Detailed description of materials
Written scope of services document
Detailed budget
Firm performs necessary code and zoning checks, entitlement requirements, etc.
Schematic design presented to client for approval
PHASE 3: DESIGN DEVELOPMENT
Firm refines schematic design plans
Designs elements and budget are finalized
Firm coordinates with consultants on structural engineering requirements
Firm presents fully developed design to client for approval
PHASE 4: CONSTRUCTION DOCUMENTS & BIDDING
Firm arranges meeting with all construction contractors, consultants and sub-consultants
Construction schedules are verified and consultant needs are identified
Firm sends out finalized construction documents
Firm finalizes technical specifications
Construction documents are issued for bidding/pricing
Necessary permits are obtained
When costs match budget, firm initiates construction
PHASE 5: CONSTRUCTION & CLOSE-OUT
Notice to proceed issued
Project kick-off meeting held
Construction and move-in schedule approved by client
Certificates of insurance submitted and building permits picked up
Demolition completed
New construction begins
Warranties and manuals submitted
“As built” drawings computerized
Project move-in, installation of furniture, equipment
Final cleaning and inspections

Table 2: Integrated project delivery.[58]

58. Richard W. Jennings, "Design Quality v. Profit, The Future & Project Delivery Overview," Design Firm Leadership Lecture Notes (Austin, Texas: The University of Texas School of Architecture, November 15, 2011).

Table 4A above is a generalization of the overall approach often used by design firms to build out a project. The specific ingredients of each project and integrated project delivery approach will depend on many variables, but this is a good generalization of the processes typically associated with the design disciplines that various CAD and GIS technologies, and GeoDesign, could apply. Illustration 4B below, shows a more simplified overview of the five phases outlined above. Integrated project management, in essence, is the preferred approach today in that it starts answering important questions regarding *what*, *how*, and *who* much earlier in the design process than the traditional approaches used in previous decades.

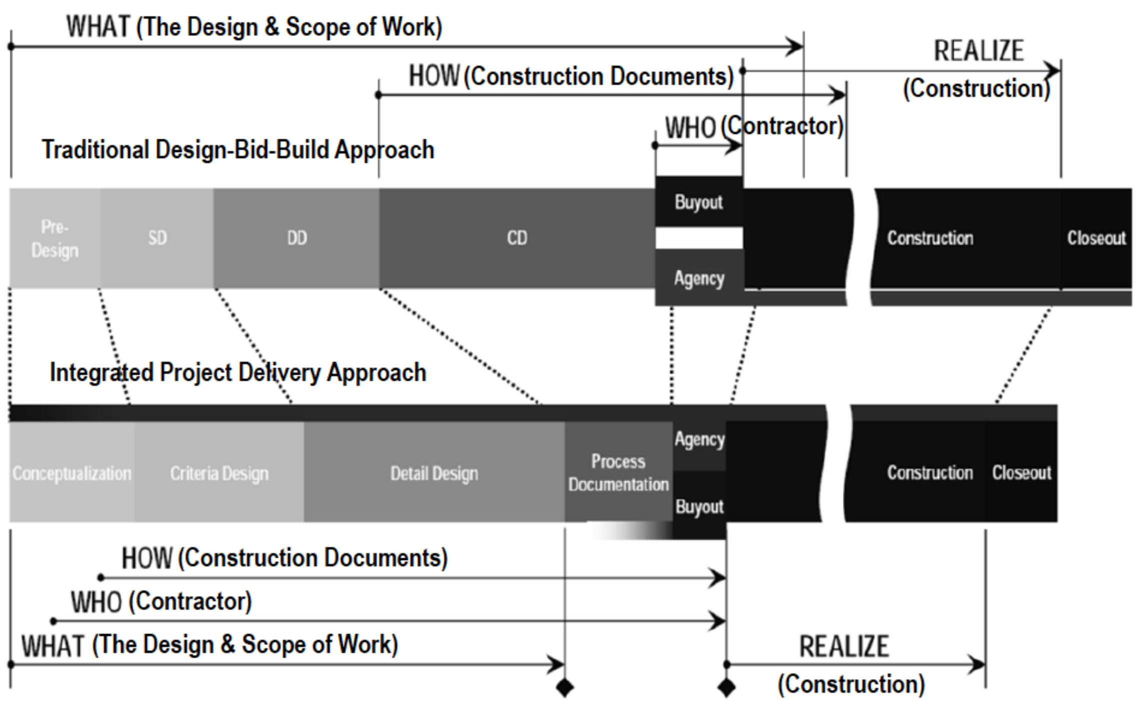

Illustration 9: Traditional project delivery versus integrated.

Integrated project delivery is very different from traditional project management styles in various design disciplines in that the owner, design firm and contractors are working together from the very start. All decisions are joint decisions; and all project team members subscribe to some form of building information modeling (BIM)—in which the use of virtual modeling is used to develop the design and communicate differing construction processes.[59] On the financial side of things, in integrated project management there is often a multi-party contract between the owner, design firm, contractor, engineers and sub-consultants that involves shared risk/profit. Therefore, for all parties involved, motivation is high to work together as efficiently and innovatively as possible to complete the project on-time; and most importantly, within the budget.

4.1.1—GeoDesign and Integrated Project Management

This is where GeoDesign can really provide great advantages for design firms and consultants alike—as a firm's computer technology and project delivery approach are often heavily intertwined. Few contest "GIS has done much to remove the traditional isolation between the fields of… cartography, geography, computer science, spatial statistics, and other disciplines with interest in the…issues of spatial data" but it seems GeoDesign will continue to be the most important link between design and science.[60] Individuals across disciplines are becoming increasingly aware that GIS and the spatial statistics thereof provide indispensable "tools for explaining spatially induced variance" and designing preferred alternatives to address issues.[61]

At the micro level, GeoDesign is bridging gaps between the hard and soft sciences by serving as a tool for collaboration on formerly divergent experiences. It is becoming increasingly important for expanding "the role of geospatial technologies in design workflows, as well as

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59. Joseph A. Demkin, The Architect's Handbook of Professional Practice, 14 (Hoboken, New Jersey: John Wiley & Sons, Inc., 2008).
60. Daw J. Wright, Michael F. Goodchild and James D. Proctor, "GIS: Tool or Science? Demystifying the Persistent Ambiguity of GIS as "Tool" Versus "Science", Annals of the Association of American Geographers (Taylor & Francis) 87, no. 2 (June 1997): 346-362.
61. Joseph K. Berry, "GIS TECHNOLOGY IN ENVIRONMENTAL MANAGEMENT: a Brief History, Trends and Probable Future", 1999.

across the entire life cycle of a project".[62] In recent years it has proven to be an excellent tool for bringing together the environmental "work that leads off projects, the engineering work, feedback from citizens, and its presentation toward all on the Web", whereas in the past, most disciplines remained isolated and "off doing their own thing and it was up to a project manager to bring them all together".[63]

Moreover, our increased ability to perform complex spatial analyses using GIS has laid the foundation for GeoDesign—which gives us the ability to "analyze the potential interplay between various factors, getting us closer to a true understanding of how our dynamic earth systems may change in the coming decades and centuries".[64] Prior to the cross-discipline communication initiated from GeoDesign, feedback about environmental concerns was often not efficiently delivered to the groups working on the project, resulting in little to no cooperation to improve the end results. GeoDesign allows divergent disciplines the ability to work together to plan designs and policies affecting the environment. It also serves as our main tool for managing anthropogenic earth issues, which has tremendous implications for present and future efforts towards reaching global sustainability.

4.2—The Paradigm Shift Towards Holistic Resource Planning and Design

In light of today's global sustainability crises, the theories formulated by Ian McHarg, discussed in Chapter 1, were ahead of the time. He was one of the first individuals to argue successfully the merit of practicing "landscape architecture, planning, and architecture by integrating the views of soil scientists, hydrologists, ecologists, climatologists, ethnographers,

62. Environmental Systems Research Institute, "Changing Geography by Design: Selected Readings in GeoDesign," (Environmental Systems Research Institute) October 2010.
63. Ibid.
64. Jack Dangermond, GIS: Designing Our Future, Environmental Systems Research Institute, 2009.

and other scientists".[65] But perhaps more importantly, McHarg "grounded his approach for landscape intervention in ecology", which set new, unprecedented standards for designers and planners across disciplines.

McHarg's work ushered in a new era in which 'rich' analyses required the inclusion of more than one variable. Moreover, good analyses were those that took into consideration as many variables as possible—soil compaction, tree canopy, sensitive watersheds, high traffic areas, etc. It became unacceptable to design with tunnel vision, focusing on only particular, or preferred, variables. It was important to be holistic—acknowledging that socially responsible design was synonymous with environmentally sensitive design.

Ian McHarg's questions regarding the linkages between ecology, geography, and humans also spoke to recurring problems associated with shortfalls of designing for the totality of a location. His fundamental argument was that all things are part of a larger system, and that the tension between humans and the ecosystems in which they lived must be acknowledged and explicitly addressed if we were to make progress on all fronts. In addition to being the 'father' of GIS, one could also argue that McHarg paved the way for "the relatively new field of earth systems engineering and management (ESEM), which concerns itself with the design, engineering, analysis, and management of complex earth systems"[66] Like McHarg's overlay mapping technique, the new field of ESEM also "takes a holistic view of multiple issues affecting our earth—not only taking environmental, social, and other considerations into account up front in the design process but also looking at challenges from an adaptive systems approach, where ongoing analysis feeds back into the continual management of the system.[67]

65. Frederick Steiner, "Healing the earth: the relevance of Ian McHarg's work for the future," Philosphy & Geography (Carfax Publishing Company) 7, no. 1 (February 2004): 141-149.
66. Jack Dangermond, GIS: Designing Our Future, Environmental Systems Research Institute, 2009.
67. Ibid.

GIS technologies and GeoDesign will remain at the forefront of global sustainability challenges because it remains the best tool for tracking complex inventories of data and incorporating geographic perspectives in decision-making. One question remains, though. If Ian McHarg's approach to mapping was so holistic, why did we turn to computer mapping? Land suitability analyses for differing designs do not always require a computer application. Planners have a long history of generating maps on transparent trace paper and then overlaying them to show relationships between environmentally sensitive and socially important parcels of land. Similarly, planners and designers can make successful presentations to clients and public audiences using paper media. In many scenarios, the inclusion of conceptual hand drawings and overlay analyses maps often lends to telling some overall story of how a design has developed overtime into a desired solution or alternative.

There are, however, some obstacles associated with McHarg's traditional hand-drawn, map overlay technique. First, there is a maximum of information layers that the human eye can understand simultaneously. Secondly, there is no effective way to quantify the differing levels of importance amongst layers. And lastly, results from paper overlay analyses cannot be applied to other problems due to the fact that they are not easily summarized or recorded. This is where the shift to the digitization of maps and spatial analyses via GIS comes into play.

The geographic information system is complex and adaptable. For some, it is used simply for automating map production for reasons of cost efficiency. Yet, to others, the merit of GIS lies in its power to solve geographic problems, analyze vast quantities of data and reveal insights and relationships that may be overlooked by human eyes.[68]

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68. Paul A. Longley, Michael F. Goodchild, David J. Maguire and David W. Rhind, Geographical Information Systems and Science, 18.

4.3—Consensus on the Economic Advantages of Modeling Alternatives

The economic advantages of using GIS and the GeoDesign approach to problem solving are vast. Geographic information systems have revolutionized many industries and fields of science. It has proven very useful for managing large amounts of data, performing spatial queries and for documenting important facets of a problem solving process. GIS has also proven itself an invaluable tool for visually communicating to an array of audiences who need to be able to work collaboratively on datasets.

Enabling designers to quantitatively layer and prioritize various ecological, socioeconomic and physical constraints occurring in geographic landscapes has improved business efficiencies and project management across disciplines. The automated 'layer cake' method has gained particular momentum in the presentation of various land use opportunities and constraints to local decision makers and public citizens.

McHarg's methods have transformed with advances in GIS technologies, and GeoDesign has provided "landscape architects, city planners, architects, engineers, and others the ability to intervene in landscapes to address the pressing issues facing communities and regions" in ways that ensure the overall viability of local economies and ecosystems.[69] GeoDesigning with GIS lets communities devise, test and evaluate various alternatives before design implementation. Evaluating design alternatives in terms of future impacts on both human and environmental resources greatly expands our potential for making maximally informed decisions.

Another economic advantage to modeling alternatives under the GeoDesign process is that information can be "presented succinctly and clearly in the form of a map and accompanying report, allowing decision makers to focus on the real issues rather than trying to

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69. Frederick Steiner, "Healing the earth: the relevance of Ian McHarg's work for the future," Philosphy & Geography (Carfax Publishing Company) 7, no. 1 (February 2004): 141-149.

understand the data" saving time costs for all involved in the decision making process.[70] When proposed alternatives still do not meet client expectations, the ability to quickly redraft geographic imagery to address additional needs becomes invaluable. Redrafting hand-rendered paper maps could take up to several days, but the same revisions using computer mapping can be done in hours. Furthermore, maps, reports and new data can be produced quickly with GeoDesign for multiple alternative scenarios—opening up new levels of decision-making possibilities.

At the organizational level, many businesses across disciplines have found that implementing GIS and GeoDesign approaches have improved "management of their own organization and resources [because] GISs have the ability to link data sets together […and] facilitate interdepartmental information sharing and communication [by creating shared databases from which] one department can benefit from the work of another—data can be collected once and used many times".[71] GeoDesign incorporates concepts from many disciplines, increasing local and nationwide resources for creating synergistic solutions geographic problems.

Most recently, the trend of monetizing "ecosystem services so as to demonstrate the necessity of incorporating both the current diminishment and the potential enhancement of these services into our economic system" has emerged.[72] The thought process being that one of the most eye-opening approaches for communicating to audiences the importance of protecting the environment is to quantify in economic terms net losses due to misuse of natural

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70. Ann E. Throckmorton, Introduction to GIS, http://www.westminster.edu/staff/athrock/GIS/GIS.pdf (accessed July 1, 2012).
71. GIS for You, Seminole County, Florida, http://www.seminolecountyfl.gov/is/gis/gis_do.aspx (accessed July 1, 2012).
72. Steven Windager, Frederick Steiner, Mark T. Simmons and David Heymann, "Emerging Landscapes: Toward Ecosystem Services as a Basis for Design," Landscape Journal (Board of Regents of the University of Wisconsin System) 29, no. 2 (2010): 107-123.
72. Ibid.

resources or neglectful planning thereof. Although, accounting for values associated with natural features of the landscape is not a new concept, today's calculations of the effects on ecosystem services have expanded to "include resources formerly taken for granted (such as clean air and water)" that have traditionally been left out of the economic modeling processes of design.

Chapter 5: The Emergence of a New Status Quo

5.1—New Efforts in Evaluating Sustainable Design

The urgent need to counteract climate change due to the impact of human alterations to the earth's ecosystems can be seen in the growing number of recent initiatives to create and evaluate sustainable design practices. While there has been an evolving definition of sustainability current consensus across various disciplines is that it is any design or practice that achieves "some balance of environmental quality, social equity, and economic efficiency".[73] However, despite the existence of an accepted definition of the term, there has yet to be any "real consensus about how sustainability might be realized or measured".[74]

This is in large part due to the intricately interwoven nature of ecosystem functions and the fact that "management, design and monitoring are complex processes that require knowledge of different fields and the consideration of different variables".[75] This is then further complicated when "different maintenance policies (e.g. reactive, corrective, preventive, time-based maintenance, condition-based maintenance, re-design)" need to be monitored

73. Ibid.
74. Ibid, 107.
75. Inês Flores-Colen and Jorge de Brito, "A systematic approach for maintenance budgeting of buildings façades based on predictive and preventive strategies," Construction and Building Materials 24, no. 9 (September 2010): 1718-1729.

simultaneously.[76] One of the most difficult things to achieve with any design is continual optimum performance—as even the most intricately engineered systems deteriorate or change over time.

In its most basic form, the answer to the question of "How would you measure/monitor the successful long term performance of a design or plan?" is simple—assess conditions before implementing a design, implement the design, then test to see if what the design was expected/intended to produce actually occurs. While this approach is often easily and appropriately implemented in some natural and social science disciplines, it has been a great challenge in landscape ecology and environmental design.

Focus on the post-occupancy performance of built projects and designing for resiliency, regeneration, or continuation of various natural and economic frameworks has also taken precedence. All disciplines now commonly subscribe to the notion that all things are part of some larger system, and therefore actions and decisions should be as informed as possible.

5.2—Research Based Design

All of the factors discussed in Chapter 4, particularly the paradigm shift towards holistic resource planning, have resulted in the emergence of many disciplines focusing more heavily on research and science based design, also sometimes referred to as evidence-based design. Research-based design is the "process for the conscientious, explicit, and judicious use of current best evidence from research and practice in making critical decisions, together with an informed client, about the design of each individual and unique project".[77] The underlying notion of research and evidence-based design is that individuals leading projects, either in the hard or

76. Flores-Colen, Systematic approach for maintenance budgeting, 1718.
77. D. Kirk Hamilton and David H. Watkins, Evidence-based design for multiple building types (Hoboken, New Jersey: Wiley & Sons, Inc., 2009).

the soft sciences, will turn to other disciplines that have related experience and/or information relevant to the project type in an effort to produce the most informed design possible.

The result of this shift has been new generations of designers and scientists that have increasing levels of knowledge beyond their respective areas of expertise. For example, a landscape architect designing a planting scheme and storm water management system for a new residential development located on a site previously used for the manufacturing of computers needs to have knowledge of the potential toxins and environmental implications of computer manufacturing industry. Similarly, an interior designer working on remodeling a children's hospital will need to know about the latest concepts in healthcare technology and the chemical properties of materials that will be used in patient rooms.

Research, or evidence-based design is more about process than product.[78] It takes a commitment on the behalf of those involved in the project to give equal consideration to variables that may be out of their range of expertise—even if it requires more time, energy and budget. The idea being that sustainable design arises from multidisciplinary collaboration and continuous feedback throughout the process of modeling alternatives—which resonates McHarg's theory to be sure. Additionally, the establishment of benchmarks (or metrics) to guide results, both before and after project completion, is considered extremely important in research-based design. Prior to starting the design process, there is also acknowledgement that there is likely something built or previously designed using similar objectives, constraints, or parameters that could be referenced while modeling alternatives to yield the most positive results.

In reality, there are often challenges associated with establishing holistic metrics from the onset of the design process. Oftentimes these come from parties external to the design

78. Ibid.

firm—such as public citizens or even endangered animal species—that design teams may not be aware of until the schematic design phases are well underway; but that should not deter designers from committing to the process. The long-term aim of the research/evidence-based design movement is to have a 'library', so to speak, that will aid designers in settling "issues once and for all. Because others have done the research, evidence-based design will surely tell [future designers] what color to paint, how large a technical space should be, and what type of roof material is most sustainable".[79] Similarly, in doing research-based design, firms are able to establish credibility amongst clients and other members of the profession for setting goals and being able to successfully measure and prove attainment of these goals both during and after construction. GeoDesign has gained momentum in that it is an approach that encourages the integration of environmental and engineering analysis into the design process from a project's outset; making the outcome of successfully attaining goals all the more likely.

5.3—Performance Based Rating Systems

5.3.1—Leadership in Energy and Environmental Design (LEED)

The U.S. Green Building Council's (USBC) Leadership in Energy and Environmental Design (LEED) rating system was a response to a growing need for accountability and regulations for members of design professions involved in altering community landscapes. According to USBC's website:

> LEED certification provides independent, third-party verification that a building, home or community was designed and built using strategies aimed at achieving high performance in key areas of human and environmental health: sustainable site

79. Ibid.

development, water savings, energy efficiency, materials selection and indoor environmental quality.[80]

Although the long-term implications of the initial LEED rating system for the post-occupancy sustainability measures have been questioned, it seems there is overall consensus on performance based rating systems being a giant step in the right direction. Since the early 2000's, LEED has been considered the best practice model to follow for sustainable design. It is now a "force to be reckoned with in the construction world. Fourteen federal departments and agencies, 34 states and more than 200 local governments now encourage or require LEED certification […while] some places offer incentives to certify".[81] Some cities even include it as mandated code.

5.3.2—The Sustainable Sites Initiative (SITES™)

A new performance based rating system has emerged in response to the call for increased knowledge and best practices lacking in LEED. While there is a sizeable amount of literature about the post occupancy evaluation of buildings, there is yet to be comparative progress made in measuring the effects of ecosystem service protection or restoration that occur beyond the building envelope. The recently formed Sustainable Sites Initiative (SITES™) by the Lady Bird Johnson Wildflower Center, American Society of Landscape Architects, and the U.S. Botanic Garden has invented a set of revolutionary standards that are the future of sustainable development best practices for landscape architecture.

In order to achieve SITES™ certification under the Initiative's Guidelines and Performance Benchmarks 2009 publication, a project team must submit documentation

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80. U.S. Green Building Council, What LEED Is, 2011, http://www.usgbc.org/DisplayPage.aspx?CMSPageID=1988 (accessed July 1, 2012).
81. Cater Franklyn, Critics Say LEED Program Doesn't Fulfill Promises, September 8, 2010, http://www.npr.org/templates/story/story.php?storyId=129727547 (accessed July 1, 2012).

showing excellence in sustainable design in accordance with a 51-credit, 250-point rating system based on the following categories:

> ***1. Site Selection*** (21 possible points): Select locations to preserve existing resources and repair damaged systems, ***2. Pre-Design Assessment and Planning*** (4 possible points): Plan for sustainability from the onset of the project, ***3. Site Design—Water*** (44 possible points): Protect and restore processes and systems associated with a site's hydrology, ***4. Site Design—Soil and Vegetation*** (51 possible points): Protect and restore processes and systems associated with a site's soil and vegetation, ***5. Site Design—Materials Selection*** (36 possible points): Reuse/recycle existing materials and support sustainable production practices, ***6. Site Design—Human Health and Well-Being*** (32 possible points): Build strong communities and a sense of stewardship, ***7. Construction*** (21 possible points): Minimize effects of construction-related activities, ***8. Operations and Maintenance*** (23 possible points): Maintain the site for long-term sustainability, and ***9. Monitoring and Innovation*** (18 possible points): Reward exceptional performance and improve the body of knowledge on long-term sustainability.

For each of these nine categories, baseline minimums for sustainable design practices are included in the form of "prerequisites". For example, in the first category: ***1. Site Selection***, a project must pass the following four prerequisites before it can begin accruing points in that category:

> ***Prerequisite 1.1***: Limit development of soils designated as prime farmland, unique farmland, and farmland of statewide importance; ***Prerequisite 1.2***: Protect floodplain functions; ***Prerequisite 1.3***: Preserve wetlands; and ***Prerequisite 1.4***: Preserve threatened or endangered species and their habitats.

Not unlike LEED, the Initiative strategically ordered prerequisites and credits throughout the nine categories to guide an integrated design team through the project phases. Projects earning 100 points receive a One Star SITES™ certification level. Projects earning 125 points, or 50% of total points), receive a Two Star SITES™ certification level. The Three Star SITES™ certification level requires 150 points, or 60% of total points. The highest honor under the rating system is the Four Star SITES™ certification level, for projects earning at least 200 points (80% of the total)

What makes SITES™ certification cutting edge is that it was created using "guiding principles of a sustainable site" that promote a collaborative, systems thinking approach to design.[82] Integrated project management is reinforced throughout the entire certification process, and making decisions based on a hierarchy of preservation, conservation, and regeneration of natural resources is rewarded. The Initiative compensates projects that draw on various forms of environmental and site design expertise and the SITES™ certification process requires design projects to include long-term maintenance plans to ensure built work continues to function properly. For example, project team members must verify that green roof or storm water management systems that they designed will continue to be monitored after construction to ensure the plants and equipment included in them are still working to increase vegetation, prevent soil erosion, or filter out pollutants present in run-off water.

As discussed previously, sustainable design means having to continually assess whether metrics are truly measuring the variables of interest. In the natural landscape, function, maintenance, and metrics may need to change—as some processes operate on a fast schedule and others slow. For example, certain trees may need up to ten years to mature, while the benefits other materials and techniques in soil restoration or storm water management might not be immediately quantifiable. The lack of inert materials and static processes in ecosystem cycles means maintenance—defined as "the ability of a functional unit… to be kept

82. American Society of Landscape Architects, Lady Bird Johnson Wildflower Center at The University of Texas at Austin, and United States Botanic Garden, "The Sustainable Sites Initiative: Guidelines and Performance Benchmarks 2009.

in, or restored to a state in which it can perform a required function… under given conditions and using stated procedures" changes over time and amongst various systems.[83] Therefore, quality site maintenance can only be achieved through quality monitoring long after a site's construction. This is where the SITES™ rating system advances concepts initially left not fully addressed by LEED.

This new rating system offers comprehensive green construction standards for large sites—such as parks, educational campuses, transportation corridors, and conservation easements—that foster the protection of vital ecosystem services and species biodiversity. According to SITES™, the central message the rating system hopes to convey "is that any landscape, whether the site of a large subdivision, a shopping mall, a park, an abandoned rail yard, or a single home, holds the potential both to improve and to regenerate the natural benefits and services provided by ecosystems in their undeveloped state".[84]

5.3.2.1—Opportunities

Prior to SITES™, the status quo was to check for a structures' initial conformance to post-occupancy goals—such as thermal controls or levels of environmental off-gassing—immediately after a project's construction. In recent years, however, there has been a concerted effort to advance 'green' rating systems towards greater long-term accountability through the inclusion of more rigorous post-occupancy evaluations and re-certification requirements. This is an important social shift that the newly established SITES™ fosters well. There is huge potential and opportunity with SITES™, particularly as an antecedent of LEED, to translate lessons learned into an ecologically performance driven rhetoric that solidifies our transition into higher-levels of post-occupancy accountability.

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83. Ibid.
84. Ibid.

Currently, only twelve of sixty-six prerequisites and credits in the SITES™ rating system are eligible for performance monitoring. This is indicative of a need for advanced research regarding additional ways to monitor the performance of designs, at both the macro and micro scale. The most pressing issue for both current and future generations will be "communicating the certainties and uncertainties and seriousness of different environmental… problems, providing alternatives to address them, and educating" others about them.[85] Because the only way for a designer/engineer to know if a design actually performs as assumed or not is to pinpoint, observe, test, and record some indicator of function, it will be crucial for SITES™ and other new rating systems to continue to evolve with new technologies and information.

As the rating system stands currently, there is still much opportunity to gain understanding about the complex nature of monitoring landscape design. SITES™ ***Credit 9.1:*** *Monitor and document sustainable design practices to evaluate their performance over time and improve the body of knowledge on long-term site sustainability* is the highest point valued opportunity within the entire rating system. This is proof of the initiative's commitment to rewarding projects that both assess and analyze the performance sustainable design practices. It is also one area in which the SITES™ Guidelines and Performance Benchmarks[86], even in its infancy, pushes professionals to aim for higher levels of pre-construction design and post-construction accountability. The requirement for this credit, to "Monitor at least three prerequisites and/or credits included in Table 9.1-A" is a confirmation of the authors' understanding that relationships among site components are complex, and that concentrating on individual ecosystem processes can be problematic—as there are inevitably tradeoffs and

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85. Jane Lubchenco, "Entering the Century of the Environment: A New Social Contract for Science," American Association for the Advancement of Science Magazine 279 (23 1998): 491-497.
86. American Society of Landscape Architects, Lady Bird Johnson Wildflower Center at The University of Texas at Austin, and United States Botanic Garden, "The Sustainable Sites Initiative: Guidelines and Performance Benchmarks 2009.

cycles involved that could be undermined if "barebones" monitoring / maintenance practices are encouraged.[87]

In addition, the requirement in Credit 9.1 that all monitoring activities are performed by "a third party or qualified person on the design team for independent peer review" are evidence that the rating system also acknowledges specialized knowledge is required to ensure the monitor can indeed verify the "legitimacy of the information" as well as contribute to the body of knowledge surrounding the "balanced tradeoffs" occurring between natural processes.[88, 89] The documentation requirements of creating separate summary reports for each design practice monitored is fairly stringent, but certainly feasible for projects that have reserved funds in advance and have done an appropriate pre-site design assessment. Credit 9.1 is important to note in that it works in parallel with many other initiatives to encourage "strong effort… to better communicate scientific information already in hand"; which has the potential to bridges gaps in many policy arenas that could greatly impact the future of the planet. The real strength in this approach is that it offers the next best alternative to monitoring site performances with any true level of predictability using a single rating system—the building up of a library of new solutions, successes, and failures that will help us learn how to create a stand-alone performance monitoring rating system that can be adapted to various projects.

5.2.2.2—Challenges and Limitations

There's been an argument permeating design disciplines about GeoDesign (and GIS) not being for ***designers***. In the eyes of some, GIS technology and GeoDesign processes are better suited for ***urban planners*** or ***policy makers***. Others believe that "GeoDesign and urban

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87. Ibid, 210.
88. Ibid, 210.
89. David W. Cash et al., "Knowledge systems for sustainable development," Proceedings of the National Academy of Sciences 100, no. 14 (July 8, 2003): 8086 -8091.

planning are probably the same thing" and that urban planners using “GIS daily to its full potential” should probably call themselves GeoDesigners rather than planners.[90] Despite the fact that GeoDesign offers so many innovative tools for all professions, the probability that the more traditional design disciplines will embrace GIS and GeoDesign principles remains in question. The inclusion of requirements that heavily encourage the performance of GeoDesign throughout the SITES™ rating system may serve as a deterrent for some projects/firms that identity more with traditional architectural design approaches that do not want to tread on the territory of planners’ GIS.

There is also a scarcity of literature regarding the linkages between GeoDesign and the SITES™ rating system—as it was only recently created and it’s guidelines are still in flux. The implications of the SITES™ two-year Pilot Program, in which 150 projects test out The Sustainable Sites Initiative: Guidelines and Performance Benchmarks 2009, will not be fully documented until 2013.[91] At which time SITES™ staff members will publish modified Guidelines and Performance Benchmarks for the year 2013—providing further difficulty for assessing the challenges and limitations associated with the burgeoning initiative.

The variety of projects that can attempt SITES™ certification is endless. Everything from “open spaces… national parks, conservation easements, buffer zones, utility corridors and transportation rights-of-way” to “sites with buildings including industrial, retail and office parks, military complexes, airports, botanical gardens, streetscapes and plazas, residential and commercial developments, and public and private campuses” can apply; and GeoDesign and GIS may be best suited for only a small subset of project types mentioned above.[92] For

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90. Environmental Systems Research Institute, "Changing Geography by Design: Selected Readings in GeoDesign," (Environmental Systems Research Institute) October 2010.
91. http://www.sustainablesites.org/pilot/
92. American Society of Landscape Architects; Lady Bird Johnson Wildflower Center at The University of Texas at Austin; United States Botanic Garden, Guidelines and Performance Benchmarks, 2009,

example, the way GIS is used to complete a city streetscape project may vary greatly from that of a wetlands protection project. All of these factors pose challenges for quickly creating specialized bodies of knowledge about certain project types.

Chapter 6: Remaining Questions and Concluding Thoughts

6.1—APPROPRIATENESS OF GEODESIGN AND GIS FOR SITES™ ?

Just as the geographic information system spawned from scholars at Harvard, academia has also been responsible for the emergence of the both of the aforementioned ‘green’ rating systems. The University of Texas at Austin’s School of Architecture (UTSOA) developed the City of Austin’s innovative Green Building Program, which served as the precursor to LEED. Following the creation of the Center for Sustainable Development in 2001, alumni of UTSOA’s Landscape Architecture program established the Lady Bird Johnson Wildflower Center, which in turn published the Sustainable Sites Initiative: Guidelines and Performance Benchmarks in 2009.

Given the origination of both LEED and SITES™ in academia, it is no surprise GIS, GeoDesign, and evidence-based requirements would be heavily integrated into the ‘green’ rating systems. Just as Harvard scholars paved the way for advances in GIS, UT Austin has long been a leader in the national sustainability movement by promoting community-based, multidisciplinary design. In examining the credits and prerequisites a project must adhere to in order to gain SITES™ certification, it seems apparent that the creators of the rating system believe the benefits of GeoDesign should be inextricably tied to landscape architecture design processes.

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http://www.sustainablesites.org/report/Guidelines%20and%20Performance%20Benchmarks_2009.pdf (accessed July 1, 2012).

The steps designers must complete for SITES™ certification is strikingly similar to how designers go about GeoDesign. There are basic questions regarding selecting an appropriate site for development that often includes mapping. Also, conducting a pre-design assessment to determine various opportunities or constraints associated with the site by quickly measuring or sketching out variables is important for both the certification and GeoDesign process in most applications. Modeling different alternatives based on site components, such as water, soil, vegetation, or human health and well-being tend to be universal across project types; as well as designing for post construction operations, maintenance and monitoring.

It seems then, that overall, GeoDesign and GIS technology are very appropriate for 'green' certifications as a whole, but particularly fitting for SITES™ in that it is sustainable landscape architecture and ecosystem restoration practices are undeniably geographic. Another important thing to note about the larger philosophical questions and fundamental principles brought about by recent sustainability-centric design movements, is that they will persist long after current day CAD and GIS software packages have been replaced.[93] It seems then, that the more lasting value resides in creating adaptable pedagogical approaches to teach the next generations of up and coming professionals; as well as continue to build a body of multidisciplinary literature accessible to all that outlines best practices for managing current and future finite resources.

6.2—Is GeoDesign Art?

As our abilities to creatively solve problems using new technologies continue to evolve, we must consider that in addition to being a *tool,* or a *science*, GeoDesign could also very well

93. Paul A. Longley, Michael F. Goodchild, David J. Maguire and David W. Rhind, Geographical Information Systems and Science (Chichester, West Sussex: John Wiley & Sons, 2005).

be an *art*. Furthermore, what is the merit of pigeon holing GeoDesign processes? What value do we gain by restricting evolving technologies and processes into categories of either or?

> Nevertheless, there remains a need to understand the nature and representational characteristics of what goes into maps if they are to provide robust and defensible aids to decision-making, as well as tactical and operational support tools. In cartography, there are few hard and fast rules to drive map composition, but a good map is often obvious once complete.[94]

All too often geographically referenced data are cited as facts, "even if they are based upon measurements of variable quality or where the very concept of a single definitive answer is suspect".[95] For example, everything from the coastline of a country to the outline of a building is considered to be 'fact' as long as other individuals attempting to represent the same part of the landscape would represent it in a similar way. This not only "negates the cartographer's art" but also limits potentially better "geographic representations of the same phenomenal as stored in different GIS".[96]

If modern day planners and designers are required to be well versed in multiple computer technologies, methods of graphically depicting landscapes via digitized maps, and all of the socioeconomic/environmental processes contained therein, perhaps there is substantive value in the argument that GeoDesign transcends the role of tool or science to that of an art? There certainly seems to be an element of art in dealing with how to manage the reality that we are all seeking a) information we want; b) the ability to model decisions we wish to make so as to see, prior to construction, inter-relationships occurring between variables occurring in real world contexts; and c) understanding of increasingly complex, evolving systems. Thus, despite

94. Ibid.
95. Ibid, 416.
96. Ibid.

evolving definitions and 'best practices', one thing is apparent: "the very nature of cartography and map making has changed profoundly in the past few decades and will never be the same again".[97] We have yet to fully grasp the entirety of the implications of these changes, so perhaps we should proceed with caution in classifying categories for them, in the hopes of extending benefits to as many differing disciplines as possible.

6.3—Concluding Thoughts

GeoDesign and SITES™, much like Ian McHarg in the 1970s, are generating big ideas. In his time, he advocated for natural environments taking precedence over human desires—which was considered at the time, a much needed, reformative approach to making alterations to the modern urban landscape. Moving into the next century, all new rating systems will need to acknowledge the growing importance of GeoDesign and ever advancing imagery technologies in understanding complex system processes. Additionally, 21st century 'green' rating systems will also need to provide new platforms for national and even global dialogue about the ways in which we are monitoring and assessing the affectivity of designs based on three-dimensional, geographic modeling.

While there may always be a level of uncertainty involved in simulating models of reality, this shouldn't deter us from putting forth a concerted effort to do the best job possible—for both human and environmental clients—based on the information available at the time. The significance of the Sustainable Sites Initiative (SITES™), is that it is the first of many future performance based rating systems that doesn't just encourage, but requires higher levels of accountability in order to gain certification—throughout all phases of the design and construction processes. It *is* the new status quo.

97. Ibid, 287.

One thing is sure. The complexity of information has matured to the point that the frameworks of decision-making have forever changed. Modern day issues are as equally environmentally complex as they are emotionally, or politically constrained. Yet GIS is the responsibility of all disciplines to come together in open dialog and continue to determine ways in which technological advances offer opportunities to create a better world for future generations—which requires new ways of thinking; new ways of collaborating—which GeoDesign certainly offers.

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