Semi-Annual Technical Progress Report for
Adaptive Management and Planning Models for Cultural Resources in Oil & Gas Fields in New Mexico and Wyoming,
DE-FC26-02NT15445

Semi-Annual Technical Progress Report

January 1, 2005 – June 30, 2005

Principal Author: Peggy Robinson

July 2005

DOE Award Number: DE-FC26-02NT15445

Submitting Organization

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DISCLAIMER

ABSTRACT

This report contains a summary of activities of Gnomon, Inc. (Gnomon) and five subcontractors that have taken place during the first six months of 2005 (January 1, 2005 – June 30, 2005) under the DOE-NETL cooperative agreement: *Adaptive Management and Planning Models for Cultural Resources in Oil & Gas Fields in New Mexico and Wyoming*, DE-FC26-02NT15445.

SRIF worked on the Final New Mexico Report to send out in draft form for peer review.

William Eckerle edited his chapter for the final Wyoming Report based on feedback from peer reviewers. This chapter was combined with chapters written by Wyoming SHPO and Gnomon. Gnomon then edited the final Wyoming draft report and sent it out for peer review on April 26, 2005.

Gnomon delivered the Cultural Resources Information Summary Program (CRISP) to Wyoming SHPO for testing and debugging. This is a web-based desktop tool to search areas within the Wyoming study area to see where cultural resource inventories have already been done and to see the sensitivity models created by William Eckerle. These models should help managers determine which areas have the highest probability of having buried cultural resources. The tool is a desktop tool that can be used by BLM field office staff, consultants, oil and gas developers, as well as SHPO personnel. Gnomon has had several demonstrations of the tool with SHPO, BLM, and oil and gas representatives. Gnomon also improved the functionality and continued to debug the Cultural Resources Management Tracker (CRMTracker) tool for Wyoming.

Wyoming SHPO wrote chapters for the final draft Wyoming report, and provided editorial input for the report before it was sent out for peer review. Provided feedback on CRISP and CRMTracker to Gnomon.

The Archaeological Records Management Section (ARMS) did not do any work for this project during this time period.

Steve Hall did not do any work for this project during this time period.

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EXECUTIVE SUMMARY

This report summarizes activities that have taken place in the last six (6) months (January 2005 – June 2005) under the DOE-NETL cooperative agreement *Adaptive Management and Planning Models for Cultural Resources in Oil and Gas Fields, New Mexico and Wyoming* DE-FC26-02NT15445. This project examines the practices and results of cultural resource investigation and management in two different oil and gas producing areas of the United States: southeastern New Mexico and the Powder River Basin of Wyoming. The project evaluates how cultural resource investigations have been conducted in the past and considers how investigation and management could be pursued differently in the future. The study relies upon full database population for cultural resource inventories and resources and geomorphological studies. These are the basis for analysis of cultural resource occurrence, strategies for finding and evaluating cultural resources, and recommendations for future management practices. Activities can be summarized as occurring in either Wyoming or New Mexico. Gnomon as project lead, worked in both areas.

Gnomon Activities

Gnomon continued oversight of the entire project and in addition worked on these components of the final products:

1. Incorporated peer reviews of the Wyoming sensitivity study chapter.
2. Wrote or co-authored several chapters for the final draft Wyoming report.
3. Combined all chapters for the Wyoming report, edited the report, and sent out for peer review.
4. Wrote chapters for final draft New Mexico report and forwarded to SRIF to incorporate into the final draft New Mexico report.
5. Rolled out the Cultural Resources Information Summary Program (CRISP) in Wyoming SHPO, BLM field offices, and for oil and gas developers.
6. Debugged CRISP based on feedback from users.
7. Maintained and debugged Cultural Resource Management Tracker (CRMTracker) tool for Wyoming SHPO and BLM field offices. Improved reporting functionality of tool.
8. Eric Ingbar gave a presentation on the results coming out of the DOE PUMP III project at the semi-annual Department of Defense (DOD) "Working Conference on Models in DOD Cultural Resources Management" in Salt Lake City on April 30.
9. Eric Ingbar and Mary Hopkins gave a presentation to DOE-NETL on the current status of the project on May 23.
10. Eric Ingbar gave a presentation on BLM Cultural Resources Data Management in a briefing to BLM Group Managers in Washington DC on May 24.

Wyoming Activities

Wyoming State Historic Preservation Office (WYSHPO) worked with Gnomon to implement CRISP and to improve CRMTracker to better serve the users. Mary Hopkins wrote chapters for the final Wyoming report and gave a presentation with Eric Ingbar for DOE-NETL.

William Eckerle of Western GeoArch Research (WGR) made revisions to the technical section of the Wyoming report based on feedback from peer reviewers. He also sent revised figures for the final draft report.

New Mexico Activities

The Archaeological Records Management Section (ARMS) completed all work for this project December 31, 2004. No additional work was done during the period of this report.

Stephen Hall of Red Rock Geological Enterprises (RRGE) completed all work for this project December 31, 2004. No additional work was done during the period of this report.

SRI Foundation (SRIF) edited the technical section of the New Mexico report based on comments from peer reviewers and wrote chapters for the final draft New Mexico report.

EXPERIMENTAL NEW MEXICO

No new experimental data were produced in New Mexico during this time period.

EXPERIMENTAL WYOMING

No new experimental data were produced in Wyoming during this time period.

EXPERIMENTAL GNOMON

Experimental Apparatus Used to Complete the CRM Tracker and CRISP tool for the Wyoming Study Area

CRM Tracker was created using Java script writing on Apache Tom Cat. It uses an SQL Server database. During these six months, this tool was debugged and enhanced based on feedback from users.

The CRISP tool was created using ESRI ArcIMS 9.0, ESRI MapObjects 2.2, and ASP.NET. This tool was implemented during this time period and was debugged and enhanced based on feedback from users.

RESULTS AND DISCUSSION

During the second six (6) months of 2004 of this project, work has been performed by Gnomon and five (5) subcontractors:

SRI Foundation, Western GeoArch Research, Red Rock Geological Enterprises, Wyoming State Historic Preservation Office, and New Mexico Historic Preservation Division

There have been no major problems encountered and all parties have been able to meet their deadlines on time and within budget. Below is a summary by participant of what has been accomplished and what each hopes to accomplish in the next three (3) months.

Gnomon, Inc.

Improved functionality of CRMTracker based on feedback from users.

Implemented the Cultural Resources Information Summary Program (CRISP). Improved functionality and debugged the program based on feedback from users.

Completed the CRISP user manual.

Assisted WYSHPO with data automation problems.

Wrote chapters for final New Mexico and Wyoming reports. The draft final Wyoming report is attached as Appendix A.

Edited and sent out final draft Wyoming report for peer review (see Appendix A).

Provided on-going technical support to all parties and monitored progress and budgets for all parties.

Submitted required reports on time to DOE.

Gave several presentations on results stemming from the DOE PUMP III project:

1. Eric Ingbar gave a presentation on the results coming out of the DOE PUMP III project at the semi-annual Department of Defense (DOD) "Working Conference on Models in DOD Cultural Resources Management" in Salt Lake City on April 30.
2. Eric Ingbar and Mary Hopkins gave a presentation to DOE-NETL on the current status of the project on May 23.
3. Eric Ingbar gave a presentation on BLM Cultural Resources Data Management in a briefing to BLM Group Managers in Washington DC on May 24.

Western GeoArch Research

Made revisions to the technical section of the Wyoming report based on feedback from peer reviewers. He also sent revised figures for the final draft Wyoming report.

Red Rock Geological Enterprises

Did not do any work for this project during this time period.

New Mexico Historic Preservation Division

Did not do any work for this project during this time period.

Wyoming State Historic Preservation Office

Mary Hopkins wrote chapters for the final draft Wyoming report, which is attached as Appendix A.

Wyoming SHPO staff helped implement CRISP and to follow up with the use of CRMTracker. CRMTracker enabled staff in Wyoming BLM offices to more quickly process lease applications. Details on this improvement and other results and discussion can be found in the final draft Wyoming report attached as Appendix A.

SRI Foundation

Wrote chapters for the final New Mexico report. They are in the process of finalizing the draft and it will go out soon for peer review.

CONCLUSION

TO BE ACCOMPLISHED July 1, 2005 – Decemer 31, 2005

Gnomon and SRIF – complete the final New Mexico report, send out for peer review, incorporate edits and submit to DOE as part of the final report.

William Eckerle – incorporate any additional suggestions from peer reviewers for Wyoming sensitivity models report that result from comments from the final report.

Gnomon and WYSHPO – incorporate suggestions from peer reviewers of the final Wyoming report. See conclusions in the DRAFT final Wyoming report attached as Appendix A.

Gnomon

1. Finalize the CRISP tool and the CRMTracker tool with modifications suggested by users or found during debugging.
2. Complete the final report for DOE, which includes the New Mexico study area, the Wyoming study area, and appendices.
3. Present the findings of the report to DOE-NETL and any other organization interested in cultural resource management in areas of oil and gas production.

REFERENCES

Please see references in the draft Final Wyoming Report attached as Appendix A.

APPENDIX A

Adaptive Management and Planning Models for Cultural Resources in Oil and Gas Fields in New Mexico and Wyoming, Wyoming Study Area

DE-FC26-02NT15445

Final Technical Report

July, 2004 - April 30, 2005

Principal Authors:
William Eckerle
Mary Hopkins
Eric Ingbar
Sasha Taddie
Judson Finley

April 2005

DOE Award Number: DE-FC26-02NT15445

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Adaptive Management and Planning Models for Cultural Resources in Oil and Gas Fields in New Mexico and Wyoming, Wyoming Study Area

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ABSTRACT

In 2002, Gnomon, Inc., was awarded a contract from the U.S. Department of Energy National Energy Technology Laboratory (NETL) for a project entitled, *Adaptive Management and Planning Models for Cultural Resources in Oil and Gas Fields in New Mexico and Wyoming (Adaptive Management and Planning)* (DE-FC26-02NT15445). The project is primarily funded by the Department of Energy under the Preferred Upstream Management Practices III (PUMP III) Cooperative Agreement program. The purpose of the project was to examine cultural resource management practices in two major oil and gas producing areas, southeastern New Mexico and the Powder River Basin of Wyoming, with the purpose of identifying more effective management practices and developing information technology tools to facilitate those practices.

The current report highlights the work completed in the Wyoming component of the *Adaptive Management and Planning* project. It includes:

1. Digitization of archaeological survey and site location information for the entire northeastern corner of Wyoming. These records are available through the Wyoming State Historical Preservation Office (WYSHPO) Cultural Records Office (WYCRO);
2. Predictive modeling of locations where the geology is suitable for the burial of prehistoric archaeological sites within the hydrological Powder River and Tongue River basins;

3. Development of web-based applications to enable integration of management, investigation, and decision-making using real-time electronic systems;
4. Development of recommendations for the use of a risk model by potential categories of users to facilitate more predictable, efficient cultural resource compliance processes for oil and gas development, as well as better management of cultural resources.

ACKNOWLEDGMENTS

Modeling Project: Sasha Taddie acted as GIS specialist, wrote portions of the methodology, and produced the graphics for this report. He also prepared accompanying digital products. Judson Finley co-authored the Protocol Handbook (Appendix A), parts of the report, performed drafting, and assisted with report editing. Rebecca Hanna co-authored the conclusions and authored the summary section, as well as assisted in editing and report compilation. Mary Hopkins and Eric Ingbar assisted in evaluating the model. Reese Tietje and Mike Drews, of Gnomon, Inc., assisted with model creation. Darlene Cobbey, Aaron Geery, Peggy Robinson, and Marissa Taddie helped edit and compile the report. William Eckerle conducted field reconnaissance, determined model parameters, authored or co-authored portions of this report, and is responsible for any errors or omissions.

WYSHPO: Ross Hilman, Ben Blasko, Tom Furgeson, Terri Given, Chris Young, and Greg Willson— all who helped create the spatial and attribute data. Gretchen Keahey who tirelessly scanned all of the site forms for the eight counties without a complaint.

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CHAPTER 1

INTRODUCTION

In 2002, Gnomon, Inc., was awarded a contract from the U.S. Department of Energy National Energy Technology Laboratory (NETL) for a project entitled, *Adaptive Management and Planning Models for Cultural Resources in Oil and Gas Fields in New Mexico and Wyoming (Adaptive Management and Planning)*(DE-FC26-02NT15445). The project is primarily funded by the Department of Energy under the Preferred Upstream Management Practices III (PUMP III) Cooperative Agreement program. The purpose of the project was to examine cultural resource management practices in two major oil and gas producing areas, southeastern New Mexico and the Powder River Basin of Wyoming, with the purpose of identifying more effective management practices and developing information technology tools to facilitate those practices.

The project evaluates how cultural resource investigations have been conducted in the past and considers how investigation and management could be pursued differently in the future. The study relies upon full database population for cultural resource inventories and known sites and geomorphological studies. Predictive models were created based on the geomorphological studies and are the basis for analysis predicting cultural resource occurrence, strategies for finding and evaluating cultural resources, and recommendations for future management practices.

Cultural resources are often considered an impediment to development of oil and gas fields, in part because they differ from many other environmentally regulated resources.

Some classes of regulated resources have the potential to be regenerated as a means to offset their destruction. Loss of a wetland can be mitigated by creating new wetlands. Loss of habitat for a rare species can be offset by protection or even creation of appropriate habitat elsewhere. Cultural resources are different from these examples, for they exist only once and cannot be re-created in some other locale; indeed, spatial location is one of the primary analytical values of an archaeological site.

The National Historic Preservation Act of 1966 and subsequent federal land management legislation and policy (e.g., the Federal Land Policy Management Act [FLPMA, 1976]) recognize that part of the value of cultural resources is the scientific information they contain. This is especially true of historic and prehistoric archaeological sites. Management of archaeological resources on public lands over the past thirty years has focused on retaining high information sites and site settings. Other factors are important too but far less common: historically important places, important examples typical of a time or place in our past, places of deep religious interest to Native Americans, and places or sites amenable to interpretation for the public.

Oil and gas exploration and development are long-term, enduring, uses of public lands. Every exploration and development effort on public lands for the past 30 years has in some fashion addressed impacts to cultural resources, especially archaeological sites. Today, far more archaeological fieldwork is done because of oil and gas development than because of traditional, academic, research. The volume of work is truly stunning: within the Powder River Basin, Wyoming study area of this project over 16,000

archaeological sites have been revealed by more than 10,000 archaeological inventories. In the southeastern New Mexico study area, more than 21,000 inventories have been conducted and over 8,000 archaeological sites are known to be present (Figure 1).

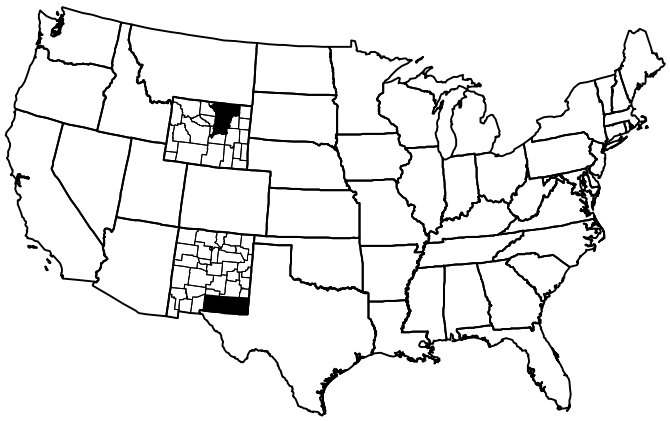

Figure 1. New Mexico and Wyoming Project Areas

Cultural resource clearances were identified in the 1996 interagency document on applications for permits to drill entitled "Report on Problems Identified with Processing Timeframes and Recommendations to Resolve Identified Issues". More recently, the Bureau of Land Management's 2002 APD Task Force identified cultural resource management practices as an area in need of practical reform in oil and gas areas.

The Wyoming Component

The project area for the Wyoming component of the *Adaptive Management and Planning* project encompasses the Wyoming portion of the Powder River and Tongue River hydrological basins (Figure 2). Both drainages are tributaries to the Yellowstone River.

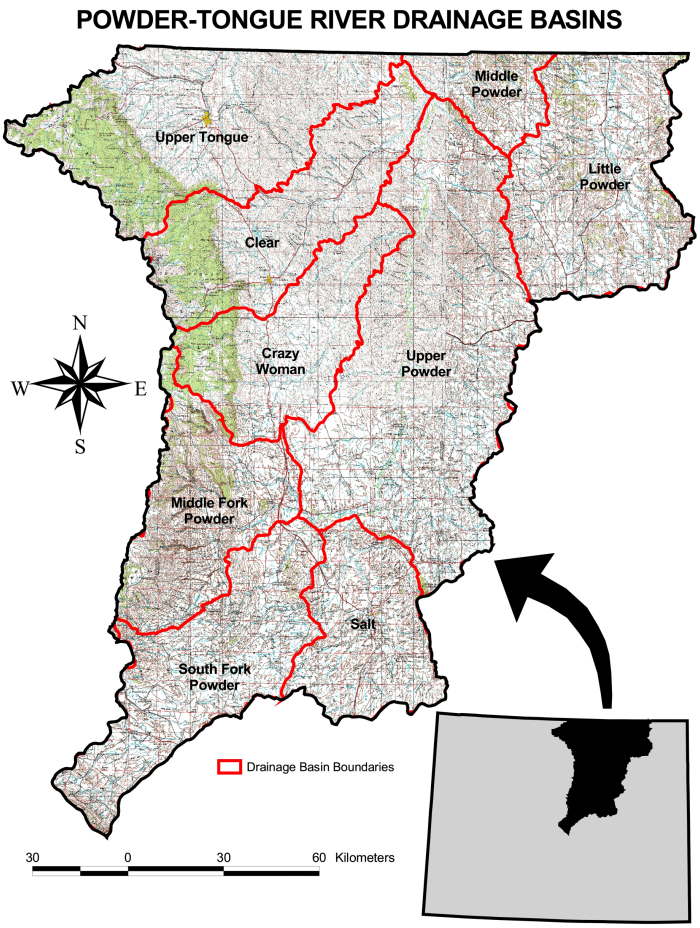

Figure 2. Map illustrating the extent of the Powder River and Tongue River hydrological sub-basins in northeastern Wyoming

Bounding drainage basins include the North Platte River to the south, Cheyenne River to the southeast, Belle Fourche to the east, Little Missouri to the northeast, Little Bighorn River to the north, Bighorn River to the west, and Sweetwater River to the southwest. The current report highlights the work completed in the Wyoming component of the project. It includes:

1. Digitization of archaeological survey and site location information for the entire northeastern corner of Wyoming. These records are available through the

Wyoming State Historical Preservation Office (WYSHPO) Cultural Records Office (WYCRO);

2. Predictive modeling of locations where the geology is suitable for the burial of prehistoric archaeological sites within the hydrological Powder River and Tongue River basins;
3. Development of web-based applications to enable integration of management, investigation, and decision-making using real-time electronic systems
4. Development of recommendations for the use of a risk model by potential categories of users to facilitate more predictable, efficient cultural resource compliance processes for oil and gas development, as well as better management of cultural resources.

Digitization of Archaeological Survey and Site Locations

WYSHPO WYCRO digitized all archaeological projects for the eight counties within the study area boundary. A total of 12,660 new survey areas were entered into a geographic information system (GIS) for a total of 38,200 inventory spatial entities statewide. A total of 13,858 new site locations were entered into GIS for a total of 46,456 sites in GIS statewide. A total of 16,634 sites were encoded into the extensive site attribute database. This database was then used to test the geomorphological predictive model that was created by Bill Eckerle of Western GeoArch Research (see Chapter 4). Also, a total of 13,747 site forms were imaged into Adobe Portable Document Format.(PDF) format for a total of 64,340 total imaged site forms statewide.

Geoarchaeological Predictive Model

Expanded development of energy resources in northeastern Wyoming brings with it the risk that archaeological sites are inadvertently damaged. Sites containing buried, intact,

and well-preserved, archaeological material are some of the most scientifically important cultural resources within the project area. In point of fact, they contain all categories of data that contribute to the significance of surface sites, as well as a number of categories of contributory data that surface sites lack. From this standpoint, the level of management effort buried sites receive should be in proportion to their scientific importance. However, these site types are difficult to find and manage because stakeholders often have a poor understanding of the geological and soil processes that led to the burial and preservation of the site. This leads to faulty prediction of which sites have potential for preserved and intact subsurface cultural materials. This lack of understanding means some sites are subjected to more investigation than is warranted given the data categories they contain while other subsurface cultural levels remain undiscovered until they are destroyed or are unearthed during construction activity. These outcomes lead to unexpected development costs from construction and production delays, as well as loss of valuable scientific information.

Having identified the potential problem, this report presents a geoarchaeological model that predicts the location of deposits that might contain buried and intact archaeological material. This model informs the user who wants to know if a particular known site is located within an area where the burial of subsurface cultural material is possible. Likewise, the model informs the user that certain landscapes have the geological qualities conducive to site burial. If applied properly, this burial model will lead to more efficient management of cultural resources so that both resource preservation and energy extraction are facilitated.

The proposed model will need to be implemented within the Section106 process by land management agencies in order to achieve its potential. In anticipation of this implementation, we suggest how to monitor, evaluate, and adjust the model so that it might fulfill its function under changing development scenarios.

Web-Based Applications

Currently, the investigation-decision-management process for actions like Applications for a Permit to Drill (APDs) is mostly completed by filling out paper forms. A consultant originates the document, the federal agency reviews the document and its findings, then the SHPO may review and comment, and only then will a finding be made on the undertaking (e.g., an APD) itself. In Wyoming, for example, the transit time from fieldwork to presence in the data system may require 3 months or more.

Gnomon developed an information management system that both mirrors the flow of paper documents and improves upon it. The greatest value of this Cultural Resources Management Tracker (CRMTracker) is to save time through a shared database application accessible via a secure Internet connection. CRMTracker efficiently captures the inventory and associated resources suite of data early in the process and provides on-line access to this information back to the project applicant.

Another web-based management tool Gnomon developed for the Wyoming component of the project is the Cultural Resources Information Summary Program (CRISP.) CRISP is an information tool for non-archaeological experts. It is useful for rapid assessment of potential project areas (PPAs). A PPA could be a contemplated well pad and road, a borrow pit, or any other action. Using CRISP, one draws a PPA on to a map image and then runs a report on the PPA. CRISP is a web-based application, and uses cultural resource inventory layers, cultural resource summary layers, and cultural resource forecasts (models) to provide the user with a summary of knowledge about their PPA.

CRISP is a planning tool for land-users and managers. It does not replace consultation with appropriate agencies, landowners, land managers, and other participants in the cultural resource management process. Although CRISP summarizes the results of scientific investigations, it also does not replace discussions with cultural resource managers or other experts. What CRISP does provide is a way to gain a quick overview of what might be present on or in the ground, and information about what is already known. CRISP's greatest utility is as a project planning tool. It is not a compliance tool.

Management Recommendations

In the past all Section 106 applications have been evaluated in the same manner, no matter where in the state the project was proposed. The result of the work completed in this project recommends varying the application process and mitigation requirements based on information provided by the geoarchaeological model. Those areas where there

is a high probability of encountering buried archaeological sites could be either avoided by the developers using the new web-based tool and sensitivity model, or could require different mitigation from those sights located in areas with a low prediction of finding buried resources. The use of the web-based tools and the predictive model has the potential to save both dollars and time for oil and gas developers.

PROJECT FUNDING

This project is primarily funded by Department of Energy (DOE) funds. DOE is contributing $1,416,121, 79.0% of the total project budget.

EXECUTIVE SUMMARY

The purpose of the *Adaptive Management and Planning Models for Cultural Resources in Oil & Gas Fields in New Mexico and Wyoming* (DOE PUMP III) was to examine current cultural resources management practices in two oil and gas producing areas of New Mexico and Wyoming, to identify more effective management practices, and to develop information technology tools to facilitate those practices.

This report highlights the accomplishments of the Wyoming component of the project, which focused on completing four tasks:

1. Digitization of archaeological survey and site location information for the entire northeastern corner of Wyoming. These records are available through the Wyoming State Historical Preservation Office (WYSHPO) Cultural Records Office (WYCRO);
2. Predictive modeling of locations where the geology is suitable for the burial of prehistoric archaeological sites within the hydrological Powder River and Tongue River basins;
3. Development of web-based applications to enable integration of management, investigation, and decision-making using real-time electronic systems;
4. Development of recommendations for the use of a risk model by potential categories of users to facilitate more predictable, efficient cultural resource compliance processes for oil and gas development, as well as better management of cultural resources.

Digitization

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total of 46,456 sites in GIS statewide. A total of 16,634 sites were encoded into the extensive site attribute database. This database was then used to test the geomorphological predictive model that was created by Bill Eckerle of Western GeoArch Research (see Chapter 4).

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Expanded development of energy resources in northeastern Wyoming brings with it the risk that archaeological sites are inadvertently damaged. Sites containing buried, intact, and well-preserved, archaeological material are some of the most scientifically important cultural resources within the project area. However, these site types are difficult to find and manage because stakeholders often have a poor understanding of the geological and soil processes that led to the burial and preservation of the site. This lack of understanding means some sites are subjected to more investigation than is warranted given the data categories they contain while other subsurface cultural levels remain undiscovered until they are destroyed or are unearthed during construction activity. These outcomes lead to unexpected development costs from construction and production delays, as well as loss of valuable scientific information.

Having identified the potential problem, this report presents a geoarchaeological model that predicts the location of deposits that might contain buried and intact archaeological material. This model ranks areas within the study area from low to very high according to the predicted risk of encountering intact, buried cultural resources. If applied properly,

this burial model will lead to more efficient management of cultural resources so that both resource preservation and energy extraction are facilitated.

Web-Based Applications

Currently, the investigation-decision-management process for actions like Applications for a Permit to Drill (APDs) is mostly completed by filling out paper forms. A consultant originates the document, the federal agency reviews the document and its findings, then the SHPO may review and comment, and only then will a finding be made on the undertaking (e.g., an APD) itself. In Wyoming, for example, the transit time from fieldwork to presence in the data system may require 3 months or more.

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Management Recommendations

In the past all Section 106 applications have been evaluated in the same manner, no matter where in the state the project was proposed. The result of the work completed in this project recommends varying the application process and mitigation requirements based on information provided by the geoarchaeological model. Those areas where there is a high probability of encountering buried archaeological sites could be either avoided by the developers using the new web-based tool and sensitivity model, or could require different mitigation from those sights located in areas with a low prediction of finding buried resources. The use of the web-based tools and the predictive model has the potential to save both dollars and time for oil and gas developers.

CHAPTER 2

INFORMATION TECHNOLOGY AND CULTURAL RESOURCE MANAGEMENT

The Current Situation in Powder River Basin of Wyoming

According to the Bureau of Land Management (BLM), approximately 21,100 coal bed natural gas wells have been drilled in the Powder River Basin (PRB) since 1996. Over 23% or 4,100 of these wells are on federal lands and another 77% or 13,400 are on private fee lands where the surface ownership is private and the minerals are federal, otherwise referred to as split-estate. The Wyoming Oil and Gas Commission anticipates an additiona1 10,000 wells will be developed in the next two years in the PRB. BLM reports that during the last two years, 673 billion cubic feet of natural gas has been produced from CBNG wells. This constitutes 44% of all natural gas produced in Wyoming during this same timeframe, with over $440 million dollars in federal mineral royalty being generated.

In the 2004, the Buffalo Field Office of the BLM approved 2,383 CBNG APDs for new wells. This single field office's number of approved APDs exceeds the total actions handled by many other western states. Minimizing the impact of this development on cultural resources as well as aiding in efficient compliance with the National Historic Preservation Act is a goal of this project. Under the current administrations National Energy Policy, Wyoming plays a key role in producing natural gas, coal, traditional oil resources, and electricity for the nation. Additional methods employed for enhanced

mineral extraction in the state are being touted. Enhanced oil recovery and the development of new technologies will continue to be developed and pursued. Historic oil fields, National Register eligible sites of themselves, are located within the eight county study area. Salt Creek and Teapot Dome oil fields are some of the earliest developed areas in Wyoming and have played a historic role in the Nation's energy development and political scandal. Sparsely populated, yet key to America's economy, Wyoming's Powder River Basin is now at the forefront of America's energy needs.

Information Technology Goals

One of the project goals was to make information more readily available to all interested parties in a timely manner in this active oil and gas producing area of America. The *Adaptive Management and Planning* study examines how resources are managed in light of the *information* that is known about them. This chapter examines technologies that *convey information* into the practice of archaeological resources management as it is currently performed and as it might be transformed in the future. We also discuss how information technology was used in the project analytical and management studies.

The term "information technology" has come to mean digital data storage, query, and display in a wide variety of ways. This digital meaning of the term "information technology" is overly limiting in the context of cultural resource management. Cultural resource experts and managers utilize many forms of information that are not digital in any comprehensive way. These information forms include paper records and maps, traditional photographs, documentary sources, experience in the field and laboratory, and

a considerable body of person to person communications both formal (e.g., professional presentations) and informal (e.g., professional discourse). Although we cannot address all of these different forms of information in anything like a comprehensive fashion, it is important to remember that "information technology" in its digital sense (which we shall refer to as "IT" throughout the chapter) is only one of several important information technologies.

The link between sound information and sound management and decision-making is so well known as to be a truism. Truisms are nonetheless true for being shop-worn, however, and in archaeology a high value has always been placed on sound sources of information. Fieldwork and decision-making are greatly facilitated by reliable information. For instance, archaeological fieldwork is guided by a series of questions that can often be answered by sound information:

- Where have investigations been performed already?
- What did prior investigations find?
- How reliable are the findings?

If these questions can be answered well, then the fieldworker has more secure answers to some important operational questions:

- Where does one need to look for new, undiscovered, resources?
- What sorts of archaeological materials are likely to be encountered?
- What level of effort will a new investigation require?

Until recently, these questions were answered using paper maps and records. So long as these were comprehensive and up-to-date, they worked very well. Paper records, especially large format maps, are not necessarily difficult to keep, but they are very limited in their distribution. Most paper archives of archaeological investigation and resource information are unique collections of materials that must be visited to be used. Travel costs and the time it takes to conduct research that is usually geographic in extent in records that are filed by date (e.g., site records are filed in sequential order regardless of site location) make the use of paper archives expensive. Digital information technology addresses many of these problems because it allows records (and maps) to be retrieved in many different ways: geographically, by index number, by information attributes or content, and by combinations of these methods.

WYSHPO Technology Goals

WYSHPO had several technology goals in this project. First, they wanted to create cultural resource information that is readily accessible and available to a variety of users and land managers. A major component of the project was to update the cultural resource database. Knowing where resources have been sought in the area, where they have been located, what is the current regulatory status of the resource, and how resources fit into or have the potential to address contextual or research questions in the future are all desired information system components. Before completion of this project, information was tedious to compile. Using the new applications developed during this project (which are described in Chapter 5) along with the updated database has made information searches

much easier and quicker. The updated database was also used to confirm the modeling component of the project and is available for future research and context development.

The WYSHPO Cultural Records Office also wanted to update and improve their Wyoming Cultural Resource Information System (WYCRIS), which is described in detail in Chapter 3. During this project WYSHPO and Gnomon worked together to develop the final parts of a fully developed cultural resources information system.

GIS creation tools were also developed for use by BLM field office staff in ESRI ArcGIS 8.3, upgrading their previous entry tool from ESRI ArcView 3.3. This upgrade allows for much more efficient updating of the statewide GIS as it reduces data entry errors, reduces the possibility of users making changes to the underlying data structure, and insures values in the table have a presence in the master WYCRIS information system.
Security of WYCRIS was also a project goal. With funding provided by BLM, a CISCO firewall was installed for the WYCRO group. The firewall is configured and administered by the University Wyoming Information Technology Section and is similar and compatible with other systems on campus. Being housed within a university environment has its pros and cons: systems analysts are readily available to aid campus users, but university students are notorious for attempting to infiltrate campus computer systems. The firewall protects the system from intruders, but it also prevents the possibility of our systems being exposed to other campus users. UW IT has set our group to be invisible on the campus network.

One information technology goal has not been met: installation and implementation of ESRI ArcSDE (spatial database engine). One reason is that the current ability of the WYCRO to maintain and administer such a system is not clear. Assessment of the needed resources and long-term costs to WYCRO will need to be completed. The advantage to using ArcSDE in WYCRO is that it would allow for the use of an enterprise geodatabase rather than numerous personal geodatabases. An enterprise geodatabase allows multiple users to check out "versions" of a GIS master dataset and return them to the master GIS. Personal geodatabases require administration in order to merge edited copies into one master file. This implementation could be duplicated within the BLM field offices for staff use, but this possibility needs to be first assessed. Due to the BLM's wide area network, the available bandwith for this product might not be adequate and security issues would need to be addressed as well. Within the WYCRO network, ArcSDE would be an optimal configuration, because updates and additions to the information would be immediately available to all staff and the ability to version the dataset would be an advantage. However, the current server capacity is maximized and disk space will need to be added. The use of MSSQL Server with ArcSDE will require in-house staff expertise or contracted services to maintain the GIS with the relational database. User level access and security in ArcSDE will need to be administrated locally and when data conflicts arise, an administrator will be needed to resolve the issue. Currently WYCRO staff have not received training on ArcSDE nor on MSSQL Server. ESRI (the primary software manufacturer of GIS software) recommends a thorough knowledge of MSSQL Server prior to their training on ArcSDE. As the master geodatabase continues to grow, the WYCRO will be faced with the task of implementing

ArcSDE due to the size limitations of personal geodatabases (2GB). Another option would be to contract for this technical service for a long-term period. Day-to-day administration of this system, once established, should not require a tremendous amount of administration. At this point, the use of enterprise geodatabases in SHPO offices is very limited, and may not be in use at all. The implementation of this technology in BLM is also limited. The most aggressive implementation of ArcSDE in Wyoming has been undertaken at the Wyoming Geographic Information Sciences Center (WYGISC) in supporting generally static datasets served in ArcIMS. They have not been using this to administer a production dataset, which is updated on a per each user keystroke. It would be optimal to have a strong local user community or another SHPO office implement this technology prior to the WYCRO implementation so that there would be an available support base.

CHAPTER 3

EXPERIMENTAL

Overview of Wyoming Cultural Resource Information System (WYCRIS)

Pursuant to state and federal law and in conjunction with data sharing agreements, the Wyoming Cultural Records Office (WYCRO) maintains a comprehensive statewide information system for cultural resources regardless of land status. This function was established by the Smithsonian Institution in the early 1940s, passed to the Wyoming Archeological Society, then to the University of Wyoming Department of Anthropology, and in the late 1970s became part of the Wyoming State Historic Preservation Office per requirements of the National Historic Preservation Act (NHPA). Before the NHPA, many Wyoming citizens felt this information was important to compile, maintain, make accessible for academic research, and preserve for future generations. The Wyoming State Archeologist's Statute (§ 36-4-106.d) enacted in 1967 specifies this collection be "permanently deposited at the University of Wyoming."

During the past decade, the WYCRO has worked toward creating sophisticated electronic data systems for the efficient management and distribution of cultural resources information. The implementation of a more robust information system has been done via a phased implementation approach. The first phase was to redesign the 1970s version of the database into a relational system and post the information on a secured Internet website. This was completed in the fall of 1999. Next was the integration and redesign

of the Historic Preservation Section 106 compliance dataset. GIS technologies were piloted in southwestern Wyoming using ESRI's ArcView shapefile format in 2000.

Through the current DOE sponsored project, significant additional parts of the information system have been created and implemented. Custom mapping applications have been created to increase the quality and efficiency of managing cultural resource inventories and sites in the GIS system. An upgrade to ESRI's personal geodatabase format has been used to better manage the extensive spatial data. The applications have also been transferred to all Bureau of Land Management field offices in Wyoming so data creation can be shared between the BLM and the SHPO. An extensive site attribute database was also created and implemented following the format of the Wyoming Cultural Properties Form, available at:
http://wyoshpo.state.wy.us/shpoweb2002/2002webpages/cpforms.htm
Over, 16,000 sites have been entered into this system during the past two years through this project.

The Wyoming Cultural Resource Internet Map Server (WYCRIMS) was revised and upgraded during the project. Additional user tools were customized and the map interface was streamlined. On-line as well as on-site training was made available to users around the state of Wyoming and at the University of Wyoming. Overall, use of the WYSHPO website has increased 850 percent since 2000, with it more than doubling between 2002 to 2004 (Figure 3). Because of significant modifications and upgrades to the information available, including imaged site forms, private consultants, researchers,

and federal agencies are using this information service on a day-to-day basis within their standard work process.

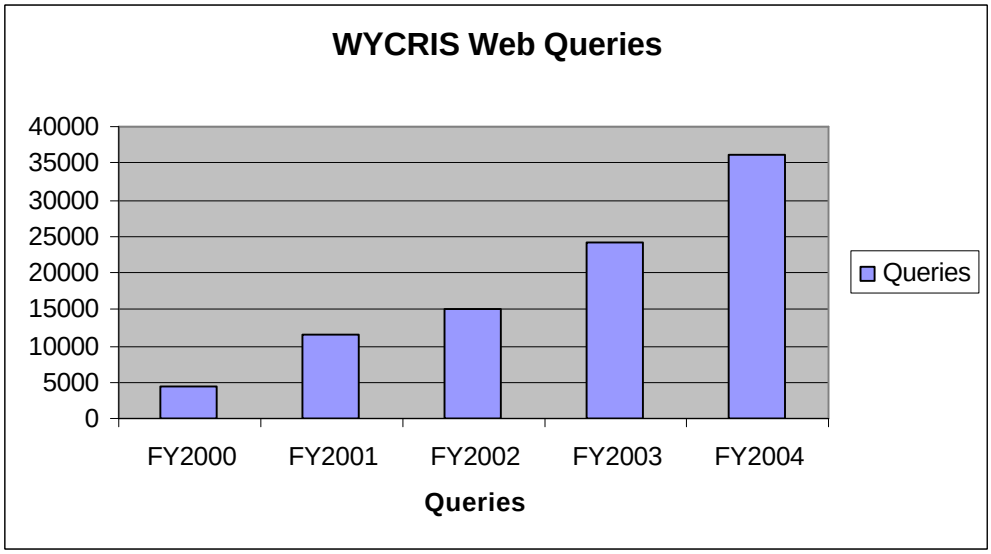

Figure 3. Wyoming web queries by year from 2000-2004.

One of the most important tasks under this project was to create an Internet-based information tracking system for projects under Section 106 of the National Historic Preservation Act. "Project Tracking" has been discussed in Wyoming, beginning in 1995, as a method to streamline the information system and reduce duplication of effort between private cultural resources consultants, the federal land managing agency, and the SHPO. It is anticipated this application will have a long-term affect on how information is managed and accessed. Because the implementation of this application is in its infancy, and many users are still adjusting to the change in their day-to-day workflow, the long-term benefit to the system is hard to quantify at this time. This truly is a paradigm shift for cultural resource consultants, federal agencies, and SHPO staff. Not only have

day-to-day processes changed, but also the responsibility for information is now closer to the data creator. Private cultural resource consultants initiate the electronic record used by the federal agencies and the SHPO. We are still experiencing a learning curve among users and are making modifications of the application based on their comments.

Below is a diagram of the current configuration of the overall Wyoming Cultural Resources Information System. It is a mixture of on-line systems as well as in-house databases. The datasets are interrelated and address different information needs for different types of uses. Some information systems are developed for the cultural resource professional, while others have been customized for planning and use by industry. Many of these information system parts, provide or "feed" data to other parts. The items displayed in the diagram below (Figure 4) in blue were created, modified, or updated under this project. For example, CRMTracker provides information to both the WYSHPO RandCDatabase and the WYCRO2 database via a web-based interface. The relationships among these system parts are displayed in Figure 4.

At this time, the information modules are in place: the Wyoming Cultural Resources Information System (WYCRIS), which is comprised of the on-line systems and the internal databases and GIS maintained by the WYSHPO and federal partners. Each part is in a different stage of development and use, yet the information system foundation has been created.

Figure 4. WYSHPO Cultural Resources Information System

Generating Datasets for the Modeling Project

The creation of a fully integrated GIS for the project area allows for expanded analysis of the prehistoric and historic resources in the area. The development of archaeological burial models for the Powder and Tongue River Basins was created independently from the creation of the cultural resources GIS and site attribute tables. The sensitivity models

are described fully in Chapter 4 and will not be repeated in this section. The following discussion is on the methods and results of queries run to test whether or not the sensitivity model is supported by the existing archeological information.

After the soil sensitivity models were developed by William Eckerle et al. (see Chapter 4), WYSHPO Cultural Records Office generated datasets of sites located within the Powder and Tongue River Basins. For the analysis, a site table was generated using ESRI's ArcMap 8.3, Microsoft Access, and Excel. Each site was assigned a sensitivity code based upon each of the four soil models to the major sensitivity class it fell within. The first query selected sites which fell within the highest sensitivity area. Those sites were then eliminated from the selection set. The next highest sensitivity was queried and again sites were eliminated from the selection and so on. This method reduced the likelihood of sites being counted more than once in the model. All known prehistoric rock shelters were also removed from the site list. In general, rock shelters in the study area are found in the foothills and mountains in rocky terrain. These shelters generally contain subsurface deposits within the shelter itself, but the formations around these sites are not usually of the same depositional context. Consequently it was felt that their inclusion in the list would skew the results. The modeling effort does not attempt to locate anomalies of deposition or cultural remains, but attempts to determine locations where soils are of the correct age, energy regime, and type to contain in situ buried deposits have potential to exist.

Over 11,000 sites in the study area were entered into the WYCRIS database during this project. An additional 1,581 sites were included from a project conducted by the University of Wyoming, Department of Anthropology, in 1991 entitled "12,000 Years of Hunting and Gathering in Northeast Wyoming" by Marcel Kornfeld and Charles A. Reher. A customized MS Access database was created following the current Wyoming Cultural Properties form jointly developed by the WYSHPO, professional archeological consulting community, and federal agencies involved in cultural resource management in Wyoming. The 3.0 revision, developed during 2003, has been used for all Section 106 related projects since this time and many of the encoded resources follow the current format. Each site form was read and reviewed for information content and site attributes. The record developed is reported as a compilation of all previous recordings; for example, if the site was originally reported in 1989 and again in 2003, all associated features and artifacts were compiled into the one record.

The initial entry screen (Figure 5) is comprised of the general information for each resource and the source of the information. The site property category as defined in "National Register Bulletin 15" along with the Smithsonian number is included in the header. Added to this data is a segment identifier for sites which have sub-parts, such as archeological or historic districts, or sites with linear segments. This addition to the data structure allows for a direct linkage to the GIS database using the "resource id" number for each individual site. The status of the record, whether it is a first recording, a full re-record, an update of parts of previous recordings, etc is encoded. The "data profile" refers to the original encoding source for the record. "DOEPump3" records refer to

everything encoded under this current project. Other profiles include “Moxa” or “CROW” records, which were other past data capture projects conducted by the SHPO and the University of Wyoming, Department of Anthropology. These records were brought forward to the current database so all encoded sites in the state can be easily accessed. The record also tracks the editing status, who originally created the electronic record, the last edit to the record, and whether or not the content has been verified for accuracy and quality. Data entry notes are included so any additional information pertinent to the site record can be captured and made available to users.

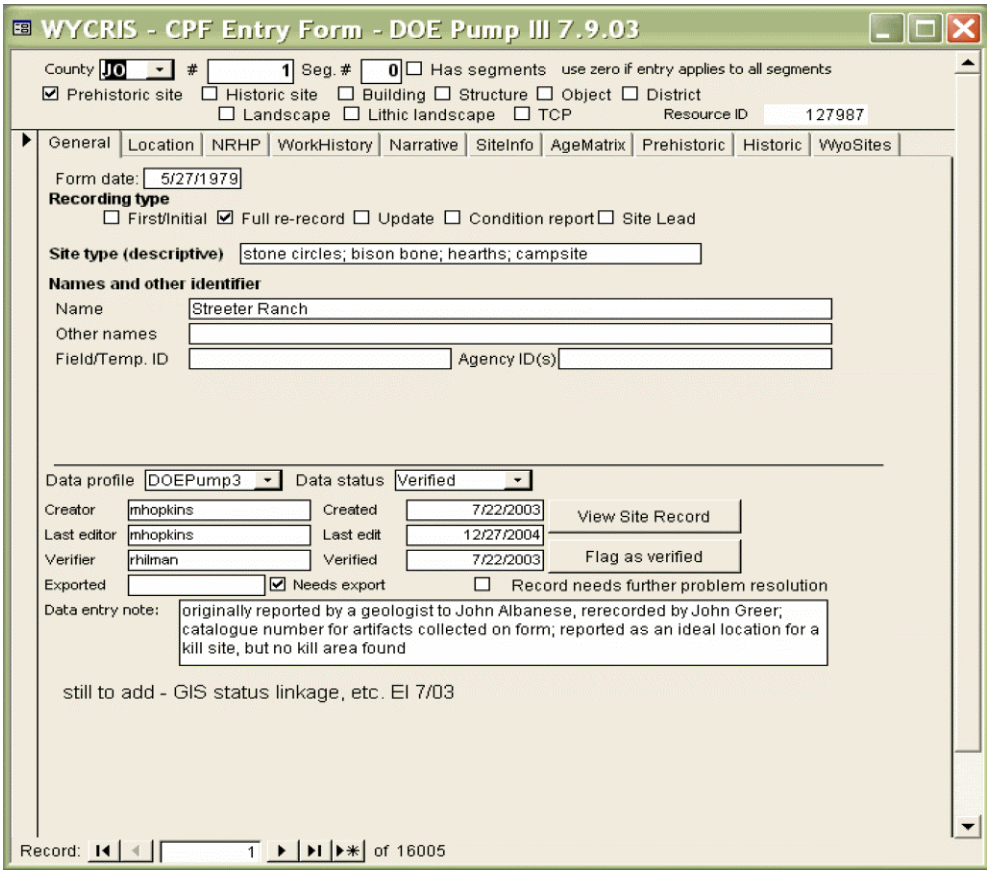

Figure 5. Screen shot of the “General” site tab of the WYCRIS DOE Pump III site entry form.

For this discussion, only a few of the database forms will be described. The other forms pertain to historic period sites, are narrative forms, or are links to other parts of the information system. The "Work History" section of the database collects the most current recording dates and name of the most recent investigator of the site (Figure 6). The context in which the site was originally recorded and what work has been done on the site is described. The section on whether the site was discovered on the surface, revealed subsurface, or during construction is used in the modeling queries. Only 18 sites in the entire study area had been discovered in a subsurface context only.

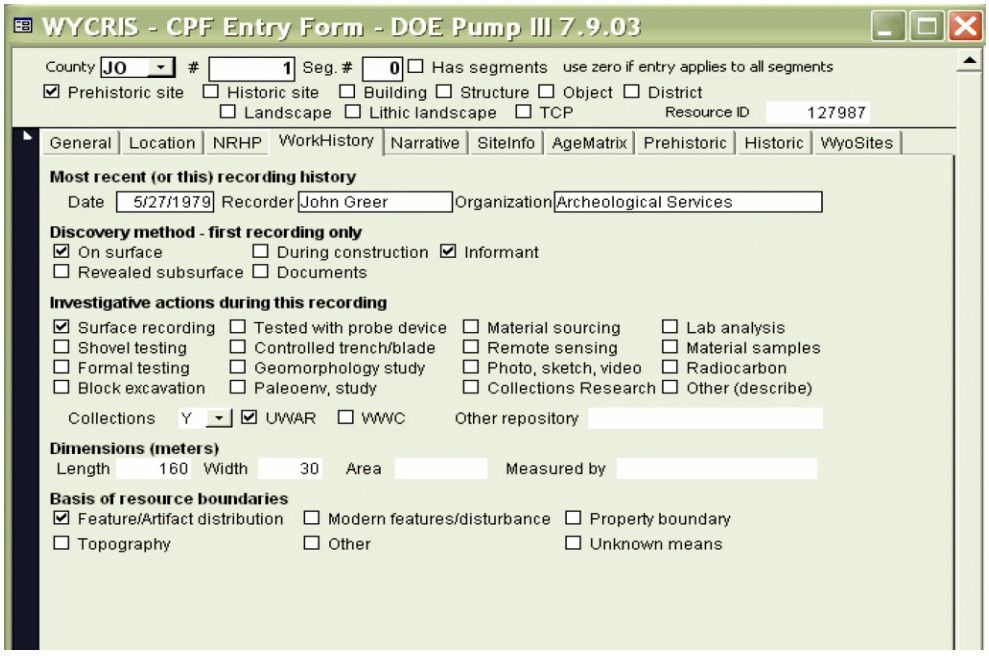

Figure 6. Work History section of WYCRIS database.

The original database designed in the late 1970s was limited to 172 characters of ASCII text. This limited programmers to a very minimal set of site attributes. Other database revisions which occurred in the 1980s did not incorporate information on site content or

associated time periods. The addition of a user-friendly temporal description of a particular resource has been a goal of this project. The "Age Matrix" tab (Figure 7) allows the user and encoder to quickly identify all known time periods represented on the site, if they are surface or subsurface manifestations, and if they are represented by artifacts or features. Because prehistoric rock art and historic buildings are important archeological and historic features, these are included so the user can immediately identify their presence on site. This set of attributes was used for the queries to test the sensitivity models (see Chapter 4).

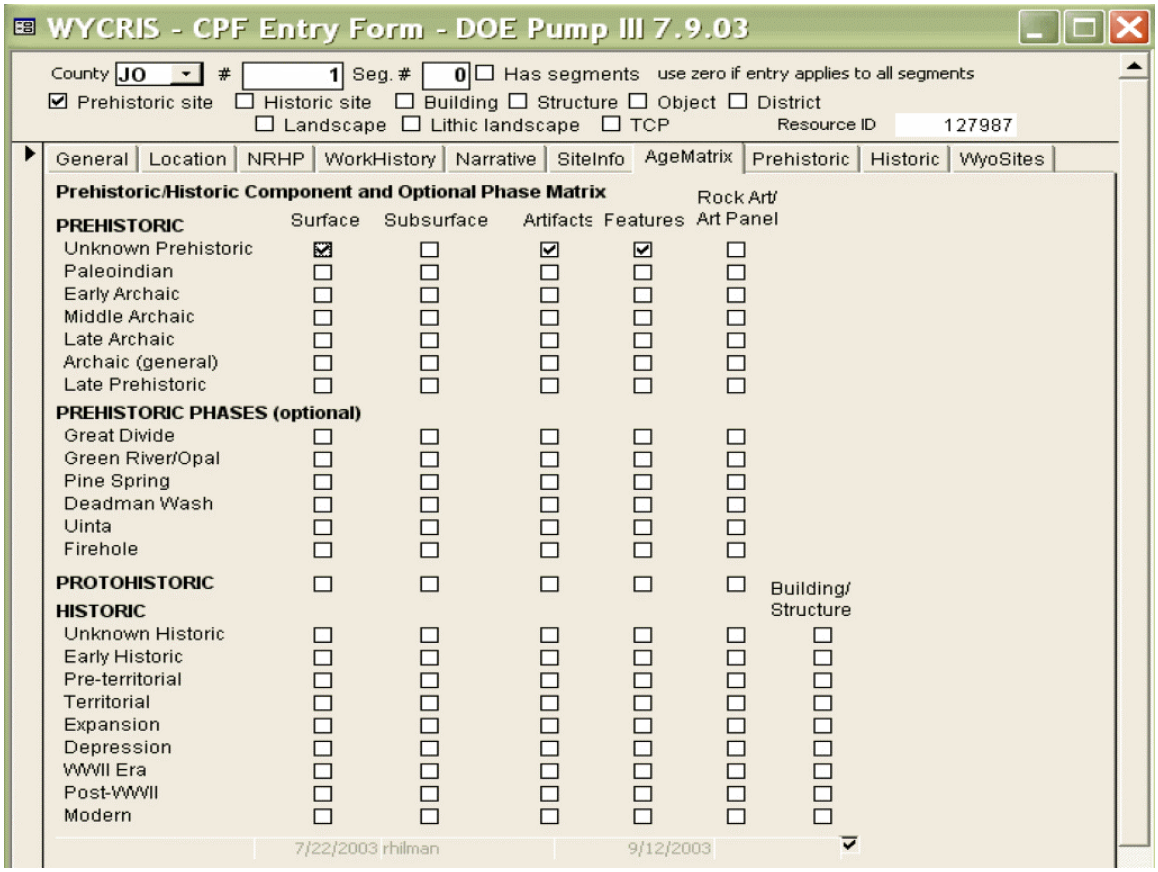

Figure 7. Age matrix section of WYCRIS database.

Prehistoric and historic assemblage data was collected for the project area. Types of artifacts and features, many with associated counts if available, are encoded into the database (Figure 8). The total estimated assemblage size is a useful attribute to when determining site artifact densities along with the spatial extent or area of a site.

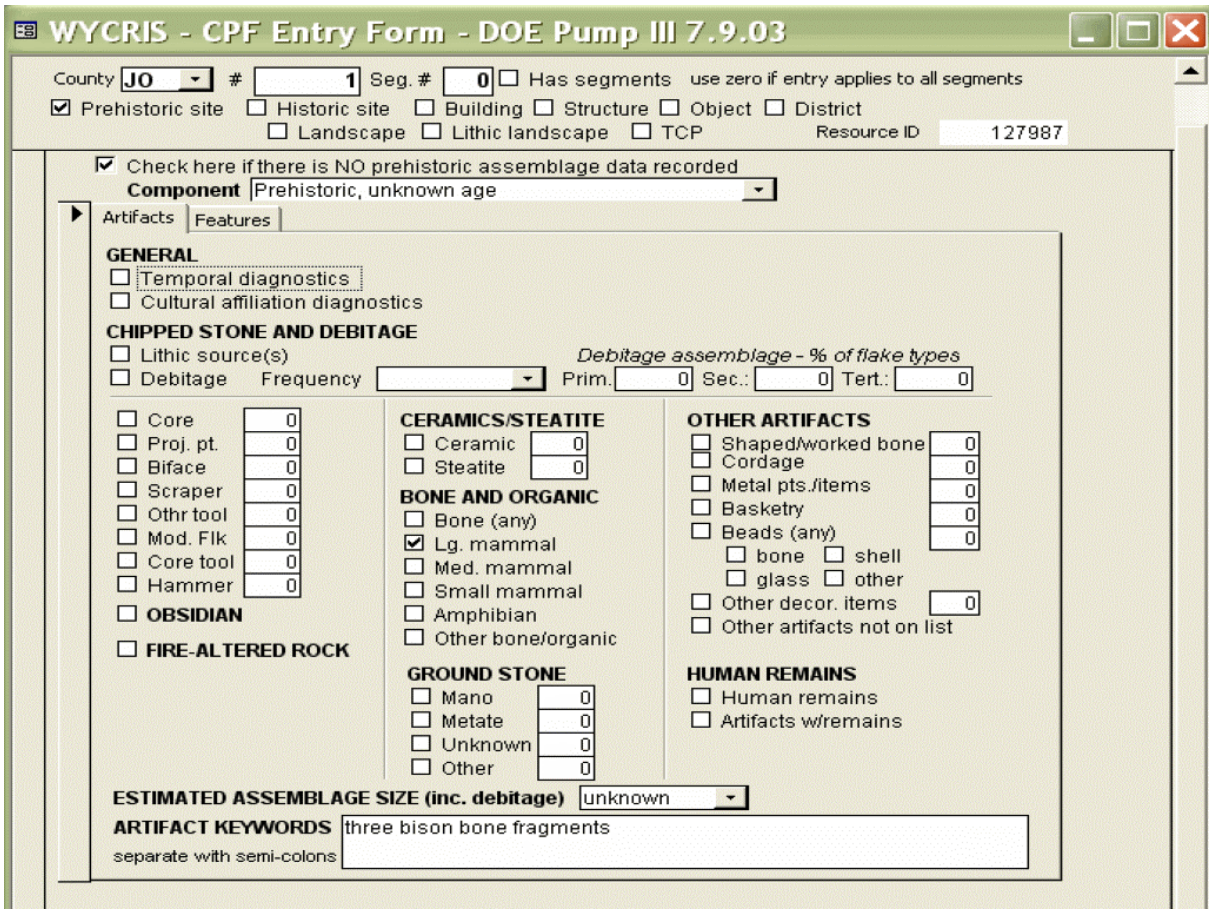

Figure 8. Prehistoric artifact encoding form in the WYCRIS database.

Feature information (Figure 9) is also encoded including types and counts of prehistoric features present. Up until this project, this information was almost impossible to quickly access. In previous studies conducted by graduate students, this type of information would require a long process of reviewing the paper documents. This tabulated information will be made available to land managers, cultural resource professionals and

academic researchers and should reduce the tedious work to synthesize and compile archeological information for a particular area of the state. Future revisions and updates of land management plans and contexts on specific cultural resources will be done more efficiently with more accurate and complex information.

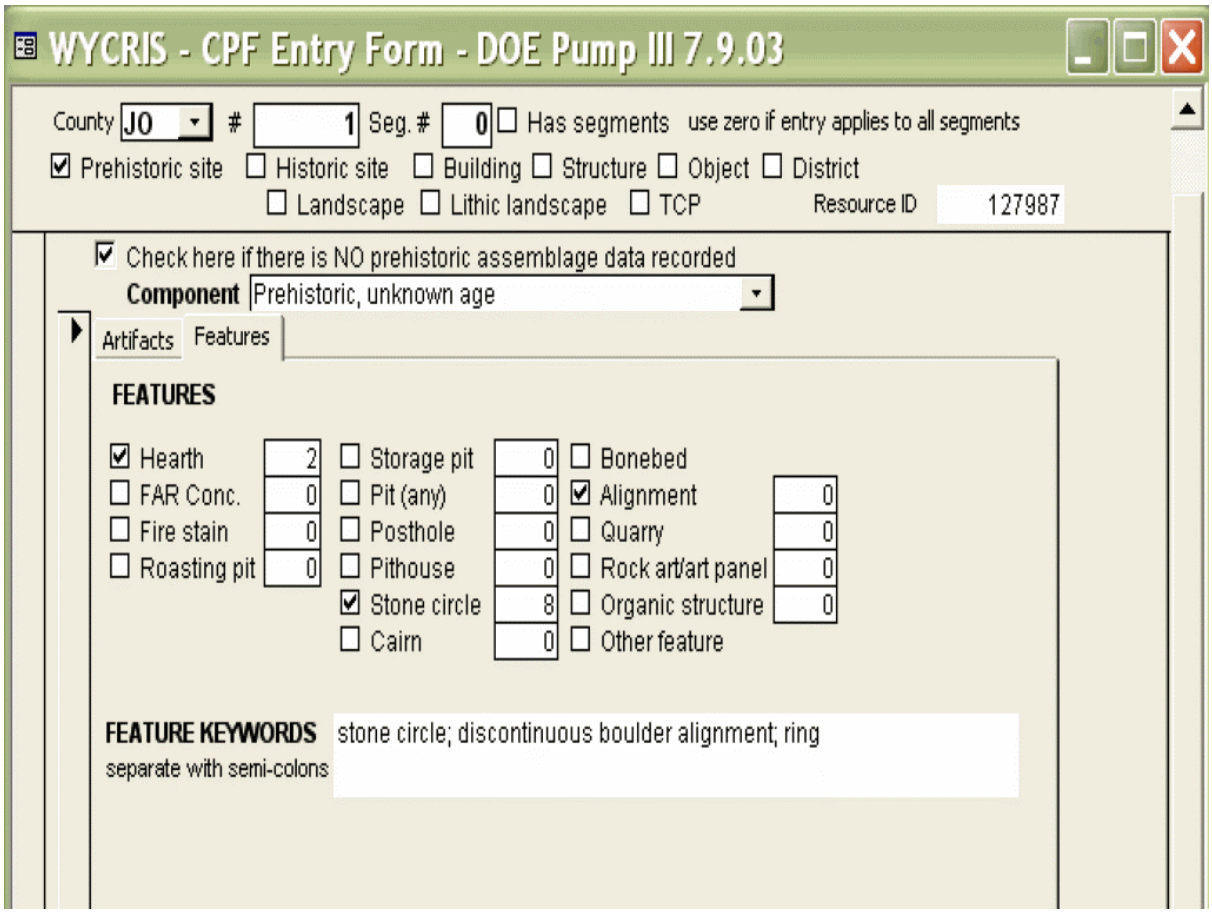

Figure 9. Prehistoric feature encoding form in the WYCRIS database.

From many of these data sets, queries were run against WYCRIS database tables of specific site attributes collected for this project. For each sensitivity model (see Chapter 4), percentages and counts of sites with buried components, sites occurring on the surface only, sites producing Radiocarbon dates, and sites with formal shovel testing and excavation units were calculated. These elements are generally the highest indicator

whether or not sites fall within the modeled soil units. The correlation between the known buried archeological sites and the very high sensitivity zone is strong across all four models. After counts and percentages of sites were tallied within MS Access, these tables were exported to MS Excel to produce charts of the information (Table 1). Below is an example of an Excel spreadsheet created for the analysis with a graph of the data (Figure 10).

Table 1. Number of sites with buried components.

MODEL	Very High	High	Moderate	Low	Very Low
SSURGO A	132	19	65	5	16
SSURGO M	175	14	49	5	9
STATSGO A	132	19	65	5	16
STATSGO M	185	40	64	2	8

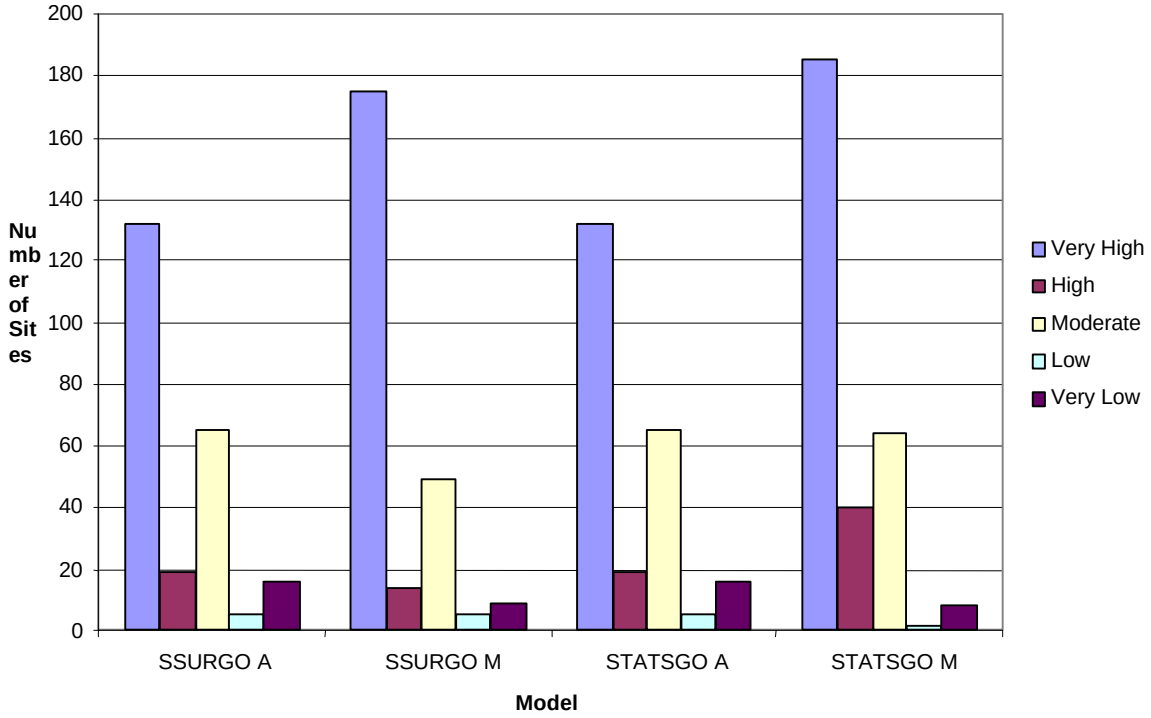

Figure 10. Number of sites with buried components.

Site types and feature types were also compiled for the models. Fire hearths and fire cracked rock scatters occurred in all sensitivity zones. Ceramic scatters and the highest number of bone beds, or bison kill sites, were reported within the very high sensitivity zone. This might be the result of the depositional environment in these areas better preserving these types of fragile resources and the fact that very high sensitivity zones follow permanent water sources. Areas with less deposition are more prone to wind, water, and other natural factors which can displace or degrade the archeological item. Prehistoric use of ceramics are generally associated with more long term occupations, thus having these artifact types only occur in the high sensitivity zone seems reasonable

given the associated water source. Further analysis testing the sensitivity models is discussed in Chapter 4.

Data Lineage

The quality of information recorded on archaeological and historic sites has varied over the past forty years. Some the earliest inventories by professional archeologists were conducted by the Smithsonian Institution in the late 1940s and early 1950s as part of the WPA River Basin Surveys. Sites were recorded on forms which included basic site information including legal location, site setting, site size, material collected, material observed, and recommendations for further work. Tool counts and types are generally given but lithic debitage is listed only as to presence, or qualitatively such as "few" or "many". The site forms do not include artifact illustrations, site sketch maps, or USGS topographic maps (which were not available at the time). Sites are plotted on small scale project maps, thus relocating and identifying many of the sites recorded during the River Basin Surveys has remained an ongoing difficulty, especially in areas with high site density.

During the 1960s and 1970s members of the Wyoming Archaeological Society (WAS) actively recorded and submitted a number of site forms on archeological sites in the state. These forms, completed by amateur and paraprofessionals, vary widely in quality. Many only indicate there is a site (such as a campsite) in some generalized location (often by quarter section). On the other hand, there are some recordings that are quite detailed with

comprehensive descriptions of artifact assemblages and detailed instrument maps. Results of excavations conducted by the WAS are often published in "The Wyoming Archaeologist" and are readily available. Again, standard topographic maps are almost never provided, relocating and identifying many of these sites is difficult and the sites can be plotted in the GIS database only as dots in the center of the specified legal locations.

During the 1970s, after Congress passed the National Historic Preservation Act of 1966, there was an increased number of inventories conducted and sites recorded by professional archaeologists. Many of these studies were conducted in the newly developed coal mines in the Powder River Basin. Early in the 1970s, the quality of these recordings varied widely with a number of forms with vague references to "chips" or "a large number of tipi rings", sometimes covering several sections. Sites were recorded on forms that varied by agency and/or contractor with many consisting only of descriptions on yellow notebook paper. Artifact illustrations and maps were often lacking and site boundaries were not defined.

By the late 1970s most site recordings were on various site forms that contained rather standardized information including site setting, soil, and artifact descriptions. Many consulting firms developed their own internal standard forms and many used the Colorado Site form. Site sketch maps, positions of sites on topographic maps, and illustrations of diagnostic artifacts were often provided. Around 1981, a standard Wyoming Site form was developed by the WYSHPO that required standard data and information categories. Much of this data is similar to current site forms and has served

as the basis for standardized recording and required documentation. The 1981 form was designed to facilitate data entry into a rudimentary computer system. Data fields were encoded for presence/absence or with numeric codes for specified text strings. However, due to funding restraints and other political issues, computerized database using most of the encoded information was not implemented at the time.

In 1982, the Intermountain Antiquities Computer System (IMACS) form was adopted for statewide use. The IMACS form provided most of the information required on the current Wyoming site form, however it was designed for use by several states (UT, NV, and ID) and was in some sections unnecessarily complicated or not entirely appropriate for Wyoming cultural resources. The IMACS form required standardized responses to administrative, environmental, artifact, and feature data fields. Again, Wyoming data was not entered into this system, even with several automation attempts. Professional consensus was to develop a more state appropriate recording format.

The current Wyoming Cultural Properties Form (WCPF), designed in part to increase data collection consistency, was developed in 2000 and substantially revised in 2003. The current form provides a more consistent method of encoding archaeological and historic components than was provided by previous forms. The data encoding portion of this project follows the current format of the WCPF. If sites are documented using the WCPF, encoding is a straightforward process and the standard documentation is complete with sketch maps, topographic maps, artifact illustrations, and photographs. Consistent documentation increased the consistency of the encoded information.

Data Limitations

Data deficiencies and inconsistencies from earlier forms can significantly hamper efforts to accurately digitize, encode, and relocate sites. Of particular concern is the lack standard maps accurately depicting site location and site boundaries. These sites must frequently be digitized as site points with site placement based on the center of cadastral locations. As the potential to use GIS to model site distributions, (such as the site sensitivity modeling described in Chapter 4) increases, the accuracy of sites plotted by legal location may not be of sufficient quality for use in some modeling projects. Further, there are instances when sites which lack sufficient maps could not be accurately identified during subsequent field work, requiring the assigning of new site numbers.

Site boundary definitions have also varied widely over time and by recorder. In the 1970s, those recording sites during block survey tended to lump nearby cultural manifestations into large, sprawling sites with considerable gaps between artifacts and features. In addition, a number of sites have been recorded with noncontiguous segments. For example, stone circles on a series of ridges have been recorded as a single site, even though cultural materials were not found in intervening drainages. More recently, sites are usually defined to be much smaller and confined. A gap in artifacts or features as small as 30 meters is now sufficient justification to record separate sites. Additionally, some of the large previously recorded sites are now being revised, redefined, and rerecorded as a number of individual smaller sites.

Imprecise descriptions of the contents of early recordings reduce the amount of information that can be encoded. Artifact types and counts as well as feature counts are often not recorded. Sites are often described simply as "chips and tools" or "many stone circles on ridges". As a result, artifacts and features are only encoded as "presence/absence" and specific tool types cannot be determined. This lack of detailed recording can require additional fieldwork in order to determine the nature and extent of the resource and whether or not it meets the criteria for inclusion in the National Register of Historic Places.

Inconsistent use of artifact terminology on older site forms may not always be easily redefined into currently used categories. For example, the term "knife" is used in older recordings can include: a) a large thin biface; or b) any lithic tool with a sharp, low angle working edge that could have been used for cutting. "Knife" is no longer a category used in the current recording standard. It now is generally categorized as a "biface" or "modified flake." When there is insufficient information for the encoder to make a determination, the artifact is encoded as "other tool" and "knife" entered in a textual field describing "other tool". As a result, "bifaces" or "modified flakes" may be under-represented in recordings that use the term "knife".

One of the major conceptual shifts which has occurred in the past 20 years is in how soil type and deposition is documented. On forms prior to the IMACS form, soils (if discussed at all) are generally recorded by textural classes (i.e. clay; silty sand; sand).

With the introduction of the IMACS form and continuing to the current Wyoming forms, the emphasis is on categories reflecting depositional processes (aeolian, alluvial, or colluvial) or lack of deposition (bare rock, regolith). The textural classes cannot be directly translated to current categories and deposition must be encoded as unknown for most sites recorded prior to the IMACS form. This limits the number of early recorded sites that can be accurately used in the modeling part of this project.

There also appears to be ongoing inconsistencies in categorizing deposition that continues into current site recordings. Deposition on nearly all sites recorded by one investigator may be characterized as aeolian while others working in the same area record nearly all sites as containing colluvial deposits or even regolith. Inconsistencies such as these could be a result of several factors. Deposition frequently results from the interaction of several processes (such as aeolian deposits reworked by slope wash) and various recorders may emphasize one process over another. Also, soft sandstone and clay deposits weathered *in situ* can be difficult to distinguish from materials transported short distances from the corresponding parent materials. Whatever the explanation, the existence of these inconsistencies should be considered when type of deposition is a factor used in site modeling.

The age of sites is one aspect of sites that is of great interest to many investigators. Only a small percentage of the sites recorded in the *Adaptive Management and Planning* project area have been dated by absolute dating techniques such as radiocarbon. Most sites have been encoded to time periods based on surface artifact manifestations and can

be compromised by a variety of factors. Users of this information should consider these limitations and use professional judgment when drawing conclusions or inferences from this data. Limitations are inherent in the nature of the resource and recoding methodologies. The majority of the sites encoded for this project are based solely on surface manifestations with very little or no subsurface testing. While surface sites can address site distribution questions and many other data gaps, they also can contain compromised data and may not accurately reflect human use or occupations on the landscape.

Implications of the Adaptive Management and Planning project for WYCRIS

In terms of information services and improving the quality and quantity of accessible data, this project will have a long term, noticeable benefit to Wyoming cultural resource management. Implications to Wyoming energy development have yet to be fully realized, but it is anticipated the information systems, the on-line project tracking application, and the CRISP tool will enable industry to better plan projects to reduce impacts to resources. Access to inventory information and risk models will reduce time and cost for oil and gas developers. An interview in April of 2004 was conducted, with then current Wyoming State Geologist, Lance Cook, to gain a better insight of the needs of industry. Mr. Cook's background includes a close working relationship with oil and gas officials and past work history with Shell Oil and Union Pacific Resources. His main comment was that the surveyed space information would be very helpful to oil and gas planning, since having this information would reduce the likelihood of redundant inventory. This has been a goal of both Wyoming and New Mexico project participants.

The implementation of the CRISP tool will allow industry to have easy access to this information in the early stages of their planning process.

The most prominent change to the WYCRIS information system is the addition of the WYCRIS SITE database. Several encoding attempts have occurred in the past without becoming an integral part of the overall information system. Consistently, users have asked for this detailed information in order to conduct research, write management plans, and develop historic contexts. Up to this point, this information has been difficult to gather and compile. Consensus on data content and format was part of the recent modifications to the Wyoming Cultural Properties Form (WYCPF) was reached among academic and agency partners in 2001. Thus, the automated format and content for this project was based upon the most current version of the site recording standard.

With the addition of the eight county area of detailed site information, future requests for detailed site information will be more quickly and accurately processed. Since the 1980s, a major draw-back to the data system, has been the lack of site temporal information. The ability to encode this data into a standard system based upon the current WYCPF is now available. However, due to limitations in the original documentation, all sites are not encoded equally. Many of the early resources lack the detailed information required on the WYCPF. Users will need to be aware of this issue when using the data system. As explained above, each record is identified as to the "profile" or source of each record and the original type of record. If a record is encoded to "DOEPump3" it has been encoded as fully as possible given the available information. If certain feature types or

artifacts are encoded to presence/absence only, it most likely infers the resource is inadequately documented. Procedures have been incorporated into the day-to-day information management process to include detailed site data into the master data system. Additional funds will need to be acquired to bring the rest of the legacy data forward. Additional technical products will need to be developed in order to automate the site information from consultant to the archive. This will require users to enter information and the WYCRO to review and insure the accuracy of the data.

Three examples of common user requests are displayed below (Figure 11). The first map represents the distribution of aboriginal stone circle sites within the study area. The rings have been normalized by the number of stone circles at each site. Many of the points in the "0-2" range are sites where the count of circles is not reported by the original investigator – only the presence/absence. Until this project, a map of this kind could not be easily generated. The inventory areas are also represented to show where investigations have occurred so the user does not assume the lack of resources in areas where stone circles are not reported.

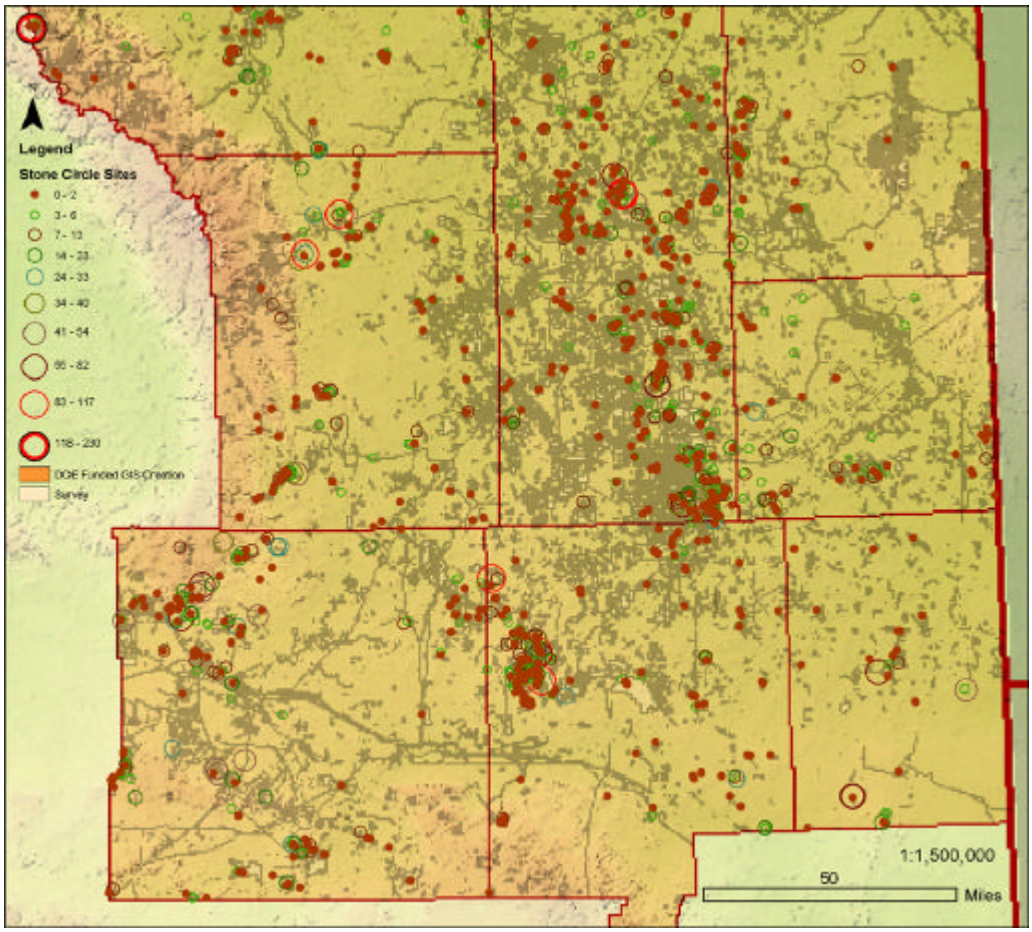

Figure 11. Distribution of Stone Circle Sites in study area; displayed by number of stone circles reported.

Subsequent queries could include sites with other types of associated features (i.e. hearths, cairns, stone alignments) and associated artifact types (i.e. tools, projectile points, ceramics). The query can be easily customized for the researcher and land manager.

The next example (Figure 12) displays the distribution of sites with ceramic artifacts. Generally, the presence of ceramics is relatively rare in Wyoming. The distribution of ceramics in the Belle Fourche drainage has been reported to be of higher frequency than

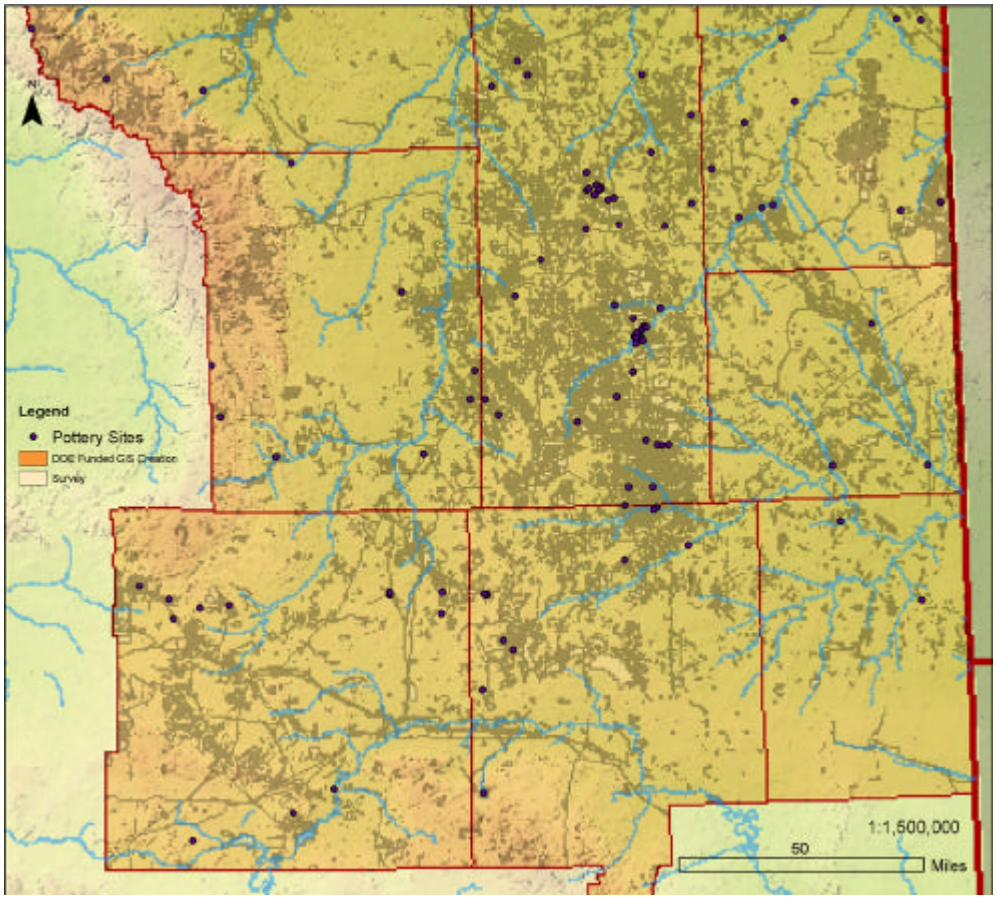

Figure 12. Distribution of sites with ceramic artifacts.

other drainages. There are 111 sites reported with ceramics in the project study area. Again, the distribution of this artifact type seems to be predominately based upon areas of inventory. However, there is a strong correlation of ceramic site locations in association with river drainages. Subsequent queries could include counts and types of associated features and other related artifact types. In general, ceramics may be diagnostic and affiliated with certain cultural groups. Many of the ceramics in the study area reported to be of Crow or Woodland origin possibly related to the Hidatsa (Frison 1991; Reher 1979) and date to the Late Prehistoric. Ceramics have the potential to address prehistoric

settlement and subsistence questions other artifacts types cannot. For years, researchers and land managers have requested efficient access to sites with ceramic artifacts.

The third example (Figure 13) displays the distribution of sites with artifacts dating to the Paleoindian period (approx. 12,000-8,000 B.P.) in the study area. Of all research related questions, this time period is the most requested. One hundred eight sites within the study area have materials dating to this period.

Past research projects have required the investigator to physically review each individual site form to gather the information needed for the study. WYCRIS does not attempt to provide all information required for an academic project, but it is designed to aid in reducing the number of site forms someone would have to review to gain the needed information. This information system serves as the first select of the data, rather than exhaustive information. Researchers can expand on this information and the digital files can be easily subset for them. Specific artifact measurements and materials have not been included since these items can be very project-specific and unrelated to the overall SHPO data system. However, the information in WYCRIS meets the needs of land managing agencies when making decisions on resource eligibility and future protection goals.

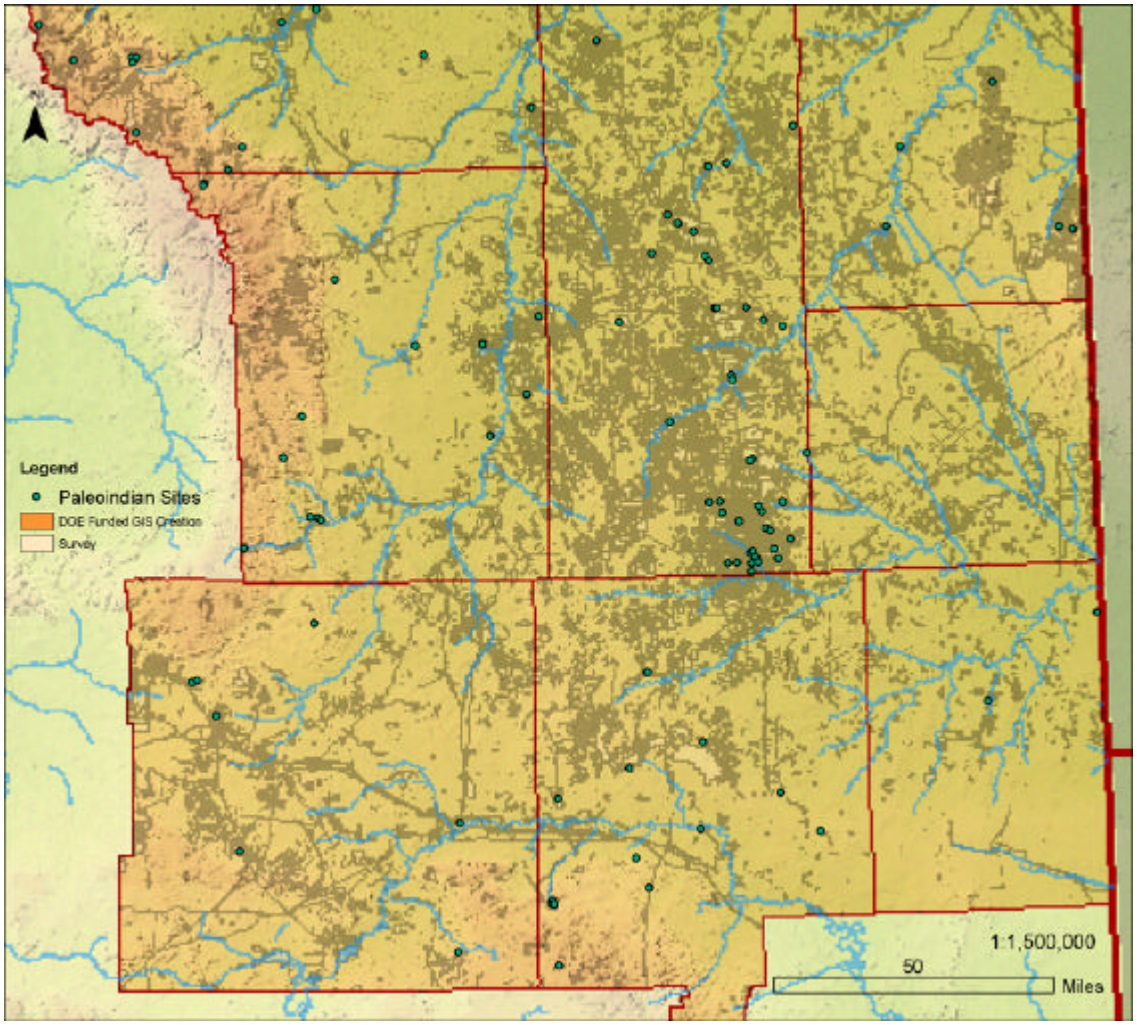

Figure 13. Distribution of Paleoindian sites within the study area.

Revised Internet Mapping Web Site

During the fall of 2003, a major revision of the WYCRIS Internet Mapping Service (ESRI ArcIMS) was undertaken. The map service software was updated to the most current version and the user interface was redesigned. The original hosting of the cultural resource data (sites and inventories) was in point, line, and polygon format. To make the map services easier to use, all sites (points, lines and polygons), and all inventories

(point, lines and polygons) were buffered and merged into one polygon file. This format helps to reduce the number of "selects" a user must perform in order to gather information on sites and projects in a particular geographic area or by common attributes. Since ArcIMS currently only supports ArcView shapefiles, the current geodatabase files are buffered, saved as polygons, then merged into one master polygon file for both sites and inventories. After this process, each file is projected to UTM Zone 12 and UTM Zone 13 (NAD27), indexed, and posted to the web.

Gnomon created a new map interface with a more sophisticated table of contents for this project. The map layers can be customized by the user to their needs. Additional themes were added, primarily more available base map data such as the 1:100k and 1:250k quadrangles. The tool bar was also redesigned for easier use. When the original ArcIMS was hosted, many of the cultural resource professionals were not accustomed to GIS software tools. The tools were redesigned to be more self-explanatory and additional tools were added so a user could make a finished map for a report, or for use in the field. They can set the scale, add a title, and export the map for use in other applications such as MS Word. Buffering and select tools and a "drill down" tool which allows a user to identify all of the information available on screen in one query were also added. The results of the "drill down" tool creates a report of all themes displayed on the map. Figure 14 below displays the previous user map interface prior to the redesign. The "Map Layers" table of contents displays the previous user options and the point, line, polygon format for sites and projects. This required more effort on the user's part to

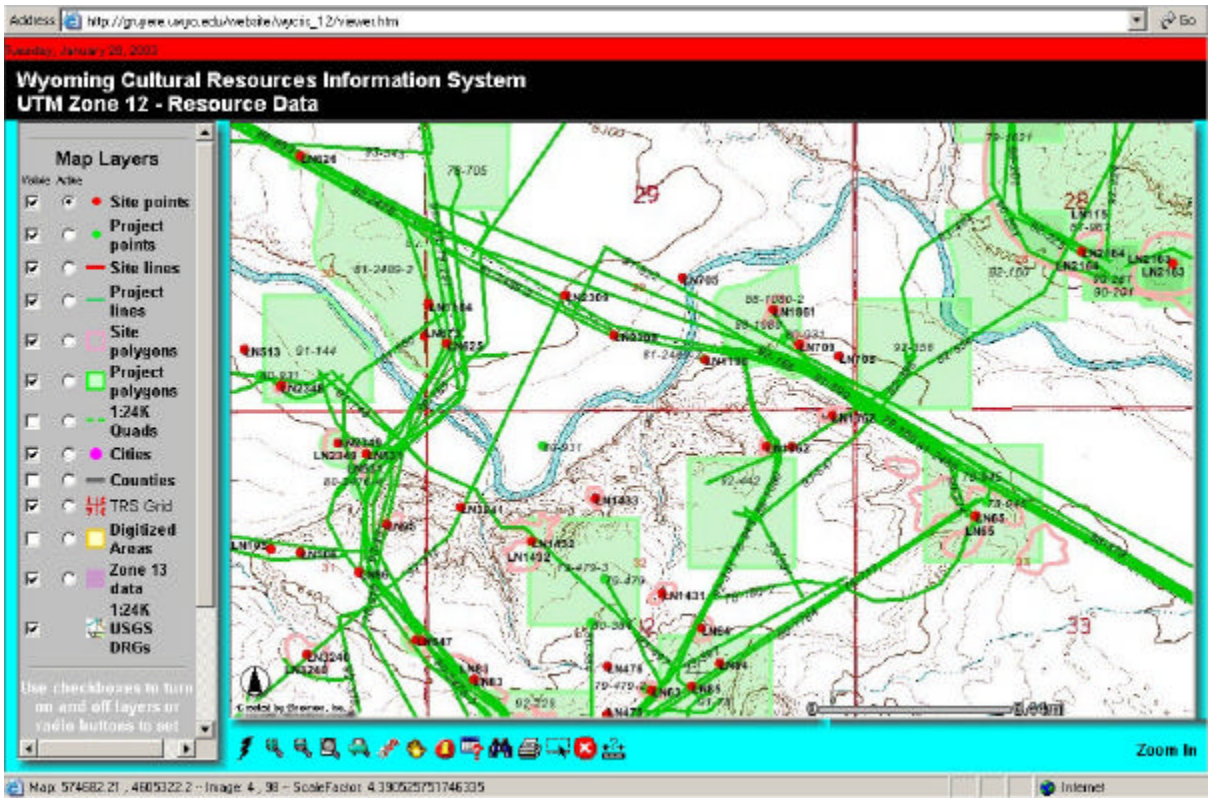

Figure 14. Previous WYCRIS ArcIMS User Interface.

identify sites and projects in a potential project area. User tools are located on the bottom of the map and require more effort to understand and use properly.

Below is the revised map interface developed by Gnomon (Figure 15). Note the revised "map layers" and table of contents along with the updated map tools on the top of the window. A help folder and more explanation of the overall application are available. Buffering and map production choices help to create selections of information for report preparation. The WYSHPO conducted training on this application for all permittees and BLM cultural resource field office staff in April 2003. After this training, the use of the ArcIMS saw a considerable increase. All of the GIS data compiled for this project is

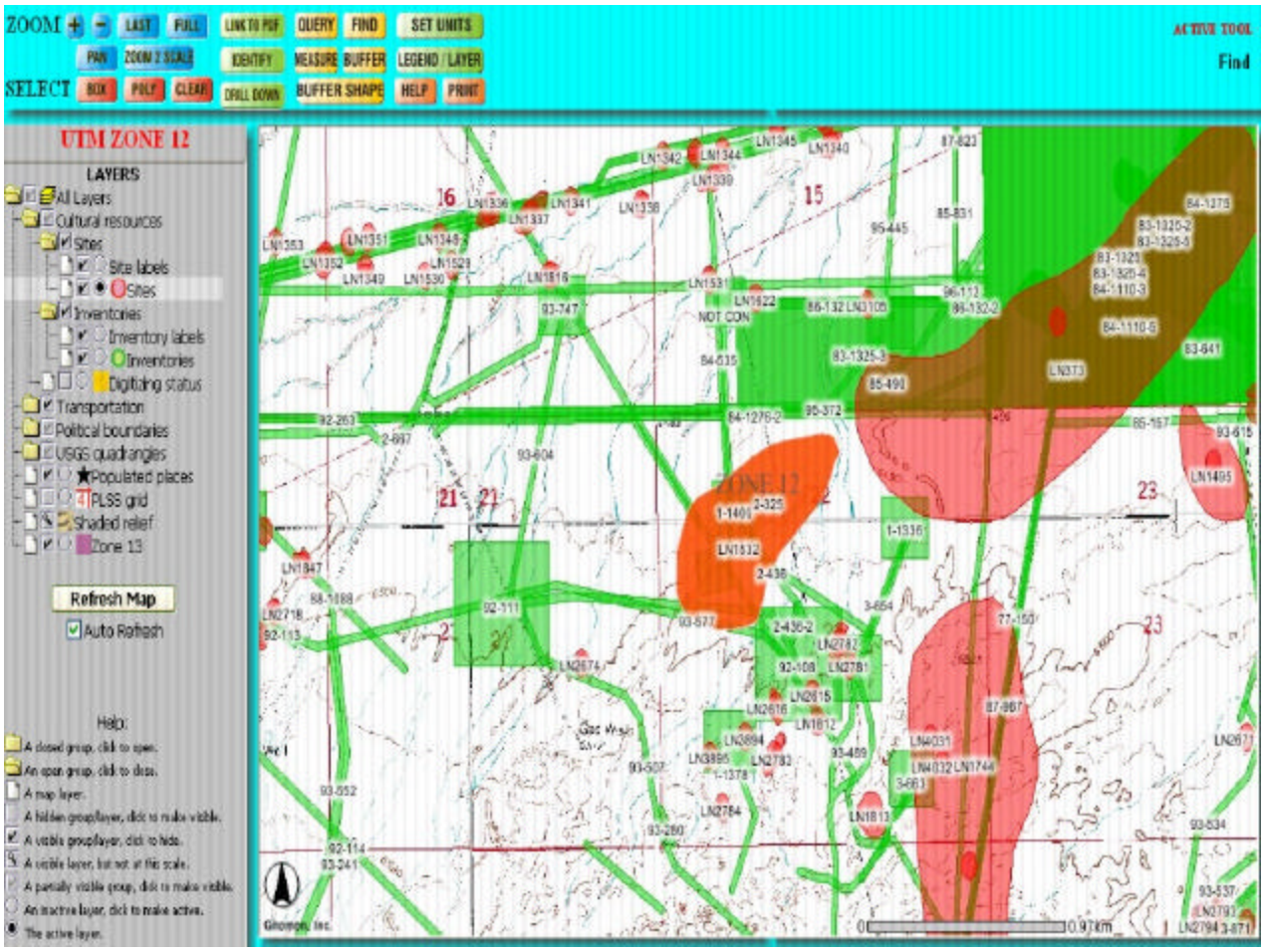

Figure 15. Current WYCRIS ArcIMS Interface (note expandable choice in the "Layers" menu).

available on this map service along with the imaged (PDF) of all site forms and the historic Government Land Office (GLO) maps.

Because of the geographic format of the digital USGS topographic maps (DRGs) the maps are served in Zone 12 and Zone 13. The Zone is prominently displayed as the header of the table of contents. The user must navigate between zones, but the revision of the display has helped to reduce confusion. Fewer user assists are needed due to the hands-on training and the available help products**.**

User Manuals, System Administration, and Install Instructions

Updated user manuals for digitizing were created for training and documentation purposes for this project. Specific installation instructions of the customized ESRI map document (.MXD), system ODBC drivers, and ArcGIS ODBC connections were written for BLM's systems administrators. The installation instructions were approved by BLM's Wyoming State Office and distributed via their network to the field offices. WYSHPO staff have been available for technical assistance to the field offices when they had any type of question on the application and the installation. BLM field offices had to first have all of their ArcGIS licenses upgraded to version 8.3 prior to the application. A typical installation takes less than ten minutes on an individual computer system.

Detailed digitizing manuals were written for BLM staff as training documents and for future reference as they map new projects and sites. The manuals contain visual aids as well as text explaining the steps of processing and mapping the information. They are required to use the customized application and associated tools when creating new data. Each field office has an identical personal geodatabase and can enter sites and projects in point, line, and polygon format. They also have the option of creating polygons for historic districts and isolated artifacts. To date, one merge of the information created in the field office has occurred. The digitizing manual can be found as Appendix A to this report.

Documentation of system administration within the WYSHPO Cultural Records Office has also been written. The administration of user names and passwords on the web site has been written and are available to office staff. Accessioning, scanning, and file search instruction manuals were written for staff training purposes and documentation of the overall system configuration. A mirrored server was configured as a system back up of all data and applications and a detailed back up and system recovery document was prepared. These documents are available in Appendix B of this report.

Overview of Digitizing Methodology

A revised digitizing methodology was developed by Gnomon in 2002, specifically for this project. The purpose of the revision was to maximize data entry efficiency, gain more consistency, and increase accuracy in the spatial data. The process of digitizing inventory and site data begins by reviewing the project report, paying special attention to the cover sheet (a standard Wyoming format), and descriptive survey methodology sections. A review of the project report provides basic information about the project, including the survey area, survey standards, and the number of sites located. This information is necessary to properly digitize the inventory and cultural resources. Locational information and surveyed acreage provided in the project report is then compared with the project maps to check for inconsistencies. If no inconsistencies are found among the legal locations in the project report, project map, site forms, and site maps, then the entire project is digitized (Figure 16).

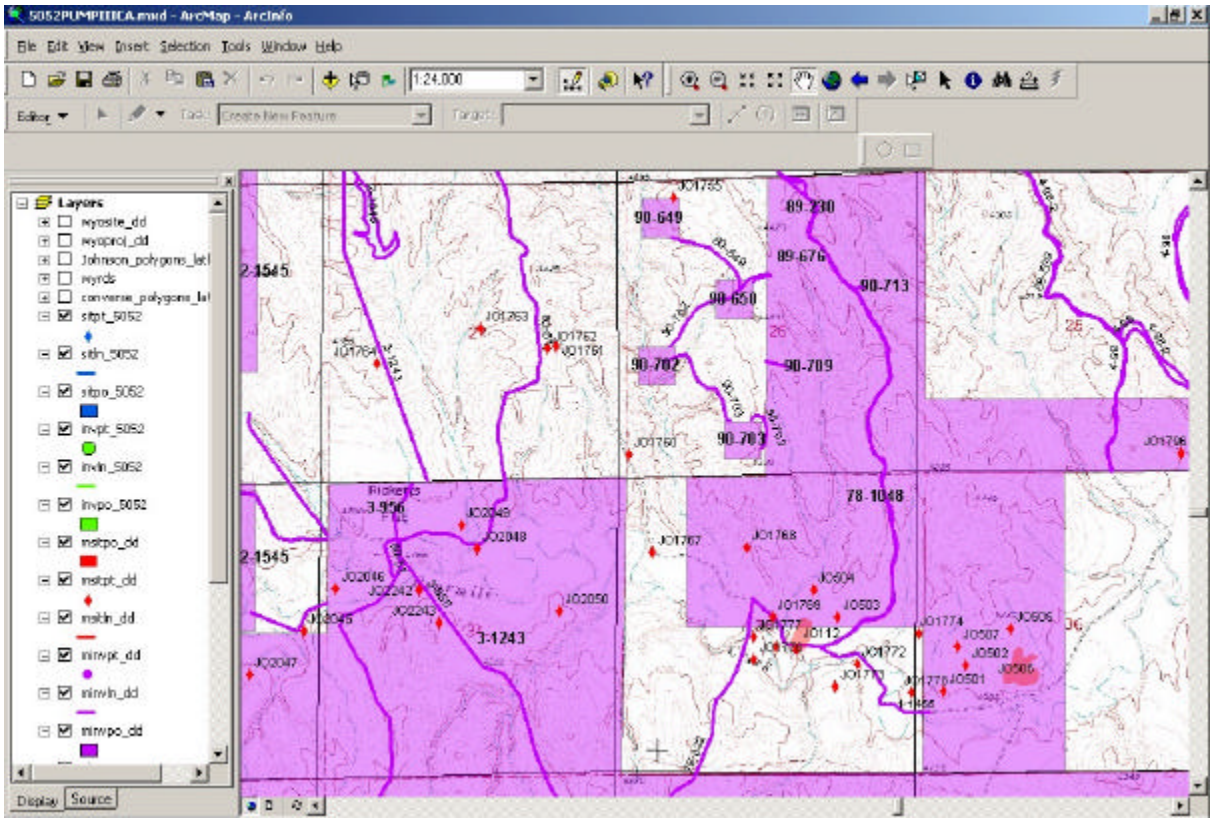

Figure 16. Digitized projects and sites user interface with customized tools.

During this process, several decisions must be made in order to provide the most complete and accurate data set. If the project is small and there are no inconsistencies between the project report and the project map, then the data can be relatively quickly and accurately digitized. However, there are several problems that could arise, each of which requires the digitizer to make decisions that have the potential to introduce inaccuracies into the data set. The lack of a map, an unreadable map, inconsistent legal location for a project or site, and inconsistent project or site areas are the most commonly encountered problems.

In some cases, no map or an unreadable map, was included with the project report or the site forms. If no legal location was provided, the project or site was not digitized. However, if legal location was provided in the form of UTMs or township, range, and section, then the site could be digitized. An entity digitized using township, range, and section information has much lower horizontal position accuracy than entities digitized heads-up using topographic maps or a georeferenced image.

Another very common problem is inconsistency in the stated size of a site (in square meters) and the area over which the site is represented on topographic maps. In some cases the difference has been in the tens of thousands of square meters. It is almost impossible to know if the text or the map is correct. For recently surveyed sites, it is possible to contact the survey organization to determine the correct placement of the site. However, for sites that have not been surveyed recently, it will often be necessary to digitize what could be a large site (greater than 10,000 sq m) as a site point in the GIS database.

The most common problem encountered is the presence of inconsistent legal locations between project reports or site forms and the maps depicting the location of the project or site. In most cases, the site or project will be digitized as it is shown on the map. The correct legal location must be determined by matching the topographic map provided with its proper legal location.

Data Quality. The quality of the data in the geodatabase is dependant upon, and limited by, the quality of the data provided by the survey organization. A number of factors, including the presence/absence of a map, the scale of the map, and the method used to digitize, influence the accuracy of site and project placement within the geodatabase. Data quality is tracked within the geodatabase using the customized attribute tool (Figure 17).

Figure 17. ArcMap Customized Site and Project Attribute Tool.

The attribute tool is used to open the "Cultural Resource Site GIS Attributes" form (Figure 18). Four fields are used to describe the accuracy of the digitized spatial data. The Horizontal Position Accuracy (Figure 19) tracks the confidence that can be given to the location at which the entity has been digitized. Digitizing from a 1:24,000 standard USGS topographic map will produce a Horizontal Position Accuracy of <20 m, meaning the center of the digitized entity is within 20 m of the actual location of the site. The Horizontal Position Source field (Figure 20) tells the user if a map was used to digitize an entity and, if so, the scale of the map used. The Boundary Precision field (Figure 21) tracks the confidence assigned to a site's boundaries as digitized. UTM coordinates, topographic maps, and georeferenced images provide the highest site boundary precision while aliquot provides the lowest precision.

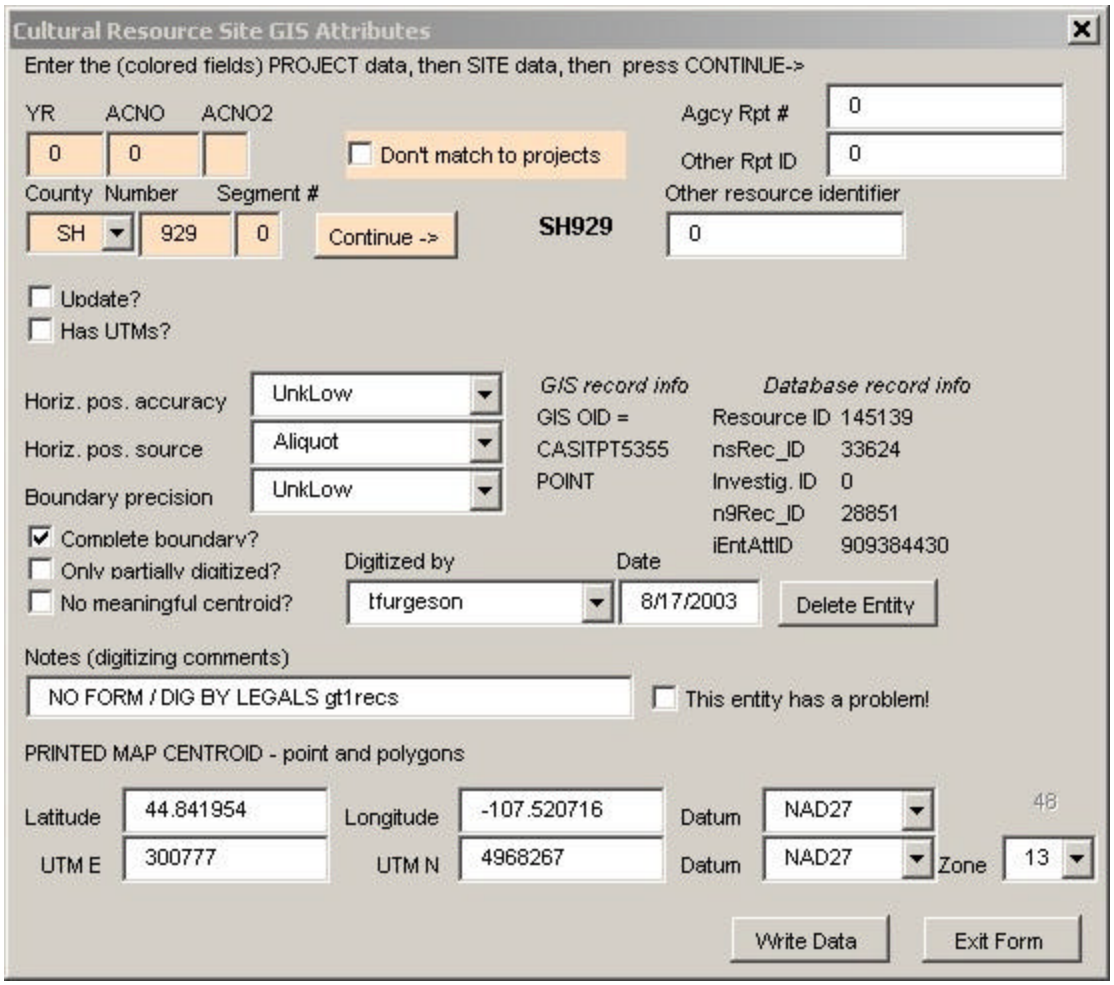

Figure 18. Cultural Resource Site GIS Attributes Form.

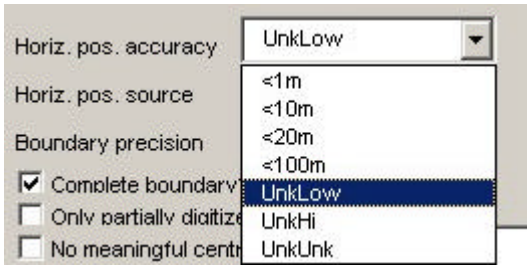

Figure 19. Horizontal Position Accuracy Field.

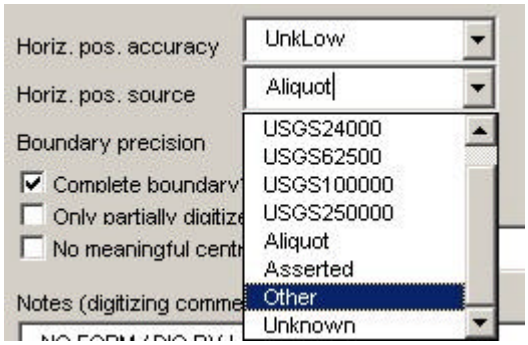

Figure 20. Horizontal Position Source Field.

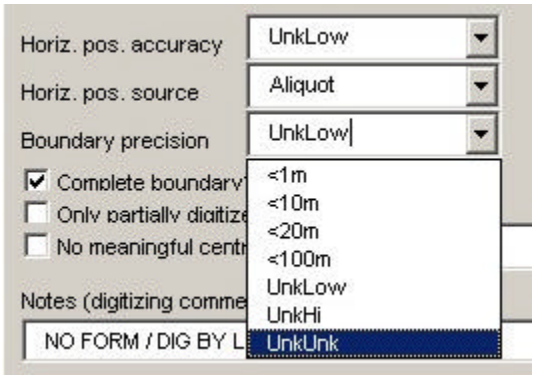

Figure 21. Boundary Precision Field.

The final field used to describe the accuracy of the digitized data is the Notes (digitizing comments) field (Figure 22). This field will describe any digitizing problems and will indicate the method used to digitize the entity. Three digitizing methods have been employed to digitize sites, the most common of which is known as heads-up digitizing. Heads-up digitizing is used when a good quality USGS topographic map has been provided for small to medium sized projects and sites. Project and site boundaries are digitized by visually matching features from the paper USGS map to the features on

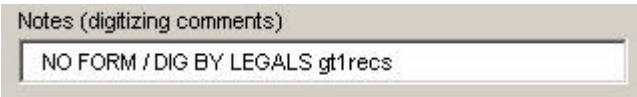

Figure 22. Notes Field (digitizing comments).

the digital topographic map files in the geodatabase. Digitizing is also accomplished using a tablet or georeferenced image. In both of these cases, the entity to be digitized is traced after the image has been georeferenced. Tablet digitizing and digitizing using georeferenced images is used primarily when dealing with large, intricate survey areas, such as seismic projects. In theory, georeferenced images should provide the highest degree of accuracy in both horizontal position accuracy and in site boundary precision. However, in practice all three methods provide comparable data accuracy due to human error.

Each project report and site form was treated individually so that the most accurate information possible could be added to the geodatabase. The quality of the information for each project and site varied by survey organization and through time, so the quality of the information contained within the geodatabase also varies. However, by tracking certain key elements that contribute to variations in the quality of the data, a database has been created that is as accurate as possible, contains the most data possible, and makes possible the comparison of data of varying quality.

In order to keep GIS data current and up-to-date the digitizing application has also been customized and installed in all BLM field offices. All of the BLM's cultural resource staff were trained on the use of the application in April of 2004. Newly recorded sites

and inventories received by BLM are being digitized when they review and process reports. The Wyoming BLM state office is coordinating the inclusion of the BLM dataset into the master WYCRIS GIS.

Cost Analysis of the Work Effort

Technologies the WYSHPO uses to provide on-line information systems are industry standard and were already in place in the Wyoming Cultural Records Office prior to the commencement of the *Adaptive Management and Planning* project. The challenge of maintaining these systems in the long term and development of stable funding sources to support the day-to-day maintenance and upkeep of the system will continue to be a challenge for the WYSHPO. Because this project has developed fully populated GIS and information datasets for an eight county study area, the northeastern part of Wyoming, including the Buffalo, Casper, and Newcastle BLM field offices have current information as of December 31, 2004. Since the posting of the Wyoming Cultural Resource Information System on the Internet, almost 100,000 queries have been conducted. In the future, cost savings are anticipated with CRMTracker and fully populated GIS systems throughout Wyoming. To date, approximately 50 percent of all spatial information is included in WYCRIMS. This project has targeted the northeastern portion of Wyoming due to the high volume of energy related projects being conducted and proposed in the area.

Examples of Time and Expense Savings Using New and Improved Technologies

- ✓ Savings to WYSHPO -Assuming all queries completed on the website save SHPO time and expenses:

- If each query saves on average 0.25 hours of SHPO staff time, then 47,526 work hours were saved. This equates to eleven and a half years of staff time since FY2000. An average wage paid by SHPO is $15.00 per hour. Over the four year time period, approximately $356,445 has been saved in staff salaries.
- If each request requires a long distance phone call (since most federal agencies and consultants are not local), and if each call on average costs conservatively $.50, then $48,450.40 has been saved in telecommunication costs.
- If each query requires a document to be mailed, postage savings is $35,853.
- If the mail takes a minimum of two days transit time, the savings in "wait time" for decision-making equates to 530 years since FY2000.
- If we assume each site form is on average five pages in length, and 3,000 forms are accessed on-line each year, $1,500.00 per year is saved in copy costs.
- Annually the WYSHPO saves approximately 2.85 FTE per year, which is approximately $88,918 per year in salary + $12,112 in telecommunications + $8,963 in postage + $1,500 in copy costs + 133 *years* "wait time". *Total annual cost savings is $101,493 + 133 years in project delay.*

- ✓ Savings to the Bureau of Land Management - BLM queries to WYSHPO web data: 23,763 queries

- If each query saves 0.25 hours of BLM staff time, then 5,941 work hours were saved. This equates to 2.9 staff years since FY2000. Assuming an average wage paid by BLM is $20.00 per hour, over the four year time period approximately $118,820 has been saved in staff salaries.
- If each request requires a long distance phone call (most federal agencies are not local), and if each call on average costs conservatively $.50, then $11,881 has been saved in telecommunication costs.
- If each query requires a document to be mailed, postage savings is $8,792.
- If the mail takes a minimum of two days transit time, the savings in "wait time" for decision-making equates to 130 years since FY2000.
- Annually BLM saves approximately .7 FTE per year, which is approximately $29,705 per year in salary + $2,970 in telecommunications + $2,198 in postage + 130 *years* "wait time". *Total BLM annual cost savings is $34,873 + 32.5 years in project delay.*

    - ✓ Savings to Industry – This section assumes all private consultant queries are generally on behalf of Industry. Consultant queries to WYSHPO web data: 34,168 queries

- If each query saves 0.25 hours of Consultant staff time, then 8,542 work hours were saved. This equates to 4.1 staff years since FY2000. If an average wage paid to consultants is $9.00 per hour (a very conservative hourly wage), over the four year time period approximately $76,878 has been saved in staff salaries.

- If each request requires a long distance phone call (most consultants are not local), and if each call on average costs conservatively $.50, then $17,084 has been saved in telecommunication costs.
- If each query requires a document to be mailed, postage savings is $12,642.
- If the mail takes a minimum of two days transit time, the savings in "wait time" for decision-making equates to 187 years.
- Since most costs are passed from consultant to client, on an annual basis Industry save approximately 1 FTE per year, which is conservatively $18,700 per year in salary + $4,271 in telecommunications + $3,161 in postage + 46 *years* "wait time". *Total Consultant annual cost savings is $81,168 + 46.75 years in project delay.*

Overall total annual cost savings to WYSHPO, BLM, and Oil and Gas Industry in Wyoming: *Dollars saved is $217,534 and 212.25 years of time is saved per year.* This analysis did not include the US Forest Service, Bureau of Reclamation, Wyoming Department of Transportation or the National Resources Conservation Service. They are also daily users of the on-line information system.

CHAPTER 4

ARCHAEOLOGICAL BURIAL MODEL: POWDER RIVER AND TONGUE RIVER HYDROLOGICAL BASINS, WYOMING

The adaptive management paradigm process model facilitates self-correction and continual improvement (Figure 23). Within the context of the *Adaptive Management and Planning* project, adaptive management refers to implementing a self-corrective process to minimize management conflicts between cultural resources and oil and gas extraction on federal land. This project poses possible solutions to be implemented, monitored, evaluated, adjusted, and assessed. Adaptive management is an on-going process.

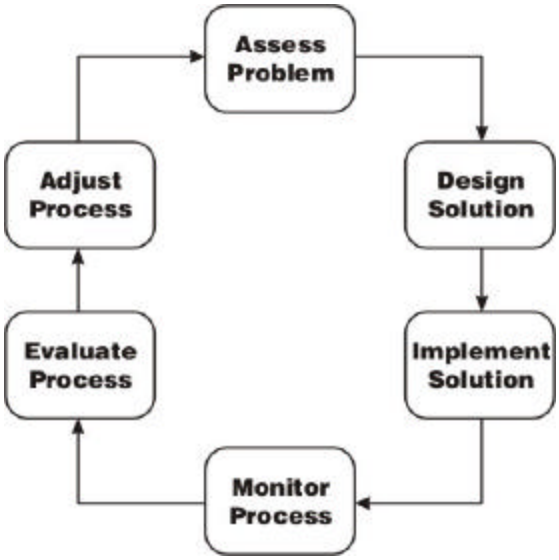

Figure 23. Adaptive Management Flow Chart

Expanded development of energy resources in northeastern Wyoming brings with it the risk that archaeological sites are inadvertently damaged. Sites containing buried, intact, and well-preserved archaeological material are some of the most scientifically important cultural resources within the project area. In point of fact, they contain all categories of data that contribute to the significance of surface sites, as well as a number of categories of contributory data that surface sites lack. From this standpoint, the level of management effort buried sites receive should be in proportion to their scientific importance. However, these site types are difficult to manage because stakeholders often have a poor understanding of the geological and soil processes that led to the burial and preservation of the site. This leads to faulty prediction of which sites have potential for preserved and intact subsurface cultural materials. This lack of understanding means some sites are subjected to more investigation than is warranted given the data categories they contain while other subsurface cultural levels remain undiscovered until they are destroyed or are unearthed during construction activity. These outcomes lead to unexpected development costs from construction and production delays, as well as loss of valuable scientific information.

Having identified the potential problem, this report presents a geoarchaeological model that predicts the location of deposits that might contain buried and intact archaeological material. This model informs the user who wants to know if a particular known site is located within an area where the burial of subsurface cultural material is possible. Likewise, the model informs the user that certain landscapes have the geological qualities conducive to site burial. If applied properly, this burial model will lead to more efficient

management of cultural resources so that both resource preservation and energy extraction are facilitated.

The proposed model will need to be implemented within the Section106 process by land management agencies in order to achieve its potential. In anticipation of this implementation, we suggest how to monitor, evaluate, and adjust the model so that it might fulfill its function under changing development scenarios.

This model is specific to the Wyoming portion of the hydrological Powder River and Tongue River basins (Figure 24). The model produces a digital map that contains polygons coded by the sensitivity or risk of encountering sediments that have suitable age and energy regime to contain buried cultural material. It is recommended that this map be used at an appropriate scale. The sensitivity criteria presented in outline form below should be not be used outside of the geographic area described in this report. To do so might lead to erroneous conclusions regarding the sensitivity of locations not modeled within this report. In principal, however, similar models can be constructed for any area. Four components are used to construct the model: (1) field reconnaissance; (2) literature review; (3) data acquisition; and (4) Geographic Information System (GIS) visualization. Field reconnaissance was conducted in Campbell, Johnson, Natrona, and Sheridan counties, Wyoming, April 26-30 and May 5-7, 2003.

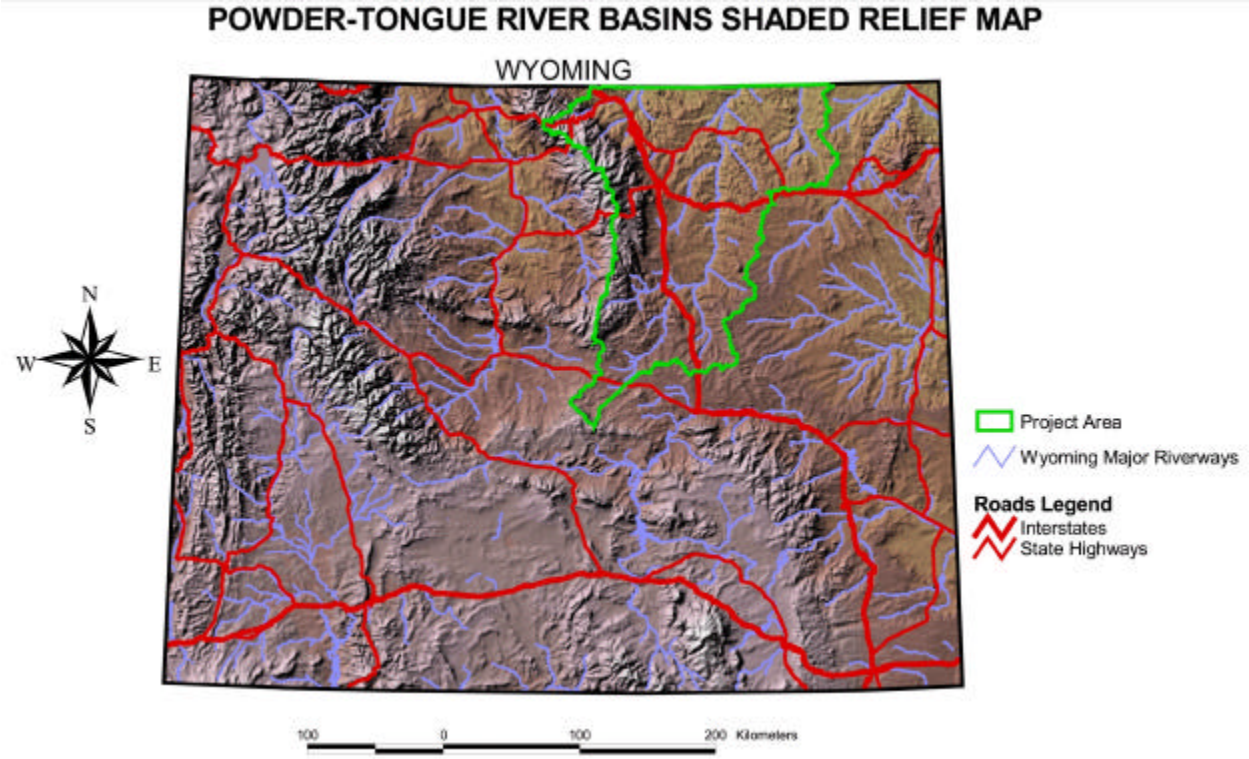

Figure 24. Map of the project area illustrating its location in the Powder River and Tongue River basins, northeastern Wyoming (USGS EROS Data Center 2003)

Burial Model Framework

A systematic attempt to model and map the spatial location of deposits in the study area that might contain preserved, buried sites has not been undertaken until now. However, a number of informative geoarchaeological studies have been conducted and provide valuable background information. John Albanese has investigated numerous sites in the Powder River Basin (Albanese 2000) and authored several regional summaries. This work has been supplemented by the soils studies of Richard Reider (Reider 1990). Much of their work has been conducted as part of archaeological research undertaken by Dr. George Frison, University of Wyoming. In addition, archaeological burial models (landscape sensitivity frameworks) have been developed and successfully applied to other

areas of Wyoming (Eckerle and Taddie 1997; Eckerle et al. 1999; Eckerle et al. 2000) as well as areas in Nevada (Drews et al. 2004) and southern California (Horne et al. 2001.)

The modeling framework presented in this report is based on the assumption that intact cultural resources (from a National Register of Historic Places [NRHP] perspective) are found in geological strata that were deposited since the end of the last Ice Age. As used here, the date for this event is 14,000 radiocarbon years ago. As well, archaeological materials that accumulated within moderate to low energy depositional environments are likely to have been buried close to where prehistoric peoples used and discarded them. Also many of these depositional environments buried cultural occupations deeply and rapidly enough to have escaped the effects of long-term surface and near-surface disturbance processes, thus maintaining stratigraphic and behavioral integrity. Buried prehistoric archaeological sites with high stratigraphic integrity are extremely important from many perspectives; however, such sites are difficult to identify and manage and expensive to treat under Section 106 of the National Historic Preservation Act (NHPA). These factors form the rationale for constructing a model specifically designed to assist in predicting areas where these types of sites might occur.

The model divides the landscape into archaeological site burial sensitivity categories ranked in a continuum from very high, high, moderate, low, to very low sensitivity. These sensitivity categories reflect the potential of a landscape to contain buried and relatively intact occupation strata, which exhibit both contextual and associational integrity. Modern earth-disturbing activities put any buried and intact sites at risk of the

loss of scientific information and thus, data that might contribute to the sites' National Register of Historic Places eligibility. Following from the model predictions, buried sites in these locations are likely to contain perishable archaeological residues, such as bone and charcoal, which are rare and valuable remains useful in archaeological interpretation.

Geological landform and soils data are used in GIS to create multiple, overlaying map images that illustrate the burial sensitivity of areas specific to the project area. Digital data used in the GIS are available in multiple forms: geological data are from the Wyoming Surficial Geology Map (Case et al. 1998); soils data are available at the state level from the National Resources Conservation Service (NRCS) State Soil Geographic (STATSGO) database (Soil Conservation Service 1994); and soils data are also available at the county level from the NRCS Soil Survey Geographic (SSURGO) database (Natural Resources Conservation Service 1998, 1999, 2000, 2002a, 2002b, 2003a, 2003b; United States Forest Service 1999).

Ultimately, modeled data can be used as the basis for informing and guiding individual, project-specific management decisions at the 1:250,000 (STATSGO) scale or, where available, at a 1:24,000 (SSURGO) scale (see qualifications below). Land managers can use this information to anticipate areas of archaeological compliance concern, while developers can use it to project the costs of development in targeted and alternative areas. Cultural resource management firms can use this information in the planning stages of their Section 106 consultations; their field archaeologists can make practical use of the model to better understand the geoarchaeological settings where they are likely to

discover significant, buried archaeological sites. A field protocol handbook manual (see Appendix C) accompanies this report. It is designed for use by four categories of users: (1) agencies; (2) industry; (3) cultural resource consultants; and (4) field archaeologists. This is a practical, condensed guide that informs users of the logic behind the model, as well as how they might implement it given their varying needs.

BURIED SITES AND SITE FORMATION PROCESSES IN THE POWDER RIVER BASIN: DEFINITION, DISCOVERY, AND PRESERVATION ISSUES

Subsurface cultural material is not equivalent in meaning to a buried site. As discussed below, artifacts from surface occupations are often turbated into the subsurface. Rarely, subsurface artifacts can be documented within buried natural strata. More often, zonation, which might be confused with buried strata, are simply soil horizons. Albanese (1981) proposed a minimum depth of burial of 20 cm to indicate a stratigraphically buried site. Although artifacts can be turbated much deeper, 20 cm seems a reasonable limit for management purposes.

Factors Affecting Site Discovery: Plan View Versus Profile

The archaeological record, as a landscape phenomenon, has both horizontal and vertical components. Human occupations deposit artifacts and features in horizontal distributions across the landscape. In time, they may become buried, adding a vertical component to the archaeological record. Archaeological survey is designed to discover horizontal

distributions. Thus, buried sites often remain undiscovered until earth-moving activities occur during development. Alluvial settings are ideal for the formation and preservation of vertical deposits, but, as Albanese (1978) noted, relatively few buried sites in the Powder River Basin have been discovered in such contexts, when compared to other areas in Wyoming despite the frequent presence of cutbanks that expose appropriate sediment. He accounted the rarity of buried sites by the fact that streams destroy many sites over time. Alternatively, it is notable that discovery of buried sites is difficult in alluvial settings compared with their upland counterparts. An experienced field archaeologist is simply less likely to discover eroding cultural material at the base of a cutbank than on flat or rolling landscapes. Surface occupations and the horizontal degradation of buried occupations leave artifacts behind as a horizontal lag deposit. Whereas artifacts that erode out of arroyo walls are generally flushed downstream during subsequent flood events, thus, failing to accumulate to any significant surface density below the cutbank. A site exposed in cross-section rather than plan view logically makes fewer artifacts visible for discovery, further reducing the probability that buried sites will be discovered during survey.

Pedestrian archaeological surface inventory (survey) involves walking the landscape looking for artifacts. Generally artifacts with a long axis of 2 cm are visible for 2 m on either side of the archaeologist. For example, suppose a circle of 2 m in radius (125,600 cm^2) representing an archaeological site (activity area) contains 100 artifacts (flakes), all about 2 x 2 x 0.2 cm in size. The total area of artifacts is 400 cm^2. The ratio of the site area to the flake area is 314:1. From the center of the circle all 100 artifacts are visible.

Now, take a string line 1 mm in diameter and randomly transect the site (plan view) circle. The probability of encountering a single flake along the 1 mm stream line can be calculated as:

Pr (flake) = 400/125600 = 0.003

and that for not encountering a flake as:

Pr (no flake) = 125200/125600 = 0.997.

This action is equivalent to viewing artifacts exposed in a cutbank. Base rate probabilities of encountering a single flake exposed in a cutbank are around 0.3 percent, so 99.7 percent of the time no artifact will be encountered.

Note that artifacts are usually exposed on edge in a buried context. If a 1-m deep trench were excavated through the 2 m wide buried occupation (100 cm x 200 cm = 20,000 cm^2) to expose the artifact-laden (400 total artifacts) surface in profile, at best, one or two flakes might be encountered (on edge; 2(2cm x 0.2 cm)= 0.08 cm^2). In that instance, the ratio of site area to flake area increases to 250,000:1 (20,000 cm2 / 0.08 $cm^{2)}$. It is easy to see why site areas exposed in arroyo walls are difficult to identify in profile. In fact, it is a wonder that buried sites are ever found in cutbanks through visual inspection.

Typically, it is the presence of generally rarer, larger indications such as culturally stained carbonaceous sediment, large animal bone, or the presence of fire-cracked rock that give the location of buried sites away. Unfortunately, many of the sediments in the Powder River Basin are dark in color and this makes cultural stains more difficult to

identify than, for instance in the Wyoming Basin where many post-Glacial sediments are lighter colored. In any case, since most surface sites are flake scatters, it is difficult to evaluate the frequency of buried versus surface sites from archaeological inventory data. From this perspective, the Powder River Basin is a problematic setting to locate buried sites as opposed to the rolling dunal landscapes in the Wyoming Basin. Buried sites in the latter are easily found by observing artifacts in plan view at the base of dunes and then identifying the highest elevation on the dune slope at which artifacts appear. This highest elevation often marks the position of an eroding zone of cultural material.

Site Formation and Destruction Processes

The purpose of the modeling is to more effectively manage buried prehistoric sites. In order to accomplish this, it is important that archaeologists understand the types of site formation and destruction processes that act to create and destroy buried sites. This section discusses common site formation and destruction processes, and provides a basis for evaluating the types of landscape settings and deposits that are conducive to the burial and preservation of sites. It is also important that concerned parties understand how various types of erosion can influence the discovery process for buried sites.

Archaeological materials originate within a behavioral context as objects used and produced by people. After the objects are lost, discarded, or abandoned, they enter the archaeological record. The archaeological record is valuable to modern society, in part, because archaeological science can derive information about history, lifestyles, and

cultural processes that influenced the people who produced the objects now categorized as artifacts and archaeological features. One of the realities of archaeology is that when artifacts are found as close as possible to the original positions where they were lost, discarded, or abandoned, the archaeologist is able to learn much more than if the artifacts were moved from their original positions sometime between their abandonment and when the archaeologist recovers them. Various cultural and natural processes can move the artifacts from their original positions and these processes make it more difficult to extract information about the original behavior of the people who left them. A discussion of pertinent site formation and destruction processes is presented here. The following categories are summarized, which generally follow Gifford (1978): occupation trampling, post-occupational (preburial) dispersal, burial dispersal, and post-burial turbation.

Occupation Trampling. The magnitude of occupation trampling (treading and scuffing) varies with respect to substrate texture, occupation traffic intensity (Rapp and Hill 1998; Schiffer 1987), and moisture content (Deal 1985). Experimental studies indicate that an occupation trample zone (or "churn zone") is formed in loose substrates. Well-sorted sands produce the thickest occupation trample zone that ranges from 5-16 cm (2-6 in) in thickness (Table 2) (Gifford-Gonzalez et al. 1985; Stockton 1973). Loamy sand will develop a 3-8 cm (1-3 in) trample zone (Villa and Courtin 1983), whereas loams produce almost no occupation trample zone (Gifford-Gonzalez et al. 1985). Clayey sediments, likewise, require extremely high levels of traffic or saturation before any occupation trample zone is produced (Eckerle, unpublished field observations). Pedestrian traffic on

cobble or larger size clasts will not produce a trample zone at all (Hughes and Lampert 1977).

Occupation trample zones can be viewed as both a positive and a negative aspect of site formation. Occupation trample zone development on a soft substrate has the effect of blurring the occupational record of finely stratified and reoccupied sites (Hughes and Lampert 1977; Villa 1982). The positive aspect of occupation trample zones is that their formation quickly hides artifacts and makes them unavailable for site cleaning and secondary refuse disposal (Schiffer 1987). In addition, items are much easier to lose in soft substrates (Schiffer 1987). As a result there is a higher potential for discriminating areas of high primary-discard (lodges, hearth activity areas, etc.) from those of low primary-discard. Additionally, scuffage (horizontal artifact dispersal due to foot traffic) is minimal on loose substrates because items are less likely to skid.

Table 2. Occupation churn zone thickness and predicted archaeological implications

SOIL TEXTURE	COMMON DEPOSITIONAL ENVIRONMENT	CHURN ZONE (in cm)	HORIZONTAL SCUFFING	EASE OF CLEANING	IDENTIFY ACTIVITIES	IDENTIFY DOMESTIC AREAS
sand	eolian dunes, well-sorted fluvial sands	5-16	low	low	high	low
loamy sand	some slope deposits and alluvium	3-8	moderate	moderate	moderate	moderate
sandy loam and finer	overbank deposits, lacustrine deposits, and most slope deposits	<5	high	high	low	high

The most important aspect of trample zones is that their thickness, as predicted by the substrate texture, can be used as a baseline for comparing the thickness of actual occupation zones. If the thickness of an actual occupation zone is much thinner than predicted, then that occupation zone is probably stratigraphically truncated. On the other hand, if the thickness is much thicker than predicted, then either the zone is a specialized feature (hearth, house pit) or it is over-thickened as a result of reoccupation under an aggradational depositional regime. Truncated and over- thickened trample zones suggest some loss of site integrity.

Post-Occupational Dispersal. Post-occupational (but preburial) dispersal can alter the contextual integrity of surface archaeological materials. In general, soft substrates tend to hold onto artifacts after they have settled into the surface (Wandsnider 1988). Additional trampling by animals, slope processes, and eolian movement are the major categories of post-occupational dispersal. However, trampling by animals, even in environments with high populations of hoofed ungulates, is a slow process (Gifford and Behrensmeyer 1976).

Slope wash and colluviation are two common processes that transport surface artifacts. The process of colluviation occurs commonly on relatively steep (>15 percent) slopes (Rick 1976). Colluviation is gravity-driven transport in which heavier and denser materials move further down slope than lighter, less dense items (Rick 1976). Slope wash, on the other hand, involves transport in a sheet flow layer of water during storms (Butzer 1982; Reineck and Singh 1980). It can occur on low angle slopes, especially if vegetation is sparse and infiltration levels are low. This type of transport follows

hydrodynamic rules in that smaller, less dense material is transported the furthest down slope.

Eolian transport of surface artifacts can occur whenever wind shear exceeds the hold of gravity (Bagnold 1941). This can be a major source of dispersal for small artifacts unless they quickly become buried (Wandsnider 1988). Eolian transport is not confined to dune fields but can occur whenever wind conditions are suitable. It is most effective on locations with minimal vegetation cover.

Burial Dispersal. Artifact dispersal occurs in most depositional environments (Butzer 1982). An exception to this is eolian silt (loess) environments. Lack of dispersal in loess is the result of a low surface wind shear (because vegetation is usually present) also causing low impact energy of silt particles. Size sorting or artifacts and patterned long axis orientation are common indicators of artifact redeposition (Brown 1997; Dibble et al. 1997).

Many surface sites on flat, vegetated surfaces are eventually, albeit slowly, buried by silt. Other depositional environments can be ranked into two categories of potential burial dispersal. The relatively low energy category includes alluvial overbank, sheet flow (including slope wash), and eolian sand environments. The high-energy category includes alluvial channel, debris flow, and colluvial depositional environments. For most water and air entrained sediments, artifact movement is a function of size and density (Gifford and Behrensmeyer 1976). Frison et al. (1988) propose a simple rule-of-thumb for determining the depositional dispersal of buried lithic artifacts. This rule states that

any artifacts smaller than the break off point for the coarsest 10 percent of a sediment sample (finer than the 90th percentile) were probably moved during burial.

Post-Burial Dispersal. A wide range of processes can act to disperse archaeological residues after burial. Erosion and subsequent redeposition can produce a secondary deposit that contains no contextual integrity (Butzer 1982; Schiffer 1987; Stein 2001). Many other dispersal processes are possible (Butzer 1982; Schiffer 1987; Waters 1992; Wood and Johnson 1978), including soil formation, bioturbation (including insect and rodent burrowing [Paton et al. 1995]), plant growth (including tree tip-out), and turbation from repeated ground freezing (frost heave).

The discussions of site formation and destruction processes suggest that many factors, especially geological and soil process can degrade archaeological sites. This necessitates thorough, project-specific descriptions of surficial geology and soils.

DESCRIPTION OF PROJECT

Modern Environment

Hydrography. The project area encompasses the Wyoming portion of the Powder River and Tongue River hydrological basins (Figure 25). Both drainages are tributaries to the Yellowstone River. Bounding drainage basins include the North Platte River to the south, Cheyenne River to the southeast, Belle Fourche to the east, Little Missouri to the

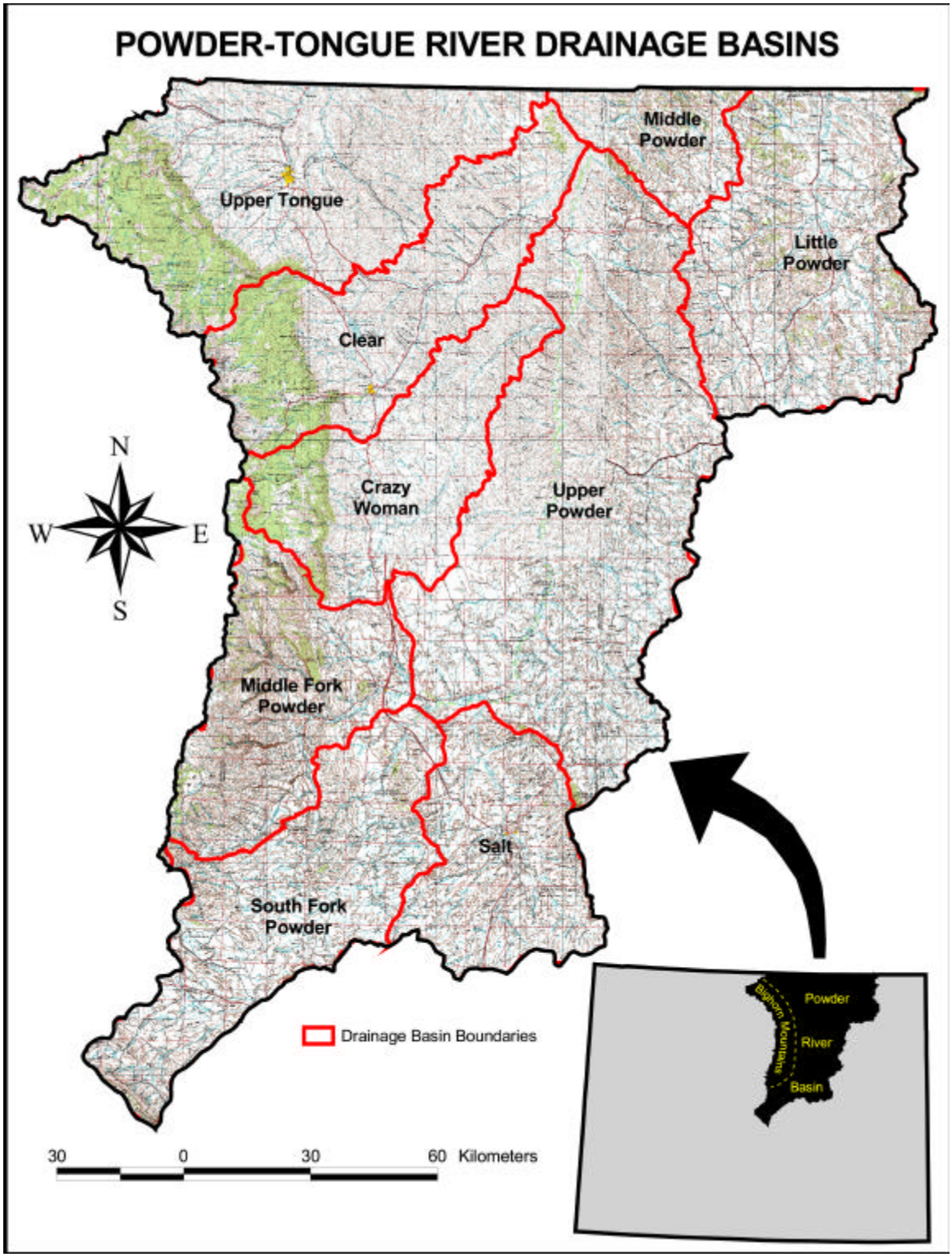

Figure 25. Map illustrating the extent of the Powder River and Tongue River hydrological sub-basins in northeastern Wyoming (Steeves et al. 1994)

northeast, Little Bighorn River to the north, Bighorn River to the west, and Sweetwater River to the southwest.

The Tongue River heads in the Bighorn Mountains near Burgess Junction and flows northeastward into Montana. Major tributaries are (from north to south with associated headwaters elevations): North Tongue River (3,098 m [10,164 ft]), South Tongue River (3,300 m [10,827 ft]), Goose Creek (3,528 m [11,575 ft]), Little Goose Creek (3,600 m [11,811 ft]), and Piney Creek, which heads on Cloud Peak (4,014 m [13,169 ft]), the highest peak in the Bighorn Mountains. The Tongue River crosses the Wyoming State line at an elevation of 1,061 m
(3,481 ft).

Major northeast-flowing tributaries of the Powder River also head in the Bighorn Mountains and their foothills. They include (from north to south with associated headwaters elevations): Clear Creek (3,744 m [12,283 ft]), Crazy Woman Creek (3,218 m [10,558 ft]), North Fork of the Powder River (3,216 m [10,551 ft]), Middle Fork of the Powder River (2,659 m [8,724 ft]), and South Fork of the Powder River (2,513 m [8,245 ft]). Northwest-flowing tributaries head at much lower elevations and include (from north to south): Little Powder River (1,390 m [4,560 ft]), Wild Horse Creek (1,330 m [4,364 ft]), and Salt Creek (1,686 m [5,531 ft]). The elevation of the Powder River as it leaves Wyoming is near 1,037 m (3,402 ft).

Structural and lithologic controls affect the drainage patterns of the basin (Albanese 1990). Areas underlain by permeable substrates are dominated by low to medium density drainages. Some shallow, internally drained basins are water collection areas. Drainage basin extent for the Tongue River basin is 13,980 km^2 (5,398 mi^2) and 34,160 km^2 (13,189 mi^2) for the Powder River (Zelt et al. 1999). Together, the Powder River and Tongue River drainage basins encompass an area approximately 48,140 km^2 (18,587 mi^2).

***Geology*.** The project area includes part of the physiographic Powder River Basin (Figure 24) and adjacent Bighorn Mountains. This basin is a structural and depositional depression formed from the downward displacement of Paleozoic and Mesozoic sedimentary rocks associated with the Laramide Orogeny, where many sedimentary strata are offset in relationship to adjacent, uplifted areas (Thornbury 1965). The axis of the basin plunges gently to the northwest (Zelt et al. 1999). Major structural features bound the Powder River Basin including the Pryor-Bighorn-Casper Arch to the west, Laramie Range-Hartville Uplift to the south, Bear Lodge-Black Hills to the east, and Miles City Arch to the north. Traditionally, the Powder River Basin is divided into two parts based on surface drainage. The western Powder River Basin (WPRB) includes the Powder River and Tongue River hydrological basins, whereas the eastern Powder River Basin (EPRB) is drained by the Cheyenne, Belle Fourche, and Little Missouri rivers. Thus, the western Powder River structural basin, along with the portion of the Bighorn Mountains drained by the Powder and Tongue rivers, correspond to the project area discussed in this report.

The Bighorn Mountains, the most prominent landform visible to the west of the Powder River Basin, formed during the Late Cretaceous and Tertiary Periods, and like the nearby Black Hills, are cored by Precambrian basement rocks. Unlike other Laramide uplifts in Wyoming, thrust faults are present on both the west and east sides of the range (Lageson and Spearing 1988). Additionally, two cross-cutting faults divide the range into three blocks: the first fault trends northeast-southwest near Tongue River Canyon, and the second trends east-west nearly parallel to Tensleep Canyon. During the Laramide Orogeny, the north block was thrust southwest over the Bighorn Basin along the Big Trails fault, the middle block moved eastward over the Powder River Basin, and the south block was shoved west over the Five Springs thrust fault (Lageson and Spearing 1988).

Geology of the project area is illustrated in Figure 26. Crystalline granitic rocks core the Bighorn Mountains, while Paleozoic and Mesozoic sandstones, limestones, and dolomites dip steeply down the eastern flank of the Bighorns into the Powder River Basin (Love and Christiansen 1985). The heavily glaciated resistant core is exposed in the middle portion of the Bighorn Mountains, which Tertiary erosion has plainated into two erosional surfaces, the Summit and Subsummit surfaces, respectively. The subsummit surface was erosionally modified by cirque carving during Pleistocene glaciation (Thornbury 1965). Cretaceous sandstone and shale crop out in the belt of foothills along the eastern flank of the Bighorns. Conglomerates shed as alluvial fans from the youthful

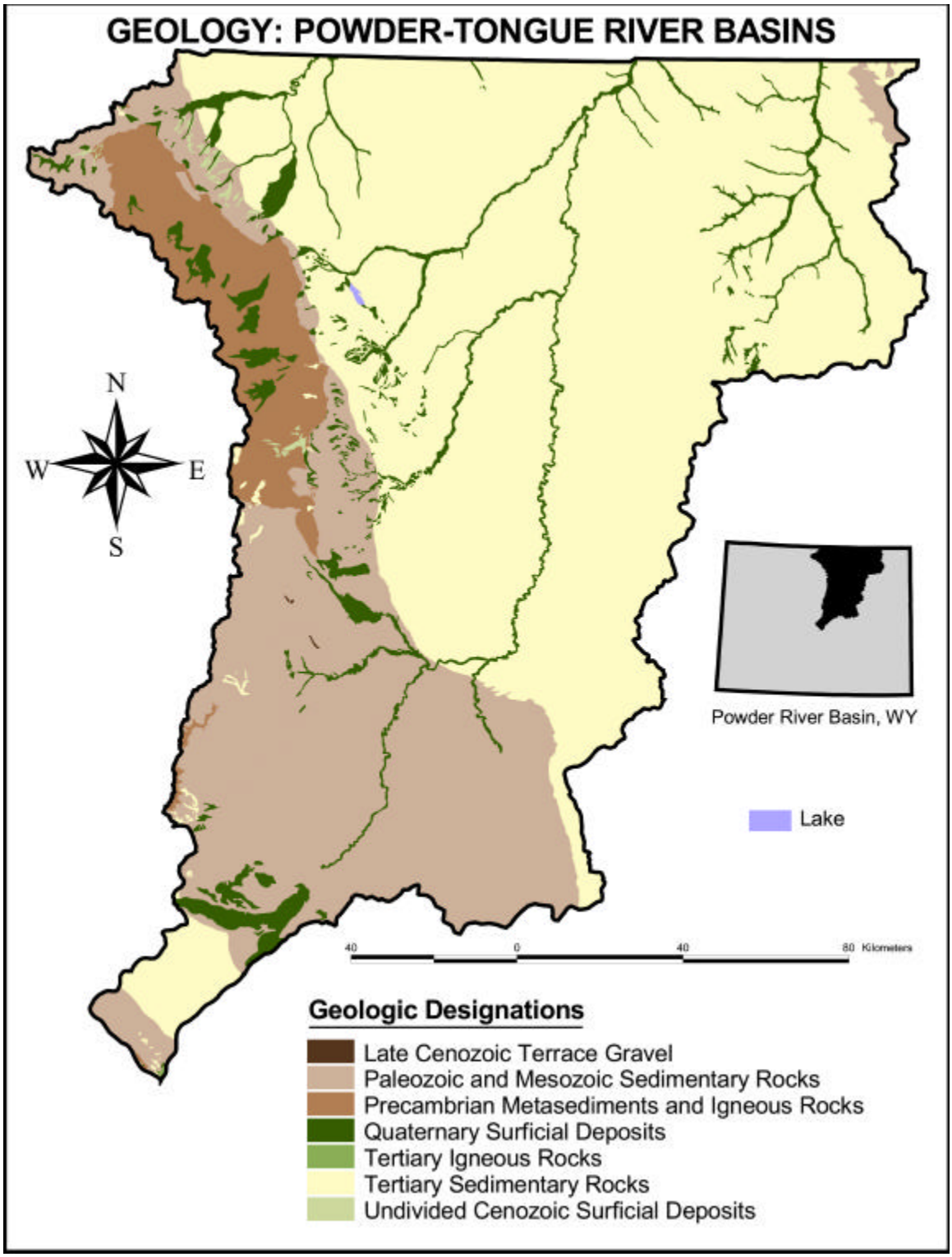

Figure 26. Project area geology (U.S. Geological Survey 1994)

Bighorn Range interfinger with the Eocene Wasatch Formation at many places along the foothills (Lageson and Spearing 1988).

The basin areas are underlain by pre-Cenozoic-age rocks, which were downwarped during the Laramide Orogeny to form a basin. This basin filled with sediment from the adjacent uplands until late Miocene or early Pliocene times when regional uplift initiated a period of basin degradation (Mears et al. 1991). The most common formations encountered formed during the basin filling cycle include (from oldest to youngest): (1) Paleocene Fort Union Formation (Tullock, Lebo, and Tongue River members); (2) Eocene Wasatch Formation (Moncrief and Kingsbury Conglomerate members); and (3) Oligocene White River Formation (Love and Christiansen 1985) (Figure 27). Coal beds are common in Cretaceous through early Tertiary units, and lightning-induced ignition of the coal seams has resulted in baked sediments, clinker beds, and pyro-karst collapse features. Quaternary gravel capped and plainated benches occur near the foot of the Bighorn Mountains, and Quaternary alluvium occupies river valleys in the basin. Eastern-flowing streams draining into the Powder River Basin carry sediments derived mostly from granite, limestone, and dolomite. Stream valley alluvium is the predominant type of Quaternary deposit along the flanks of the mountains (Hunt 1986). Basin-area drainages erode and carry sediments derived from younger, mostly sandstone and shale, rocks.

Soils. Soils of the project area are illustrated in Figure 28. Although a variety and diversity of soils are illustrated on this map, several trends are apparent. Soils along the

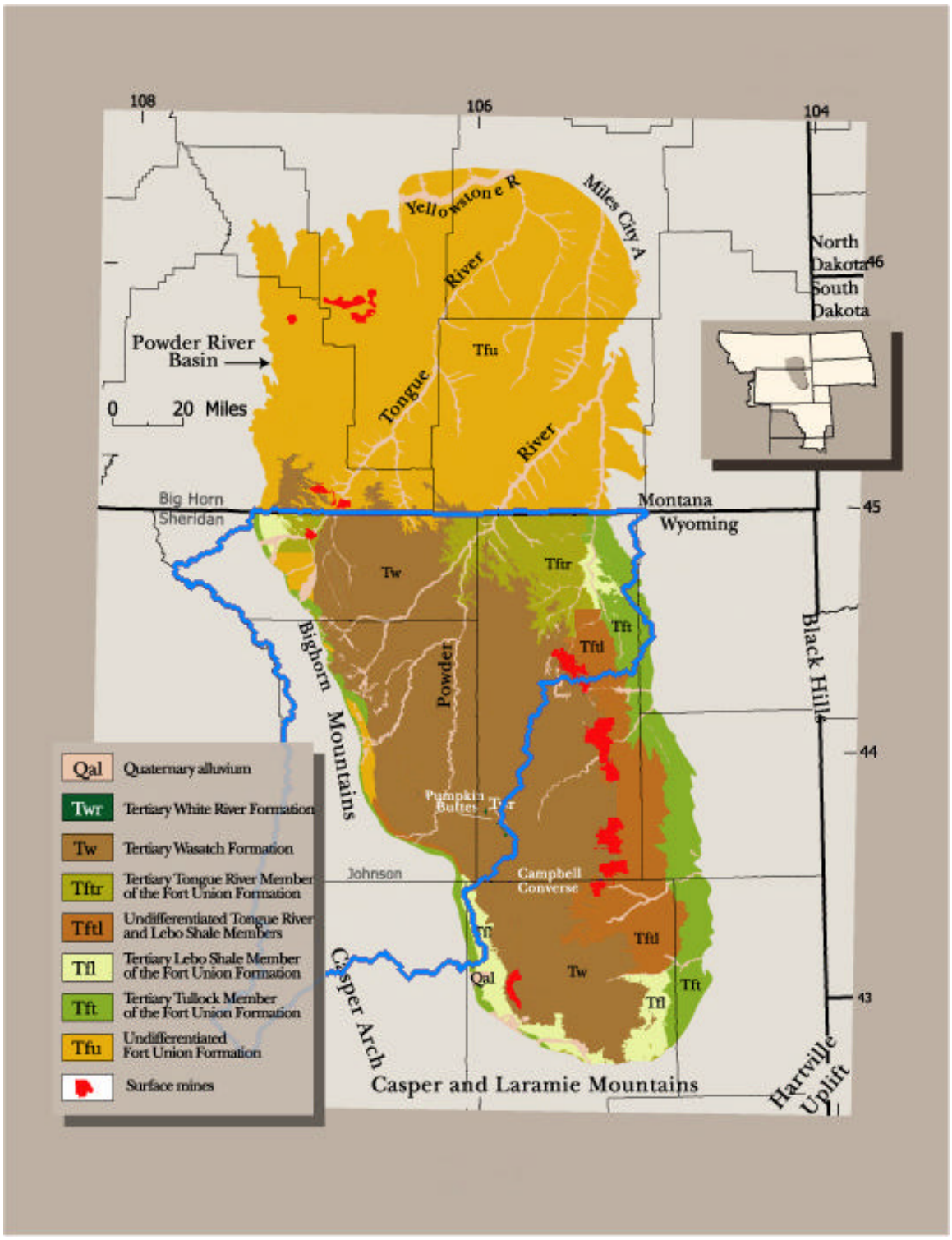

Figure 27. Tertiary bedrock geology of the Powder River and Tongue River basins showing axis of Powder River structural basin (Flores et al. 2001, Figure PS-50).

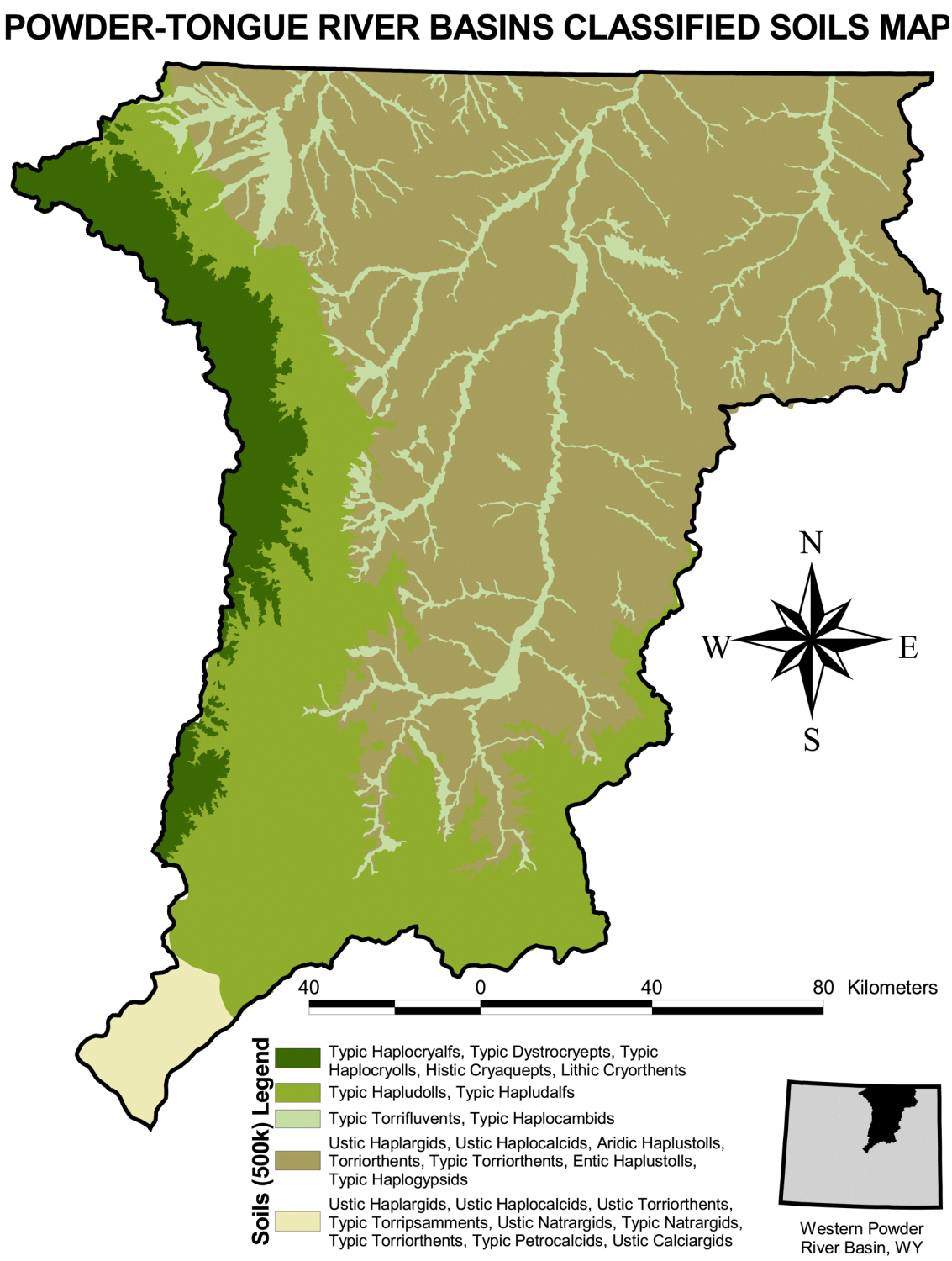

Figure 28. Map (1:500,000) illustrating the distribution and composition of soil-map units classified by soil taxon groups (Munn and Arneson 1998).

foothills-basin margin reflect a relatively moist precipitation regime (Kronenberger et al. 1977). Most of the soils receive enough precipitation to support the vegetation necessary for the development of humic A horizons. Areas of hard, resistant bedrock are mantled by thin, weakly formed soils (Lithic Ustic Torriorthents). Soils on soft, easily eroded bedrock are thick but only weakly horizonated (Ustic Torriorthents). More geomorphically stable locations exhibit soils with weathered and structured B horizons (Camborthids). Landscapes that have remained relatively uneroded for the longest period of time contain soils with clay-enriched B horizons (Ustollic Haplargids). Soil temperature regimes are generally frigid in the northwest and mesic in the remainder of the basin. Soil moisture regimes range from aquic along perennial streams to aridic in the drier portions of the basin.

***Vegetation*.** Porter (1962) indicates that vegetation zonation in Wyoming is dependent on elevation. Küchler (1966) delineated various zones of potential vegetation in the project area. A west-to-east transect from the crest of the Bighorn Mountains out into the basin yields the following vegetation types: (1) Alpine meadow along the crest of the range; (2) Western spruce- fir forest on the upper montane slopes; (3) Douglas fir forest on the lower mountain slopes; (4) grama-needlegrass-wheatgrass grassland in the western basin; and (5) sagebrush steppe along incised river breaks. As well, an area of eastern Ponderosa forest is present between the Tongue and Powder rivers.

***Climate*.** Climate of the study area is continental and characterized by cold winters and warm summers. Precipitation is distributed throughout the year and varies by elevation. Mountains are cold and moist whereas the basin is warmer and drier. In the high

mountains the average maximum January temperature is -4.4° C (24° F; all temperatures are monthly means) and the average maximum July temperature is 22.2° C (72° F) (National Oceanic and Atmospheric Administration 1985). Minimum temperatures for January and July are -17.8° C (0° F) and 2.2° C (36° F), respectively (National Oceanic and Atmospheric Administration 1985). Temperatures in the basin vary but are colder in the winter due to the intrusion of cold continental air masses.

Maximum basin January temperature is 2.2° C (36° F) and the average maximum July temperature is 31.1° C (88° F). Minimum basin temperatures for January and July are -17.8° C (0° F) and 11.1° C (52° F), respectively (National Oceanic and Atmospheric Administration 1985). Average precipitation varies from 76.2 cm (30 in) in the high mountains to 35.6 cm (14 in) in the basins (Soil Conservation Service 1983). Most of the precipitation falls in the spring, and winds typically arrive from the northwest (Martner 1986).

Present and Historic Wildlife. Some of the fauna found within the area were important to prehistoric peoples. Various avian species are sagebrush specialists, with the sage grouse being an example. Big game species such as wapiti, mule deer, whitetail deer, and pronghorn are found in the area. Bison, grizzly bear, and wolf were present prehistorically. Smaller species include jackrabbits, cottontail rabbits, various rodents, coyote, mountain lion, badger, and bobcat (Soil Conservation Service n.d.).

PATTERNING OF SURFACE GEOLOGY AND SOILS IN THE PROJECT AREA

The patterning of deposits and soils in the project area is complex but structured (Hallberg et al. 1999; Hallberg et al. 2000a, Hallberg et al. 2000b; Love and Christiansen 1985; USGS 1994). Bedrock formed during a long history of structural and depositional events, but surficial sediments were derived from bedrock and were redeposited in the relatively recent geological past (Case et al. 1998; Hunt 1986). Soils result from the interaction of soil formation factors such as parent material, surficial deposits, climate, topography, vegetation, and the duration of soil formation (Jenny 1941; Soil Conservation Service 1994).

Map Categories from the Digital Wyoming Surficial Geology Map (Case et al. 1998)

Several important surficial regimes are described (as taken from Case et al. 1998) in the following section: exposed bedrock, clinker, grus, residuum, eolian sand, glacial deposits, landslides, playas, alluvial fans, bench deposits, slope wash, colluvium, valley alluvium, terrace deposits, dissected terraces, and shallow terrace deposits (Figure 29). Each category is described using standard U.S. Geological Survey (USGS) geologic map terms, and common soil types are summarized from NRCS maps and reports. Soils types found on each surficial unit are characterized by visually overlaying 250k soils mapping over the surficial geology map. Some of these landforms are illustrated on Figure 30. The surficial geology map and the visual associations observed when overlaying the soils

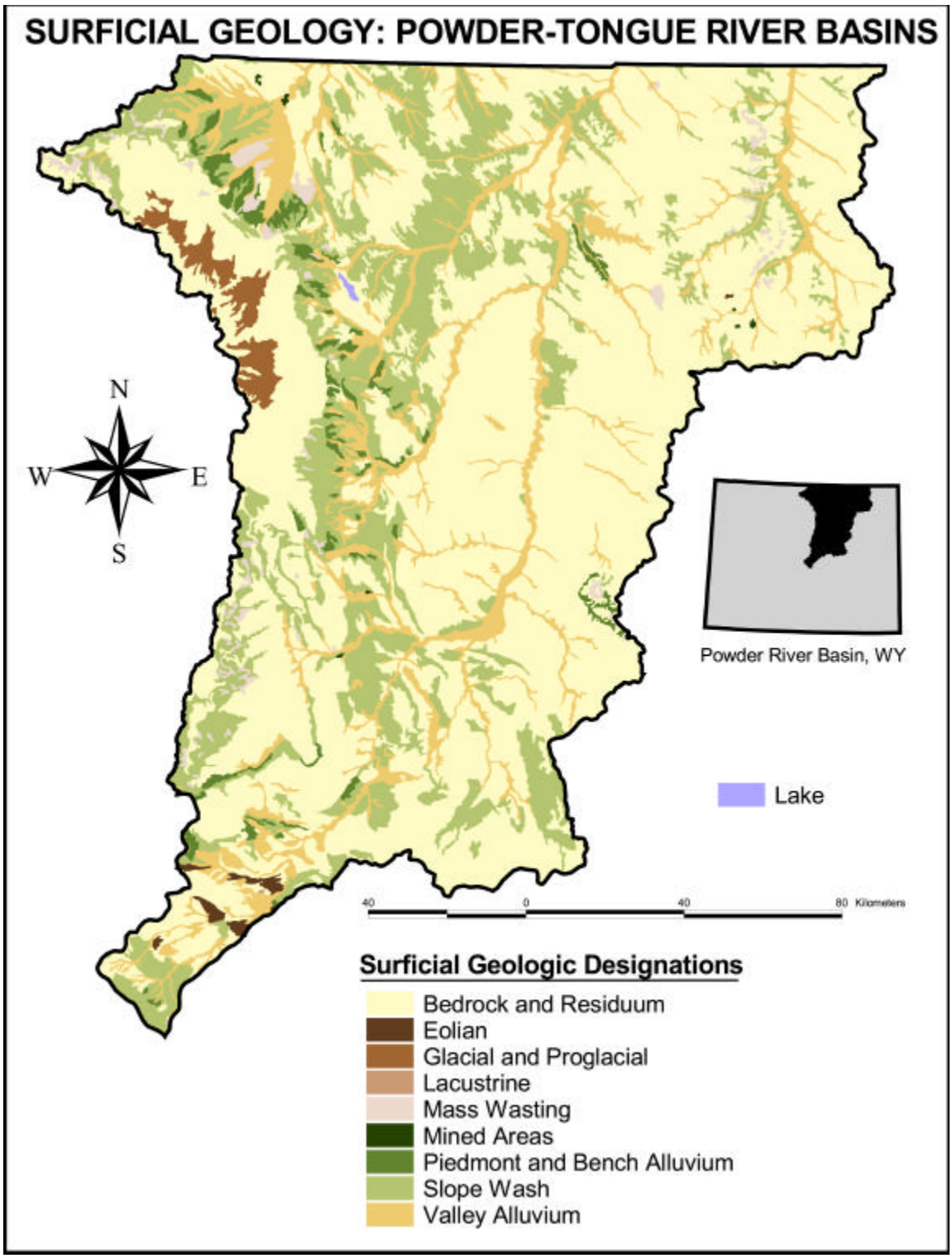

Figure 29. Surface geology map of the Powder River and Tongue River basins illustrating the distribution of major landforms and depositional environments (Case, et al. 1998).

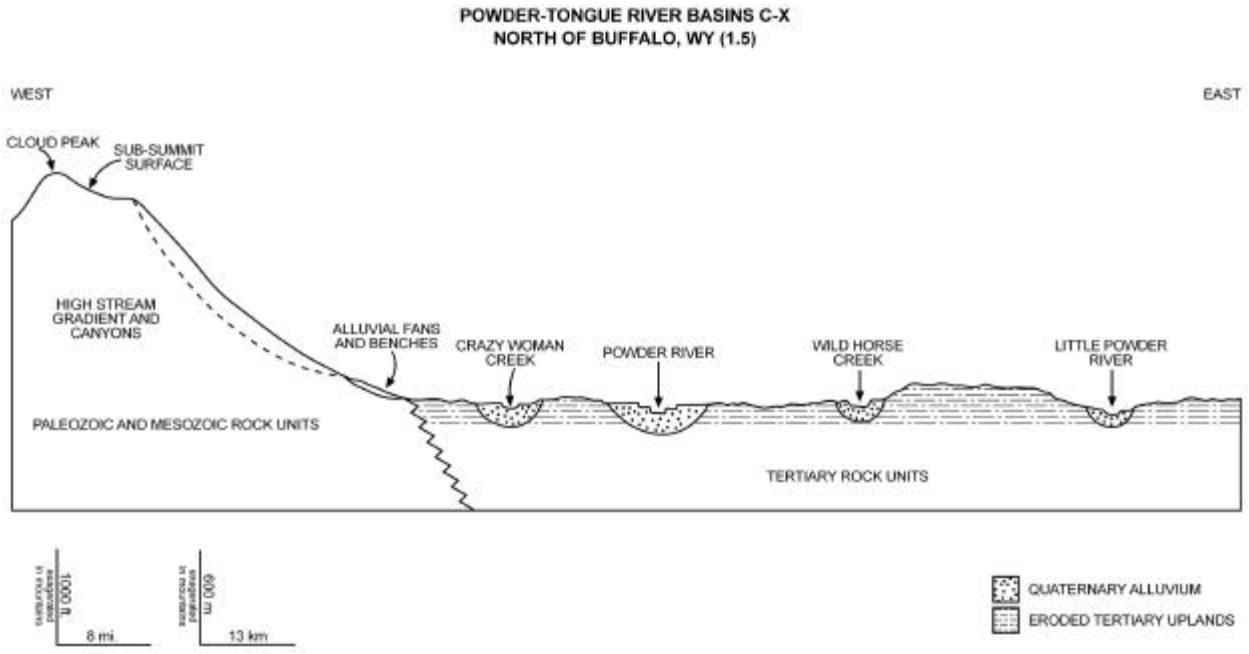

Figure 30. Schematic cross section of the study area illustrating topography and surface geology

maps are used to identify the types of landscapes, deposits, and soils that are important to the model building undertaken in this report. The surficial geology map was not used as a digital database in the model compilation.

Bedrock and Residuum.

Exposed Bedrock. Areas of exposed bedrock and glaciated bedrock have hard rock that is exposed at the ground surface or only covered by a thin zone of residuum or surficial deposits. These areas occur in several settings, including the steep eastern slope of the Bighorns, dissected uplands in the basin, and alpine areas that were scoured by glaciers. In glaciated areas, older soils with clay accumulation in their B horizons (Cryoboralfs)

are common, as are soils lacking well-developed B horizons (Cryoborolls, Cryumbrepts). Soils on the bedrock areas in the basins are sensitive to slope position with more well-developed soils (Haplargids) occurring on flat areas, and less well-developed soils (Torriorthents, Haploborolls) on steeper slopes.

Clinker. Areas mapped as clinker are situated on geologic formations that contain coal, primarily the Fort Union and Wasatch formations. The clinker is formed from the heat alteration of lithic impurities when coal beds burn. It consists of altered non-coal rocks (sandstone, shale, mudstone) that are lensed within or adjacent to the burning coal seam. Areas of clinker are common in the basin and its presence is often an indication that bedrock is close to the surface. Like bedrock areas, flat areas have soils with well-developed B horizons (Argiustolls, Haplargids) while steeper areas have thinner and poorly horizonated soils (Torriorthents).

Grus. In some areas of the high mountains, granitic rocks are exposed at the surface. Intercrystalline weathering of these granitic rocks has produced a grus deposit consisting of loose individual crystals derived from the granite. Grus is essentially a regolith that is formed into the upper part of the granite. It is most common in the northwestern portion of the project area. Predominant soil formation consists of clay-enriched B horizons (Cryoboralfs) with smaller areas of less developed soils that have organic accumulation in the A horizon (Cryoborolls).

Residuum. Residuum consists of bedrock that is weathered in place. Areas mapped as residuum are very common in the project area, and occur on a variety of rocks such as Mesozoic bedrock in the foothills and Tertiary bedrock in the basin. Soil formation in most areas is controlled primarily by slope with well-developed basin soils (Haplargids) on flatter areas and poorly developed soils (Torriorthents) on slopes. Well-developed soils (Argiustolls and Paleustolls) predominate on more stable areas within the foothills.

Eolian.

Eolian Sand. Eolian sand occurs in the project area, although it is not as common as in the adjacent areas of the Wyoming Basin to the west and south. Mapped areas of eolian sand are most common near the head of the South Fork of the Powder River and the head of Casper Creek, north of the Powder River, Wyoming. These areas consist of mostly stabilized dunes and sandy interdune areas. The majority are downwind of the easily eroded Wind River Formation. Soils vary from poorly horizonated recent sands (Torripsamments) to buried or stabilized middle Holocene sands capped with clay-enriched B horizon (Haplargids).

Glacial and Proglacial.

Glacial Deposits. Areas mapped as glacial deposits occur in the mountains along the western margin of the project area. They are common at the base of the higher peaks in the Bighorn Mountains and in stream valleys draining these areas. Deposits consist

primarily of till, which is a mixture of sand and gravel within a matrix of mud. These deposits are derived from Precambrian gneiss and granite. The sediment was transported by glaciers and emplaced in morainal deposits. Soils consist of well-developed mountain types with clay-enriched B horizons (Cryoboralfs), as well as some less well-developed types (Cryoborolls, Cryumbrepts). A single area of glacial outwash is mapped on a tributary of Big Goose Creek in the high mountains. The surface soils in this map unit are classified as Cryoboralfs, with clay accumulation present in the B horizon.

High Energy Mass Wasting.

Landslides. Landslide deposits are mapped in a variety of areas, but generally occur directly below steep slopes. Landslides have occurred on the flank of the Bighorn Mountains where large sections of Paleozoic bedrock have detached and fallen. Several landslide deposits also occur in the extreme southern part of the project area in an area where deformed Mesozoic rocks are overlain by Tertiary deposits. Only a few landslide deposits occur in the basin. One such area where they occur is around the flat-topped mesas named Pumpkin Buttes. The mesas are erosional remnants capped by the Tertiary White River Formation.

Soil formation on landslides in the project area is variable and relates primarily to local climate and age of the landslide deposit. In both the mountains and basins, some landslides have clay-enriched B horizons (Cryoboralfs, Paleborolls, Paleustolls, and Argiborolls in the mountains, and Haplargids in the basins), whereas less well-developed

soils occur elsewhere (Cryoborolls in the mountains, and Torriorthents in both the mountains and basins).

Lacustrine.

Playas. Two playas, which are internally-drained seasonal lakes, are mapped in the project area. Lacustrine sediments accumulate in playas where they interfinger with slope wash and intermittent alluvial deposits. One playa occurs on the divide between the Little Powder River and Donkey Creek, near Moorcroft, Wyoming, in an area underlain by Fort Union Formation rocks. It has soils characterized by clay accumulation in the B horizon as well as less well-developed soils (Torriorthents). The other playa is in the sand hills area on the South Fork of the Powder River north of Powder River, Wyoming. It is underlain by Cody Shale, and soils exhibit evidence of clay accumulation in the B horizon (Haplargids). These playas probably contain Holocene-age lacustrine sediments.

Piedmont and Bench Alluvium.

Alluvial Fans. Alluvial deposits are poorly sorted and accumulate in moderate to high-energy depositional environments at the mouths of drainages. Sometimes fans from separate, adjacent drainages coalesce into a fan-apron. Other fans merge laterally with slope wash. Fans, while generally subdued, occur in several locations within the project area, including the mouths of mountain canyons, and within the basin where side streams flow into a main stream. Fans that occur at the mouths of mountain canyons are debris-

flow dominated, and include material derived from intrusive igneous rocks as well as Paleozoic and Mesozoic bedrock. Soils formed on this type of fan are relatively old and well developed, containing humic surface horizons as well as thick, clay-enriched B horizons (Argiustolls, Paleustolls, Argiborolls). Fans formed within the basin contain some debris flows, but also a high percentage of intermittent stream overbank sediment and slope wash. They also include more sediment derived from locally occurring Tertiary bedrock sources. Basin fans have less organic matter in their A horizons. They are younger and generally possess less well developed or no B horizons (Ustorthents, Torrifluvents, Ustifluvents, Torriorthents, Haplargids, Calciorthids, Camborthids). Dissected alluvial fans are mapped separately from non-dissected fans, but are otherwise similar.

Bench Deposit. Bench deposits are gravel-capped, isolated remnants of old river valleys and stand at the elevations of former basin floors. They are formed by topographic inversion whereby gravel-armored valleys erode slower than the surrounding softer (non-gravelly) bedrock, resulting in elevated, flat-topped features that are often dissected into several isolated planar remnants. Only one non-dissected bench is mapped in the project area; however, soil evidence suggests that other deposits might have been included within this map unit. Typically, well-developed soils occur on benches; however, the mixed variety of soil types (Torrifluvents, Ustifluvents, Argiustolls, Paleustolls, Haplargids, Torriorthents) present on the mapped areas suggests that some of the landforms may have a different origin. Dissected benches are slightly more common than undissected benches and have similar characteristics.

Slope Wash

Slope Wash and Colluvium. A large portion of the project area is mapped as slope wash and colluvium. Deposition of this material occurs by overland flow and rill fill during runoff events. Some debris flows and intermittent stream sediments are also present. The unit occurs in both the basins and the mountains. Generally, it is found on gently to moderately sloping ground. Most occurrences are probably Holocene-age, which is reflected by relatively weak soil formation at these locations. In the mountains, soil formation is predominantly limited to humus accumulation in the A horizon (Cryoborolls), and only a few areas of slope wash have weathered (Cryochrepts) or clay-enriched (Cryoboralfs) B horizons. In the basins, poorly-developed soils (Torriorthents) are common although soils with weathered (Camborthids) or clay-enriched (Haplargids) B horizons also occur.

Valley Alluvium.

Valley Alluvium. Alluvium occurs in valleys and consists of post-glacial (less than 14,000 years old) sediment (Albanese 1990). Included in this category are channel and overbank sediments which grade laterally into slope wash and post-glacial alluvial fan deposits along the valley margins. Mapped areas of alluvium are found mostly in the foothills and the basins proper, in active and former floodplains. Much of the alluvium in the mountains is mapped as minor components of larger stratigraphic units. The few

units that were mapped separately in the mountains have soil with well-developed A horizons (Cryoborolls) or clay-enriched B horizons (Cryoboralfs). In the basins, soils with some clay accumulation in their B horizons (Haplargids, Argiustolls, Natrargids) occur on slightly higher terraces while more poorly developed soils (Torrifluvents, Torriorthents, Ustifluvents) are common on lower terraces and floodplains.

Terrace Deposits. Terrace deposits are present in some areas, both in the mountains and the basin. They are mapped adjacent to valley deposits along perennial streams on relatively flat-lying landforms. Some of these are probably too high above stream level or have very well-developed soils (Paleustolls) to be Holocene terraces. Many others have poor horizon development (Torrifluvents, Torriorthents, Ustifluvents) and might be Holocene-age. Still others have soils that are moderately developed (Haplargids, Natrargids, Argiustolls) and might be Holocene occurrences.

Dissected Terrace Deposits. Dissected terrace deposits occur in the project area and are found adjacent to and slightly higher in elevation than post-glacial valley alluvium. They have a similar range of soil types as the terrace deposits (Argiustolls, Paleustolls, Torrifluvents, Ustifluvents, Haplargids, Camborthids, Natrargids), along with the potential range in ages. Dissected terrace deposits occur at the foot of the Bighorn Mountains as well as throughout the basin.

Shallow Terrace Deposits. A few areas with shallow terrace deposits are mapped on intermittent tributaries of the Powder River in the vicinity of Kaycee, Wyoming. These

occur in drainageways within a setting underlain by a variety of Mesozoic and Tertiary rocks. Soil types are varied (Torriorthents, Natrargids, Haplargids) and range in age from Late Pleistocene to Holocene.

VALLEY BOTTOM DEPOSITS

As identified on the surficial geology map (Figure 29), post-glacial valley alluvium and alluvial terraces are common surface deposit types within the project area. In addition, alluvial processes deposit large volumes of sediment in a low-to-moderate energy regime and so are conducive to the preservation of buried archaeological sites. Because of the potential of alluvium to preserve buried archaeological remains, deposits found in and adjacent to valley bottoms are investigated in more detail in this study.

Powder River Basin Alluvial Model

The Powder River Basin is a classic landscape for understanding the Late Quaternary history of alluvial valleys in western North America. Leopold and Miller's (1954) seminal work set the stage for decades of subsequent investigation (e.g., Albanese 1990). These previous studies are very important for understanding how valley bottom locations fit into our sensitivity and burial model, which is discussed in detail below.

A considerable amount of work has been done to decipher the alluvial history of Quaternary river valleys in the Powder River Basin. Initial investigations were

performed by Leopold and Miller (1954) and Haynes and Grey (1965). Subsequent testing of the model was conducted by a variety of investigators, but especially Albanese (1990). Mears et al. (1991) provide a review of some of these studies. The results of these investigations are discussed here and are used to help derive a valley bottom sensitivity model later in this chapter.

The Leopold and Miller Model. Leopold and Miller recognize strong patterning in the geomorphic relationships of Late Quaternary river valleys within the Powder River Basin. They designate three inner-valley terraces (from lowest to highest): (1) Lightning (1.2-2.1 m [4-7 ft]); (2) Moorcroft (2.4-3.7 m [8-12 ft]); and (3) Kaycee (6-15.2 m [20-50 ft]) (Figure 9)(Leopold and Miller 1954). Leopold and Miller also propose that these terraces are underlain by a predictable set of sediments they designate as geologic formations. Deposits associated with the youngest Lightning terrace (the Lightning Formation) are composed of fine-textured overbank alluvium. The Kaycee Formation is composed of mixed slope wash and alluvium underlying the Moorcroft terrace, and also forms the uppermost bed on the Kaycee terrace. Leopold and Miller identify a "modern" soil with a "columnar" structure on the Kaycee terrace that formed into Kaycee Formation alluvium. The Ucross Formation, a recent (post-Wisconsin) pebbly gravel, underlies the Kaycee formation within the Kaycee terrace. They observe a well-developed calcium carbonate enriched paleosol that formed in the upper 0.6-0.9 m (2-3 ft) of the Ucross formation; where the Ucross was absent this soil occurs in underlying sediment. Finally, the Arvada Formation, the oldest Late Quaternary deposit observed, is a weathered, periglacially modified, limonitic stained, cobbly gravel containing the

remains of extinct late Pleistocene fauna. Arvada sediments fill deeply cut channels on the valley floors and overlie a bedrock strath under the Kaycee terrace.

Based on the relationships between the terraces and deposits, Leopold and Miller reconstruct a sequence of erosional and depositional events that they correlate with extant alluvial chronologies in the western U.S. During the early 1950s, these chronologies were calibrated, predominantly with relative dates (mostly archaeologically derived) supplemented by a handful of dendrochronological and radiocarbon dates.

Leopold and Miller propose the following alluvial sequence for the Powder River Basin (Figure 31; Table 3) (Leopold and Miller 1954). The history of the alluvial sequence begins with cutting a relatively wide valley floor into bedrock. This took place at some unspecified time, presumably during the Pleistocene, and was followed by deposition of the Arvada Formation onto the valley floor. Subsequently, an inner valley was entrenched into this Arvada "floodplain", an event that occurred during the Late Wisconsin. This was followed by aggradation of floodplain gravel up to and possibly overtopping the former Arvada floodplain. An indeterminate interval of chemical weathering (i.e., redoximorphic processes) took place, resulting in limonitic staining within the Arvada gravel. Renewed deposition occurred with aggradation of finer textured gravel at canyon mouths near the mountains, and sand aggradation

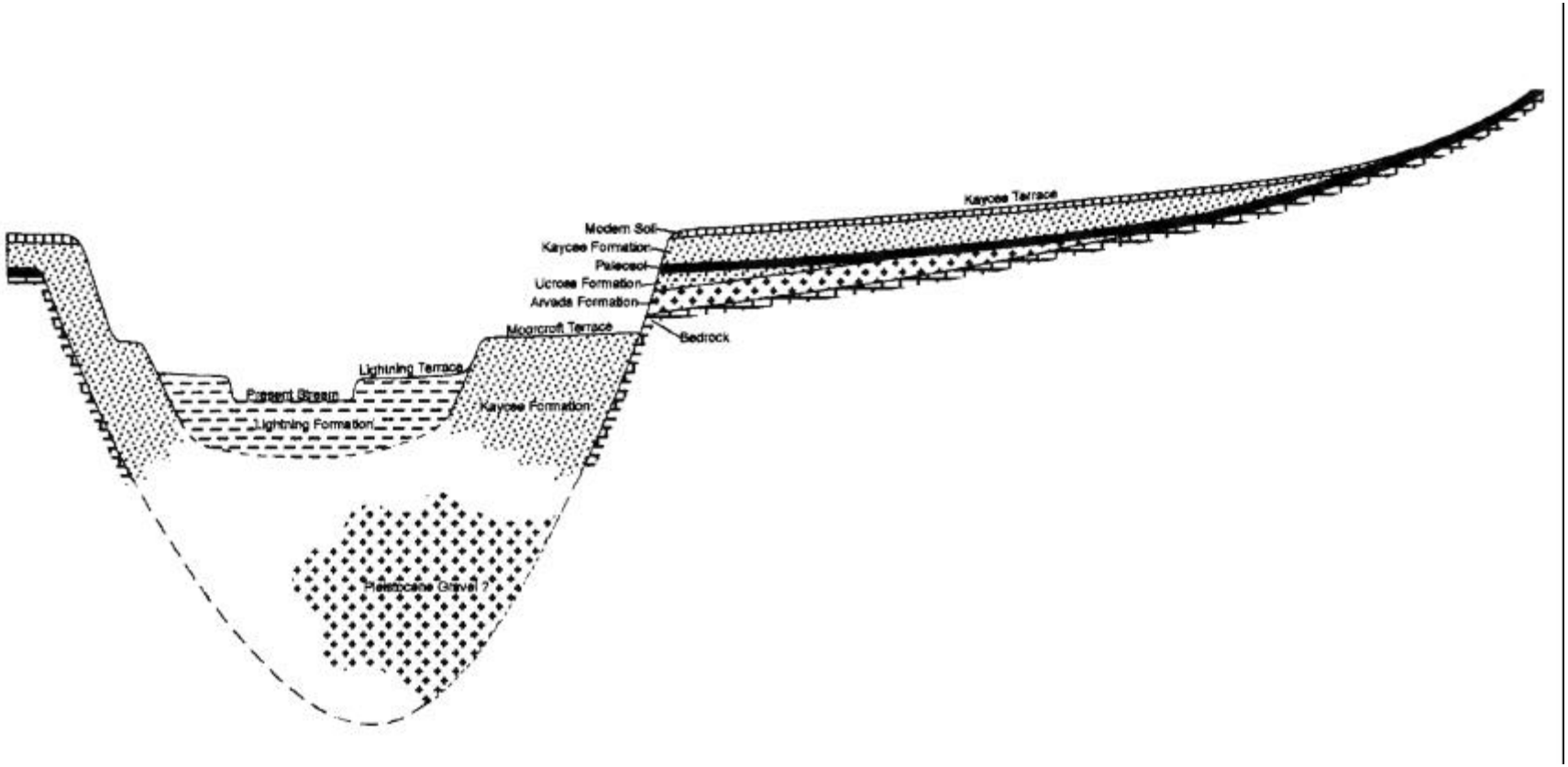

Figure 31. Schematic cross section of typical Powder River and Tongue River basins stream valley illustrating relationships between Late Quaternary alluvial deposits and landforms (Leopold and Miller 1954, Figure 5)

Table 3. Summary of Leopold and Miller (1954) alluvial model for the Powder River Basin

Formation/Post-depositional Modification	Landform or Parent Material	Depositional, Environmental, or Pedogenic Regime	Deposit/Soil Characteristics	Age Indicators and/or Proposed Age
1. Unconformity on Tertiary bedrock				Tertiary
2. Basal gravel	Fill underlying Recent channels	Fluvial channel	Gravel	Pleistocene
3. Unconformity				
4. Arvada Fm. (very rare)	Deposit on cut bedrock strath	Fluvial channel	Gravel and gravelly sand	Extinct fauna
5. Weathering - poor drainage on bedrock and lower part of gravel	Formed into bedrock	Possible perched drainage	Red iron staining on gravel (but not lower parts of wedges)	Evidence for iron mobilization
6. Evidence for periglacial conditions on bedrock	Bedrock	Periglacial	Periglacial wedges	Pleistocene
7. Possible erosional unconformity				
8. Ucross Fm.	Deposit overlying Arvada Fm. on bedrock strath	Channel and floodplain	Fine gravel with silt in upper part and redeposited, red-stained Arvada clasts	Anathermal
9. Calcareous Soil	Formed into Ucross and sometimes into Arvada Fm.	Calcification	Carbonate mottling and rinds	Altithermal
10. Erosion removes much calcareous soil				
11. Kaycee Fm.	Deposit overlying Ucross and forming Kaycee fill terrace	Slope grading into alluvium along valley axis	Generally silty with lenses of sand and gravel	Post-Altithermal, no extinct fauna
12. Surface soil on Kaycee Fm.	Non-deposition/ non-erosion of Kaycee terrace tread	B horizon formation	Columnar or cloddy B horizon with some $CaCO_3$	Post-Altithermal
13. Channel incision cutting to Moorcroft surface	Incised into Kaycee alluvium	Occasional deposits		Post-Altithermal - no flakes on this surface?
14. Renewed channel incision	Continued incision into Kaycee alluvium	No deposits	None	During or slightly before Historic era
15. Lightning Fm.	Fill terrace inset into Kaycee Fm.	Alluvium	Silty, fine or medium sand; lenses of fine gravel and coarse sand	Historic era

predominating further into the basin. This resulted in the deposition of the post-glacial-age Ucross formation, which is correlated to the early Paleoindian period based on the presence of extinct megafauna associated with Folsom-Plainview artifact associations. Then an erosional cycle removed part of the Ucross formation, partially rescouring Arvada-filled channels. Following this was the formation of a well-developed, calcium carbonate enriched paleosol into the Ucross Formation. Leopold and Miller correlate this soil formation with the Altithermal interval. Deposition of slope wash and.alluvium of the Kaycee Formation followed. These deposits are associated with the presence of modern fauna and an age estimate of late Paleoindian to 4000 years before present (B.P.) is postulated. Erosion followed the deposition of the Kaycee Formation, during which the Kaycee Formation was incised down to the Moorcroft floodplain. Stabilization occurred at the Moorcroft strath or floodplain, an event that is correlated to approximately 2500-1000 years B.P.

After 800 years B.P., erosion and entrenchment reoccurred below the Moorcroft tread, producing the Moorcroft terrace. This was followed by overbank aggradation on the Lightning floodplain sometime around or after 800 years B.P. Finally, entrenchment of the modern channel occurred, resulting in the formation of the Lightning terrace tread.

Leopold and Miller (1954) conclude that the reconstructed alluvial sequence resulted from regional climatic events. Although subsequent work by Schumm (1981) indicates that alluvial sequences can be affected by factors other than climate, some aspects of the Leopold and Miller model remain viable.

The Alluvial Sequence in the Eastern Powder River Basin. Albanese (1990; 1984; 1978; Albanese and Wilson 1974) has spent several decades in an ongoing effort to test and evaluate Leopold and Miller's model, especially as it pertains to the eastern Powder River Basin.

He makes several important observations:

1. Terraces in the eastern Powder River Basin are not always underlain by the age of sediments predicted by the Leopold and Miller model.
2. Local processes can lead to local terrace sequences.
3. The number of terraces present at any particular location varies by stream order.

As well, Albanese reports that at some locations the Kaycee correlative is capped by overbank alluvium which contains dates as young as 1580 ± 20 B.P. This suggests continued aggradation at some locations on the Kaycee floodplain, long after the date for its incision proposed by Leopold and Miller.

Significance of Alluvial Models for the Present Project. Complexities of alluvial system dynamics are well known and have been adequately described elsewhere (Schumm 1973, 1981; Schumm and Brakenridge 1987; Schumm and Hadley 1957; Wolman and Leopold 1957). For the present study there are two significant aspects of the Albanese (1990) and Leopold and Miller (1954) alluvial models. First, is the presence of a textural contrast between potential archaeological bearing deposits (latest

Pleistocene and Holocene) and older Pleistocene deposits (>14,000 B.P) (Porter et al. 1983). Both Albanese (1990) and Leopold and Miller (1954) indicate that this contact can be identified by a distinct break in grain size (Hunt 1953). Typically, older Pleistocene gravel deposits (>14,000 B.P.) underlie Holocene sand and silt near the mountains and grade into coarse Pleistocene sand which underlies Holocene silt and clay in the interior basin. In addition, both Albanese (1990) and Leopold and Miller (1954) note that non-gravelly valley fill younger than 14,000 years old is present in most valleys. Finally, both studies agree that the upper part of this post-glacial era valley fill underlies the highest Holocene- age terrace (the Kaycee). Although the Kaycee tread is referred to as an alluvial terrace, it should be noted that as the tread rises as it approaches the valley wall, the surface transitions from an alluvial terrace to a slope wash-deposited footslope. The wedge of slope wash thins as the valley wall becomes steeper, whereupon weathered bedrock and colluvium begin to crop out and eventually predominate on the back slope.

Here, we use points of agreement between the alluvial models to delimit the width of non-gravelly valley fill, including alluvium and slope wash, along the watercourses in the project area. Other details of the alluvial models are not pertinent to the burial model. Our purpose is to provide as much specificity to the location of Holocene alluvial fills as possible and to characterize the sedimentary geometry of post-glacial-era deposits. Specific occurrences of fine-textured valley fill are important to delineate since stream valleys are known to contain Holocene alluvium deposited within a low depositional energy regime, and these settings are likely to preserve archaeological sites. Thus, we

use existing alluvial models (Leopold and Miller 1954; Albanese 1990) to predict the relative width (and height) of fine textured Holocene alluvial and slope wash deposits within the valleys of the project area.

SENSITIVITY MODELING OF VALLEY BOTTOM DEPOSITS

The predicted width of valley bottom deposits are modeled using the height above stream of the highest portion of the highest Holocene terrace (Kaycee) as derived from the literature and field reconnaissance (Appendix D). Width of valley deposits was calculated from contours on 1:24,000 topographic maps. The position of the valley fill is mapped onto a digital version of the stream courses (hydrography). This process is discussed more fully below.

Management and Planning Stream Buffers

A 1:100,000 (100k), digital hydrography dataset was used to model the width of valley bottom deposits (Wyoming Gap Analysis 1996). Examination of USGS 1:100,000 scale topographic maps indicate the presence of various permanent and intermittent stream channels in the project area (Figure 32). The topographic variability of the mountain and basin areas requires treating drainages in the respective areas differently. The mountains consist of rugged peaks with high gradient streams, a sub-summit surface (plateau) that has relatively low gradient streams, and a steep mountain front consisting again of high gradient streams. By contrast, the basins have much less diversity in gradient. Because

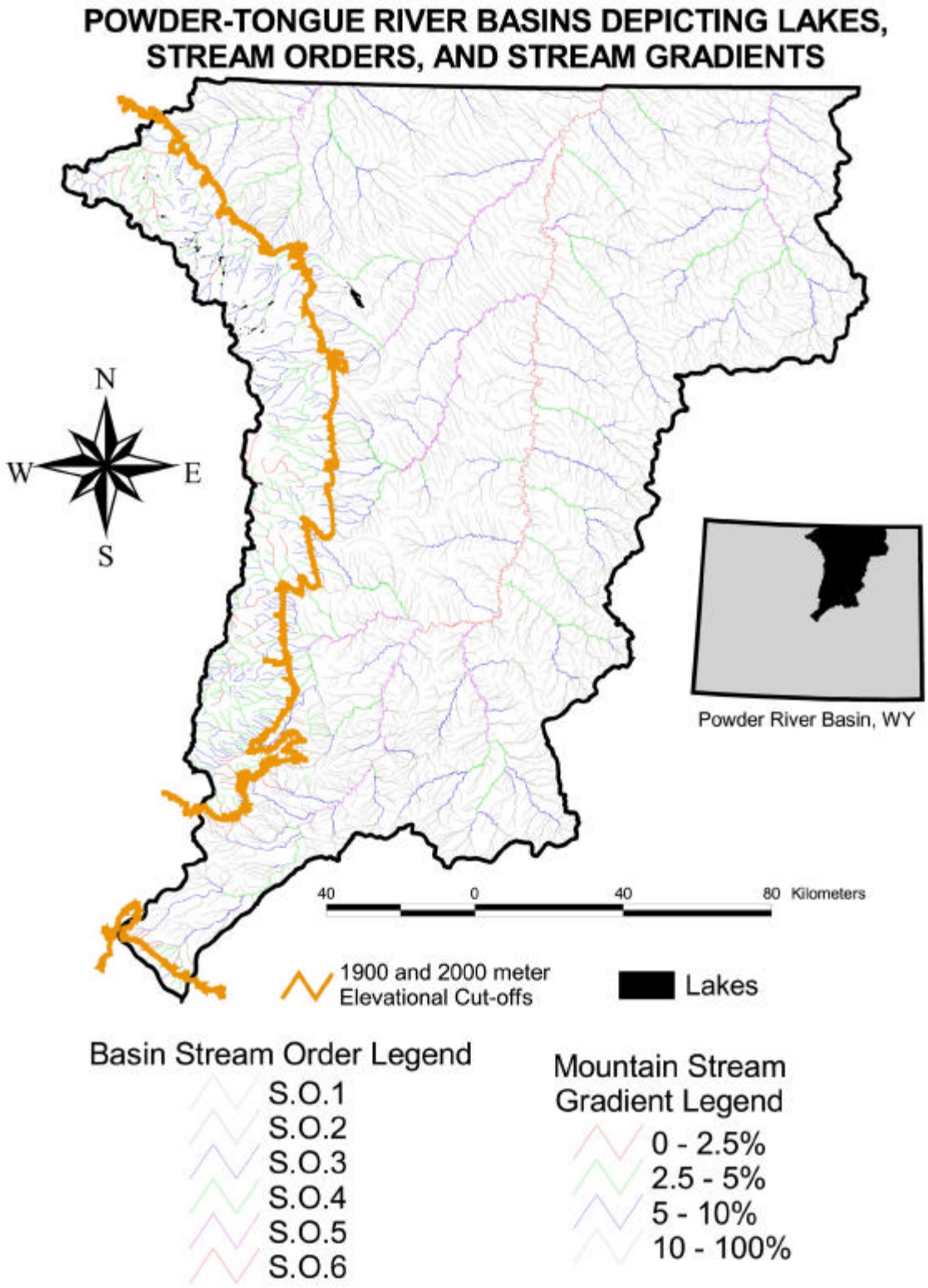

Figure 32. Map of the Powder River and Tongue River basins drainage network showing stream orders, gradient classes, and lakes.

of this contrast in topography we used gradient to classify stream segments within the mountains, whereas, we used stream order for basin streams. In both cases, stream channels serve as the centerline for defining valley fill (here referred to as stream buffers). Note that all streams indicated on the 100k maps are buffered, regardless of if they are permanent or intermittent streams. Buffering proceeds through a number of stages as discussed below.

Stream Buffering Using Sample Streams. The mountain-basin distinction is based on the break in slope at the base of the mountains as observed on topographic maps. The elevation used to reflect this break is different for the Bighorn Mountains versus the Rattlesnake Hills (1900 m [6232 ft] versus 2000 m [6560 ft], respectively). Everything below these elevations, for their respective areas, is automatically grouped into the basin areas.

Stream orders and stream gradient classes are used to classify the varying widths of different valley bottom reaches. Stream order follows Strahler's (1952) system and is a way of categorizing streams into orders to show their hierarchical position within the entire stream network. Stream gradient classes are a way to classify streams into groups based on slope gradient, again to model different widths of valleys based on similar gradient.

We estimated the height of the highest post-glacial valley fill for each gradient or stream order class. Since a footslope grades to and merges with the highest alluvial terrace within most valleys, we estimate the upper height of this footslope. This is the elevation

above stream level where the footslope pinches out on bedrock on the upper part of the footslope. This height is generally marked by a distinct break in slope where the generally gently sloping and non-gravelly valley fill meets the steeper and rocky valley wall slope. Height of valley fill (relative to active stream channel) is calculated from: (1) survey of the literature; (2) observations acquired during field reconnaissance; and (3) inspection of landforms on topographic maps.

Reconnaissance indicated that there were very few instances where Ice Age gravel terraces stood within valleys but above post-glacial era fine-textured terraces. These gravel terraces are most common in foothills locations. Gravelly terraces can generally be identified in map view due to the presence of illustrated gravel pits. Thus, for many stream gradient or stream order classes it was a simple matter to identify upper terrace/footslope tread on 1:24,000 topographic maps. Maximum height above the active stream channel reflects the thickness of the valley bottom deposits. Estimated thicknesses of post-glacial fill (upper elevation footslope grading to highest fine textured terrace) for basin streams used in this report are: Stream Order 6 = 24.38 m (80 ft), Stream Order 5 = 21.34 m (70 ft), Stream Order 4 = 18.29 m (60 ft), Stream Order 3 = 15.24 m (50 ft), Stream Order 2 = 12.19 m (40 ft), and Stream Order 1 = 9.14 m (30 ft); whereas for mountain streams: 0-2.5 percent Gradient = 12.19 m (40 ft), 2.5-5 percent Gradient = 12.19 m (40 ft), 5-10 percent Gradient = 6.10 m (20 ft), and 10-100 percent Gradient = 3.96 m (13 ft).

Height above the stream was projected cross-valley to the valley walls to establish the width of various stream order and stream gradient classes. For this exercise we select stream gradient and stream order segments from a variety of sub-basins within the project attempting to sample diverse stream types. Identifying the intersection of any topographic contour line with the stream channel on USGS 24k topographic maps provides a reference point for projecting the height of valley fill. At each intersection, a line is drawn from the stream-contour line intersection in an upslope direction (perpendicular to the stream channel) until the required elevation above stream shoreline is plotted. The longest line segment (stream-right or stream-left) is chosen to represent the half-valley width of the valley fill. When half-valley widths are determined for all sample streams, the measurements for each stream order or stream gradient class are summed and averaged. The half valley width is then used as the value to create a buffer (corridor) along each stream class within the digital hydrographic dataset (1:100,000) using the GIS software.

Next, the buffers or corridors, representing the width of post-glacial valley fill, were overlain on a sample of 24k USGS topographic maps. The buffer width was then examined visually to see if it encompassed the valley width. Buffer width was then judgmentally adjusted in width in a consistent way for each gradient or stream order class so as to encompass the valley bottom width at the 1:24,000 scale.

Natural lakes were also buffered because they generally are situated in low slope depositional basins and usually in stream valleys. Like stream valleys, lakes generally

have a toe slope that grades to their shoreline. A GIS dataset containing the lakeshore boundaries was procured (Wyoming Gap Analysis 1996). All lakes within the mountain regions were included, and also one lake within the basin region, Lake De Smet, was included. Although the latter is now dammed, a natural lake preceded the reservoir. Most of the other lakes situated in the basin are reservoirs that are not treated as lakes. Also, mountain reservoirs were buffered to their existing shorelines, since many reservoirs in the mountains are dammed and inundated prehistoric lakes.

Stream Buffer Models: Management and Analytical

Management Stream Valley Buffers. The map resulting from the analysis described above is termed the "management" stream buffer map (Figure 33). It is designed for use as non-technical management dataset in the sensitivity models we construct later in this report, as it provides an estimate of valley fill, which strongly favors a site preservation goal. The map is constructed to illustrate the maximum extent of post-glacial valley fill at scales of 1:100,000 or smaller. A considerable amount of visual checking and judgmental readjusting of the buffer width was conducted in this way to make the map as useful as possible at the 24k scale. We achieved a satisfactory level of success; however, no warranty is made for the accuracy of the stream buffers at a scale larger than 1:100,000.

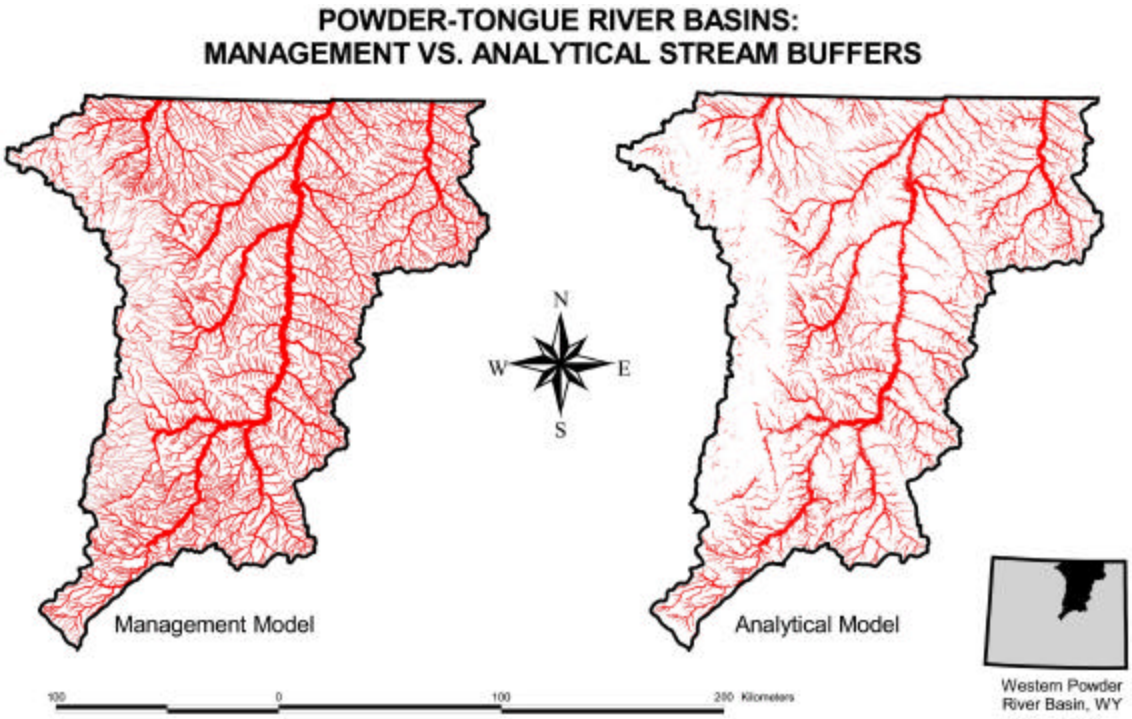

Figure 33. Map illustrating stream buffers created for the Powder River and Tongue River basins risk-sensitivity model

Analytical Stream Valley Buffers. We developed an "analytical" stream buffer map that removes portions of the management buffer. In this buffer, we remove areas adjacent to valley fill that are included within the management map but which have streams with steep gradients or steep valley walls. We constructed this map for the purpose of testing the buffering method using site data from the Wyoming Cultural Records Office (WYCRO). The "steep area" cutoff is any area with a slope greater than 10 percent. Therefore, areas within the management buffer which contain a slope greater than 10 percent are excluded from the buffered streams areas. Removal of the steep areas results in the elimination bedrock-cut valley walls from the buffers, as well as some stream segments that are too steep to have consistently preserved occupation zones from the ravages of burial disturbance.

Steep areas were identified using a 30-m digital elevation model (DEM) grid to create a slope map for our project area. The slope map was divided into two zones: areas with 10 percent or greater slope and areas with less than 10 percent slope.

A stream layer was developed to use in conjunction with the slope map. To create this dataset, vector streams were split into segments approximately 250 m (820 ft) in length. This provided a good balance between detail and size. Larger segments did not reveal short, steep sections, while smaller segments made the dataset too complex. The elevations for the beginning and ending nodes of each segment were added using the 30-m elevation grid. Change in elevation along with length was used to calculate the gradient of each segment. Those segments with 10 percent or greater gradients were removed from the dataset.

The remaining segments were buffered based on stream order as described above for the management buffers. The buffers were then converted to a 30-m grid and adjacent areas with a 10 percent or greater slope were subtracted from the buffers. The resulting valley bottom buffers have slopes less than 10 percent. Small areas were removed by running a majority filter on the resulting grid twice. That grid was converted back into polygons and further filtered by removing all polygons less than 10,000 m^2 (107,639 ft^2) area. In addition, any non-buffer "island" polygons within the buffers that are less than 30,000 m^2 (322,917 ft^2) in area were removed. Finally, lakes were added back into the model. These manipulations reduced the complexity of the dataset while retaining its salient characteristics. The "analytical" stream buffer model (illustrated in Figure 11) is

ultimately incorporated along with non-valley areas into the Archaeological Landscape Sensitivity Model using both STATSGO and SSURGO data, which is discussed in more detail below.

It is important to understand that each model (analytical and management) has an appropriate use. The analytical model is more precise and is best used to evaluate the validity of the model itself, e.g., to compare results of fieldwork with predictions. The management model is more conservative as a management tool (because the high sensitivity areas are larger) and so it is used in the management tools created by this project (such as the Cultural Resources Information Summary Program, or CRISP). This application is discussed in detail in Chapter 5. The management model is best used as a *planning* tool, e.g., to determine where one is least likely to encounter buried archaeological material.

SENSITIVITY MODELING FOR NON-VALLEY LOCATIONS

Modeling the alluvial valleys comprises one part of the model we present here. Non-valley locations are modeled using a different method. Here, we outline a methodology for subdividing the non-valley portion of the project area into zones, which are more or less likely to contain depositional settings conducive to preservation of buried and relatively intact prehistoric occupations. This is accomplished by: (1) estimating if the depositional energy regime of the sediment which buried the site is low enough to preserve the site during burial, (2) considering post-burial site formation and destruction

factors that might have affected the contextual integrity of the site, and (3) assessing if the age of the deposits is within the range of human occupation (<14,000 years old).

Thus, sediments that are either too old or were deposited within a high-energy depositional regime, or were subject to high levels of post-burial site destruction are predicted to have very low or low sensitivity. Conversely, sediments that are younger than 14,000 radiocarbon years old, were deposited within lower energy depositional environments, and have not been subject to extensive site destruction processes, are more likely to contain prehistoric cultural occupations that possess stratigraphic and behavioral integrity. Landscapes possessing characteristics conducive to site preservation are considered to be more "sensitive" (at greater risk) from the perspective of site burial potential.

Spatial variation in the intensity of site destruction processes across the landscape is primarily a function of depositional environment. This variation is controlled by slope, transport energy, and resultant sediment. Artifact dispersal occurs in most depositional environments (Butzer 1982), though an exception to this is eolian silt (loess) environments. Lack of significant burial dispersal in loess is the result of a low surface wind shear (because vegetation is usually present) and the low impact energy of the silt particles. Many surface sites on flat, vegetated surfaces are eventually, albeit slowly, covered with a shallow mantle of loess. As mentioned in the methodology section above, other common depositional environments can be ranked into two categories of potential burial dispersal. A relatively low to moderate energy category includes alluvial

overbank, sheetflow (including slope wash), and eolian sand environments. The moderate-to- high-energy category would include alluvial channel, debris flow, and colluvial depositional environments. For most water and air entrained sediments, artifact movement is a function of their size and density (Gifford and Behrensmeyer 1976).

The considerations discussed above, allow the construction of a model that classifies the landscape in terms of its archaeological sensitivity. This model is used to predict the spatial occurrence of sediment younger than 14,000 years B.P. at non-valley locations. It also predicts locations where site formation processes might better preserve significant archaeological resources (very high and high archaeological landscape sensitivity). Favorable locations are mapped and differentiated from locations with surface sediments older than 14,000 B.P. and/or with little potential to preserve reasonably intact archaeological sites (very low and low archaeological landscape sensitivity).

Natural Resources Conservation Service (NRCS) soil maps are used to help classify the relevant depositional and site formation criteria. Individual soil map units are the smallest spatial unit used in the analysis. Map unit descriptions acquired from the NRCS contain information on the soil taxon, sediment type, and landform type within each map unit. Early attempts to classify archaeological sensitivity utilized a light table to superimpose soil taxon, deposit type, and landscape characteristics to determine archaeological landscape sensitivity (Eckerle and Eakin 1989). A GIS approach is used in this project to simplify the process of assigning archaeological sensitivity to soil map units.

Scale of Soil Map Data

Several scales of soils mapping (1:24,000, 1:250,000) are utilized in this project. Coverage at 1:24,000 during the critical stage of project data acquisition (winter 2003-2004) was incomplete (Figure 34). County level mapping (1:24,000; SSURGO) is used where possible. SSURGO mapping is available for southern Campbell, southern Johnson, Natrona, Sheridan, as well as the small portions of Washakie, Converse, and Crook counties within the project area. Bighorn National Forest soils mapping is available from the United States Forest Service (1999), and provides nearly identical spatial geometry as would be provided by SSURGO. Unfortunately, the southern part of Johnson County is not available in a digital format and was omitted from the 24k analysis. To adjust for the lack of coverage in the areas lacking digital 24k mapping, we supplemented the SSURGO data with multi-county NRCS soils mapping (STATSGO; 1:250,000).

Data Acquisition

Both 1:250,000 (STATSGO) and 1:24,000 (SSURGO) scale soil mapping data was extracted from NRCS sources and entered into a custom Microsoft Access database designed for

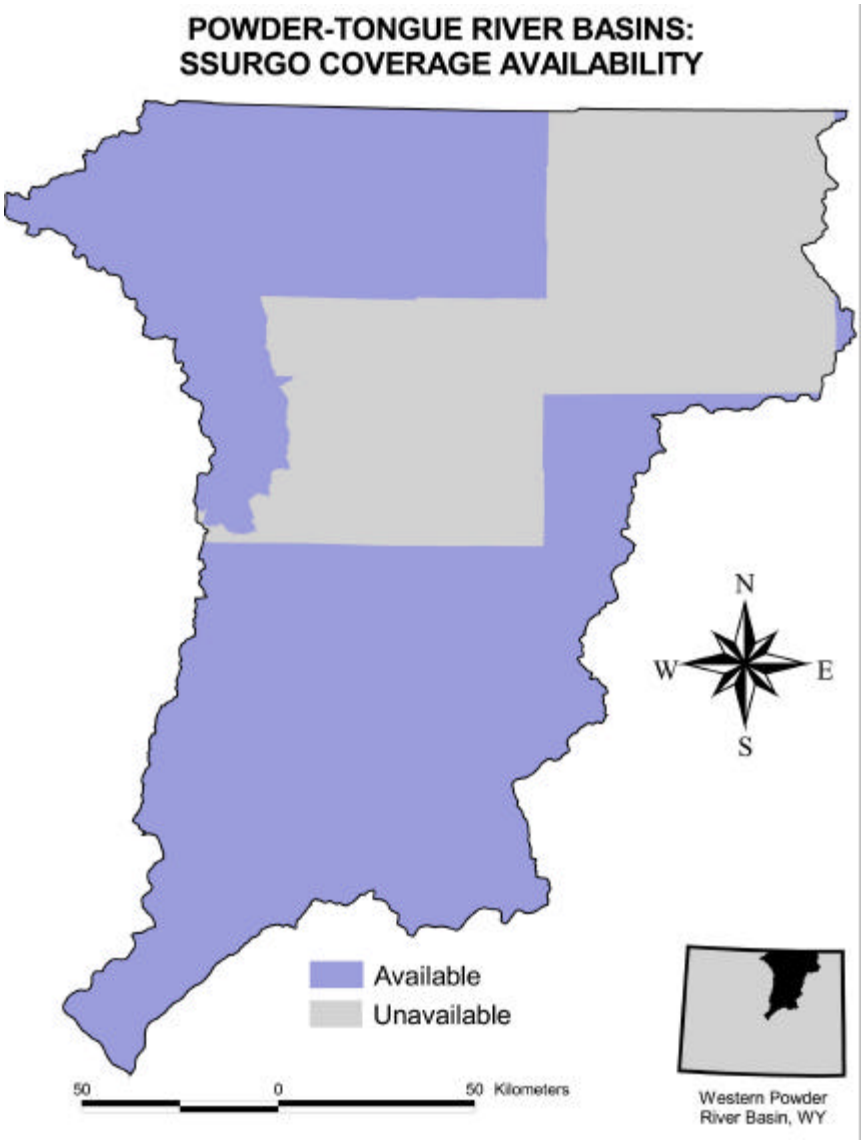

Figure 34. Soils mapping availability for SSURGO (1:24,000 base soil mapping) soils data.

sensitivity modeling. Population of the database required two primary data sources: (1) hard copies of NRCS soil surveys for individual survey areas (mostly defined by county), and (2) a digital Soil Survey database. For the hard copy surveys, all attribute values are taken from the survey, including series descriptions. Three parts of the NRCS soil surveys are primarily used: (1) the map unit number description section, (2) the soil series description section, and (3) the engineering table appendix.

Series name, parent material, landform, precipitation, slope, and percent composition are all extracted directly from the map unit description section of the soil survey reports. Depth to bedrock, percent coarse sediment >2.0 mm (0.08 in), and range site are all extracted directly from the soil series description section of the soil survey reports. Great group taxon names are from the Classification of the Soils table contained within the soil survey reports. Percent gravel >7.6 cm (3.0 in) are all taken directly from the Engineering Index Properties table contained within the soil survey reports. For soil survey areas that did not have a hard copy soil report, we used a digital database provided by the NRCS. Unfortunately, this digital database did not contain all of the data provided by hard-copy series descriptions, thus we had to use the Official Soil Survey Descriptions (http://soils.usda.gov/technical/classification/osd/index.html) provided by the NRCS to supplement the digital information. These descriptions are virtually identical to the ones provided within the soil survey reports, however they are more generalized to the entire geographic range where an individual soil series occurs.

Sensitivity Considerations

The goal of the archaeological landscape sensitivity model is to use the soils mapping, surficial geology, and alluvial valley information to help predict the location of sediments that are the right age and type to contain significant buried archaeological sites. Soils mapping generates information on a number of variables relevant to this goal. For this analysis the following variables were tabulated from the NRCS soil mapping data: (1)

map unit number; (2) depth to bedrock; (3) slope; (4) soil taxonomic classification; (5) landform; (6) deposit type; (7) percent gravel; and (8) percent coarse gravel.

The sensitivity analysis systematically followed rules presented in a sensitivity outline (presented below) using the criteria provided therein. Each step was done separately and saved to an ArcView shapefile. The shapefiles were then either intersected with each other, or added to the final intersection, based on the individual criterion and its operator (i.e., AND/OR). A discussion of each of the variables follows.

NRCS Data Categories

Natural Resource Conservation Service (NRCS) soils mapping that was used in the model is described below. NRCS soil scientists are not geoarchaeologists and soils mapping is not designed specifically to facilitate geoarchaeological modeling. Despite this, NRCS mapping contains valuable information about landscapes that is relevant and useful for constructing burial sensitivity models.

Map Units. Soil map units delineate areas of similar soils. Map units consist of a single series, an association composed of two series, or a complex of three or more soil series. The soil map units are described in the following NRCS county soil survey reports and related SSURGO digital soils data: Soil Survey of Crook County, Wyoming (Elwonger 1983); Soil Survey of Bighorn National Forest (Nesser 1986); Soil Survey of Natrona County, Wyoming (Malnor and Arnold 1997); Soil Survey of Sheridan County,

Wyoming (Lupcho 1998); Soil Survey of Washakie County, Wyoming (Liams 1983); Soil Survey of Converse County, Wyoming (Reckner, 1986); Soil Survey of Johnson County, Wyoming, Southern Part (Stephens 1975); and SSURGO data for Campbell County, Southern part (National Resource Conservation Service 1998). County surveys were clipped to the project area so not all areas of the listed counties are included. Some of the important variables extracted from the map unit descriptions are described below.

Depth to Bedrock. Depth to bedrock is used to estimate the potential for a sedimentary mantle over bedrock, which would protect and preserve archaeological deposits. Sedimentary environments aggrading at a moderate to rapid rate generally offer a better chance of site preservation than do sites that form a soil surface for many thousands of years. Exceptions are made, however, for high-energy depositional regimes transporting gravel size material, as destruction of archaeological context is likely to have occurred. Other depositional environments often allow differentiation of multiple occupations, especially when sterile sediment occurs between the occupation zones. Perishables, including charcoal and butchered animal bone, are more likely to be preserved in aggradational environments, than in environments where little aggradation is occurring and the perishables are exposed to the elements or destructive soil processes.

Slope. Slope steepness characterization provides one measure of depositional energy. Steeper slopes occur in colluvial and mass wasting environments as well as high gradient alluvial channel environments. More moderate slopes produce slope wash environments and moderate gradient stream channels, while low slope characterizes floodplains.

Soil Taxonomic Classification. The taxonomic classification of the principal surface soil(s) in each map unit is tabulated. These are listed to the family or great group level of classification. Implicit in the classification are soil features that have genetic and chronological significance (Soil Survey Staff 1975), and thus provide insight to where sediment younger than 14,000 years old is located. Both the regional and local studies (Birkeland 1999; Birkeland et al. 1991; Reider and Karlstrom 1987; Reider 1983; Reider 1980; Albanese 1991; Albanese 2000; Eckerle 1986a) suggest that a general, time-dependent sequence of horizon development can be identified and includes from youngest to oldest: A (surface organic accumulation); Bw (oxidation or weak structural development); Bt and Bk (clay accumulation and calcium carbonate accumulation, respectively); K (very well-developed calcium carbonate accumulation); and Bym (very strongly developed gypsum accumulation). In terms of the taxonomic classes present in our study area, a relevant sequence would be as follows from youngest to oldest: (1) Orthents and Fluvents; (2) Camborthids at the great group level, and calcic and argic variants at the family level of other great groups; (3) Argids and Calciorthids; and (4) Paleargids and Paleorthids. According to the authors above (especially Birkeland), a tentative age estimate for these taxonomic groupings is: (1) <1,000 year B.P.; (2) 1,000 to 10,000 years B.P.; (3) 10,000 to100,000 years B.P.; and (4) >100,000 years B.P. Rare exceptions to this chronological sequence exit. Nevertheless, these estimates can be used to calculate the age of the deposits on which a soil is formed. We use these estimates to identify soils that are unlikely or questionably formed on Holocene-age sediment.

In Wyoming Haplargids are mapped on sandy-textured Middle to Late Holocene deposits, most commonly on eolian sand (Eckerle 1997), but also on slope wash and intermittent stream alluvium. Haplargids such as the Hiland (and catena-related Vonalee) soil series have been observed in map units containing extensive areas of Holocene-age eolian sand sediment. Although as indicated above, Haplargids are considered to be 'Pleistocene-age' soils, their occurrence on Holocene-age eolian suggests that they be considered potential Holocene-age soils when they occur on sandy sediments.

Landform. Landform is a good indicator of depositional setting. Good potential depositional settings for archaeological sites are often found in floodplains, low (overbank) terraces, inset alluvial fans, and footslopes. Some areas such as badlands, rock outcrops, and cliffs contain no significant soil mantle and are poor settings for the potential preservation of buried archaeological materials with integrity. The NRCS maps these areas as non-soil areas. Landform was specifically used to help identify the locations of eolian sand sediment forming sand dunes.

Deposit Type. Parent material characterizations in the NRCS data provide an estimate of both the depositional energy regime and depth of burial (or lack of as in 'badlands', or 'residual'). Like landform, we used deposit type (eolian sand) to help identify dune fields and to informally cross-check other categories to assure that they compared favorably to sensitive deposit types. Depositional settings most likely to contain sites with good integrity are floodplain deposits, low energy alluvial fan deposits, and slope wash deposits. In contrast, locations not likely to preserve site integrity include residuum,

regolith, channel gravel, and talus. Note that regardless of the map unit deposit type, stream buffers are mapped through and crosscut all deposit types, including residuum and regolith. Thus, locations likely to preserve buried sites within these overall locations of poor burial potential can be classified appropriately. Analysis of deposit type was supplemented by the use of a digital map of Wyoming surficial deposits (Case et al. 1998).

As mentioned earlier in this report, the intent of this model is to predict the location of deposits that might contain stratigraphically buried cultural levels. As such, there is no attempt to predict locations where features and occupation debris from surface occupations (0-20 cmbs) might intrude into or be turbated into the occupation substrate. For instance, archaeological materials might be found to have intruded into or be turbated into residuum. Despite the fact that these intrusive or turbated zones might contain preserved bone or charcoal, they are not stratigraphically buried. This is not intended to obviate the need to evaluate other potentially important data categories in these surface occupations (that just so happen to have deeper turbated or intrusive cultural material).

Historically, there has been some variability among earth scientists as to the use of the term slope wash. Some have grouped it with colluvium. As discussed earlier in this repot, we distinguish between colluvium as gravity-derived deposits from slope wash that is a sheetwash (alluvial) deposit. Thus, we consider colluvium, which generally forms at the foot of a cliff or other very steep slope from more typical footslope deposits that are made up mostly of slope wash.

Gravel. Percent gravel (clasts >2 mm) is tabulated for the soils. Percent gravel for each horizon within each soil series is presented as a range of values from which the median percent is selected to represent the series. This variable provides a good proxy measure for the energy regime of the deposit. Note that the gravel is measured within the surface soil thickness (as defined by the NRCS as 0-1.5 m [0-60 in] below surface). There are situations where nongravelly sediment may be located stratigraphically under the surface soil. In these situations there is a possibility that these less gravelly deposits formed at a lower energy regime might contain intact cultural zones. However, these situations are uncommon.

Cobbles and Boulders. The content of cobbles and boulders (clasts >7.6 cm) present in each map unit is tabulated. The maximum percentage for each soil series is weighted according to percent that the soil series comprises of the total map unit. Rock outcrop and/or bedrock are considered to contain 100 percent fragments >7.6 cm. For this size of sedimentary clasts the weighted averages for each soil series is derived and then all the component series are averaged to get a representative figure for the map unit as a whole.

ARCHAEOLOGICAL LANDSCAPE SENSITIVITY OUTLINE

The criteria discussed above are used to construct rules that are used to categorize sensitivity classes. These rules are outlined to facilitate the intersection and reclassification of the soil map units into archaeological landscape sensitivity areas. GIS

tools are used to classify and display the sensitivity criteria into sensitivity areas using the rules specified in the outline. The process used to generate the final sensitivity areas is analogous to classifying each sensitivity criteria, displaying the classification on a transparent map, and then overlaying all the transparent maps on a light table and outlining the intersection of all the similarly classified criteria.

The analysis utilized the stream buffer data and NRCS map unit data to identify the sensitivity zones in a sequential manner based on what we determined to be the most clear-cut and reliable characteristics. Class boundaries were confined by the distribution of data within particular variables and between several variables. The overall goal in determining various percent cut-off figures used in the outline was to find some balance in the relative distributions of the various sensitivity classes while at the same time not violate the theoretical and methodological precepts outlined earlier in this report. This involves a certain amount of subjectivity, which is tempered by geoarchaeological experience. Once an area (NRCS map unit or stream buffer) was assigned to a particular sensitivity zone, it was excluded from further analysis. The sensitivity zones are classified as very high, high, very low, and low. Remaining areas are classified as moderate. Manual inspection of post-classification variables/values suggests that the moderate category is transitional between high and low with regards to sensitivity criteria. A soil component generally means a soil series and some adjustments were needed to accommodate both the STATSGO and the SSURGO databases specified below. Note that the term “inclusion” refers to a soil series that is present in a map unit,

but which composes a very low proportion of the map unit. Inclusions were excluded from the analysis.

STATSGO/SSURGO Sensitivity Outline

Below we use the NRCS soils mapping variables either in combination or alone to define sensitivity classes within a series of 'and/or' statements, respectively. Due to the fact that there are no recognized empirically derived values to use as absolute limits for burial sensitivity, we selected a combination of values linked by 'and' statements for defining the limits of depth of burial, slope steepness, and gravel content for high, poor, and very poor settings. Since these variables are interrelated this method provides built in redundancy and increased confidence in our method.

1. VERY HIGH SENSITIVITY AREAS meet the following criteria:
    a) are defined as "very high sensitivity" on the stream valley model both analytical and management stream buffer model), or;
    b) contain a soil component where the parent material is eolian sand (only used for STATSGO), or;
    c) contain Soil Series (Decolney, Dwyer, Hawkstone, Hiland, Moskee, Orpha, Ryan Park, Tullock, Valent, Vonalee, Whiteriver) that are formed in eolian sand, or sand dunes, and the sum of the included soil components compose 30 percent for STATSGO, 50 percent for SSURGO, or more (≥30/≥50) of the map unit.
2. HIGH SENSITIVITY AREAS meet the following criteria:

a) contain Soil Series (Decolney, Dwyer, Hawkstone, Hiland, Moskee, Orpha, Ryan Park, Tullock, Valent, Vonalee, Whiteriver) that are formed in eolian sand, or sand dunes, and the sum of the included soil components compose less than 30 percent for STATSGO, 50 percent for SSURGO, (<30/<50) of the map unit, or;

b) contain a soil component where the depth to bedrock is 1 m or more (≥1), and the sum of the included soil components compose 30 percent or more (≥30) of the map unit, and;

c) contain a soil component where the minimum slope is 10 percent or less (≤10) (excluding map unit inclusions), and;

d) contain a soil component where clasts 7.6 cm or greater in diameter compose less than 3 percent (<3) by volume of the soil matrix (excluding map unit inclusions), and;

e) contain a soil component where clasts 2 mm or greater compose 14 percent or less (≤14) by volume of the soil matrix (excluding inclusions), and the sum of the included soil components compose 50 percent or more (≥50) of the map unit, and;

f) contain a soil component having a likely Holocene-age soil taxon (Camborthids, Cryaquolls, Cryoborolls, Cryochrepts, Cryorthents, Cryumbrepts, Fluvaquents, Haploborolls, Haplocambids, Haplustepts, Haplustolls, Torrifluvents, Torriorthents, Torripsamments, Ustifluvents, Ustipsamments, Ustochrepts, Ustorthents), and the sum of the included soil components compose 25 percent or more (≥25) of the map unit.

3. VERY LOW SENSITIVITY AREAS meet the following criteria:

a) are made up of non-soil land including badlands, cirque land, colluvial land, gravel pits, gullied land, pits, dumps, rock land, rock outcrop, rubble land, shale outcrop, shale rock land, water, and the sum of the included non-soil land compose 75 percent or more (≥75) of the map unit, or;

b) contain a soil component having a very unlikely Holocene-age soil taxon (Paleargids, Paleborolls, Paleustalfs, Paleustolls), and the sum of the included soil components composes 75 percent or more (≥ 75) of the map unit, or;

c) contain soil components where the depth to bedrock is 25 in or less (≤ 25) (excluding inclusions), and the sum of the included soil components compose 30 percent or more
(≥ 30) of the map unit, and;

d) contain a soil component where the average slope is 20 percent or more (≥ 20), and;

e) contain a soil component where clasts 3 in or greater in diameter compose 7 percent or more (≥ 7) by volume of the soil matrix, and;

f) contain a soil component where clasts 2 mm or greater compose 40 percent or more
(≥ 40) by volume of the soil matrix, and the sum of the included soil components compose 25 percent or more (≥ 25) of the map unit.

4. LOW SENSITIVITY AREAS meet all of the following criteria:

a) are made up of non-soil land including badlands, cirque land, colluvial land, gravel pits, gullied land, pits, dumps, rock land, rock outcrop, rubble land, shale

outcrop, shale rock land, water, and the sum of the included non-soil land compose 55 percent or more (≥ 55) of the map unit, or;

b) contains a soil component where the depth to bedrock is 35 in or less (≤ 35) (excluding inclusions), and the sum of the included soil components compose 30 percent or more
(≥ 30) of the map unit, and;

c) contains a soil component where the average slope is 15 percent or more (≥ 15), and;

d) contains a soil component where clasts 3 in or greater in diameter compose 3 percent or more (≥ 3) by volume of the soil matrix, and;

e) contains a soil component where clasts 2 mm or greater compose 30 percent or more
(≥ 30) by volume of the soil matrix, and the sum of the included soil components compose 10 percent or more (≥ 10), and;

f) contains a soil component having a questionable Holocene-age soil taxon (Argiaquolls, Argiborolls, Argiustolls, Calciargids, Calciborolls, Calciorthids, Cryoboralfs, Eutroboralfs, Gypsiorthids, Haplustalfs), and the sum of the included soil components compose 25 percent or more (≥25) of the map unit.

5. MODERATE SENSITIVITY AREAS

a) Since the process is subtractive, moderate sensitivity constitutes the areas that remain after the previous operations have occurred, i.e., after the previous sensitivity areas have been delineated.

RESULTS AND CONCLUSIONS

This chapter describes two sensitivity maps for the study area, one derived from 1:250,000 base mapping using STATSGO data (Figure 35), and the other derived from 1:24,000 base mapping using SSURGO data (Figure 36). Both maps contain stream buffering that is constructed at a scale of 1:100,000. Figure 35 presents sensitivity maps using STATSGO data for both the management and analytical stream buffer models. Likewise, Figure 36 presents sensitivity maps using SSURGO data for both the management and analytical stream buffer models. Figure 37 presents a comparison of the two maps using the management stream buffers. The STATSGO map is included because digital SSURGO coverage is incomplete for parts of the study area. Areas lacking SSURGO soil mapping include northern Campbell County and southern Johnson County. The STATSGO map should be viewed at a scale no larger than 1:250,000, whereas the SSURGO map, excluding stream buffers, is appropriate for viewing the sensitivity classes at a scale no larger than 1:24,000. Stream buffer data are accurate at a scale of 1:100,000. Note that some effort was made with the 1:100,000 stream buffer data to make it useful at a scale of 1:24,000. We feel that this process was relatively successful, but no warranty is made. The STATSGO sensitivity map (Figure 35) uses the same attributes and values as the SSURGO sensitivity map (Figure 36), with some minor exceptions noted in the outline presented above. A similar comparison is presented for the management maps in Figure 37.

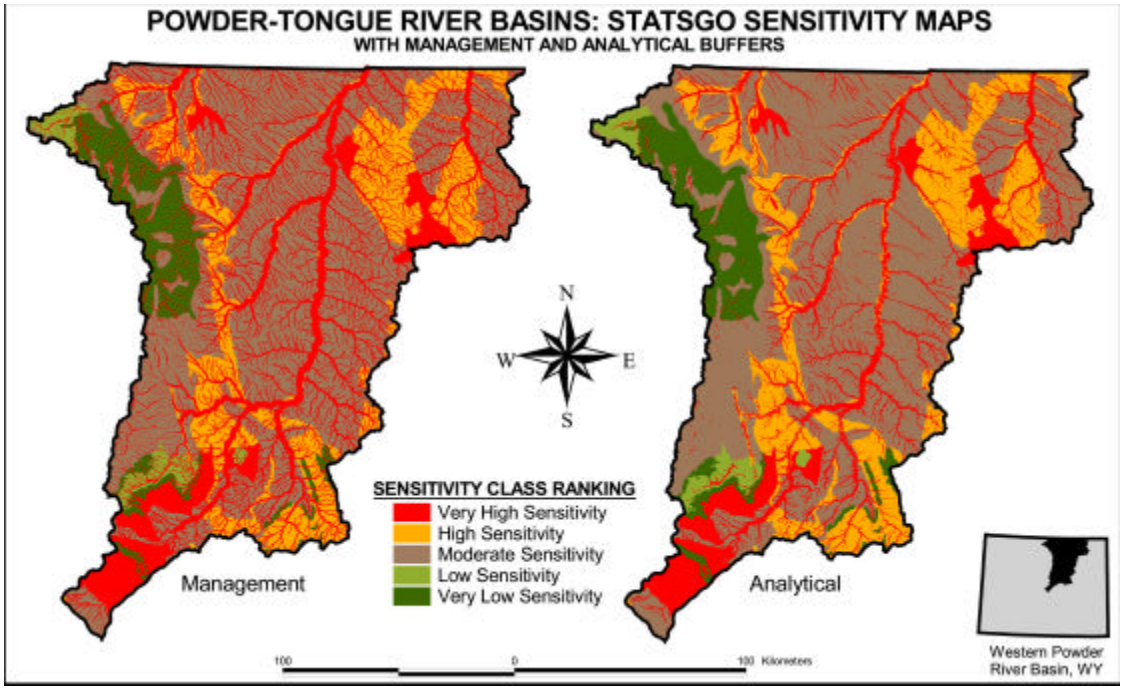

Figure 35. Sensitivity map based on STATSO (1:250,000 base soil mapping) and stream buffers

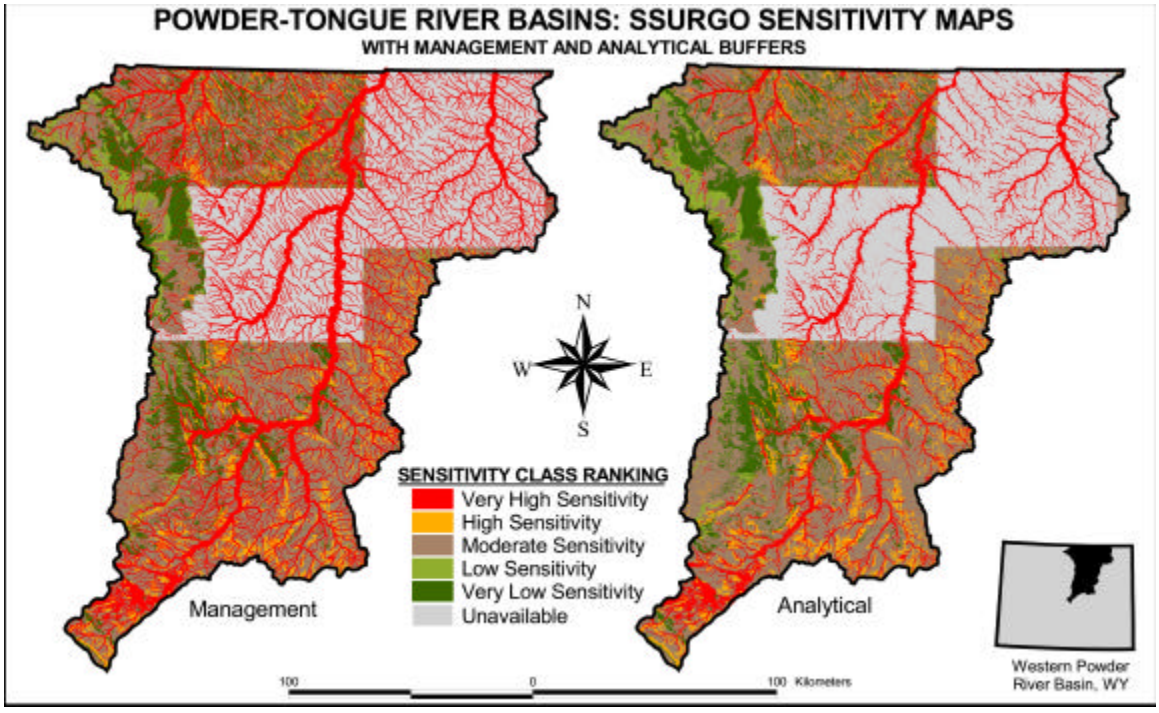

Figure 36. Sensitivity map based on SSURGO (1:24,000 base soil mapping) and stream buffers.

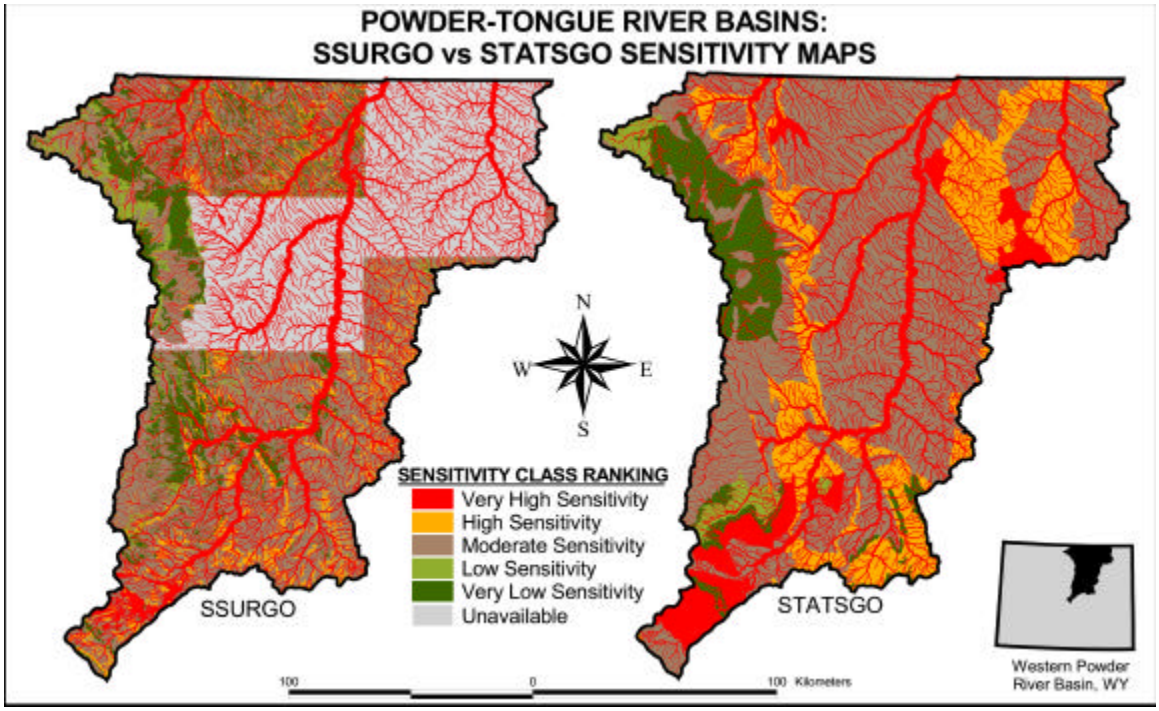

Figure 37. Side-by-side comparison of SSURGO and STATSGO (1:24,000 and 1:250,000 base) sensitivity maps using management stream buffers

The sensitivity classification system ranks areas according to potential geological conditions that favor buried site preservation (Table 4). Zones rated as very high and high predict locations where conditions are favorable for: (1) retention of archaeological behavioral-spatial context; (2) preservation of perishable archaeological materials (bone and charcoal); and (3) stratigraphic separation of archaeological occupation zones. The very high sensitivity reflects the distributions of landscapes of previous known important burial contexts, eolian sand and valley alluvium, respectively. Otherwise, the very high and high might be viewed as similar in terms of their management implications.

Table 4. Summary characteristics for sensitivity classes

Sensitivity Ranking	Landforms	Soil Parent Material	Engulfing/ Overlying Soil Age	Depth to Bedrock (60 ")	Minimum Slope	Average Slope	% Clasts =3 "	% Clasts =2mm
Very High	**Low-Gradient Stream Valleys** Floodplains, Terraces, Sand Dunes	Alluvium Eolian	—	—	—	—	—	—
High	Moderate-Gradient Stream Valleys Alluvial Fans	Alluvium Eolian Slope Wash	Holocene Age Soils	60-40”	0-10%	n/a	0-2.9%	0-14%
Moderate	All Moderate areas fail to completely meet the criteria for other sensitivity classes. They may meet one or many criteria, but not all. This category can’t really be given value ranges that would produce the selected areas within ArcView.							
Low	Non-Soil-Bearing Landforms (Badlands, Cirques, Bedrock, etc.) Steep-Gradient Stream Valleys Uplands, Interfluves	Colluvium Residuum Channel	Questionable Holocene Age Soils	25.1-35”	n/a	15-19.9%	3-6.9%	30-39.9%
Very Low	**Non-Soil-Bearing Landforms** Very Steep-Gradient Stream Valleys Uplands, Interfluves	Colluvium Residuum Channel	Very Unlikely Holocene Age Soils	0-25”	n/a	20-100%	7-100%	40-100%

Ultimately, this information should be supplemented by training in its use. The proper application of this information will require targeted field visits by agency and project archaeologists. A Field Protocol Handbook (Appendix C) facilitates use of the sensitivity map in the field, and provides a quick reference to its recommended use.

Moderate, low, and very low sensitivity classes predict areas where there is a lessened chance of buried site preservation. Caution is warranted as the sensitivity model only predicts where site preservation conditions might be favorable, and not locations that may have been attractive to human activity. Note that there are some special considerations concerning the use of the moderate category, especially within the STATSGO model (discussed below).

SPATIAL ASSOCIATION OF SENSITIVITY ZONES WITH KNOWN SUBSURFACE SITES AND RECOVERED RADIOCARBON DATES

Data from the Wyoming SHPO Cultural Records Office are used to evaluate the fit between archaeological data and the sensitivity model. Area and percent of study area within the sensitivity zones for each model (SSURGO [24k base]) analytical, SSURGO management, STATSGO [250k base] analytical, and STATSGO management) are presented in Tables 5 and 6 and Figures 38 and 39. Moderate sensitivity composes the highest proportion of the study area in all four models although less so in the SSURGO models. Additionally, the SSURGO analytical model exhibits the most even aerial distribution of very high and high combined compared to low and very low combined.

Table 5. Area by sensitivity class for each model

	STUDY AREA (ha)				
MODEL	Very High	High	Moderate	Low	Very Low
SSURGO A	413358	185780	1036473	66218	320363
SSURGO M	746570	153686	895480	62139	279676
STATSGO A	519127	516868	1501808	58645	241361
STATSGO M	837562	430224	1301170	50481	218415

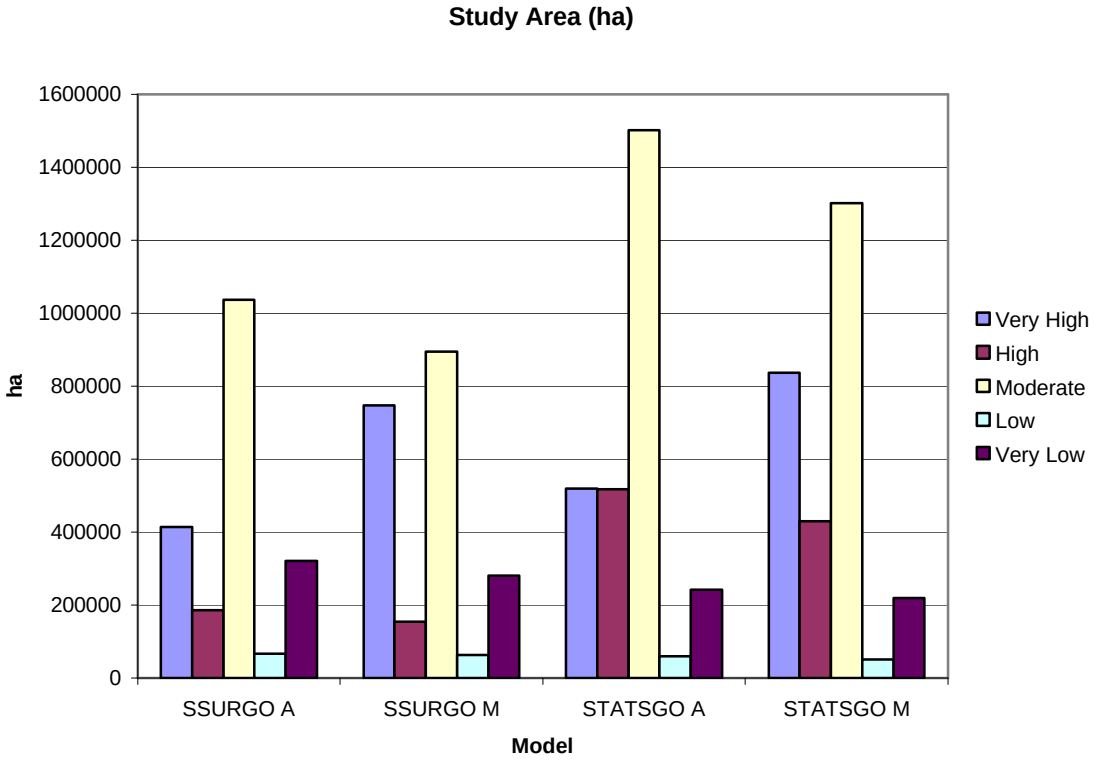

Figure 38. Area by sensitivity class for each model.

Table 6. Percent sensitivity class for each model

	PERCENT OF STUDY AREA				
MODEL	Very High	High	Moderate	Low	Very Low
SSURGO A	20.44	9.19	51.25	3.27	15.84
SSURGO M	34.93	7.19	41.89	2.91	13.08
STATSGO A	18.29	18.21	52.92	2.07	8.51
STATSGO M	29.51	15.16	45.85	1.78	7.70

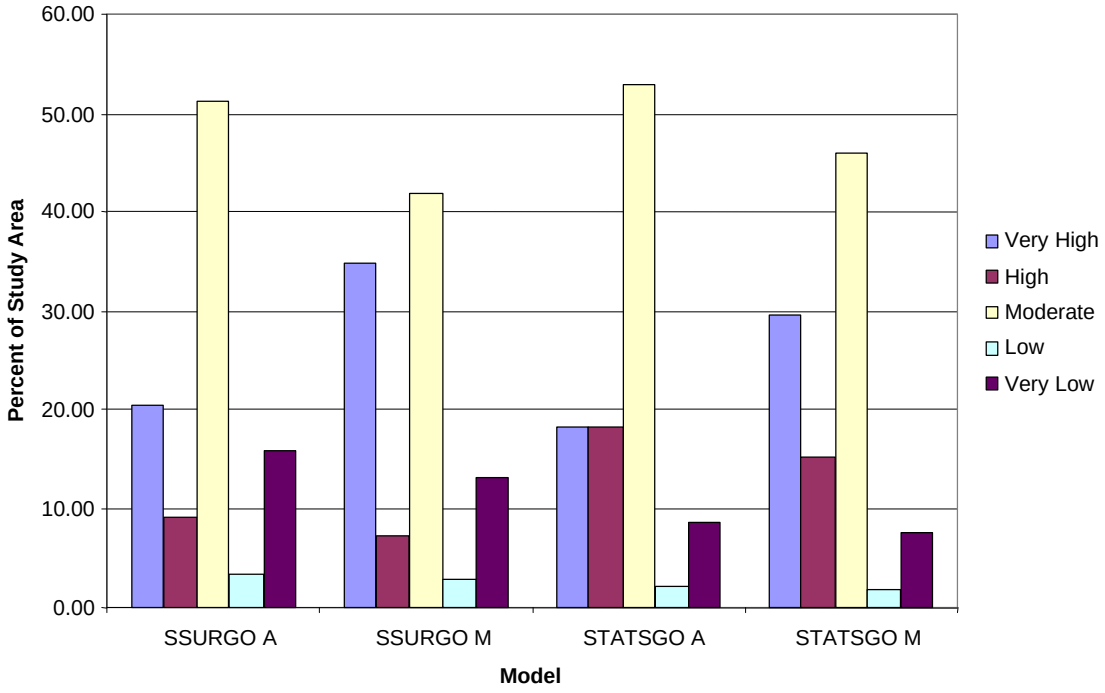

Figure 39. Percent sensitivity class for each model.

Note that components within rockshelter sites are omitted from the analysis presented below. Because of their small aerial extent, the sensitivity model makes no attempt to model the location of rockshelters, despite the fact that these geomorphic features are important archaeological sites. In fact, rockshelters are often located on areas otherwise exhibiting low or very low burial sensitivity due the fact that they occur in steep, rocky locations.

Inventory (archaeological pedestrian survey) coverage (Table 7, Figure 40) provides important data to help evaluate the evenness of archaeological investigation among the different sensitivity zones. When evaluated on a percentage basis (Table 8, Figure 41) there is a relatively equitable distribution of inventory among all sensitivity zones. It can be seen that the very high sensitivity class has had the most inventoried acreage at 12 percent, with all other classes falling around or below 11 percent inventoried. The very low sensitivity classes within SSURGO Analytical and

Table 7. Inventoried area of sensitivity classes for each model

	Inventoried Study Area (ha)				
MODEL	Very High	High	Moderate	Low	Very Low
SSURGO A	41116	16738	93940	6865	14448
SSURGO M	71959	14001	80931	6464	12148
STATSGO A	62334	54554	127366	5780	21213
STATSGO M	91061	45819	110206	5211	18951

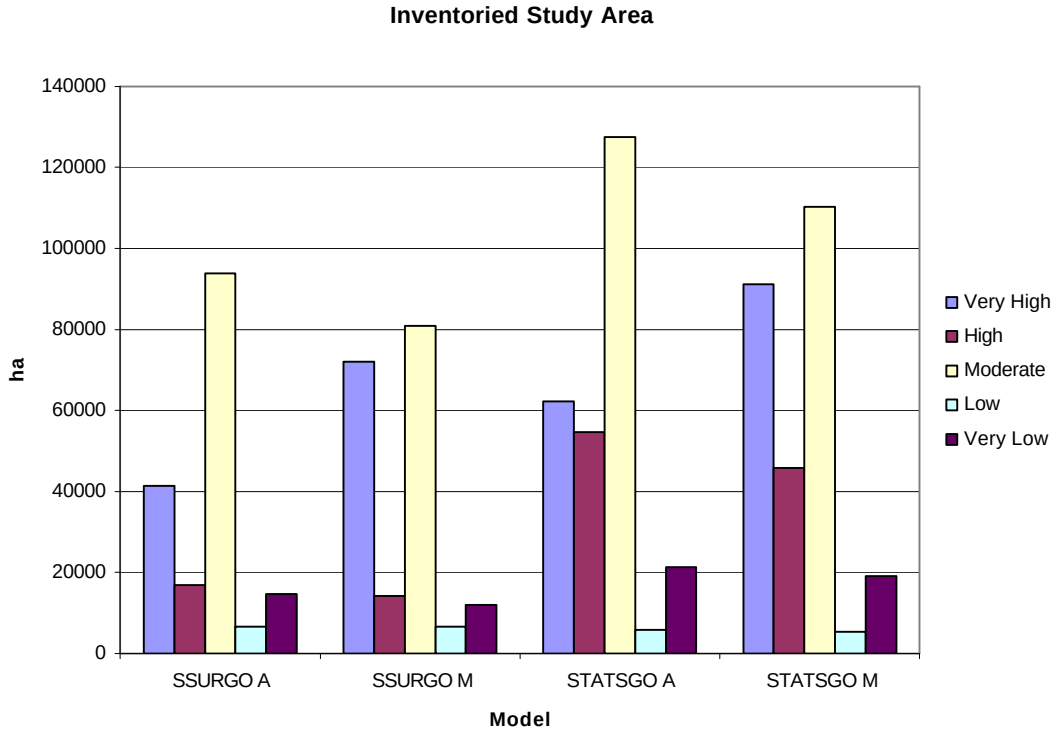

Figure 40. Inventoried area of sensitivity classes for each model.

Table 8. Percent inventoried area of sensitivity classes

	Percent of Category Inventoried				
MODEL	Very High	High	Moderate	Low	Very Low
SSURGO A	9.95	9.01	9.06	10.37	4.51
SSURGO M	9.64	9.11	9.04	10.40	4.34
STATSGO A	12.01	10.55	8.48	9.86	8.79
STATSGO M	10.87	10.65	8.47	10.32	8.68

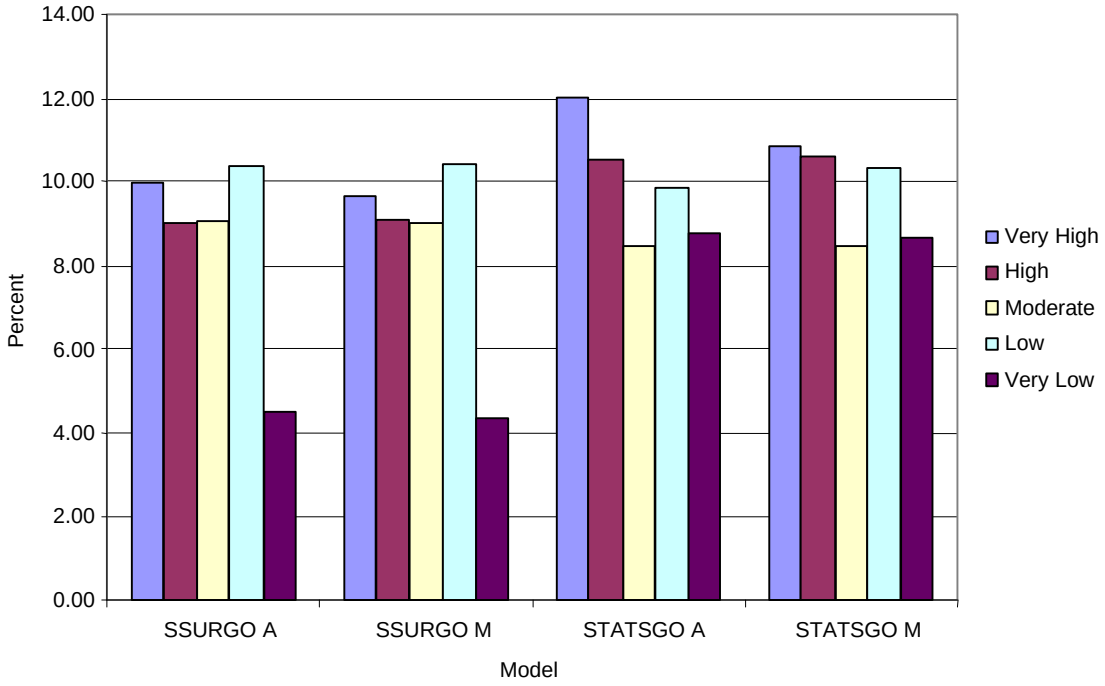

Figure 41. Percent inventoried area of sensitivity classes for each model.

SSURGO Management models have had the least amount of previous inventory. The highest concentration of previous inventory has occurred in Campbell and northern Converse Counties. Areas within the Tongue and Powder river basins have just begun to see more Class III inventory due to the increase in coal bed natural gas development. However, a very consistent percentage of the very high, high, moderate and low are

represented within the study area. Site occurrence within the sensitivity zones indicates that more surface sites occur within the very high and moderate zones (Table 9, Figure 42). The frequent occurrence of sites in the very high sensitivity zones is probably a result of an association of sites near drainages. The low frequency of sites in the high sensitivity zone may be an artifact of thick deposits and limited testing.

Buried components (Tables 10-11, Figures 43-44) are evaluated to see if their distribution parallels the sensitivity classes. One consideration in evaluating any association of buried cultural materials with the sensitivity model is defining a subsurface component. Artifacts found at depths of less than 20 cm below surface are easily bioturbated downward to this depth from an occupation on the existing soil surface (Albanese 1981). One of the problems in compiling this data on subsurface components is variation among investigators (crew chiefs) regarding their individual concept of subsurface and stratigraphic context.

Subsurface, as used in the site form, refers to any buried materials. This includes artifacts in the 1-20 cm layers that in many settings result from a combination of bioturbation, trampling, freeze-thaw cycling, or churning. However, the near-surface mixed materials should NOT be considered in good stratigraphic context. Stratigraphic context, as used in the site form, means the presence of one or more distinct depositional episodes (excluding the surface context). This can be demonstrated by geological stratigraphy, by buried soil horizon associations, or cultural stratigraphy, e.g. (by multiple artifact vertical-frequency peaks). Nearly all surface sites, however, contain at least a few artifacts in the near surface deposits. For the purposes of the DOE PUMP III data

Table 9. Number of sites by sensitivity class for each model

	Number of Sites Per Category				
MODEL	Very High	High	Moderate	Low	Very Low
SSURGO A	552	134	811	34	184
SSURGO M	921	98	649	29	137
STATSGO A	731	453	853	60	162
STATSGO M	1071	337	671	47	133

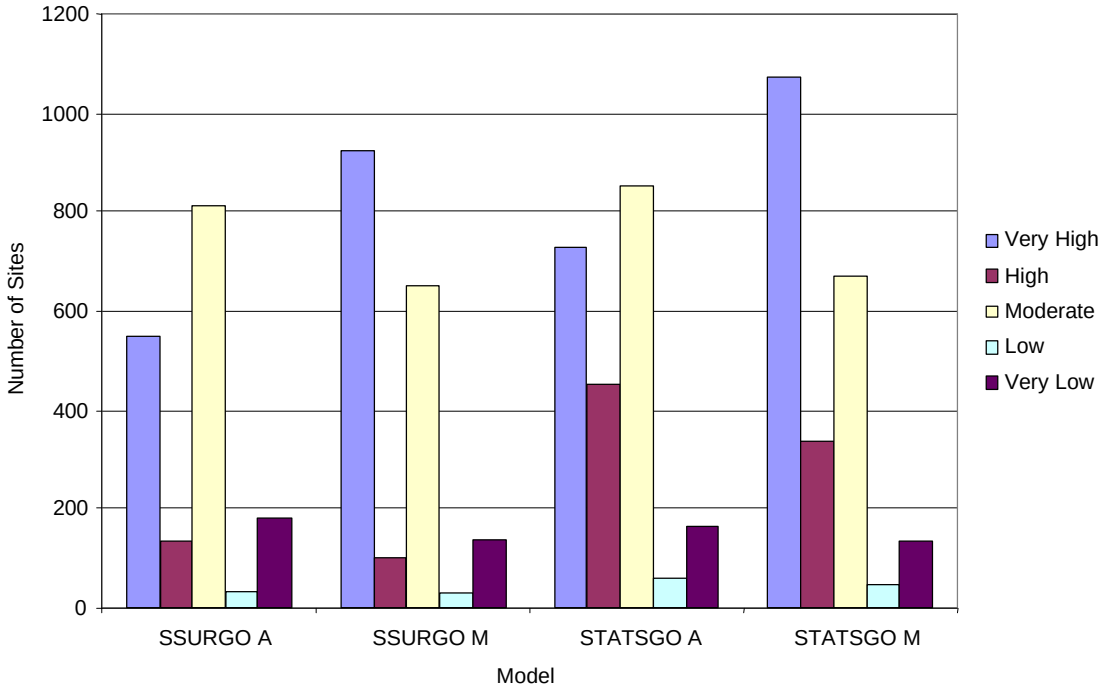

Figure 42. Number of sites by sensitivity class for each model.

Table 10. Number of sites with reported buried components by sensitivity class for each model

	Number of Sites with Buried Components				
MODEL	Very High	High	Moderate	Low	Very Low
SSURGO A	132	19	65	5	16
SSURGO M	175	14	49	5	9
STATSGO A	132	19	65	5	16
STATSGO M	185	40	64	2	8

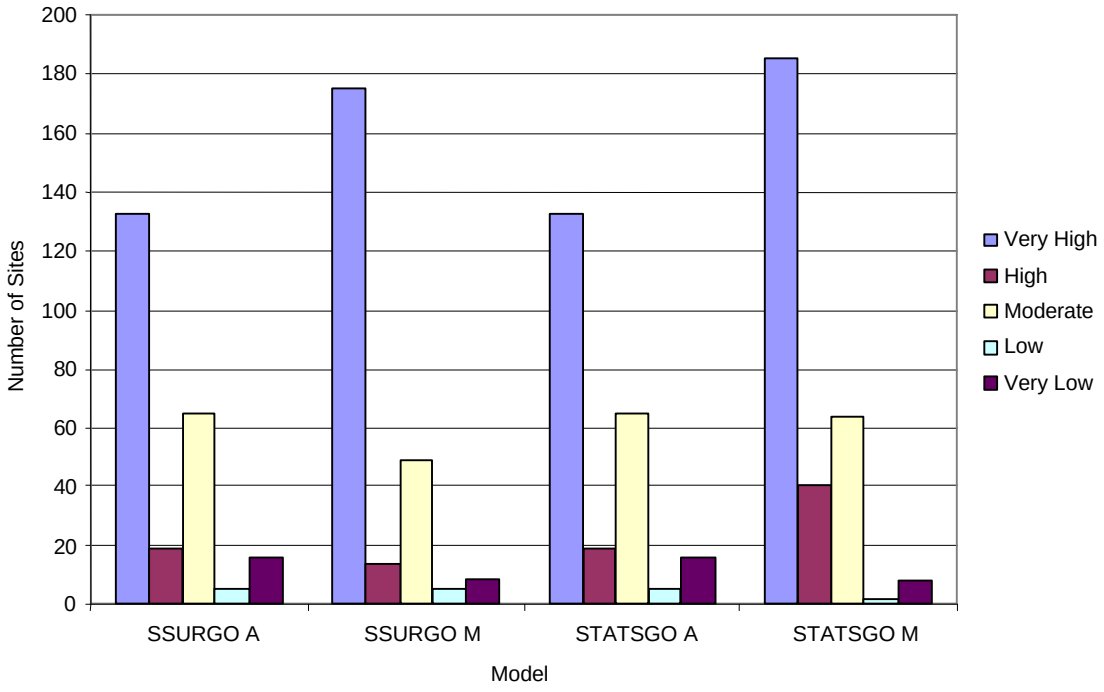

Figure 43. Number of sites with reported buried components by sensitivity class for each model.

Table 11. Percent of sites with reported buried components by sensitivity class for each model

MODEL	Very High	High	Moderate	Low	Very Low
SSURGO A	23.91	14.18	8.01	14.71	8.70
SSURGO M	19.00	14.29	7.55	17.24	6.57
STATSGO A	18.06	4.19	7.62	8.33	9.88
STATSGO M	17.27	11.87	9.54	4.26	6.02

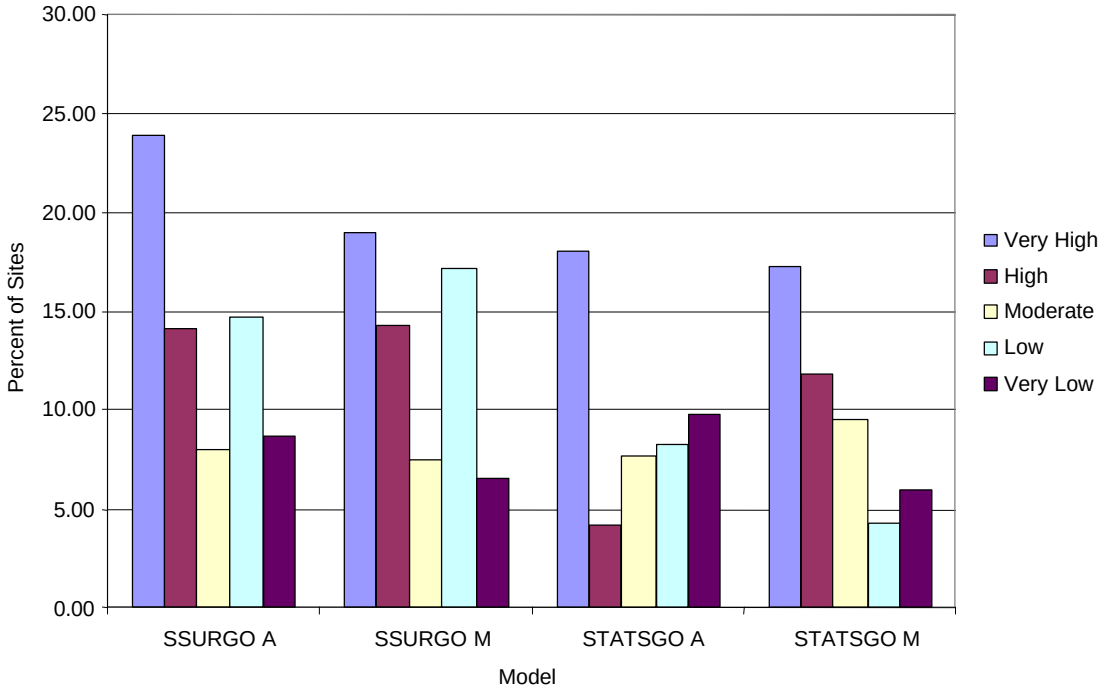

Figure 44. Percent of sites with reported buried components by sensitivity class for each model.

encoding summarized here, a site is described as having a potential for subsurface components only when cultural remains are found below a depth of 20 cm or more or when a subsurface component with good stratigraphic context is demonstrated to exist in the upper 20 cm of deposition.

There is a very high correlation with reported sites having buried components within the very high sensitivity class across all four models. The high number of buried sites which fall into the very high sensitivity classes is a strong indication that the model adequately predicts the potential of buried resources within the very high sensitivity class. The high sensitivity class does not seem to represent the reported sites as well as the very high sensitivity class. Additional fieldwork would be helpful to determine if sites are properly reported and evaluated. Figure 45 shows where known buried sites occur superimposed over the STASGO sensitivity model.

Surface components are also analyzed (Table 12; Figure 46. In general the analysis indicates sites that contain only surface components are more likely to occur in the lower sensitivity classes.

Sites that have produced radiocarbon dates (Tables 13-14; Figures 47-48) are a suitable measure to use in the evaluation of the sensitivity model. Because of their substantial cost, radiocarbon dates are derived from either relatively intact hearth features, or organic remains within known or suspected intact archaeological components, both the types of remains we assume to be important data categories for buried components. Sites in the Powder River Basin have a greater sod cover than sites in more arid and more deflated portions of Wyoming so most of the radiocarbon dates are expected to be from components that are subsurface. There is a high correlation of number of sites producing radiocarbon dates with the very high sensitivity classes. The majority of radiocarbon dates, approximately 75 percent, collected within the study area fall within the very high sensitivity class. It is interesting to note there are no sites producing radiocarbon dates within the low sensitivity classes. Table 15 is a summary of the site data.

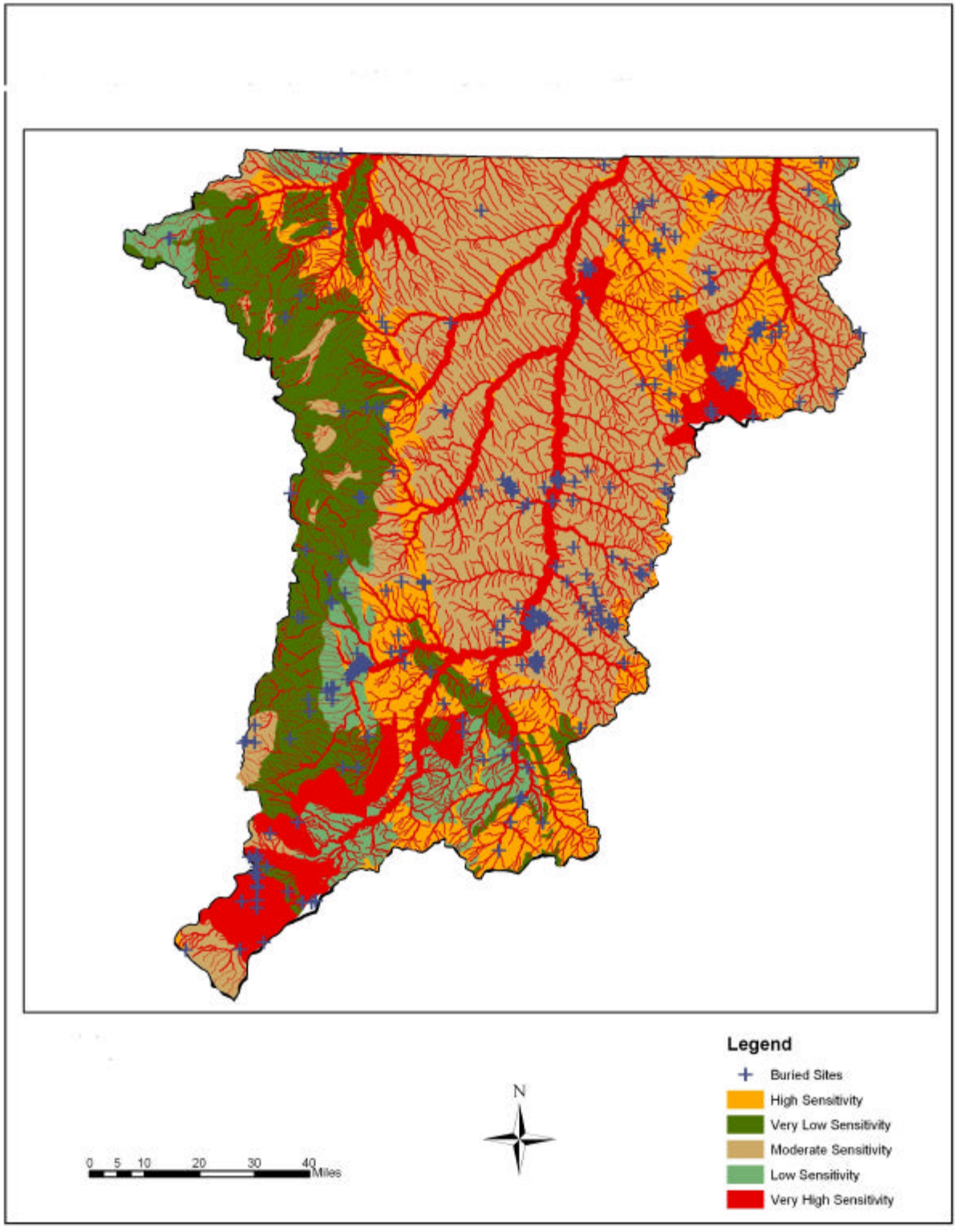

Figure 45. STATSGO Management Sensitivity Model with known buried archaeological sites

Table 12. Percent of sites with surface components only

MODEL	Very High	High	Moderate	Low	Very Low
SSURGO A	76.09	85.82	91.99	85.29	91.30
SSURGO M	81.00	85.71	92.45	82.76	93.43
STATSGO A	81.94	95.81	92.38	91.67	90.12
STATSGO M	82.73	88.13	90.46	95.74	93.98

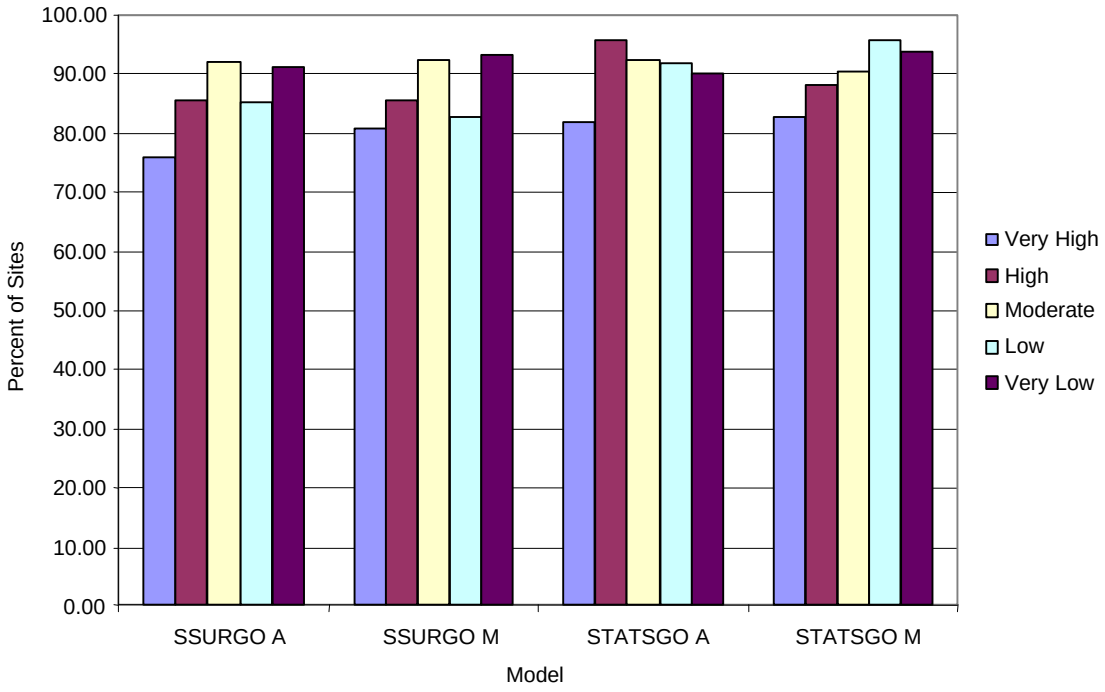

Figure 46. Percent of sites with surface components only

Table 13. Number of sites with radiocarbon dates by sensitivity class for each model

	Number of Sites with Radiocarbon Dates				
MODEL	Very High	High	Moderate	Low	Very Low
SSURGO A	50	7	11	0	3
SSURGO M	63	5	7	0	2
STATSGO A	50	7	11	0	3
STATSGO M	67	3	10	0	0

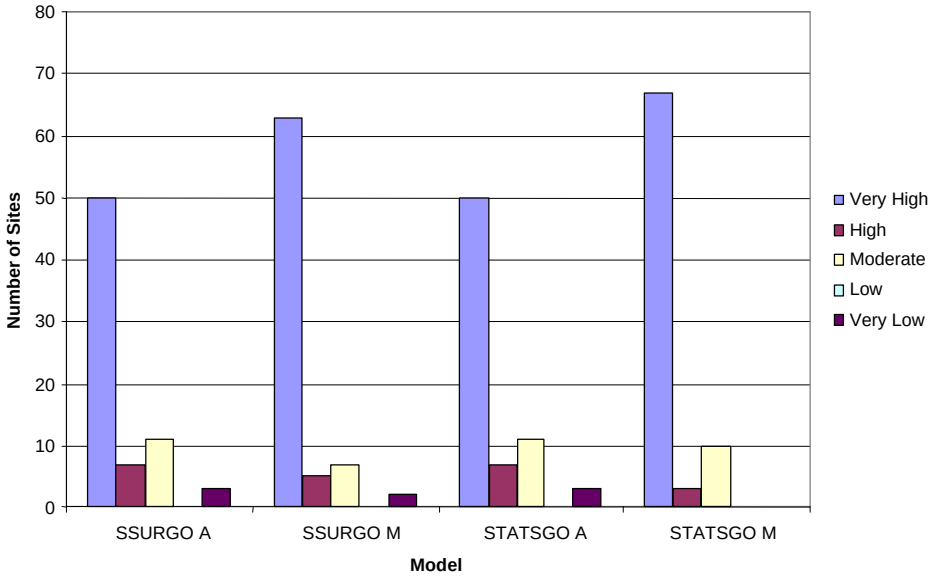

Figure 47. Number of sites with radiocarbon dates by sensitivity class for each model

Table 14. Percent of sites with radiocarbon dates by sensitivity class for each model

MODEL	Very High	High	Moderate	Low	Very Low
SSURGO A	9.06	5.22	1.36	0.00	1.63
SSURGO M	6.84	5.10	1.08	0.00	1.46
STATSGO A	6.84	1.55	1.29	0.00	1.85
STATSGO M	6.26	0.89	1.49	0.00	0.00

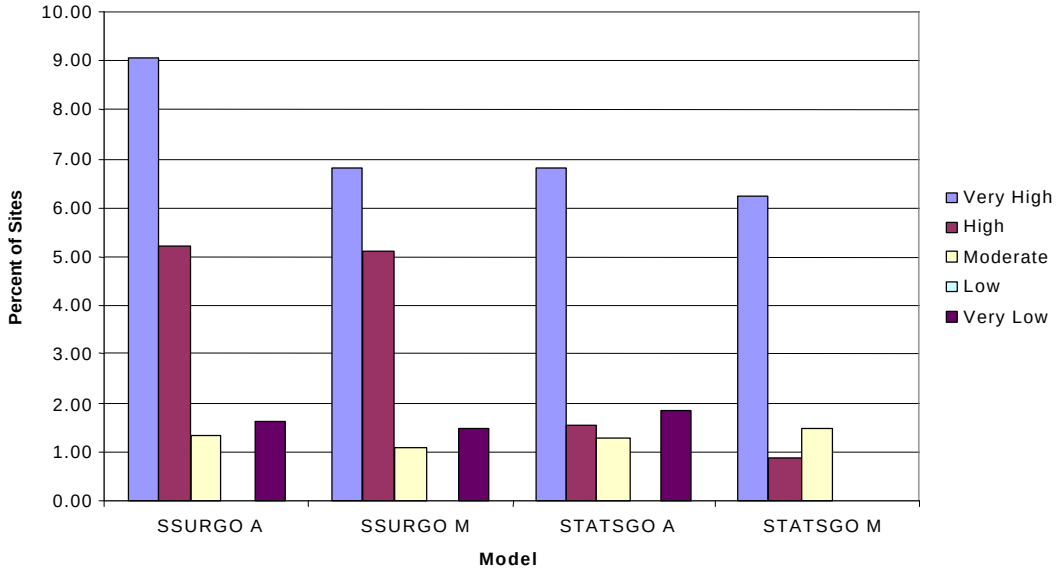

Figure 48. Percent of sites with radiocarbon dates by sensitivity class for each model

Table 15. Summary table of study area archaeological characteristics by sensitivity class for each model

Category	Area (ha)	Percent Study Area	Area Inventoried (ha)	Percent of Category Inventoried	Number of sites per Category	Number of sites with buried component	Percent Sites With Buried Component	Percent Of Sites With Surface Component Only	Number of Sites with Radiocarbon Dates	Percent Of Sites Producing Radiocarbon Date (excluding rockshelters)	Number of Buried Sites with Shovel Tests and Formal Excavations	Percent of Buried Sites with Shovel Tests and Formal Excavations
SSURGO A												
Very High	413358	20.44	41116	9.95	552	132	23.91	76.09	50	9.06	10	7.58
High	185780	9.19	16738	9.01	134	19	14.18	85.82	7	5.22	2	10.53
Moderate	1036473	51.25	93940	9.06	811	65	8.01	91.99	11	1.36	5	7.69
Low	66218	3.27	6865	10.37	34	5	14.71	85.29	0	0	0	0
Very Low	320363	15.84	14448	4.51	184	16	8.7	91.3	3	1.63	1	6.25
Total	2022192					237					18	7.59
SSURGO M												
Very High	746570	34.93	71959	9.64	921	175	19	81	63	6.84	13	7.43
High	153686	7.19	14001	9.11	98	14	14.29	85.71	5	5.1	1	7.14
Moderate	895480	41.89	80931	9.04	649	49	7.55	92.45	7	1.08	5	10.2
Low	62139	2.91	6464	10.4	29	5	17.24	82.76	0	0	0	0
Very Low	279676	13.08	12148	4.34	137	9	6.57	93.43	2	1.46	0	0
Total	2137551					252					19	7.54
STATSGO A												
Very High	519127	18.29	62334	12.01	731	132	18.06	81.94	50	6.84	10	7.58
High	516868	18.21	54554	10.55	453	19	4.19	95.81	7	1.55	2	10.53
Moderate	1501808	52.92	127366	8.48	853	65	7.62	92.38	11	1.29	5	7.69
Low	58645	2.07	5780	9.86	60	5	8.33	91.67	0	0	0	0
Very Low	241361	8.51	21213	8.79	162	16	9.88	90.12	3	1.85	1	6.25
Total	2837809					237					18	7.59

Category	Area (ha)	Percent Study Area	Area Inventoried (ha)	Percent of Category Inventoried	Number of sites per Category	Number of sites with buried component	Percent Sites With Buried Component	Percent Of Sites With Surface Component Only	Number of Sites with Radiocarbon Dates	Percent Of Sites Producing Radiocarbon Date (excluding rockshelters)	Number of Buried Sites with Shovel Tests and Formal Excavations	Percent of Buried Sites with Shovel Tests and Formal Excavations
STATSGO M												
Very High	837562	29.51	91061	10.87	1071	185	17.27	82.73	67	6.26	19	10.27
High	430224	15.16	45819	10.65	337	40	11.87	88.13	3	0.89	5	12.5
Moderate	1301170	45.85	110206	8.47	671	64	9.54	90.46	10	1.49	4	6.25
Low	50481	1.78	5211	10.32	47	2	4.26	95.74	0	0	1	50
Very Low	218415	7.7	18951	8.68	133	8	6.02	93.98	0	0	1	12.5
Total	2837852					299					30	10.03

CULTURAL RESOURCES MANAGEMENT RECOMMENDATIONS FOR SENSITIVITY ZONES

Recommendations presented here supplement and suggest, but should not be inferred to require any changes to minimum 106 management practices. No reductions in inventory are recommended. Minimal testing requirements are supported and deeper testing is recommended where indicated. This description of sensitivity zones will give stakeholders an idea of where the risk of encountering sediments that might contain buried sites is high/low.

Very High Sensitivity Zone

Locations predicted to have very high archaeological landscape sensitivity (Figure 37) are situated, either within fine-textured alluvial fill located in low gradient, basin valleys, or in eolian deposits. Earth-disturbing construction activities within this zone should only occur under the most controlled circumstances. Intensive archaeological inventory, subsurface prospecting of non-site areas, and complete construction monitoring are recommended to prevent inadvertent destruction of significant archaeological resources within this zone. Experience within other areas in Wyoming suggests that it is reasonable to postpone data recovery efforts at some site types slated for impact by pipeline trenching until after archaeological open-trench inspections are completed. The reason for this is that often-times highly significant buried components are found during open trench inspection whereas, these components are difficult to locate using traditional site prospecting and testing methods. To facilitate data recovery at discoveries made during

open trench inspection, it is generally desirable to have administrative and budgetary contingencies built into the permit process.

High Sensitivity Zone

Some locations, not necessarily situated along major drainages in the project area, are mapped as having high archaeological landscape sensitivity. These areas are derived from NRCS map units and have low slope, exhibit thick accumulations of surficial sediment, lack evidence of old surface soils, and contain little large and small gravel. At the SSURGO scale (Figure 37), high sensitivity zones occur in fine-textured alluvial, eolian, alluvial fan, and slope wash depositional environments. The high sensitivity zone is predicted to contain buried cultural occupation zones that exhibit similar site preservation as those in the very high sensitivity zone. Management implications and suggested recommendations are identical for high and very high sensitivity zones. As with the very high sensitivity zone, earth disturbing construction activities within the high sensitivity zone should only occur under controlled circumstances. Intensive archaeological inventory, prospecting, and construction monitoring, including 100 percent inspection of construction trenches, will be necessary to totally prevent the inadvertent destruction of significant archaeological resources.

Moderate Sensitivity Zone

Some areas within the project area failed to meet the distinctive criteria that characterized the very high, high, low, and very low sensitivity classes. These areas are classified as moderate sensitivity (Figure 37). At the SSURGO scale, the moderate class encompasses low and very low areas delineated by STATSGO, especially in the basin area. While sizeable tracts of the moderate zone have a low risk, other, smaller areas (especially at the STATSGO scale) might be more sensitive. As the NRCS makes SSURGO data available for the remaining portions of the project area, it will be desirable and possible to reclassify additional areas of low and very low concern within basin areas. Until that time, professional archaeologists working in STATSGO areas mapped as a moderate zone will need carefully assess slope, depth to bedrock, percent sediment less than 7.62 cm (3 in), and percent sediment less than 2 mm (0.08 in) to distinguish areas of higher sensitivity from those of lower sensitivity within the basin. Project-specific, geoarchaeological evaluations are highly recommend for projects in this zone as they can help identify which portions of the moderate zone are more or less sensitive. In addition to normal Section 106 process inventory and evaluation, this zone would benefit from construction monitoring of known archaeological resources and monitoring of construction trenches as recommended by a geoarchaeologist. The moderate sensitivity zone has the potential to contain some deep deposits.

Low Sensitivity Zone

Areas predicted to have low archaeological landscape sensitivity include NRCS map units that exhibit characteristics such as a thin mantle of sediment, steep slope, and

coarse-grained texture. As well, this zone is mostly mantled by questionable Holocene-age surface soils (i.e., Argiaquolls, Argiborolls, Argiustolls, Calciargids, Calciborolls, Calciorthids, Cryoboralfs, Eutroboralfs, Gypsiorthids, and Haplustalfs). Although small areas of probable Holocene-age soils are included, the surface soil age of the bulk of the included map units suggests that the sediments in and under the soils are too old to contain intact archaeological material. Thus, the potential for preserving occupation integrity, perishables, and stratigraphic separation of occupations in this zone is lower in comparison to the higher-ranked (very high, high, moderate) sensitivity zones. In addition to normal Section 106 process inventory and evaluation, construction monitoring would be necessary on a case-by-case basis, as identified by agency or project archaeologists.

Very Low Sensitivity Zone

Areas at the lowest extreme of the sensitivity scale are characterized as the very low sensitivity zone. Some areas within the project area contain a combination of attributes that render them unlikely to contain intact, well-preserved, and stratigraphically separable occupation zones. This prediction is based on one or more of the following attributes, which correspond to the NRCS map units they occupy: (1) a large amount of non-soil land is present (e.g., badlands, gravel pits, rock outcrops, etc.); (2) surface soil type is thought to be too old to engulf any intact and buried cultural material; (3) depth to bedrock is very shallow; (4) slopes are steep; and/or (5) gravel comprises a relatively large proportion of the soil component. Generally speaking, much of this zone is situated

on steep slopes in mountainous areas. As with the low sensitivity zone, small inclusions of other soils occur within the boundaries of the very low sensitivity zone, and thus some of these areas could potentially contain intact, well-preserved, and stratigraphically separable occupation zones. However, if smaller potential sensitive inclusions are not identified in the field by agency or project archaeologists, construction monitoring and other post-inventory discovery techniques can be omitted without overt risk to sensitive cultural resources.

In addition to the recommendations presented above, we also recommend project-specific geoarchaeological evaluations be conducted for projects that will impact large areas. These evaluations should include field reconnaissance and be performed during the permitting of linear projects such as pipelines and highway construction that exceed 1 km in length. These investigations can help test the model presented here and also provide larger scale and more detailed project-specific predictions on burial risk. Also, geoarchaeologists should be involved in the documentation and interpretation of buried archaeological discoveries during the open trench inspection phase, especially at locations that might be considered for data recovery. The geoarchaeologist can lend enterprise to evaluating the site formation and destruction processes at these locations and potentially help discriminate sites with good context from those that might have poor burial context, thus maximizing effective data recovery and eliminating unwanted, poorly conceived data recovery efforts.

MAINTAINING THE MODEL

When implemented, the model will need to be subjected to ongoing maintenance to fulfill its adaptive management goal. This should include monitoring, additional testing, periodic reevaluation, and adjustment. Monitoring should include the specific tracking of CRM management and field archaeological actions taken in which the model was used. This should especially include tracking any construction monitoring such as open trench inspections. A logical way to do this is to periodically retest the model against the growing WYCRO database.

Additional testing of the model is a priority. Spatial association of the sensitivity zones with WYCRO site data gives initial support to the model and warrants implementation. However, additional testing is recommended as part of the adaptive management process. Although open trench inspections can be minimized or eliminated in the low and very low areas, adequate testing of the model can only occur if some percentage of open trench inspections occurs through the entire range of sensitivity zones, including low and very low sensitivity zones. Data from these open trench inspections in all sensitivity zones must then be evaluated to test the model.

Two geoarchaeological issues to consider when testing the model are: (1) NRCS data that was used in the model should be field tested; (2) areas the model predicts having the correct age and depositional energy regime to bury and preserve sites should be field tested.

In addition to the above (essentially geological questions), there is an important archaeological question: What is the frequency with which buried cultural material occurs within each sensitivity zone? Although this has nothing to do with actually testing the age and depositional energy aspects of the model, it is an important part of evaluating how useful the model might be in a management context. The usefulness of the model as a management tool can be judged within overall management goals. These goals refer to prevailing management risk-comfort levels with the rate at which buried cultural materials are accidentally encountered by heavy equipment in pipeline trenches, but then overlooked (by lack of investigation) and not included within the 106 process. As discussed above, the model was not designed to predict the density of surface or subsurface cultural materials.

Field-testing of the model by a geoarchaeologist will facilitate formal testing of the model. Geoarchaeological testing on a small percentage of open trench inspections can lead to an assessment of the adequacy of the sensitivity outline and the accuracy of the NRCS data. It is recommended that geoarchaeological review of the model be included as part of open trench inspections. The geoarchaeologist can spot check and assess the fit of the field data with the NRCS mapping data and also assess the adequacy of the sensitivity outline. This assessment can be accomplished at a much-reduced cost if the geoarchaeologist is ordinarily retained to perform a geoarchaeological assessment at discover locations found during open trench inspection that might have data recovery potential.

Data gathering by non-geoarchaeologists during open trench inspections might also provide useful (but more limited) data to formally test the model. Equally important, discoveries documented by archaeologists as part of open trench inspections can be used to determine the encounter rate of archaeological material within the different sensitivity zones. Appendix D presents field forms that can be used to facilitate this goal. Results of open trench inspections need to be carefully evaluated with regard to the encounter rate of archaeological material, and a geoarchaeologist should be involved in this evaluation since site preservation and visibility of cultural materials require careful consideration. We caution that any conclusions that are drawn from the evaluation of cultural material encounter rates should take into consideration the both the difficulty of seeing cultural stains in the Powder River Basin and also the very low probability at which artifacts will be visible in a vertical cutbank (trench wall) even if the trench cuts through a site (discussed earlier in this report).

Adjust Process

Yearly review of the use of the model and the results of the open trench inspection monitoring by the relevant agencies is recommended. These reviews should recommend changes to the model when appropriate. In addition to periodically testing and evaluating the burial model in open trenches, it is desirable to add coverage to the model at two-year intervals as 1:24,000 NRCS data becomes available. The current model is hampered by the absence of 1:24,000 NRCS soils maps for the entire area. The STATSGO model based on 1:250,000 scale soils maps contains few very low and low sensitivity zones within the basin area, although these classes are mapped in the mountains. Areas within

the basin for which SSURGO (1:24,000 scale) data are available do have areas mapped as low and very low. With more complete coverage, additional areas of low and very low sensitivity within the basins could be delineated with the result that the moderate class could be reduced in size. This would allow better planning and help reduce conflicts between management goals of site preservation and resource development.

SUMMARY

Geoarchaeological modeling of the Powder River and Tongue River hydrological basins is undertaken in this report. Modeling is based on sediment age and depositional energy regime. This project was conducted for Gnomon, Inc., under a PUMP III Cooperative Agreement Program from the Department of Energy (DOE). The purpose of the project is to build a spatial model allowing prediction of geological settings conducive to the preservation of significant, buried, prehistoric archaeological sites. Modeling utilizes information taken from literature review, fieldwork, and geological and soils mapping.

The project area includes the western Powder River Basin as well as the eastern Bighorn Mountains. Intrusive igneous rocks and tilted sedimentary beds predominate in the mountains and gently dipping rocks are most common in the basin. In the mountains, glacial, colluvial, and residual surficial materials are most common with lesser amounts of alluvium. Larger areas of surficial fluvial deposits are present in the basin accompanied by residual and eolian materials. The climate of the area is strongly influenced by elevation. Mountains experience colder temperatures, more precipitation,

and a shorter growing season than the basin. Entisols, Alfisols, Mollisols, and Inceptisols are the most common soils in the mountains. Entisols and Mollisols also occur in the basins where they are accompanied by Aridisols. Mountain vegetation communities includes, in descending elevation, alpine meadow/tundra, spruce-fir forest, and Ponderosa pine-Douglas fir forest. Grassland dominates the foothills and the basin and areas of sagebrush steppe also occur.

We assume that important buried prehistoric cultural resources are usually, and perhaps always, found in geological strata less than 14,000 years old. Archaeological materials buried within moderate to low energy depositional environments can be buried deeply enough to have escaped the effects of disturbance processes and maintained integrity. Sites with high stratigraphic integrity are important but difficult to manage and expensive to treat under Section 106 of the NHPA.

NRCS inventories generate two data sets for these variables, one at a scale of 1:24,000 (24k) and another at a scale of 1:250,000 (250k). We manipulated these data sets separately. The analysis utilizes geological and soil characteristics such as sediment type, geomorphic setting, sediment texture, slope, and soil type as variables. A range of values occurs for each of the variables. Each variable is classified to approximate its appropriate contribution to a particular sensitivity class. The classified data becomes part of a geographic information system that uses NRCS soil map units and stream valley boundaries to plot the occurrence of the classified variables. The plotted classified variables are then combined by sensitivity class. This results in a map that represents the

potential of the landscape to contain sediment of the appropriate age, and depositional regime to contain relatively intact buried cultural material. Individual maps were generated at the 24k and 250k scales.

Caution is warranted as the sensitivity model only predicts where site preservation conditions might be favorable, and not locations that may have been attractive to human activity. In addition, utilization of the 250k scale data can only provide a general view of landscape sensitivity. Where available, use of the 24k data is recommended, and then only down to the limits of this scale. Enlarging the 24k data by optical or digital means will not yield more accurate locational information regarding the boundaries of the sensitivity zones. As a final caution, sensitivity maps are used as part of a process that include field visits by competent field archaeologists. Professional geoarchaeological field assistance should be sought when the map predictions do not seem to reflect the landscape observed in the field.

WYCRO site records are used to evaluate the model. Data on the locations of buried components and sites that have produced radiocarbon dates tend to support the validity of the model.

Locations with very high archaeological landscape sensitivity are situated primarily along the floodplains and low terraces of low gradient, basin alluvial valleys with lesser areas of eolian sand. Earth-disturbing construction activities within this zone should only occur under the most controlled circumstances, including a pre-construction

archaeological inventory, and monitoring of construction activity, or at a minimum post-disturbance (pre-refill or pre-regrade) inspection.

High sensitivity zones occur on low slopes, exhibit thick accumulations of surficial sediment, lack evidence for mature soils, and contain little large and small gravel. Monitoring of construction activity or at a minimum post-disturbance (pre-refill or pre-regrade) inspection should be considered in these areas.

The moderate sensitivity zone consists of areas that did not fall into the very high, high, low, and very low zones. As such, they either have a "moderate" or an "unpredicted" sensitivity. Some areas of sensitive sediments will be situated within areas mapped as moderate. STATSGO lumps small areas of higher and lower sensitivity in with the moderate class, especially within the basin portion of the project area. In areas where SSURGO mapping is lacking, common sense use of the sensitivity outline by professional archaeologists can help discriminate areas of higher sensitivity from areas of lower sensitivity. On-site, geoarchaeological evaluations are recommended to help discriminate these areas from larger portions of the moderate zone that might be less sensitive. Post-disturbance (pre-refill or pre-regrade) inspection should be considered in all moderate areas.

Areas predicted to have low archaeological landscape sensitivity include areas with a thin mantle of sediment, steep slope, and coarse-grained texture. As well, this zone is mostly mantled by surface soils that are of questionable Holocene-age. The potential for

preserving occupation integrity, perishables, and stratigraphic separation of occupations in this zone is lower in comparison to the moderate sensitivity zone. Agency and consulting archaeologists should make an effort to identify smaller areas of higher sensitivity within this zone. The protocol handbook presented in Appendix C is designed to assist in identifying these areas.

Areas at the lowest extreme of the sensitivity scale are within the very low sensitivity zone. Included are large areas of non-soil land such as badlands, gravel pits, rock outcrops, etc.; areas containing soil types thought to be too old to engulf any intact and buried cultural material; depth to bedrock is very shallow; slopes are very steep; and/or gravel comprises the largest proportion of the soil component. Generally speaking, much of this zone is situated on steep slopes in mountainous areas. As with the other zones, inclusions of other soils occur within the boundaries of the very low sensitivity zone, and thus some of these areas could potentially contain smaller areas of higher sensitivity. As with the low zone, agency and project archaeologists should attempt to identify these areas. Only at these specially identified areas are open trench inspection and other monitoring recommended.

CHAPTER 5

CULTURAL RESOURCE MANAGEMENT APPLICATIONS

One aim of AMP was to create tools to improve the Section 106 process itself. The Section 106 review, determination, and mitigation determination decisions all rely upon timely and accurate information. Toward these ends, this projected created one entirely new information tool and enhanced a prototype application. These software applications are described in this chapter.

Two kinds of information are of fundamental importance in Section 106. The first is knowledge of the archaeology of an area. This information assists fieldworkers as to expected types of sites, length of time that fieldwork may require, and so on. General archaeological knowledge is also the basis for many of the decisions that the evaluation processes require. Criterion D of the National Register criteria is the most commonly applied criterion for archaeological sites considered as eligible to the Register. Criterion D essentially states that an historic property is important for its potential to yield valuable scientific information. In general, archaeologists decide the scientific value based upon what is already known about the sites in an area, known as the archaeological context of a particular site. The CRISP information tool developed by this project is one means for conveying such information to non-specialists. WYCRIS – the professionally accessible database and automated map system that was augmented by this project – is a second such tool.

The second kind of information relevant to Section 106 is more work-oriented than the first. As the phrase implies, cultural resources identification, evaluation, and mitigation are *processes* themselves. Work flows that span more than a few days generally have some identifiable milestones. So, this second kind of information is about where a given project – a field investigation spawned by a proposed land use – lies along the Section 106 workflow curve. Examples of questions are: Which milestones have been achieved? Which have not? Who is currently reviewing the project document? These sorts of questions can be answered by utilizing CRMTracker. AMP enhanced the CRMTracker application, which follows the work flow of typical 106-driven projects, capturing milestones as the project proceeds.

Gnomon developed or enhanced two technical applications as part of the AMP:

Cultural Resource Management Tracker (CRMTracker)

Cultural Resources Information Summary Program (CRISP)

CRMTracker is a web-based application, requiring only a web browser software. It captures major milestones in cultural resources driven by the Section 106 process. These include:

- Initiation of fieldwork by a third party seeking lead agency authorization
- Review and Approval/Disapproval by the lead agency
- Reporting of the results of fieldwork

- Creation of summary information and a printed report cover sheet when fieldwork is reported
- Logging of review decisions

The application uses role-based security to ensure confidentiality and to prevent conflicting edits to the same information.

Currently, the investigation-decision-management process for actions like Applications for a Permit to Drill (APD's) is mostly completed by filling out paper forms. A consultant originates the document, the federal agency reviews the document and its findings, and then the SHPO may review and comment. Only then will a finding be made on the undertaking (e.g., an APD) itself. In Wyoming, for example, the transit time from fieldwork to presence in the data system may require three months or more.

Gnomon developed CRMTracker, which is an information management system that both mirrors the flow of paper documents and improves upon it. The greatest value of this application is saving time through a shared database application accessible via a secure Internet connection. CRM Tracker efficiently captures the inventory and associated resources suite of data early in the process and provides on-line access to this information back to the project applicant. All concerned parties have ready access to all information as the application process proceeds. CRMTracker has been utilized for more than a year in Wyoming by several field offices and major consulting firms.

Estimating how much time and effort CRMTracker achieves is difficult. First, CRMTracker is intended to accumulate information as work "flows" through the Section 106 process. Because it has only been used for a year and a typical review cycle is about six to eight months, we do not have as much longitudinal information as one would like. A second difficulty is that use of the application is inconsistent. Some consultants are consistent users, some field offices of BLM request or require its use, and others do not. It is extremely difficult to gain the benefits of an information management system when information is populated partially or inconsistently. A third problem is that the expectations of CRMTracker from BLM in particular exceed its original design. For example, BLM field offices in Wyoming routinely require consultants to provide the office with a statement of project effect and proposed mitigation measures. Because consultants do not assess project effect (agencies do so), CRMTracker does not contain data columns or entry fields for these statements.

Nevertheless, we have some information that supports CRMTracker as a time-saving tool. Fieldwork authorizations are transmitted instantly. This saves at least a one day turnaround time in many cases. Similarly, the ability for BLM to communicate a decision about a proposed fieldwork instantly saves time for consultants and their clients. Extraction of information from CRMTracker to the statewide data systems that support WYCRIS and CRISP will save about one person-year of effort within the records archive. Automated generation of many of the "widget counts" required in annual reporting saves each field office approximately three to five person-days yearly (we have

run two trials with the Worland Field Office). These savings accrue *if the system is utilized and populated comprehensively*.

The second application, CRISP, is an information tool for non-archaeological experts. It is useful for rapid assessment of potential project areas (PPA's). A PPA could be a contemplated well pad and road, a borrow pit, or any other action. Using CRISP, one draws a PPA onto a map image and then runs a report on the PPA. CRISP is a web-based application, and uses cultural resource inventory layers, cultural resource summary layers, and cultural resource forecasts (models) to provide the user with a summary of knowledge about their PPA.

The first step in the development of CRISP was to digitize all of the archaeological survey and site location information for the entire northeastern corner of Wyoming. These records are available through the Wyoming SHPO Cultural Records Office (WYCRO). This enables easy access to large quantities of data through a web-based application. The second step was to develop the cultural resource sensitivity models (see the section above on how the models were developed).

CRISP is a planning tool for land-users and managers. It reports how many cultural resource inventories have been completed in an area of interest, and also what percentage of the area of interest falls into sensitivity zones ranging from low to very high. The user can also view the sensitivity model results throughout the Powder River Basin study area.

CRISP is designed to be easy to use for common forms of analysis. The steps to create a CRISP report are simply:

1. Locate your proposed project area (PPA) by navigating to the appropriate part of the map.
2. Draw the PPA, buffering each feature as needed, to create one or more polygon search masks ("cookie cutters") for analysis.
3. Run the report (the analysis) and save the report as a PDF format file if you wish.

There are two ways to zoom to an area of interest: use a zoom tool or type in a desired township and range. There are layers present in the application that help the user navigate in the study area. Examples are:

USGS topo maps at three scales

Major waterways and major highways

Township and range grid

Hillshade relief

Populated places

UTM zone boundaries

County boundaries

State boundary

BLM office locations and district boundaries

The final step is to create a report for the PPA. The report summarizes several things about the PPA and provides maps of it. These include:

- The size of the PPA
- The percent of the PPA that has already been inventoried for archaeology
- Known cultural resources and a count of the number of inventory reports within each section touched by the PPA. Note that a PPA may have no inventoried ground within it and yet still be in a section with inventories – this summary is by section, not by PPA.
- The forecast from the first model (currently a model of the likelihood of finding buried archaeological sites in scientifically useful contexts).
- The forecast from the second model.

The report can also be saved locally on a computer as a Portable Document Format (PDF) file.

The benefit of CRISP to lease applicants is that it helps remove some of the unknowns from the application process. By seeing areas where there is a very high probability of encountering buried cultural resources and areas where cultural resources have been discovered in the past, applicants can make decisions early in the project development process, which should save time and money.

CRISP does not replace consultation with appropriate agencies, landowners, land managers, and other participants in the cultural resource management process. Although

CRISP summarizes the results of scientific investigations, it also does not replace discussions with cultural resource managers or other experts. What CRISP does provide is a way to gain a quick overview of what might be present on or in the ground, and information about what is already known. CRISP's greatest utility is as a project-planning tool. It is not a compliance tool.

A copy of the User Manual for CRISP is attached as Appendix E.

CRMTracker is currently in place in Wyoming and CRISP will be in place by the end of the year. It is currently in the testing phase.

CHAPTER 6

RESULTS AND DISCUSSION

This project, Adaptive Management and Planning (AMP), was sought because the project team thought it had a high likelihood of yielding practical reforms to management practices. In this chapter, we consider the project outcomes from the standpoint of upstream management practices. First, we define "upstream" in terms of the most common cultural resources investigation and decision processes. We then consider how the products produced in AMP have practical utility in creating better management of archaeological resources and, especially, more adaptive management of the entire cultural resource regulatory mechanisms and procedures.

Accomplishments within Wyoming

Within the Wyoming study area, we have accomplished several important goals. These have been discussed above. We list them here in a more geographic form to emphasize the general benefits and how these contribute to a more rational management process.

- **Accomplishments within Wyoming**
  - **Region-specific accomplishments**
    - Data creation and update
    - Forecast models for buried archaeology
    - Better knowledge of the archaeology and contexts for decision-making about archaeology in the region
      - example: count of paleoindian sites

- **General (state-wide) accomplishments**
    - CRMTracker
        - Established common core fields
        - Created initial summary report capability
        - 1+ years of field use
        - Prototype use has interested other states
    - **CRISP**
        - Established mechanism for industry and manager planning
        - Integrates statewide data and models appropriately
        - Has utility in planning especially, but also in review
    - **IT user education**
        - Training sessions for CRMTracker
        - Manual for CRMTracker
        - GIS tool training
        - GIS manual
    - **GIS data entry system for BLM and other agencies**
        - ArcGIS entry tool for interaction with WYCRIS
        - standardized entry processes aid quality control
        - shortens time frame for release of information to users through WYCRIS, CRISP, CRMTracker
    - Upgrades to WYCRIS for ease of use and better performance

Relevance to Wyoming Energy Development. Oil and gas field development in Wyoming has historically been accomplished through field development projects. An oil and gas field is established through exploration on leases and then oil and gas operators develop their leases within the field. A large field may involve many operators; at least there will be many leases in different stages of development. Although a large area may be targeted for development, ultimately, on-the- ground permitting and associated work

required by NEPA and the NHPA occurs at the lease level or (more frequently) on an action-by-action basis.

Archaeological resources at the field level of development have been treated in an overview fashion. Individual development actions have triggered action-specific fieldwork. Most of the time, action-specific fieldwork follows a standard course: identification of archaeological resources from surface inventory, evaluation under the National Register of Historic Places (NRHP) of the archaeological materials found which may require some limited excavation (testing) at particular locations, and then if potentially NRHP eligible sites are within the area of potential effect (APE), the site will either be mitigated to offset damage that it will incur or the APE will be redesigned. The overview approach to cultural resources at the field level meets the requirements of NEPA but does not change the most common parts of the management process for archaeology: APE-specific fieldwork, reporting, and decision-making.

Coalbed natural gas (CBNG) development differs from the scenario sketched above in some significant ways. First, coalbed development exploits a widespread potential that is fairly uniform in occurrence – there are no “fields” in the usual oil and gas sense of the term. Each lease has a fairly consistent potential to yield gas, so development does not necessarily focus on “hot spots”, instead being driven by other economics like transport, dewatering costs, and accessibility. Lease development does not have to “prove” value with an exploratory well so much as it must simply extract natural gas in a rational way. Lease development occurs in plans of development (PODs) that lay out the extraction,

processing, transport, and access infrastructure in a single pass. CBNG development is generally less costly than “traditional” oil and gas, so companies tend to implement PODs as a whole. Increases in well density are usually foreseen in the original POD, if not put in place as part of the initial POD implementation.

Cultural resources investigation in CBNG development settings tend to be “one pass” across a lease. Identification, evaluation, and mitigation or redesign on a lease take place once. Once done, little further cultural resources investigation is likely to ensue, because little additional disturbance will be called for in the POD. In essence, each lease (if developed) gets treated as a single unitized NEPA and NHPA. This is distinctly different from the action-driven NEPA and NHPA processes that occur in petroleum lease development. This is not to say that CBNG leases have no further actions in them at all. Wells and PODs are extraction locations. Gathering facilities and transport facilities will continue to develop throughout CBNG regions as sheer volume of gas produced demands more pipelines, tanks, and other distribution infrastructure. Archaeological investigations to assess APEs for these activities will continue.

This project is relevant to Wyoming energy development in several ways: information, process, and upstream best practices. All three of these benefits are intertwined. Nevertheless, each is discussed individually, if somewhat redundantly.

Information is a key to adaptive, rational, decision-making about use of the public lands. The full population of the WYCRIS database, shortening data availability time frames

with CRMTracker, the CRISP information tool, and the forecast models for buried archaeology all provide decision-makers, energy developers, land managers, and consultants with far more knowledge of the study area than they had before. Too, the study area encompasses almost all of the Wyoming Powder River Basin and Upper Tongue River Basin in which CBNG development is contemplated, including areas that are not yet leased.

Oil and gas developers consider cultural resources to be a hurdle to development on public lands. This project does not abolish or remove these hurdles – we have neither the authority nor the brief to do so. Archaeology occurs unpredictably from an oil and gas developer's viewpoint: sites occur in the strangest places, and their importance to the archaeological experts seems to have no grounding in the developer's own world view. Even if a developer disagrees with the need for the regulatory process, cannot understand why archaeology occurs where it does, and sees the evaluative process as arcane and idiosyncratic, a forecast of what is likely to be found and how it may be evaluated is tremendously useful.

The regional benefits of better, faster, more available information on known and forecasted archaeology has statewide, and multi-state implications. The Montana portions of the Powder River Basin and Tongue River Basin (PRB/TRB) are obvious candidates for extending the "information environment". On a more general level, a sound information infrastructure – in advance of development – will yield benefits because development decisions can be made that avoid legal, administrative, and procedural

entanglements. For example, a member of the company that held a very contentious lease in Weatherman Draw, Montana, told us that if the company had known the archaeological "risk" was so high, they probably would not have bid on the lease at all.

Process change is another area in which AMP has relevance to energy development in the PRB/TRB, in Wyoming, and on public lands in general. AMP makes process change feasible in three significant ways. One of these has to do with timing and the use of consulting experts, the second is in how fieldwork is conducted, and the third is in how management plans and requirements are presented to developers and planners.

The first process and management change is in the timing of decision-making and the role of archaeological consultants in the decision. In the PRB/TRB, the CRISP tool involves oil and gas developers in assessing the "risks" their project may face directly. Until now, this has usually been done by hiring a consultant and in discussion with the land managing agency cultural resource specialists. This makes possible a change in the process of development from the standpoint of cultural resource management because developers can employ consultants at more appropriate points in the process. For instance, rather than hiring a consulting archaeologist as part of creating a first pass at a POD, a developer could create several fairly informed POD alternatives and *then* hire a consulting archaeologist to aid in finding the most efficient (from an archaeological standpoint). The decision-making locus is moved earlier in development. Downstream from this decision nexus, the lead agency staff will receive PODs that are clearer in their assessment of potential archaeology. Consulting archaeologists can be brought in early in

the process too – and will no doubt have very high value in it – but there may be less fieldwork to evaluate alternative plans. This change is especially important because archaeology can consume a significantly higher portion of POD development costs than it does in petroleum development. Using consultants and staff time efficiently is sound business practice anywhere, but probably essential in CBNG development.

The second process and management change in the PRB/TRB lies in archaeological field protocol, especially for finding buried cultural materials. The buried archaeology model created in this project can change the requirements for how sites are evaluated and even when they must be evaluated. Appendix C of this volume is a field protocol for assessing whether a site is likely to contain buried materials. Using this protocol as the basis for an agreement about evaluation fieldwork could be in the best interests of federal agencies and the State Historic Preservation Office. The field protocols provide an objective, standard assessment tool. This can become a baseline for evaluations (rather than the sole means of evaluation).

How can such a baseline procedure work in practice? Each archaeological crew chief working in the PRB/TRB can be required to understand the observation and evaluation criteria (this could be done through workshops, for instance). Upon encountering an archaeological site, the crew chief then makes the appropriate observations. This is part of the standard site documentation in the PRB/TRB. In order to avoid confirming the consequent – not finding anything buried because the protocol says one need never look for anything buried – a random sample of “surface only” evaluations should be re-

examined by a geoarchaeologist and a small crew. This re-evaluation can be done years later and in one pass throughout the study area, i.e., as a distinct investigation funded separately. The geoarchaeological investigation's purpose is to validate and refine the field protocols (and the buried site model), not to review the management decisions made already. Participating in the evaluation process could be made part of lease stipulations – pushing the change far upstream from development actions.

Open trench inspection (OTI) needs to be treated like any other form of archaeological investigation until confidence in the buried site model is gained. If this confidence is gained, then OTI needs can be forecast and even presented as a layer in the CRISP tool.

The benefits of these changes in the PRB/TRB extend beyond the study area. Again, the CBNG development in southern Montana is obviously suited to a similar approach. Even in areas of petroleum development, though, similar approaches can work well. Indeed, at the Beaver Creek Field south of Lander, Wyoming, a programmatic agreement uses geoarchaeological research results to justify changes in inventory procedure. This sort of approach can be part of a regional stipulation package, whether in the PRB/TRB or in specific regions of the public-lands-dominated western U.S, avoiding the well-by-well (or POD-by-POD) time and costs by which work is currently done.

One frustration of energy developers that we encountered is they think management requirements for cultural resources are inconsistent and obscure. Above, we refer to creating stipulations that are appropriate for different settings and areas within energy

development on public lands. For cultural resources planning and assessment, this project has already created the tool – CRISP – that can convey these different management requirements or stipulations. If they can be mapped, then they be displayed using CRISP. We think this would be beneficial within the PRB/TRB and in any area of development on public lands. Stipulation packages in general could be conveyed using the CRISP tool. This will enhance the ability of industry to plan for cultural resources management.

Forecast Models – Implementing and Using the Buried Deposit Model

Archaeologists have created models as hypotheses or propositions amenable to testing for more than 50 years. Models take many, many forms, ranging from subjective "crayon on the map" to elegant formal sets of equations. They all share the same basic goal: to systematically extend our knowledge about something by both simplifying it into fewer key observations and extending knowledge by generalizing across unexamined cases. For example, the simple prediction that "sites are near water" means we need to seek water if we wish to find sites (a simplification of what we must observe to find sites), and furthermore that any new water location should or may have sites near it (a generalization about unexamined cases). Models continue to find favor because they are useful (Clarke 1968).

Cultural resource management has used model-based approaches since the early 1970s, and saw a major period of interest and use in the 1980s (Judge and Sebastian 1988). Models as management aids or tools fell out of use in the 1990s due to deficiencies

perceived in the models of the 1980s. Many of the deficiencies noted in the 1980s models are still characteristic of models today. These include a lack of provision for realistic testing that then leads to a lack of confidence in the model, overly complicated predictions that cannot be observed in the field, and no way to revise a model once it is created. Some other shortcomings have been made up in part or full. These include the ability to gather basic spatial and attribute data swiftly (once it is in a GIS and database system), the ability to do calculations rapidly (e.g., spreadsheets) and the ability to communicate results in useful, often geographic, forms (GIS and on-line map services).

Archaeological model building has often been characterized as "predictive" modeling. "Forecast" is a better, more appropriate, verb, for it conveys the generalized and probabilistic nature of archaeological models. Archaeological models summarize the likelihood of observing something that is the outcome of one or more complex, hard-to-know, historical processes. Whether one chooses a deductive approach, an inductive approach or a combination (Kohler 1988), the resulting model is more of a forecast than a certainty. Too, when it comes to testing forecasts, like testing a weather model, one can never be certain that a test outcome is what it seems. For instance, if we had a weather model in which we forecast rain, and a few drops fell at the right time and place, was the model upheld? What if we had instead phrased the prediction as "not sunny" – would the outcome have been more easily interpreted? Archaeological models face these same challenges. Finding a site where none was anticipated does not mean the model is falsified, does it? What about finding nothing where we expected something?

Shifting the frame of reference in archaeological models from prediction to forecast is important, because it also changes the actions one considers reasonable to implement, test, and evolve an archaeological forecast.

This report presents a forecast of where one is likely to find buried archaeological sites in the PRB/TRB. This forecast has immediate utility (which we have discussed above), and like all models, immediate problems. First, the model is formed using imperfect data. The soil surveys, geomorphology, and maps that were used to define areas of fine-grained, Holocene or Late Pleistocene, gently deposited sediments are not equally accurate. Where their errors overlap, the forecast will be poorest. Second, the model is difficult to test. *A priori*, if one uses the model as we have suggested and avoids trenching in areas of high buried archaeological probability, then a sample of observations to test the validity of this forecast can never be assembled.

Archaeological models need maintenance to stay useful, and the models presented here are no exception. If models are not improved over time, then the users of the model stop trusting the model when anomalies build up. Long-term maintenance of the PRB/TRB model requires regular, periodic, investment in its maintenance. Maintenance for the PRB/TRB model consists of these actions:

Improve the source information

Map and evaluate areas of effective model testing

Reformulate the model, perhaps in part

The PRB/TRB model sources relies upon soils information, topography, land form maps, and valley fill definition. We can expect that better information on soils, topography, and valley fill will be forthcoming, especially as development continues in northern Wyoming. For instance, if a 10 m digital elevation model became available, then slope and flat valley floor definitions should be re-created and the model should be updated with the new definitions, at least in those areas where the new information exists and there is management or scientific information.

One of the reasons why models do not get updated with new information is because "getting the data" the first time is expensive and no funding is available for a second round. However, the update of information and recalculation of a model is usually far less costly than building a new model. The most significant difficulty is in knowing that new information of relevance is available. The Geospatial Portal managed by the Wyoming Oil and Gas Commission is a logical place to require posting of new datasets so that one would seek them in a single internet-accessible place.

Mapping areas where the model has been evaluated is essential. As Eckerle noted, no systematic large-area trenching has been conducted to test this model. There is no reason to expect that there will ever be sufficient basin-wide geomorphological or gearchaeological projects to really test the deposit model in one pass. Instead, one must rely upon individual excavation projects to accumulate information. Every trenching project needs to be mapped accurately and should receive some examination for

archaeological materials in trench walls and backdirt. The entire extent of an examined trench should be mapped by survey instrument (resource-grade GPS is sufficient) – this is the "survey area" for buried cultural materials. New archaeological finds within the trench (i.e., with no surface expression) need to be mapped in their extent along the trench. Buried archaeological materials (more than 20 cm deep) observed in the trench walls within existing surface sites need to be mapped too. Then, for each trench inspection, a summary page should be created.

Each completed trench inspection report should be treated as an investigation in the WYCRIS database. It should be entered in WYCRIS, the coordinates or GIS data provided used to populate one or more GIS layers of subsurface investigations, and the associated sites (if any) should be given standard site numbers. This will create an accessible, systematic, database of records to used in evaluating the model's forecast capabilities and revising the model too. Site testing is essentially the same as a small subsurface investigation and should be reported in a similar, non-burdensome, fashion.

These protocols can be established as part of stipulations made on each oil and gas lease, cultural resource use permit, or other regulatory mechanism. They need not require a geomorphologist, so long as the field archaeologists have been properly trained in how to check for subsurface materials and take other appropriate observations. BLM Wyoming and Wyoming SHPO may wish to consider one or more workshops on geoarchaeology and reporting for consultants and staff doing fieldwork within the model forecast area.

Reformulation of the model is an expert task. Calculating a new model is only warranted if the current forecast is ineffective or wrong *and* there are good reasons to think a better forecast can be made. Above, we have noted that inventory and excavations in the study area are not equally distributed across the forecast strata of the depositional model. It would not be surprising to find that strata with almost no investigations in them have poor forecasts. Until we have some new information (investigation results, base data, etc.) with which to improve the model there would be no point in recalculating it. We would simply not rely upon the forecast of the current model *in those particular settings.*

The model need not be recalculated or revised as a whole. As the example above provides, one could instead take a particular setting or geographic area and update only that part of the model. A user of the model would of course want to know that different "parts" have different issue dates – in essence the model becomes a quilt of sub-models. This has been provided for already in the CRISP tool model presentation and documentation.

The strongest model will only have value if its use is sanctioned and even promoted. This is a management issue, not a problem of archaeology or information technology. Cultural resource specialists, in the field office and the state historic preservation office, must be willing to utilize the model. This involves a degree of experimentation that some may find unacceptable in a regulatory environment. Yet, this would be "experimentation" only if one decides it falls outside of the consultative process. Kincaid, writing in a BLM

issued volume published in 1988 on the very topic of models in cultural resource management, stated:

> The decision as to whether or not modeling should be part of an inventory and evaluation approach depends on individual circumstances. A decision to use modeling complies with the regulations if it was reached in accordance with the consultation procedures [of Section 106 of the National Historic Preservation Act]. (Kincaid 1988:550)

For the DOE Wyoming study area an ideal management solution would be a programmatic agreement between the BLM and the Wyoming SHPO defining how the model will be implemented and maintained. If this agreement is well-crafted, then it should add little to anyone's current workload because much of the model use, evaluation, and implementation tasks occur anyway.

Administrative and management support may be easy to obtain over the next two to three years, while the model is new. If history is any guide, then support will either be solidified or wane, depending upon the perceived utility of implementing the model. Measuring whether the model is "working" in planning, compliance, and preservation is the key to making support decisions objectively. In brief, one really wants to know how much the model "saved": in lost time, in dollars, in archaeological sites, or some other measure. There is a paradox here though – how does one evaluate what would have happened if the model did not exist?

Over time, the cost of inspection and monitoring in "high sensitivity" areas should be compared to the cost of doing work (with whatever inspection is required) in low sensitivity areas. The cost per unit of ground disturbance should be compared to determine if the model is saving money. Similarly, CRMTracker and the Wyoming SHPO review database should be queried to see if "low sensitivity" projects proceed faster from fieldwork start to decision date than "high sensitivity" projects. Finally, one of the most important things that the buried deposit model can do is to open up areas for ground disturbance without requiring inspection or monitoring. Here, one can measure what was "lost" by allowing disturbance without monitoring – so long as discoveries (buried unexpected sites) are reported anyway. These long term costs and benefits will take time to calculate – we think 10 years is not too short a period over which to accumulate this information.

The modeling approach taken here could be broadened in several ways. First, within the area of CBNG development itself, it would be straightforward to extend this model northward into the Montana portions of the PRB/TRB. Second, a similar approach for buried deposits would use very different analyses but would be equally useful in southwestern Wyoming where ground disturbance is just as intense. Third, the buried deposit model should be seen as one of several models that could be created and have great utility. A surface archaeological density model might be useful, as might a model of historic settlements (this might even just be a thorough map drawn from historic records).

The framework for making these models available will accommodate any number of models – CRISP will simply analyze each appropriate model for a proposed project area.

There are many reasons to think that the use of models of cultural resources occurrence and character will continue to grow, as it has over he past five to ten years. Model-based management is sensible because, even if the models are flawed, they summarize and communicate knowledge. Models broaden out the availability of information, and as the complexity of decision-making in which cultural resources are a factor grows, the use of models as summaries of information will grow too. Model outcomes can be various and still be quite useful: the risk of encountering something (buried or on the surface); the character of resources likely to be encountered (site content or likely NRHP significance); the potential to find materials of a particular age. Models are also popular because they aid in rough planning of work effort to conduct an investigation. The use of public lands, where field investigations are nearly always mandated, has escalated in the past 25 years, and consequently so has the acreage and cost of archaeological inventory needed to use those lands. Managers and land use proponents have a keen interest in reducing these costs through more tightly defined land use envelopes and through eliminating redundant or useless inventory. Models are an important basis and have value for both of these purposes.

CONCLUSIONS

Future Directions for Management and Research

Much of the AMP is concerned with summarizing information in ways that are useful to land users and land managers. Management on the public lands is guided by management documents that go through public review processes. BLM's Resource Management Plans, for example, are formal documents that state management goals and procedures for specific areas under BLM management. Cultural resources are always an element of such plans.

An immediate benefit of the AMP is that by making information much more available, the cultural resources elements of management plans should be far less costly and time-consuming to create. Whether this will result in higher quality, more appropriately tailored resource management plans, or simply lower costs and faster delivery times for planning documents remains to be seen; these are decisions that managing agencies need to make. Potentially, better cultural resource elements in management plans will make the plans more informative for land users, and also give more explicit rationales for decision-making about cultural resources preservation. For example, a "better" cultural resource management plan can consider whether a particular kind of archaeological site is common or rare in the management area, and thus justify preserving or allowing destruction of a *particular* site of that type.

The use of models as tools in the cultural resource managers toolbox is, generally, lacking. In our discussion of models, we touched on the importance that they can have for effective planning. During the course of this project, we spoke with many agency cultural resource specialists. All were interested in the outcome of model-formation. Few were comfortable with the notion of using a model of archaeological phenomena to guide decision-making about the appropriate treatment of archaeological sites. We think this reluctance stems from three systemic sources, which we might call the model-phobia syndrome. First, many cultural resource specialists do not understand the *improbabilities* of model formation: they wish for a "right" answer. Above, we have taken some pain to dispel this idea about models, for they are always "wrong" in some way. Second, and in turn then, cultural resource managers think that using a model to justify a decision will be seen as insufficiently thorough. Third, there is no management mandate or support for changing the work process by using model-based approaches, even just as a component of the regular management actions. These three system conditions create the model-phobia syndrome.

Addressing the model-phobia syndrome is an important management need for implementing changes that the Wyoming and New Mexico portions of the AMP are suggesting. Better education of field staff about how models are used effectively and upper management insistence that models get used (and maintained) once they are created will alleviate the syndrome. Perhaps an analogy will make this clearer. In the early years of aviation engineering, the only way to determine whether a design worked was to build it and then fly it – with all the attendant perils and costs. As aviation

engineering advanced, engineers realized they could use an actual model in a wind tunnel to forecast *some* aspects of aircraft behavior. At some point, a commitment was made to rely upon these *model-generated* results in assessing aircraft designs. Further tests still relied upon the actual aircraft prototype, but forecasts generated by a model were considered okay. There must have been some point at which a leap of faith was made, and an engineer (and manager, and investor) made a decision to rely upon the model. Cultural resource management in oil and gas settings has reached the point at which the leap of faith is needed. This project has done its best to make that leap as little a jump as possible.

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