Final Report:

Technical Support for Trail Restoration and Maintenance for Arches and Canyonlands National Parks

By

Henry Shovic, PhD

Rocky Mountain Cooperative Ecosystems Study Unit
Department of Ecology, Montana State University

May 4, 2009

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Henry Shovic, PhD
Rocky Mountain Cooperative Ecosystems Study Unit
May 5, 2009

Objectives and Summary

This report is part of RM-CESU Cooperative Agreement Number: H1200040001 (IMR) titled "Technical Support for Trail Restoration and Maintenance for Arches and Canyonlands national Parks". It is designed to be a pilot project to support a larger effort to increase road and trail sustainability in these National Parks, responding to growing visitor use, increasing resource damage, and climate change.

Scope: The present tasks and products are designed to be a pilot project to support a larger effort to increase road and trail sustainability in these National Parks, responding to growing visitor use, increasing resource damage, and climate change.

Because this is a pilot project, data collection is limited to available GIS data, other spatial data, and field review as specified below. Specifications or tasks may, however, be modified to fit emerging needs as they are identified. To assure project objectives continue to be relevant, the cooperator will coordinate closely with National Park Service (NPS) personnel, especially with Trails and Roads, GIS, and Resource Management.

Following are the project objectives and the sections in this report that address each one.

Objective One: To provide a synthesis of current trail maintenance methods and a perspective on the sustainability program in Arches and Canyonlands National Parks.

- Task A: Research and synthesize technical documents and methods of trail restoration used in arid landscapes, including literature used in the BLM, USFS, and NPS; and field review with trails and roads specialists. This includes both general soil conservation and erosion control recommendations for trails and roads, and specific methods used in Arches and Canyonlands National Parks.

The reports listed under Objective Two include specific reference to trail maintenance and construction methods used in Arches and Canyonlands National Parks and their effectiveness. A general literature search was performed to locate both government and NGO documents pertaining to trails, including the most up-to-date information used in

Federal land management agencies. An annotated bibliography is included in Appendix Five.

Objective Two: Re-route projects - alternative development analysis and support.

- Task A: Provide site-specific project services, including analysis and display of vegetation, landscape, and soils information in map form and development of reroute alternatives using landscape data, visitor use information, local NPS management and specialist input. This can include 3-D scientific visualization, viewshed analysis, quantitative analysis of potential soil and vegetation impacts, and field review and documentation.

Three project areas were investigated and reported. These were by request of Park Management.

- *Arches National Park – Devil's Garden Trail System – Appendix Two*
- *Canyonlands National Park – Fort Bottom Trail System – Appendix Three*
- *Canyonlands National Park – Salt Creek Road Analysis – Appendix Four*

Objective Three: to help inventory and prioritize potential trouble areas, as well as support decision making on use management, as well as to provide factual support for trail condition classification for one National Park (selected by NPS).

- Task A: Synthesize and spatially present available soil survey and landscape data (including elevation, vegetation, slope, and available condition inventories).
- Task B: Develop and implement a way of spatially showing potential trouble areas in on a Park-wide basis for management. This spatial analysis will use geology, soils surveys, landscape data, interviews with resource specialists, and site visits.
- Task C: Increase the factual database of effects and conditions on the ground, including representative field observations and expert opinion of resource specialists.

Two map/posters were developed showing various aspects and interpretations of existing landscape spatial data, in particular the old published soil surveys of both Parks, and the new draft vegetation mapping for both Parks. An attempt was made to obtain new, nearly completed soils information, but the request to the Region was turned down.

An example structured decision model was developed and presented for showing potential trouble areas on a Park-wide basis for managers. This is included in this report.

Factual effects and conditions on the ground were documented by the three project reviews shown above.

Products: Products include reports, maps, spatial data, site reviews with specialists, and presentations for management. For the defined scope of this pilot project, the following are anticipated.

- Up to 10 different maps at 36 in by 48 in and 8.5 x 11 size suitable for presentation (provided in hard-copy, Adobe Acrobat (pdf), and images for Powerpoint (jpg) at appropriate resolution).
- 3 documents in WORD format presenting results under each objective.
- 1 presentation of results for on-site managers.
- Remote briefings as requested.
- Two field excursions of 3 days each (GPS data collection and QA/QC field verification, and final presentations of project results).
- Spatial and analysis data provided via FTP or DVD, including collected and synthesized base data, metadata, and all GIS analysis projects. All new spatial data will meet all NPS spatial data standards.

Two field excursions were completed (Nov, 2008 and April, 2009) of three days each. A zip file has been created containing all generated spatial data, maps in PDF and image format, analytical products, literature, and this document. A presentation for on-site managers was made on April 14, 2009. The Powerpoint slides are included in the zip file. Copies of the presentation maps and reports were forwarded to Jeff Troutman on or before this date.

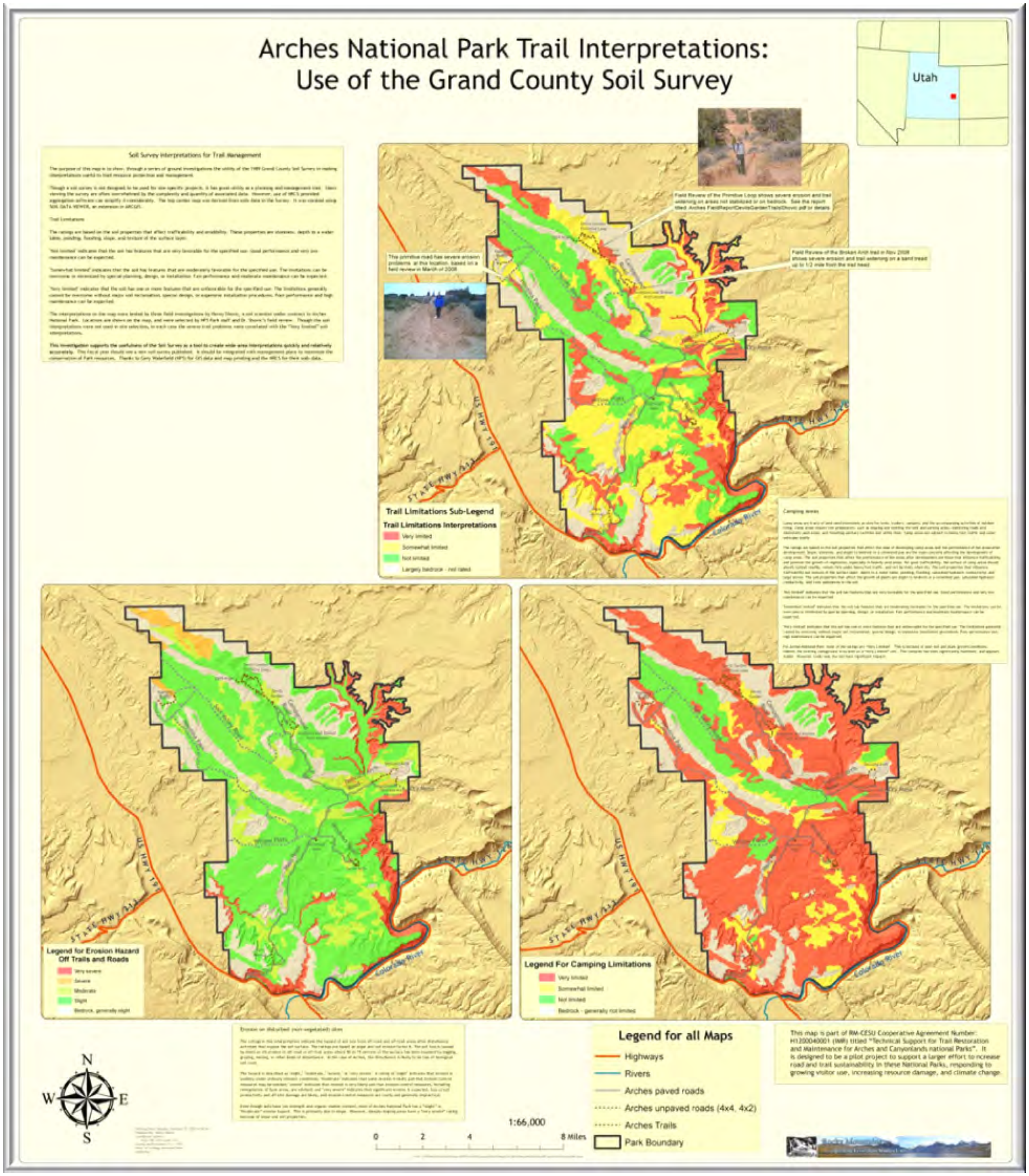
Results

Soil Survey Interpretations for Trail Management

The purpose of this map is to show, through a series of ground investigations the utility of the 1989 Grand County Soil Survey in making interpretations useful to trail resource protection and management.

Though a soil survey is not designed to be used for site-specific projects, it has great utility as a planning and management tool. Users viewing the survey are often overwhelmed by the complexity and quantity of associated data. However, use of NRCS-provided aggregation software can simplify it considerably. The top-center map was derived from soils data in the Survey. It was created using SOIL DATA VIEWER, an extension in ARCGIS.

This investigation supports the usefulness of the Soil Survey as a tool to create wide-area interpretations quickly and relatively accurately. This fiscal year should see a new soil survey published. It should be integrated with management plans to maximize the conservation of Park resources. Thanks to Gery Wakefield (NPS) for GIS data and map printing and the NRCS for their soils data.



Arches National Park Trail Interpretations: Use of the Grand County Soil Survey Full Map

Trail Limitations

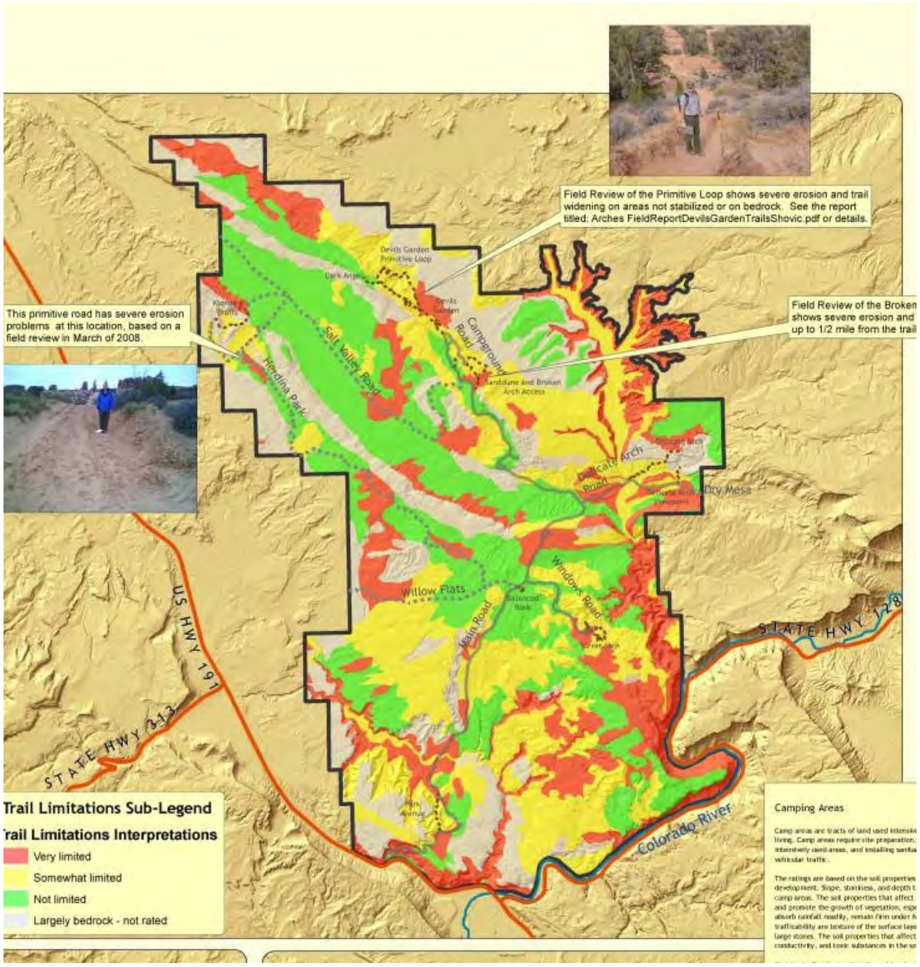
The ratings are based on the soil properties that affect trafficability and erodibility. These properties are stoniness, depth to a water table, ponding, flooding, slope, and texture of the surface layer.

"Not limited" indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected.

"Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected.

"Very limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

The interpretations on the map were tested by three field investigations by Henry Shovic, a soil scientist under contract to Arches National Park. Locations are shown on the map, and were selected by NPS Park staff and Dr. Shovic’s field review. Though the soil interpretations were not used in site selection, in each case the severe trail problems were correlated with the “Very limited” soil interpretations.



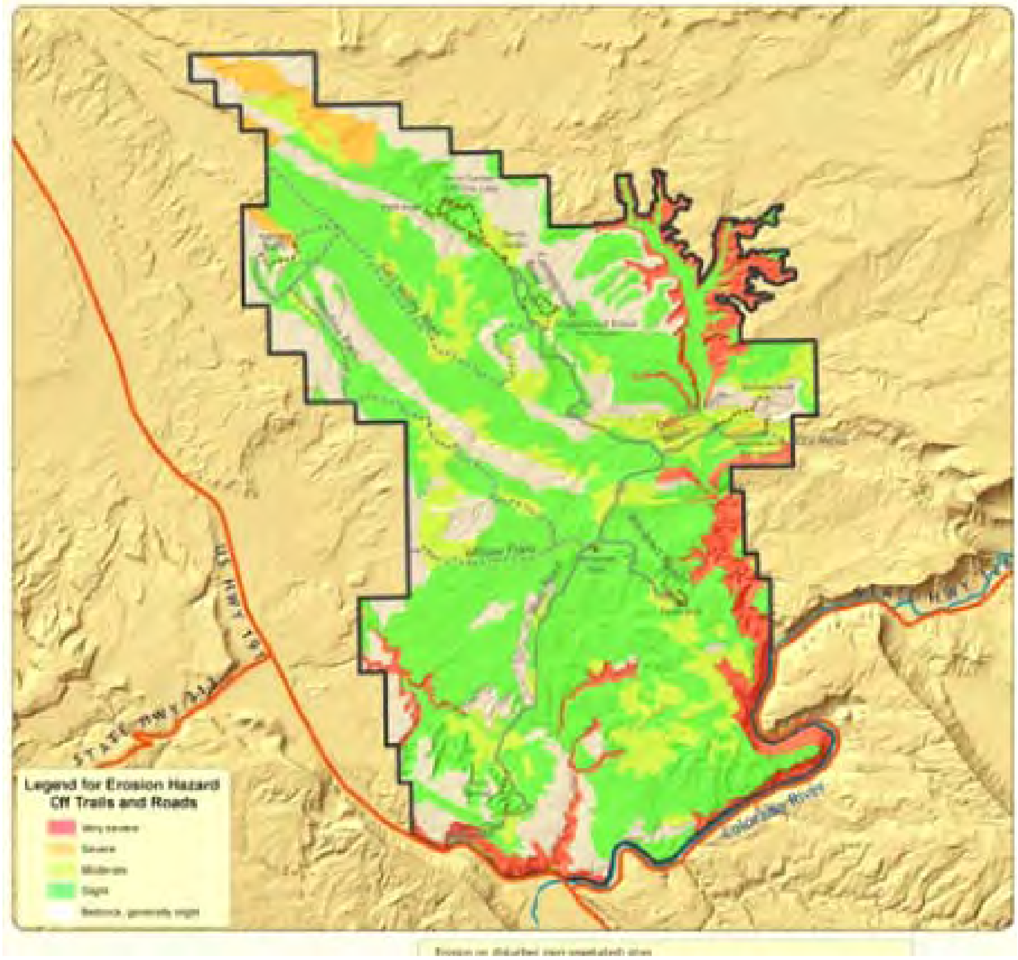
Trail Limitations

Erosion on disturbed (non-vegetated) sites

The ratings in this interpretation indicate the hazard of soil loss from off-road and off-trail areas after disturbance activities that expose the soil surface. The ratings are based on slope and soil erosion factor K. The soil loss is caused by sheet or rill erosion in off-road or off-trail areas where 50 to 75 percent of the surface has been exposed by logging, grazing, mining, or other kinds of disturbance. In the case of Arches, the disturbance is likely to be loss of biological soil crust.

The hazard is described as "slight," "moderate," "severe," or "very severe." A rating of "slight" indicates that erosion is unlikely under ordinary climatic conditions; "moderate" indicates that some erosion is likely and that erosion-control measures may be needed; "severe" indicates that erosion is very likely and that erosion-control measures, including revegetation of bare areas, are advised; and "very severe" indicates that significant erosion is expected, loss of soil productivity and off-site damage are likely, and erosion-control measures are costly and generally impractical.

Even though soils have low strength and organic matter content, most of Arches National Park has a “slight” or “moderate” erosion hazard. This is primarily due to slope. However, steeply-sloping areas have a “very severe” rating because of slope and soil properties.



Erosion Hazard

Camping Areas

Camp areas are tracts of land used intensively as sites for tents, trailers, campers, and the accompanying activities of outdoor living. Camp areas require site preparation, such as shaping and leveling the tent and parking areas, stabilizing roads and intensively used areas, and installing sanitary facilities and utility lines. Camp areas are subject to heavy foot traffic and some vehicular traffic.

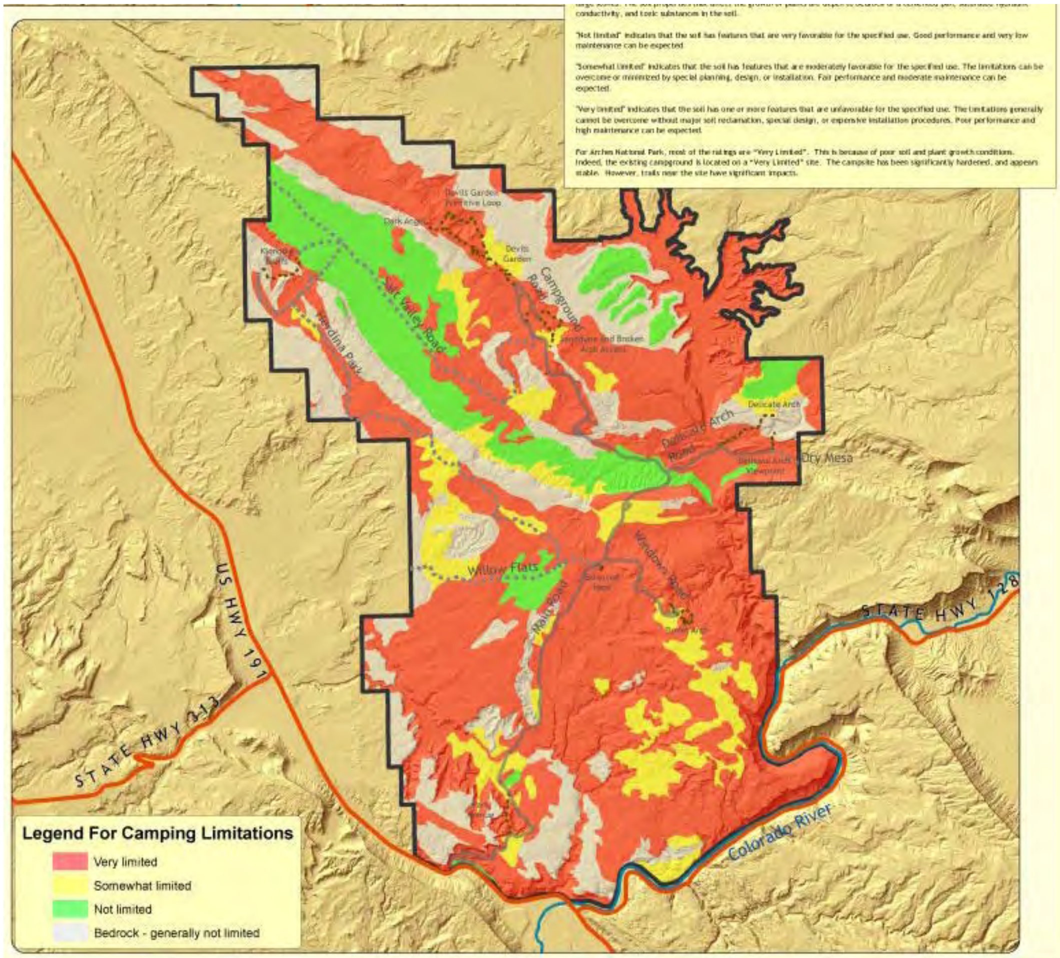
The ratings are based on the soil properties that affect the ease of developing camp areas and the performance of the areas after development. Slope, stoniness, and depth to bedrock or a cemented pan are the main concerns affecting the development of camp areas. The soil properties that affect the performance of the areas after development are those that influence trafficability and promote the growth of vegetation, especially in heavily used areas. For good trafficability, the surface of camp areas should absorb rainfall readily, remain firm under heavy foot traffic, and not be dusty when dry. The soil properties that influence trafficability are texture of the surface layer, depth to a water table, ponding, flooding, saturated hydraulic conductivity, and large stones. The soil properties that affect the growth of plants are depth to bedrock or a cemented pan, saturated hydraulic conductivity, and toxic substances in the soil.

"Not limited" indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected.

"Somewhat limited" indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected.

"Very limited" indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

For Arches National Park, most of the ratings are “Very Limited”. This is because of poor soil and plant growth conditions. Indeed, the existing campground is located on a “Very Limited” site. The campsite has been significantly hardened, and appears stable. However, trails near the site have significant impacts.



Camping Limitations

Biological Soil Crusts, Soils, and Vegetation

Biological soil crust retention and restoration are important management issues for all desert National Parks. Much is known about crust composition, importance to ecosystem health, ecosystem and soil relationships, and disturbance effects. However, no explicit maps of crust distribution have been developed.

This exploratory project uses simple geostatistics techniques to make a first cut at biological soil crust distribution in Arches National Park. Two additional maps are included on soils surface texture and draft vegetation data to help visualize potential soil/vegetation relationships.

Biological Soil Crust

Independent crust distribution Preliminary was created using plot data from the National Park Service Inventory and Monitoring Program. Three components of ground cover on plots were used (ground lichen, dark cyanobacteria, and moss). Note this refers to absolute proportion, not relative proportion compared to total ground cover. Defined this way, these results show biological soil crusts cover 0 to 97% of the ground surface and have significant geospatial "hot spots" of high and low crust cover (see top map). The reasons for these "hot spots" may not be readily apparent. Gypsiferous soils are not shown here, but may be a significant influence. Relating absolute ground cover to total non-crust cover and past use patterns could also prove useful. Using a more robust geostatistics method could also potentially provide better results (a relatively simple method (inverse distance weighting)) was used in this exploratory project. Transforming the data and applying more sophisticated techniques should improve its usability. Finally, there is a conceptual difference between present crust condition and status of crust recovery. This would need further require further exploration of the data.

Soils

Some general relationships have been discovered using monitoring data from the USGS. In Arches National Park, coarse-sandy soils show some crust recovery from grazing and other disturbances. Because of their low productivity, invasive species are not common. However, growth rates are low. This is probably due the unstable nature of these sandy soils.

Silty soils show poor recovery. Though soil productivity is much higher, annual invasives compete for habitat. Soils on Mancos shales have very poor recovery, probably because their high shrink-swell properties. Gypsic soils have high stability and few invasives, so have high crust cover. Some of these properties are shown on the map of surface soil texture, excepting gypsic soils and Mancos shales.

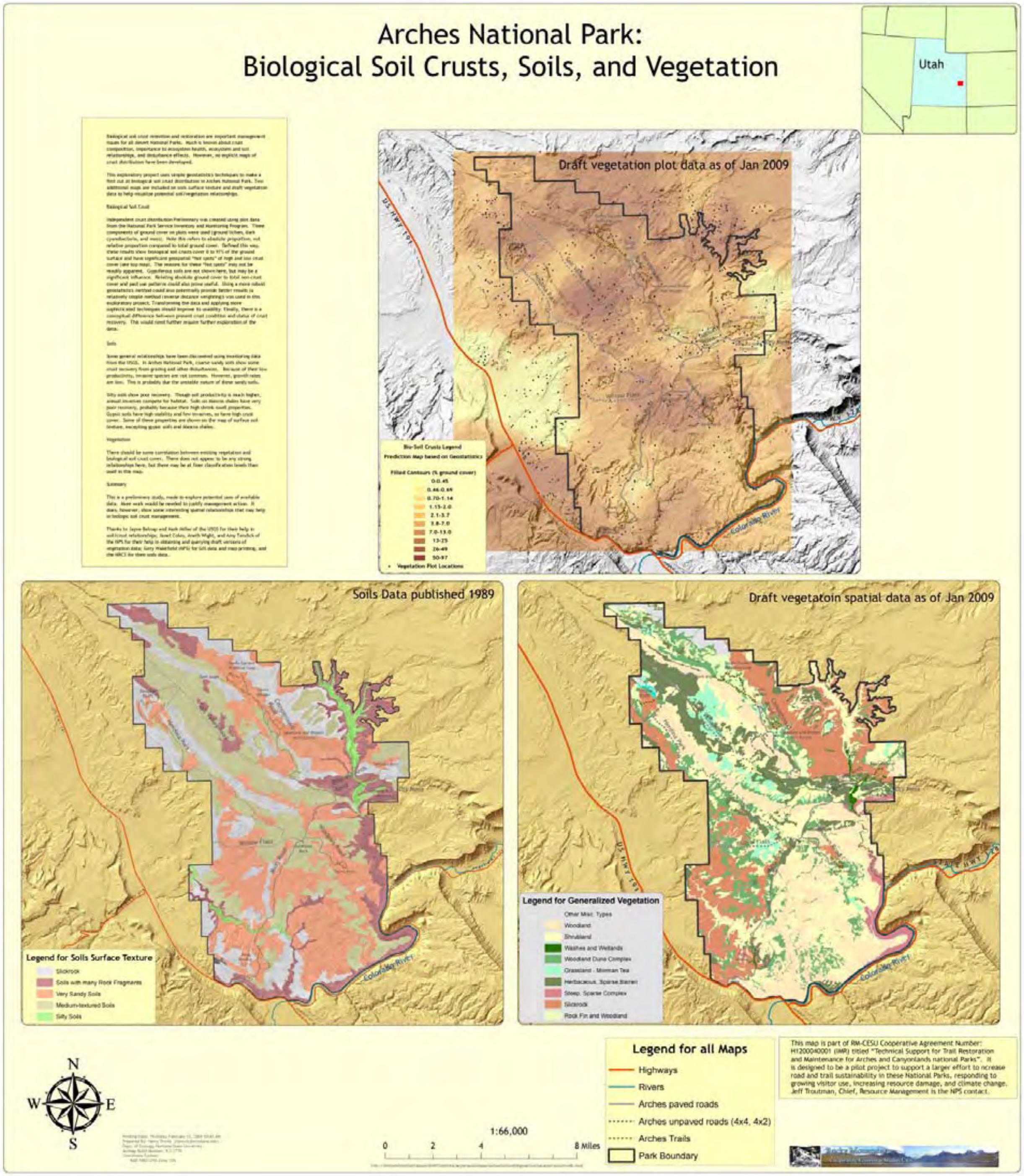
Vegetation

There should be some correlation between existing vegetation and biological soil crust cover. There does not appear to be any strong relationships here, but there may be at finer classification levels than used in this map.

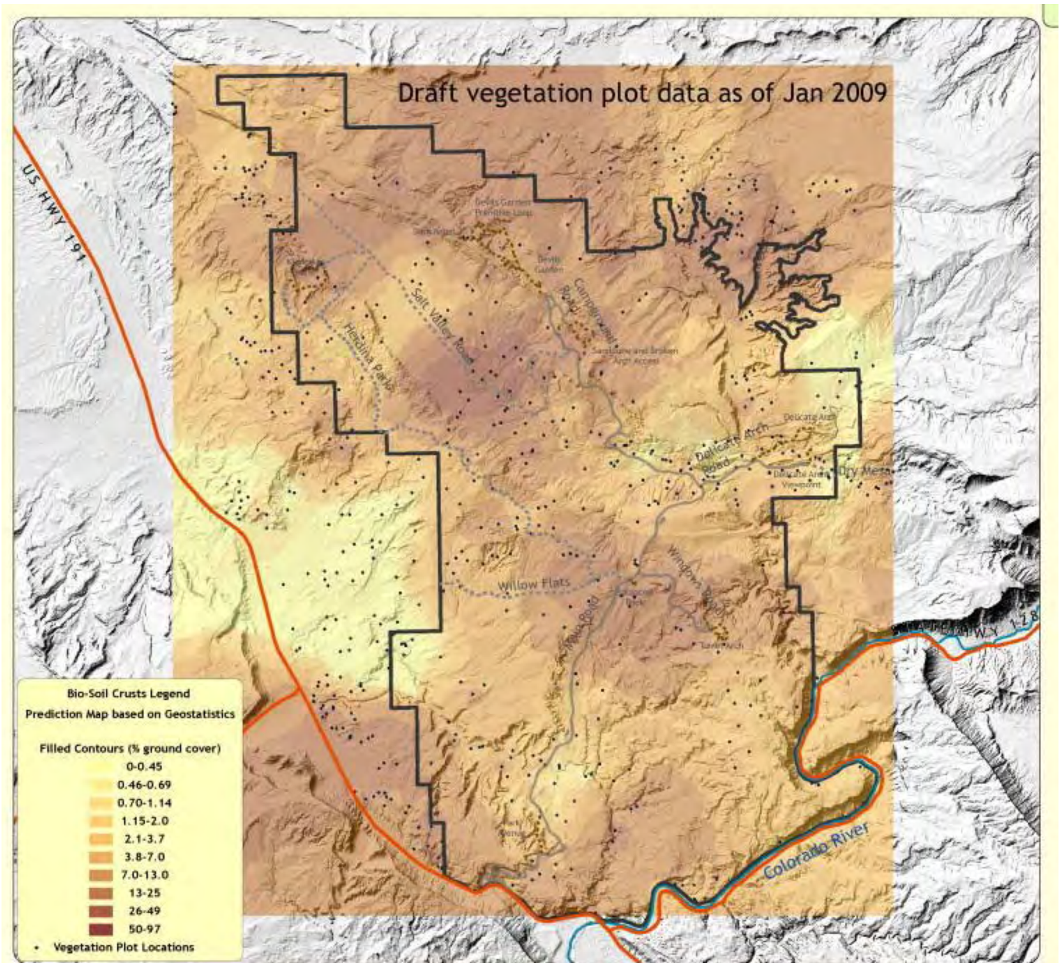
Summary

This is a preliminary study, made to explore potential uses of available data. More work would be needed to justify management action. It does, however, show some interesting spatial relationships that may help in biologic soil crust management.

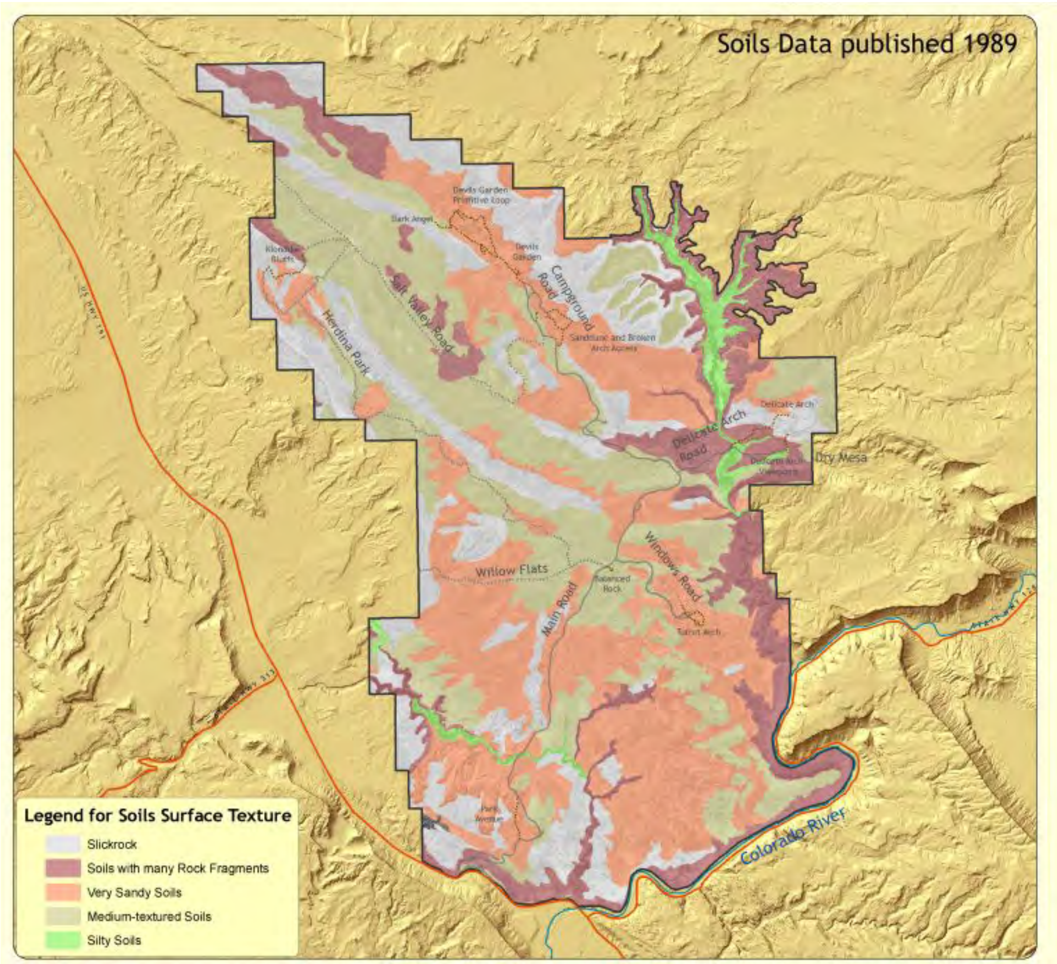
Thanks to Jayne Belnap and Mark Miller of the USGS for their help in soil/crust relationships; Janet Coles, Aneth Wight, and Amy Tendick of the NPS for their help in obtaining and querying draft versions of vegetation data; Gery Wakefield (NPS) for GIS data and map printing, and the NRCS for their soils data.



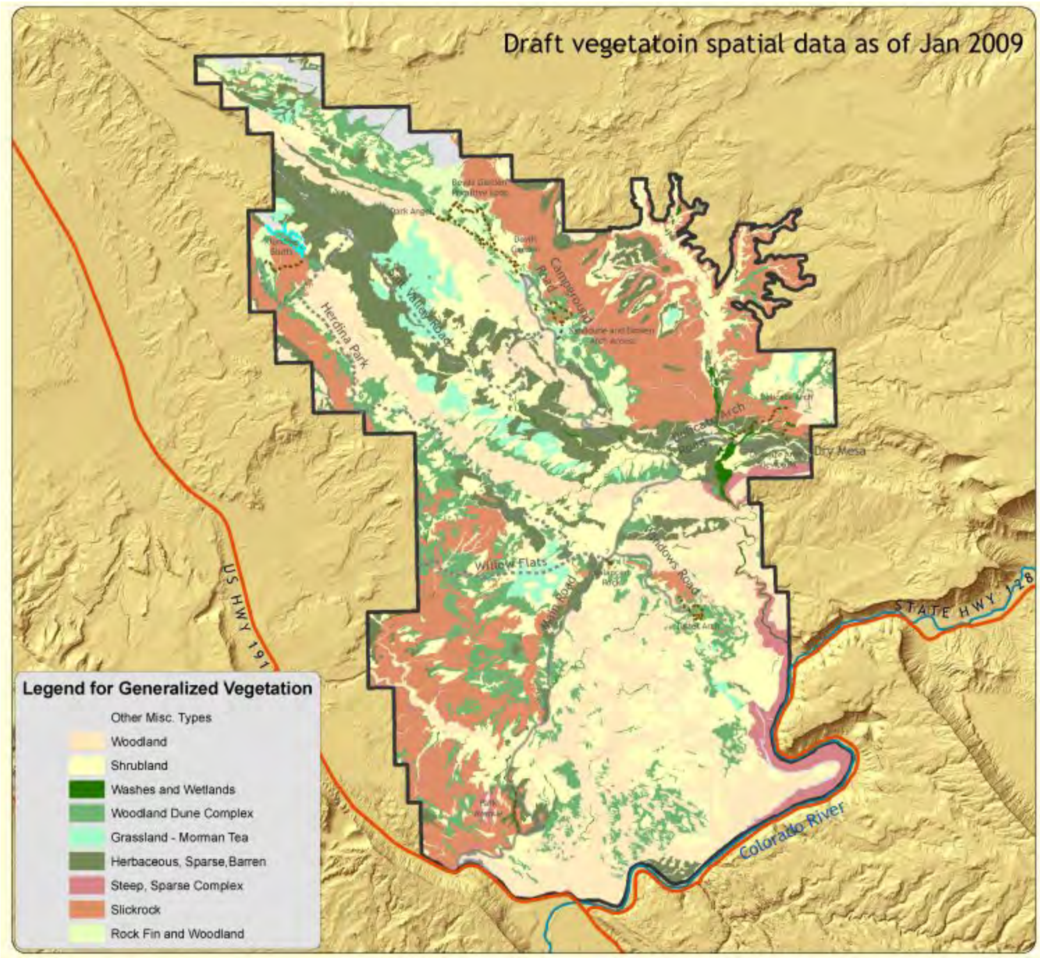
Arches Biological Soil Crusts, Soils, and Vegetation Full Map



Bio-Soil Crust Interpretations from Vegetation Mapping



Soils Surface Texture



Vegetation of Arches

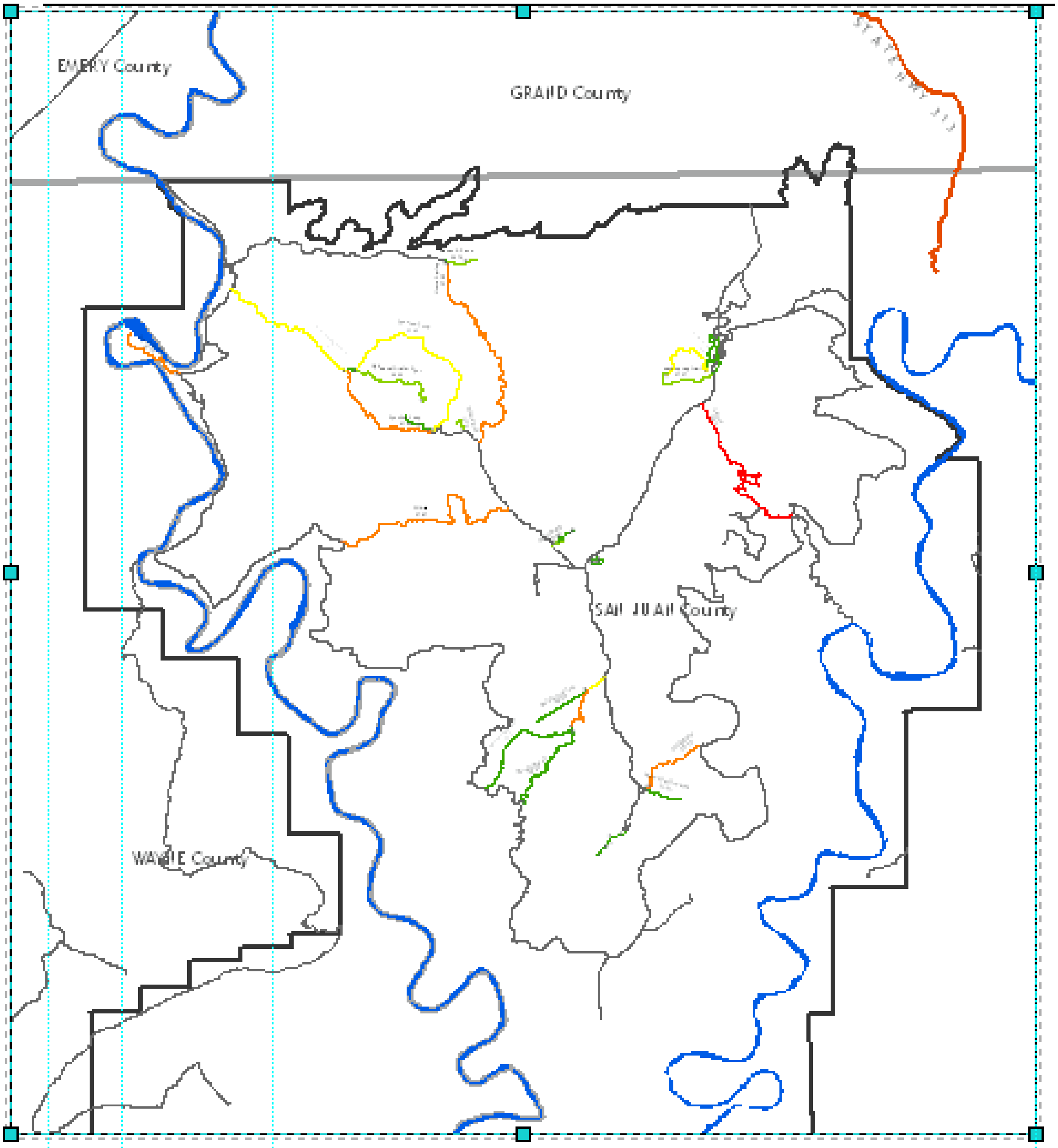
Canyonlands National Park Decision Support Systems: Giving Structure to Decision Making

This section presents a conceptual way of structuring decision making for trail management. It can help prioritize potential trouble areas and support structured use of information in decision making. The system is made up of two parts: Spatial presentation of interpretations on a comprehensive basis, rating all trails for physical sensitivity to erosion; and secondly a way of integrating those interpretations with management decision factors to rate all trails for management priority.

The Island in the Sky District of Canyonlands National Park was use as an example. Since the San Juan Soil Survey was not particularly accurate for soils or interpretations, a physical model was developed on more reliable data. In this case, field data and existing spatial data were used to determine what factors are important, and then to apply those factors across the landscape. A trail spatial layer was attributed from the following spatial query. Sensitive trails were defined as:

- Not bedrock and
  - Slope > 20 or
  - Geology = Moenkopi, and Veg = barren, and slope > 10 or
  - Eolian deposits

Spatial representations came from the geology layer, a 5m slope layer, and the recently-completed draft vegetation layer.



Spatial representation of Trail Sensitivity for Island in the Sky District, Canyonlands National Park

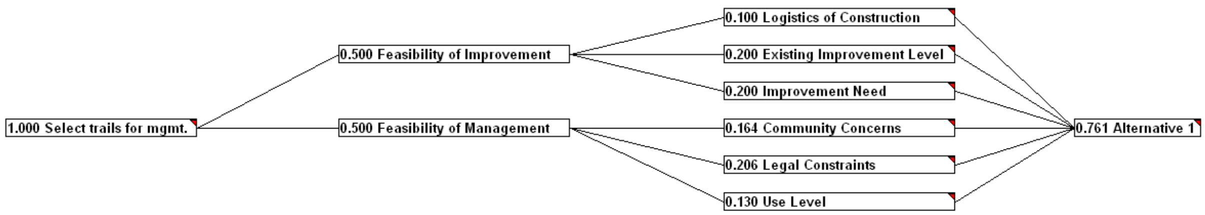
Though this is a useful product on its own, it does not reflect feasibility criteria that Management uses to prioritize actions, such as resource allocations, political considerations, legal constraints, logistical considerations, and use levels. These criteria are captured in the second part of the the decision making system. This part was developed from EMDS (Ecosystem Management Decision Support) , created by the Forest Service and used by many agencies. The modification made here retains the integration of spatial factors, the documentation system, the systematic decision-making process, but replaces the complex physical factor model with a simpler, more usable one.

The software used for this is based on DECISION PLUS (© Criterium Software), and a spatial linkage (PRIORITY ANALYST) developed by that company used in ARCGIS. It includes a structured way of developing criteria, a method of rating those criteria for importance to management, and a spatial linkage to both obtain spatial data and to output results. For this example 40 trail segments were rated, making manual calculations difficult, but easily handled by this software.

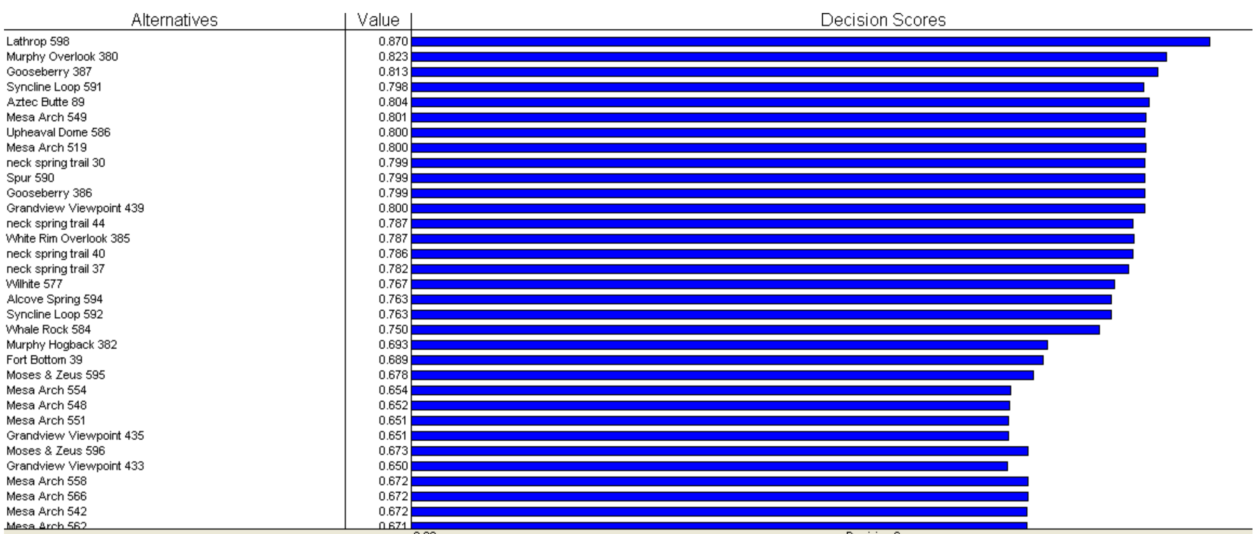
The decision factors used in this example include:

- Feasibility of improvement
  - Logistics of construction (trail length)
  - Existing improvement level (present trail surface)
  - Need for improvement (Sensitivity)
- Feasibility of management
  - Community Concerns
  - Legal Constraints
  - Level of Use (Distance to paved road)

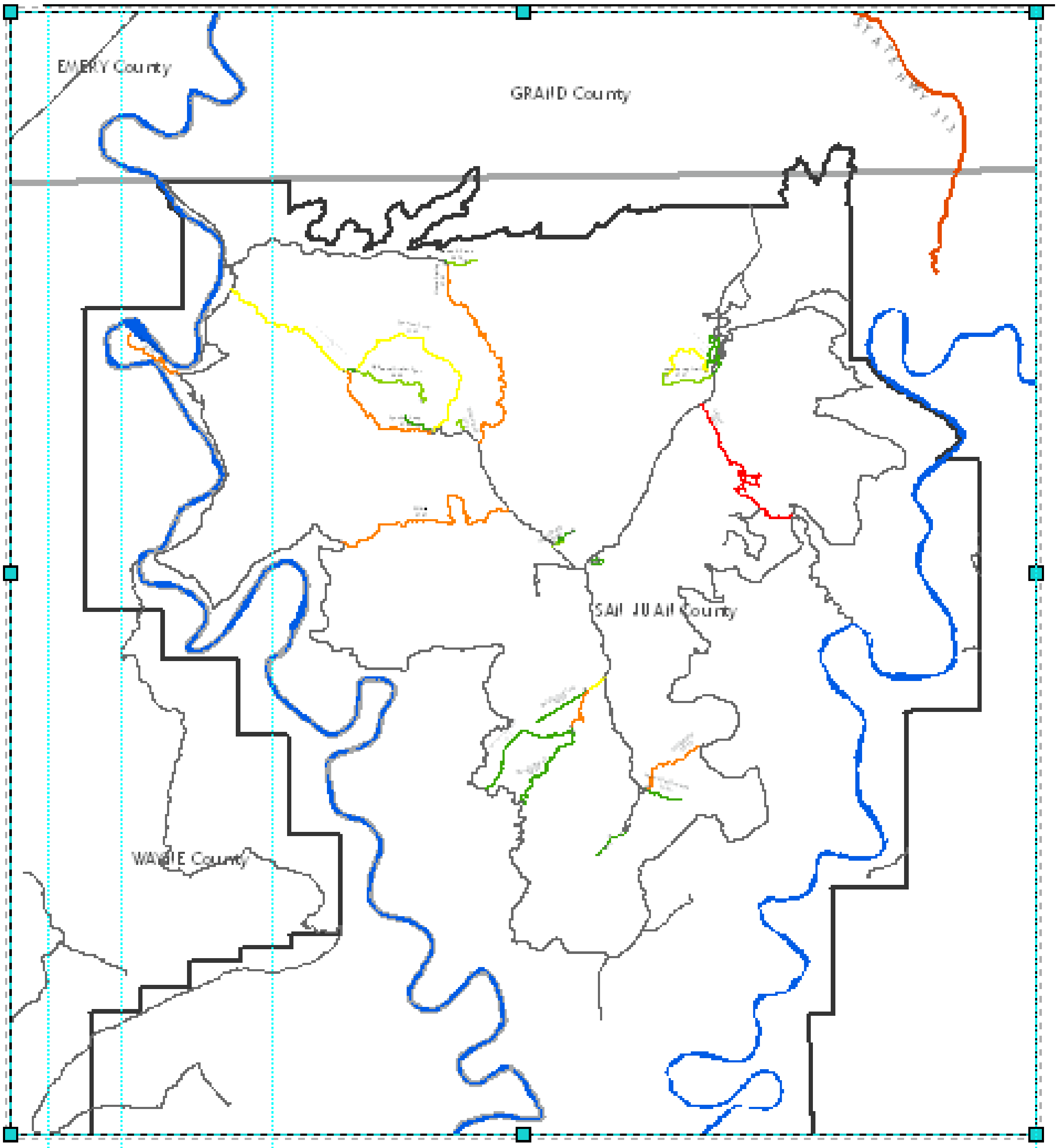
Though legal and community concerns are all rated identically in this example, they could easily be changed in actual applications. The decision model is shown below. Note the numbers next to criteria are weights developed by Management to show relative importance of factors.



Results can be shown in many graphical and tabular forms.



Spatial results are shown below. Note colors refer not to trail sensitivity as shown above, but to the total score of the ratings for all the factors, giving Management a tool for structured decision support, documentation, and the ability to run scenarios of many different weightings and factor ratings. Compare this with the trail sensitivity shown above.



EMERY County
GRAND County
SAN JUAN County
WAYNE County

.

Appendix One: The Project Description

RM-CESU Cooperative Agreement Number: H1200040001 (IMR)

PROJECT COVER SHEET

TITLE OF PROJECT: Technical Support for Trail Restoration and Maintenance

NAME OF PARK/NPS UNIT: Arches and Canyonlands National Parks

NAME OF UNIVERSITY PARTNER: Montana State University

NPS KEY OFFICIAL:
Jeff Troutman, National Park Service, Chief, Resource Management, 2282 S. West Resource Blvd., Moab, Utah 84532; Phone: 435-719-2130 Email: jeff_troutman@nps.gov

PRINCIPAL INVESTIGATOR:
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Montana State University
Department of Ecology
Bozeman, MT 59717-3460
406 994-4548
droberts@montana.edu

RESEARCHER:
Henry Shovic, PhD, Montana State University, Department of Ecology, hshovic@bridgeband.com

COST OF PROJECT:

Direct Cost: $13,075
Indirect Cost (17.5% University-CESU overhead): $2,288
Total Cost: $15,363

NPS ACCOUNT NUMBER: 1341-1000-NZI

NAME OF FUND SOURCE: Park Base

PROJECT SCHEDULE, FINAL PRODUCTS, AND PAYMENTS:

Date of Project Initiation: September 15, 2008 with a completion date six calendar months from project initiation, subject to weather constraints.

List of Products: Products include: reports, maps, spatial data, site reviews with specialists, and presentations for management. For the defined scope of this pilot project, the following are anticipated.

- Up to 10 different maps at 36 in by 48 in and 8.5 x 11 size suitable for presentation (provided in hard-copy, Adobe Acrobat (pdf), and images for Powerpoint (jpg) at appropriate resolution).
- 3 documents in WORD format presenting results under each objective.
- 1 presentation of results for on-site managers.
- Remote briefings as requested.
- Two field excursions of 3 days each (GPS data collection and QA/QC field verification, and final presentations of project results).
- Spatial and analysis data provided via FTP or DVD, including collected and synthesized base data, metadata, and all GIS analysis projects. All new spatial data will meet all NPS spatial data standards.
- Final completion report due to the RM-CESU

Payment Schedule: Payment of regular invoices from the University, as received by the NPS.

> Invoices are payable only if the reports and/or products have been received and approved by the NPS key official. The NPS will withhold payment of the final 10% of project funds until the NPS Key Official receives and approves the final report and/or products. The NPS will not pay invoices for less than $200, unless it is the last invoice to close the project account.

Due Date for Final Report and/or Other Products: October 30, 2009

End Date of Project: March 1, 2010

CONTRIBUTION OF PROJECT TO OBJECTIVES OF CESU:

The NPS RM-CESU Research Coordinator indicates, by initials here, that this project contributes to the purpose of the CESU and is consistent with the approved Mission Statement, Strategic and/or Annual Work Plan.

/s/ Initialed by Kathy Tonnessen, RM-CESU Research Coordinator, on August 7, 2008

ATTACHMENTS

Attach, to this project cover sheet: 1) a Scope of Work that includes a detailed budget, list of products, and project schedule; and 2) Attachment Form 4.9 (substantial involvement and public purpose).

FINAL REPORT: DISTRIBUTION

Upon project completion, the NPS park/unit must submit a copy of the final products and/or final report (electronic copy required; paper copy optional) to the NPS RM-CESU Research Coordinator and to the RM-CESU host university (The University of Montana). Send electronic copies to **rmcesu@forestry.umt.edu** and/or kathy_tonnessen@nps.gov. Mail paper copies to RM-CESU, The University of Montana, College of Forestry and Conservation, Missoula, MT 59812.

In addition, send a copy of the final report to the NPS Technical Information Center, which is the official repository for all NPS technical reports: National Park Service, Technical Information Center, P.O. Box 25287, Denver, CO 80225.

RM-CESU CONTACTS

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DETAILED SCOPE OF WORK, SCHEDULE, PRODUCTS

Scope: The present tasks and products are designed to be a pilot project to support a larger effort to increase road and trail sustainability in these National Parks, responding to growing visitor use, increasing resource damage, and climate change.

Because this is a pilot project, data collection is limited to available GIS data, other spatial data, and field review as specified below. Specifications or tasks may, however, be modified to fit emerging needs as they are identified. To assure project objectives continue to be relevant, the cooperator will coordinate closely with National Park Service (NPS) personnel, especially with Trails and Roads, GIS, and Resource Management.

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- Task A: Research and synthesize technical documents and methods of trail restoration used in arid landscapes, including literature used in the BLM, USFS, and NPS; and field review with trails and roads specialists. This includes both general soil conservation and erosion control recommendations for trails and roads, and specific methods used in Arches and Canyonlands National Parks.

Objective Two: Re-route projects - alternative development analysis and support.

- Task A: Provide site-specific project services, including analysis and display of vegetation, landscape, and soils information in map form and development of reroute alternatives using landscape data, visitor use information, local NPS management and specialist input. This can include 3-D scientific visualization, viewshed analysis, quantitative analysis of potential soil and vegetation impacts, and field review and documentation.

Two project sites are included:

  - Salt Creek Re-route – Canyonlands N. P.
  - Maze District "Fault-line" Trail – Canyonlands N. P.
  - Fort Bottom Ruin Social Trail Problem – Canyonlands N. P.

Objective Three: to help inventory and prioritize potential trouble areas, as well as support decision making on use management, as well as to provide factual support for trail condition classification for one National Park (selected by NPS).

- Task A: Synthesize and spatially present available soil survey and landscape data (including elevation, vegetation, slope, and available condition inventories).
- Task B: Develop and implement a way of spatially showing potential trouble areas in on a Park-wide basis for management. This spatial analysis will use geology, soils surveys, landscape data, interviews with resource specialists, and site visits.
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- Spatial and analysis data provided via FTP or DVD, including collected and synthesized base data, metadata, and all GIS analysis projects. All new spatial data will meet all NPS spatial data standards.

<u>BUDGET</u>

Professional Services	
H. Shovic, PhD	
(256 hours @ $40/hr)	$ 10,240
Travel (6 working days; two site visits)	
PerDiem (meals, incidentals)	$ 307
Lodging	$ 420
(waived if NPS provides powered trailer pad)	
Mileage	
2968 miles (two site visits)	$ 1,409

@$.475

Materials	$ 200
GIS equipment and license	$ 500
Total Direct Costs	$ 13,075
IDC @17.5%	$ 2,288.
Total	**$ 15,363**

SUBSTANTIAL INVOLVEMENT DOCUMENTATION

Task Agreement No. or PR No.______________

Project Title: Technical Support for Trail Restoration and Maintenance, Arches and Canyonlands National Parks

Type of funds to be used for this project (select one): ONPS

l. Why was this cooperator selected?

Dr. Shovic was selected because of his knowledge of and experience working with soils, geology, and geomorphology related to trail planning, trail building, and trail maintenance. Mr. Shovic also has GIS related skill that will prove useful to this project.

2. Explain the nature of the anticipated substantial involvement?

The NPS will provide guidance in objective-setting, monitor results, provide site-specific requirements and data, and act as liaison with Park Management. Estimated involvement is as follows.

- 20 hours Trails Coordinator
- 5 hours Resource Manager
- 5 hours GIS specialist
- Available digital spatial data and trail documentation

The NPS Resource Manager and the cooperator will jointly participate in developing, reviewing and modifying project proposals, data, and or reports. The NPS Resource Manager and cooperator will jointly participate in project research and/or fieldwork. The NPS will have substantial direct involvement prior to project activity to insure compliance with the National Environmental Policy Act (NEPA) and the National Historic Preservation Act (NHPA). The project findings will be incorporated into NPS operations for maintaining trails and backcountry roads.

3. Why is the substantial involvement considered to be necessary for this project?

Site specific analysis by the resource manager with local knowledge of use, previous problems/fixes and associated resource issues combined with the scientific knowledge and hands on skills of Dr. Shovic is necessary to provide solutions to the trail/road problems facing managers.

4. What are the products expected?

- Up to 10 different maps at 36 in by 48 in and 8.5 x 11 size suitable for presentation (provided in hard-copy, Adobe Acrobat (pdf), and images for Powerpoint (jpg) at appropriate resolution).
- 3 documents in WORD format presenting results under each objective.
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- Spatial and analysis data provided via FTP or DVD, including collected and synthesized base data, metadata, and all GIS analysis projects. All new spatial data will meet all NPS spatial data standards.

5. What is the purpose of the agreement?

Research and synthesize technical documents and methods of trail restoration used in arid landscapes, including literature used in the BLM, USFS, and NPS; and field review with trails and roads specialists. This includes both general soil conservation and erosion control recommendations for trails and roads, and specific methods used in Arches and Canyonlands National Parks.

Provide site-specific project services, including analysis and display of vegetation, landscape, and soils information in map form and development of reroute alternatives using landscape data, visitor use information, local NPS management and specialist input. This can include 3-D scientific visualization, viewshed analysis, quantitative analysis of potential soil and vegetation impacts, and field review and documentation.

Help inventory and prioritize potential trouble areas, as well as support decision making on use management, as well as to provide factual support for trail condition classification for one National Park (selected by NPS).

6. Explain why the project or activity entails a relationship of <u>assistance</u> rather than a contract for services.

This project involves sharing skills, work experience and local knowledge to improve the capacity of NPS Staff to plan for trails in appropriate areas, build trails, maintain trails and keep appropriate records to monitor trail conditions/maintenance needs. Site specific analysis by the resource manager with local knowledge of use, previous problems/fixes and associated resource issues combined with the scientific knowledge and hands on skills of Mr. Shovic will provide solutions to the trail/road problems facing managers. Properly designed and well maintained trails will improve public safety and enjoyment of our National Parks and promote stewardship of these public lands.

7. How was the determination made that the costs proposed are accurate and proper?

Cost estimates were based on government per diem rates, mileage figures from maps, estimates of hours of work based on past experience with similar projects, and actual costs of needed materials to support the work.

Jeff Troutman 08/05/2008

_________________________ __________ ___________________________ ________

Key Official/ATR Date Contracting Office Date

NOTE: THIS FORM IS NOT PART OF THE TA AND IS FOR NPS INTERNAL USE ONLY. CONSEQUENTLY, IT SHOULD BE SEPARATED BY A PAGE BREAK AND FOLLOW THE TA BUDGET.

Appendix Two: Arches Devil's Garden Trails Field Review

Project Report: Arches Devil's Garden Trails
Field Review, Analysis, Conclusions, and Recommendations

Henry Shovic, PhD
Rocky Mountain Cooperative Ecosystems Study Unit

Jan 23, 2009

Objectives

This report is part of RM-CESU Cooperative Agreement Number: H1200040001 (IMR) titled "Technical Support for Trail Restoration and Maintenance for Arches and Canyonlands national Parks". It is designed to be a pilot project to support a larger effort to increase road and trail sustainability in these National Parks, responding to growing visitor use, increasing resource damage, and climate change.

This document addresses, in part all three objectives as listed in the agreement. The first objective is "to provide a synthesis of current trail maintenance methods and a perspective on the sustainability program". Current stabilization methods were reviewed below. It also addresses objective Two in the agreement "to provide alternative development analysis and support" for three project areas as designated by NPS staff. This report focuses on the Arches National Park Devil's Garden trail system, emphasizing the Primitive Loop. It also contributes to objective Three which includes "inventory and prioritize potential trouble areas", using the base data to correlate to existing resource inventories, in particular the existing Grant County soil survey and other available spatial data.

Methods

This set of trail interpretations is based on synthesis of data from a field review (Appendix One), the Grant County Soil Survey, draft vegetation spatial data from the National Park Service Inventory and Monitoring program, other digital geographical data provided by Arches National Park and the State of Utah, and interviews with Arches National Park staff.

Analysis

Landscape Description

The Grant County soil survey shows the entire Loop as composed of eolian deposits derived from sandstone. Surface texture is rated as fine sands and loamy fine sands. Based on the field review, on the average, soils on trails are composed of 60% fine sand; 10% sandy colluvium;

25% bedrock; 5% weakly-cemented sandstone rock layers (distributed as noted in field review notes). Off-trail soil biologic crust is wide-spread, with an average of 50% of surface cover.

Relatively undisturbed soil surface showing biologic soil crust and sandy texture.

Figure 1 shows the landscapes of the trail area. Slopes are generally moderate to gentle. The orientation of bedrock "ribs" and viewing related features (such as arches) are the basis for trail location, and those features actually make up part of the trail tread in places. Vegetation is shrubland, woodland, and complexes of rock outcrop and woodland. Ground cover is primarily biological soil crust (about 50% of the soil surface).

Figure 1. Devil’s Garden trail system looking to the north.

Trail Inventory

Trail segments were defined in the field on the basis of relatively similar landscapes and trail characteristics. Conditions on those segments were interpreted from field review data (Appendix One). Trail segments were rated for current condition and stabilization needs using the definitions in Table 1.

Table 1.Trail Condition Rating Description

Trail Condition Rating	Description
Good:	Trail tread elevation and surface is stable, less than 1’ downcut, banks are stable (revegetated); no apparent widening
Moderate:	Trail tread is over 50% stable, 1-2’ downcut, some widening; steep areas have eroded up to 4’. Resource damage is isolated.
Poor:	Trail is entirely unstable, more than 2’ downcut; banks are unstable (un-vegetated); active widening; unstable sand trail tread is difficult to traverse.

Description of Trail Conditions

Trails that are in “Good” condition require little maintenance. They are relatively stable (either on bedrock, mechanically stabilized, or in relatively-stable colluvium).

A trail rated in “Good” condition.

Those rated “Good” would still benefit from maintenance and signing to reduce creation of social trails. However, some impacts are still apparent (removal of lichen beds).

Bedrock trail showing lichen removal.

Trails in “Poor” condition are unstable, and are actively damaging resources, both on-site (soils, vegetation), and off-site (sediment, trail widening). They should be stabilized along their entire length, given additional maintenance, or closed.

Trail in “Poor” Condition

Natural revegetation is unlikely to occur on steep, eroding cutslopes. This is probably because of active removal of tread material, which oversteepens banks. Vegetation slough is common in eroding areas.

Active erosion, vegetation slough, and steep downcuts.

Trails in “Moderate” condition should be reviewed for spot stabilization on steep grades or in sandy portions, and trail margin marking with stones where widening is occurring. Stabilization needs are estimated at 10% of the trail length.


Trail in “Moderate” condition showing areas of stabilization needs in foreground and better condition in background.

Geological tread “armor” occurs in some places. It is apparently a weakly-cemented sandstone/siltstone layer that is relatively resistant to further erosion, when the overlying sand has been eroded. This layer may be advantageous to stabilization efforts, but is not considered in the above recommendations. This is because its occurrence is sporadic and may not be at the final recommended design grade for trail stabilization.


Actively-eroding social trail on left, with geological armor on lower trail.

Stabilization Methods

Based on this field review of local methods effectiveness, adequate stabilization can be achieved using magnesium-chloride cementation on a graded base of native or imported material. The stabilized material should be at least six inches in depth, and have a well-packed base. Trail widening and cutslope steepening can be reduced by rock borders in areas having high potential for off-trail use.

Chemical trail stabilization including rock borders.

Most trails in “Poor” condition have steep, actively eroding cutslopes. Trail stabilization measures will not directly improve these cutslopes. However, tread improvement will slow their development by decreasing oversteepening and mechanical trampling, giving vegetation a better chance of re-establishment.

Steep cutslopes

Relocation of some segments would benefit the system, especially from eroding hillsides to active washes.

Social trail in wash showing minimal impacts.

Results

Figure 2 graphically displays results for landscape limitations, results of the field review, and interpretations.

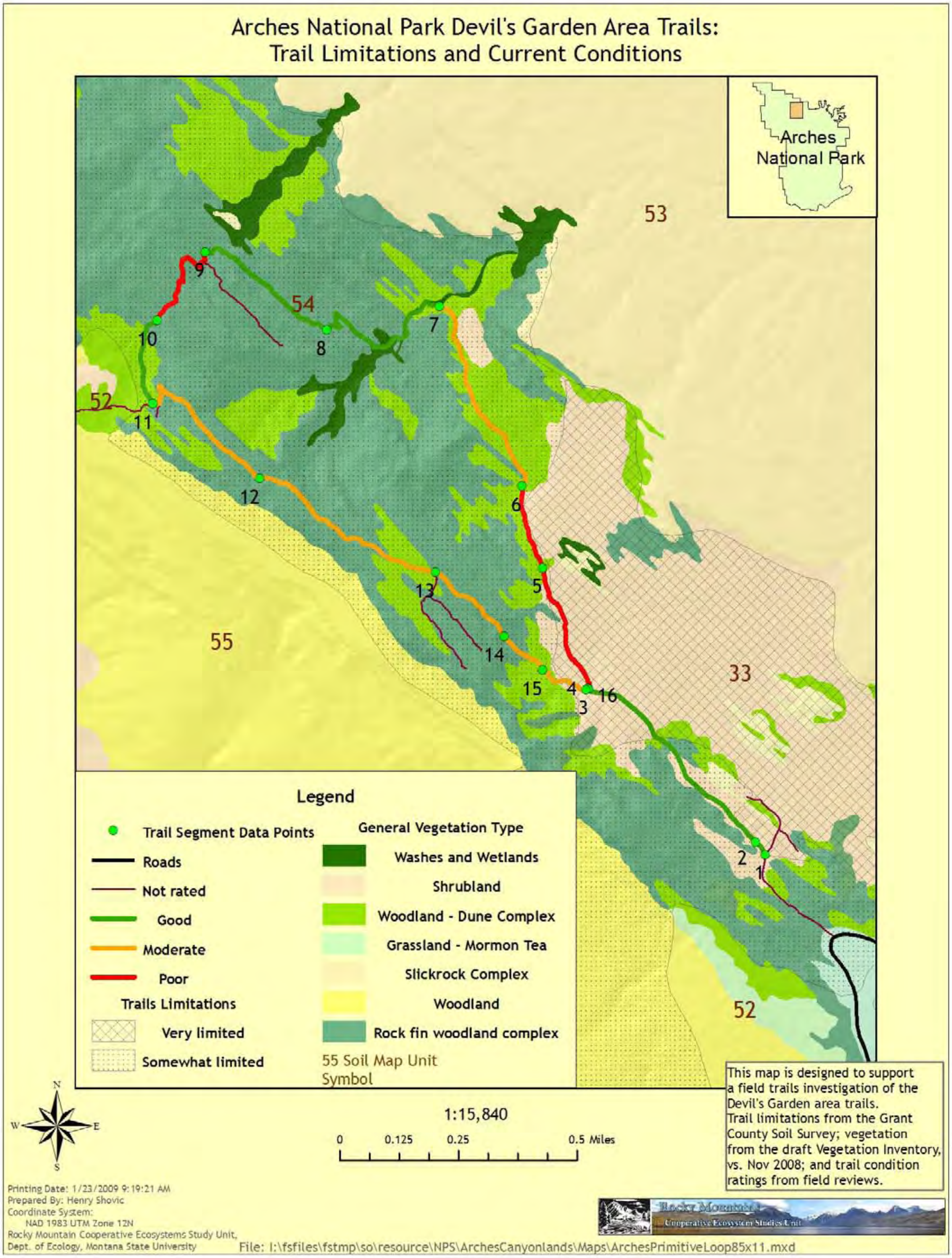


Figure 2. Geography and Trail Condition Results for Devil’s Garden Trails.

Landscape Potential – Interpretations and Limitations

The Grant County soil survey rates the entire area as having "severe" (crosshatch) or "moderate" (stipple) limitations to trail construction, use, and maintenance; in particular, the "poor" conditions on segments 4-5 and 5-6), and the "moderate" and "poor" conditions on the remainder of segments. These are based on soil properties that affect trafficability and erodibility (primarily soil texture in this area). Appendix Two contains a description of these interpretations as well as soil map unit descriptions.

General vegetation types include a significant amount of woodland developed on sand dunes (Woodland Dune Complex), especially near trails as well as areas of intermixed bedrock and woodland, based on draft vegetation data obtained from the National Park Service. These data are consistent with those given in the soil survey as well as the aerial view in Figure 1.

Landscape Conditions - Trail Review

Ratings of trail condition in Figure 1 are based on interpretation of the data in Table 2, which in turn came from the field review data in Appendix One. Poor conditions occur on 20 % of the entire loop trail. This is particularly true on the "primitive" part of the Primitive Loop (Segments from Point 4 to Point 11, on Figure 2), with 36% in "poor" condition. Relocation of some segments would benefit the system, particularly in segment 9-10, where a social trail in a wash could be utilized. Of the four miles of reviewed trail a total of almost one mile (23 % of the total reviewed trail length) should be stabilized to reduce active erosion and encourage natural recovery of cutbanks.

Table 2. Trail Segment Ratings

Trail Segment	Trail Conditions	Trail Condition Rating	Total Segment Length (miles)	Stabilization Needs (Miles)
1-4	Surfaced trail	Good	0.6	0
4-5	Trail deflation, rutting, in loamy sand and sand. Up to 5' trail deflation; average is 2'; Low strength soil, topsoil is < 2 cm; Soil crust binds top 2-3 cm of soil, unvegetated, no crusts on cutslopes; lost material is not evident, but likely washed to low spots.; entire area is sand, likely eroded from higher sandstone cliffs;	Poor	0.3	0.3

	surrounding area is stable-looking except for near trail (50% soil crust; vegetation away from trail)			
5-6	near wash; trail slope 20% ruts are 3.5 to 4.5 ft' deep; but a hard trail tread, possibly a geologic layer, not evidently human-stabilized; moderate deflation; partial hard trail	Poor	0.2	0.2
6-7	deflation 2-4 ft; 50% geologically stable tread; 50% sand tread Pic 151, 152 and social trail erosion	moderate	0.5	0.05
7-8	in wash (20%) or on bedrock (70%) little deflation, but lichens removed from rock; 2 ft deflation in sandy areas (10%)	Good	0.4	0
8-9	50% rock, 50% sand; soils have 20% sub-angular gravel and "natural tread armour" as noted before.	Good	0.3	0
9-10	These pictures show trail location about 20' above wash; wash is social trail; few visible impacts in wash, but trail has 4 ft. deflation.	Poor	0.3	0.3
10-11	low impacts; slopes < 5%; deflation 2 ft. or less; soils have some gravel	Good	0.2	0
11-12	Trail is 80% on bedrock; Pic 161, 162 after leaving rock fin; eroded to bedrock 2 ft. sandy colluvium	Moderate	0.4	0.04
12-13	% on bedrock; 50% on sand, but dominantly eroded to bedrock (2 ft)	Good	0.5	0
13-14	50% eroded to bedrock (2') 50% on sand.	Moderate	0.2	0.02
14-15	50% on bedrock (pic 165); 50% eroded to bedrock (2' deflation)	Moderate	0.1	0.01
15-16	relatively stable; some gravel and older MGCL2 stabilized areas; some sand	Moderate	0.1	0.01
Totals			4.1	0.93

Discussion and Conclusions

The soil survey ratings for trail limitations (which infer landscape potential) support the trail ratings based on field data (which describe landscape conditions).   The results in turn support the concerns voiced by Arches National Park staff on both field condition and maintenance levels specified by current plans. Vegetation types also are consistent with the kinds of soils probably occurring in the area. These facts all support the conclusion that these landscapes are sensitive to disturbance, in fact have been significantly disturbed.

Actual trail conditions reflect not only the landscape potentials, but also effects of high use on these sensitive areas. Trail impacts (especially those in the “Poor” category) have apparently become more severe than would occur under the low level of use implied by the “primitive” designation.

These impacts are evident throughout the Devil’s Garden trail system. Active erosion will continue as cutslopes retreat, adding material to the tread, where it is mixed by traffic, and washes or sloughs into channels. Cutslopes will probably not revegetate under these conditions. Trail widening will continue in these areas, as visitors widen the trail in search of a better tread. Some form of stabilization is recommended to reduce this active erosion and increase the potential for natural revegetation.

Appendix One

Arches Field Review Data
Primitive Loop
Henry Shovic
Nov 22, 2008

Reviewed Nov 20, 2008 with Jeff Troutman, NPS.

See Figure 2 in the main text body for point and segment references. This was derived from a hard-copy field map used in the review.

1. 40 ft. on right hand first junction toward Pine Tree arch. $MgCL2$ treated trail, using reject sand (from quarries) mixed with gravel and native material; still wet from treatment; moderately hard; mixed to at least 6 inches in depth. Pic 138

2. 140 ft. on main Landscape Arch trail, $MgCL2$ treated trail Pic 139

1-4 surfaced

3 pic 140 jcn with primitive trail

4. pic 141 4.5' of trail deflation, next to trail sign.

4 – 5 Trail deflation, rutting, in loamy sand and sand. Up to 5' trail deflation; average is 2'; Low strength soil, topsoil is < 2 cm; Soil crust binds top 2-3 cm of soil, unvegetated, no crusts on cutslopes; lost material is not evident, but likely washed to low spots.; entire area is sand, likely eroded from higher sandstone cliffs; area is stable-looking except for near trail (50% soil crust; vegetation away from trail)
Pic 142, 143

Between 4 and 5 moderate deflation (rutting) 2' average

Pic 144 social trail next to fin, soil crust 60% of area on sand

Point 5. high deflation, rutting Pic 145

Pic 146, 147 near wash; trail slope 20% ruts are 3.5 to 4.5 ft' deep; but a hard trail tread, possibly a geologic layer, not evidently human-stabilized. Pic 147 shows cactus slough;

Pic 148 closeup soil crust

Pic 149 hard surface geologic material

Between 5 and 6; moderate deflation; partial hard trail tread Pic 150

Point 6 high deflation, rutting near wash

Points 6 – 7 deflation 2-4 ft; 50% naturally stable tread (cemented rock layer); 50% sand tread Pic 151, 152 and social trail erosion

Point 7 – 8 in wash (20%) or on bedrock (70%) little deflation, but lichens removed from rock; 2 ft deflation in sandy areas (10%) Pic 153; trail widening; low impact in wash

Point 8 Pic 15 from Buttslide North 200yds, 50% rock, 50% sand; soils have 20% sub-angular gravel and "natural tread armour" as noted before; social trails common along rock ribs.

Between point 8 and 9; similar to at point 8; Trail slope is up to 17%. Where steep deflation is 2'. Low impacts on shallow slopes.

Pic 154 lichen rubbed off rock on trail (indicates high use)

Between point 9 and 10; Pic 155, 156, 157 near summit
These pictures show trail location about 20' above wash; wash is social trail; few visible impacts in wash, but trail has 4 ft. deflation.

Soils overall on the primitive loop trail: 60% sand; 10% sandy colluvium; 25% bedrock; 5% resistant rock layer; off-trail soil crust is wide-spread, locally 50% of surface is covered;

History: grazing probable before last 50 years;

From Point 11 on, not on primitive trail

Point 10 – 11 low impacts; slopes < 5%; deflation 2 ft. or less; soils have some gravel

Point 11: at Double O arch; social trails cover the area (where there isn't rock); no soil crust remains in local area.

Pic 158, 159, 160 panorama at Black arch overlook.

Between 11 and 12

Trail is 80% on bedrock; Pic 161, 162 after leaving rock fin; eroded to bedrock 2 ft. sandy colluvium

Between 12 and 13 50% on bedrock; 50% on sand, but dominantly eroded to bedrock (2 ft)

Point 13 jcn Partition Arch pictures of graffiti Pic 163, 164

Point 13 – 14 50% eroded to bedrock (2') 50% on sand.

Point 14 Reroute around Wall Arch is 50% on bedrock (pic 165); 50% eroded to bedrock (2' deflation)

Point 15 Landscape Arch trail

Between 14 and 15 similar to point 14.

Between 15 and 16 trail is relatively stable; some gravel and older MGCL2 stabilized areas; some sand

Appendix Two in Arches Devil’s Garden Report

NRCS Soil Interpretation Descriptions and Map Unit Descriptions from the Grant County Soil Survey using SoilDataViewer software.

Appendix Three: Canyonlands Fort Bottom Trails Field Review

Project Report: Canyon Lands Fort Bottom Trails
Field Review, Analysis, Conclusions, and Recommendations
Henry Shovic, PhD
Rocky Mountain Cooperative Ecosystems Study Unit
Mar 4, 2009

Objectives

This report is part of RM-CESU Cooperative Agreement Number: H1200040001 (IMR) titled “Technical Support for Trail Restoration and Maintenance for Arches and Canyonlands national Parks”. It is designed to be a pilot project to support a larger effort to increase road and trail sustainability in these National Parks, responding to growing visitor use, increasing resource damage, and climate change.

This document addresses, in part all three objectives as listed in the agreement. The first objective is “to provide a synthesis of current trail maintenance methods and a perspective on the sustainability program”. Current stabilization methods were reviewed below. It also addresses objective Two in the agreement “to provide alternative development analysis and support” for three project areas as designated by NPS staff. This report focuses on the Canyonlands Fort Bottom Area trail system. It also contributes to objective Three which includes “inventory and prioritize potential trouble areas”, using the base data to correlate to existing resource inventories, in particular the existing San Juan County soil survey, geology data, and the existing trail inventory for this area.

Methods

This set of trail interpretations is based on synthesis of data from a field review (Appendix One), the San Juan County Soil Survey, a detailed trail inventory provided by Canyonlands National Park staff, draft vegetation spatial data from the National Park Service Inventory and Monitoring program, other digital geographical data provided by Canyonlands National Park and the State of Utah, and interviews with Canyonlands National Park staff.

Analysis

Landscape Description

Figure 1 shows the landscapes of the trail area. Slopes are gentle to steep, with the main trail (blue) following a rocky ridge to the river, and numerous social trails (in red) on steeper slopes.

The underlying landform is an eroded, colluvial slope having little vegetation. The gently-sloping alluvial “bottom” is heavily vegetated with Tamarask and other shrubs.
This area can be reached by a primitive and difficult 4WD road, which limits user density. However, the Green River provides most access, and users from the river are probably responsible for most social trail development.

Figure 1. Landscapes of the Fort Bottom Area

The San Juan County soil survey shows most of the area as either bedrock or residuum weathered from sandstone (Figure 2). Surface texture is rated as absent or gravelly loamy sand. However, based on the field review, soils on trails are gravelly (primarily on the main trail) and silty on the southern non-system trails. The area mapped as “residuum weathered from sandstone” is actually primarily poorly-indurated siltstone, eroding in a “badlands” manner. This shows as lighter gray areas in Figure 1. Lower slopes are covered with desert pavement, consisting of small planar gravels covering silty residuum. This “pavement” is quite fragile, and is easily disturbed by walking.

Off-trail soil biologic crust is intermittent, with an average of 20% surface cover. Crust is apparently absent on steeper slopes, probably because of rapid erosion and deposition.

Most of the steeper area is mapped as Moenkopi Formation (siltstones and fine-grained sandstones) (Figure 3) The Chinle Formation (sandstone and siltstone, conglomeratic sandstone) caps the narrow ridge and associated rocky sideslopes). Coarse-textured alluvium occurs near the river.

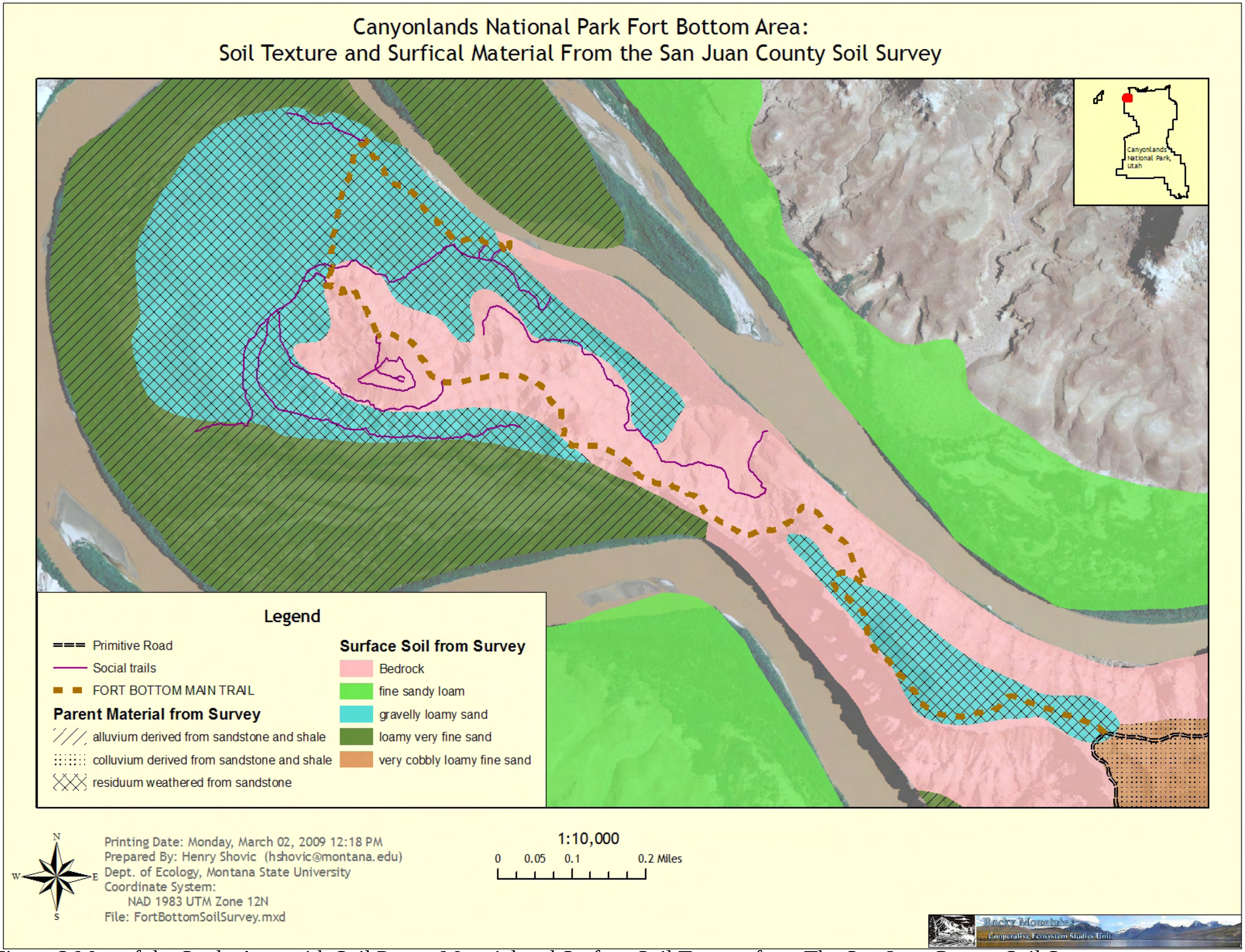


Figure 2 Map of the Study Area with Soil Parent Material and Surface Soil Texture from The San Juan County Soil Survey.

Soils on the Main Fort Bottom Trail eastern part – from field review

Soils on the non-system trails on the southern side, showing absence of bio-crust – from field review

Desert pavement on relatively-stable parts of the western “badlands” area.

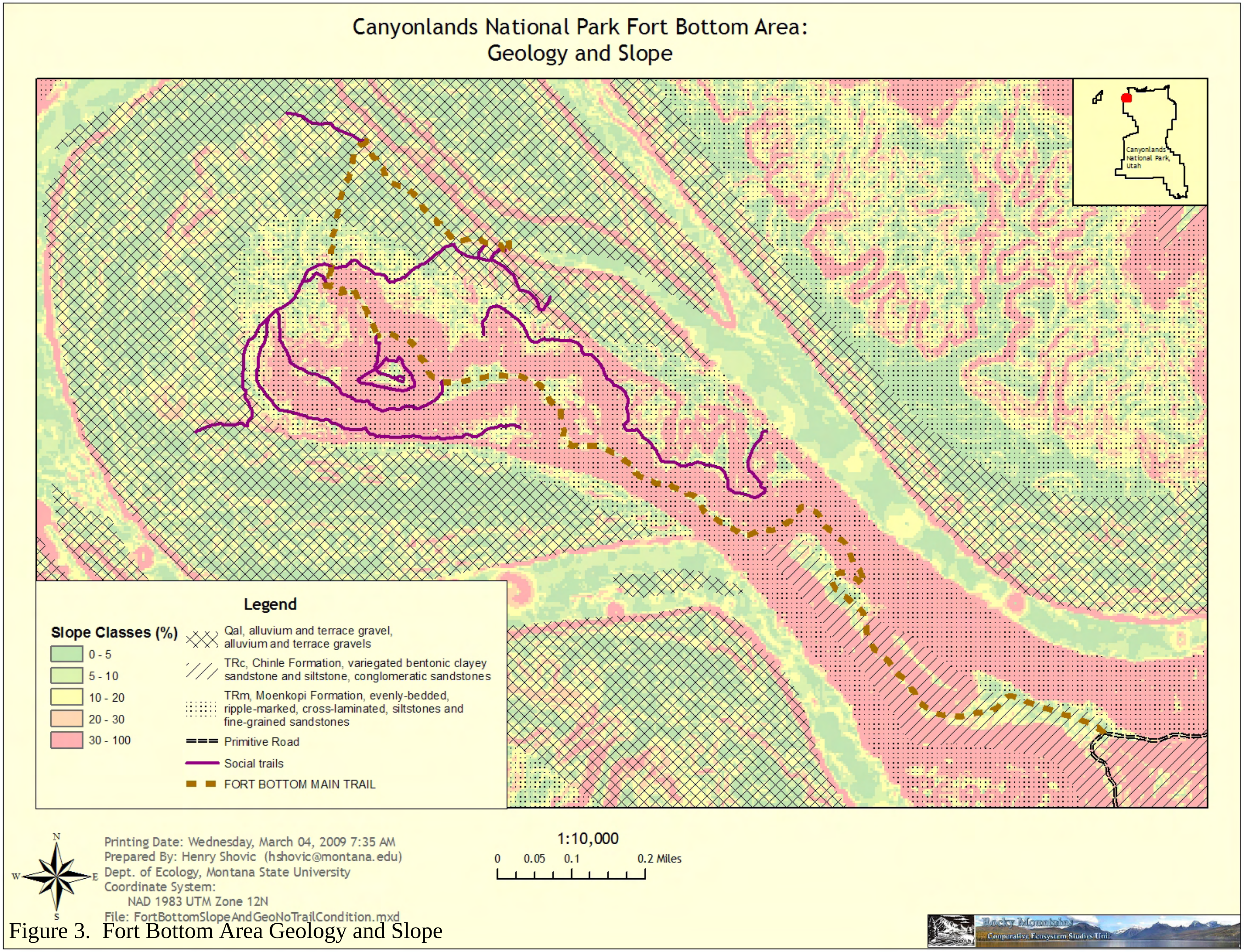


Figure 3. Fort Bottom Area Geology and Slope

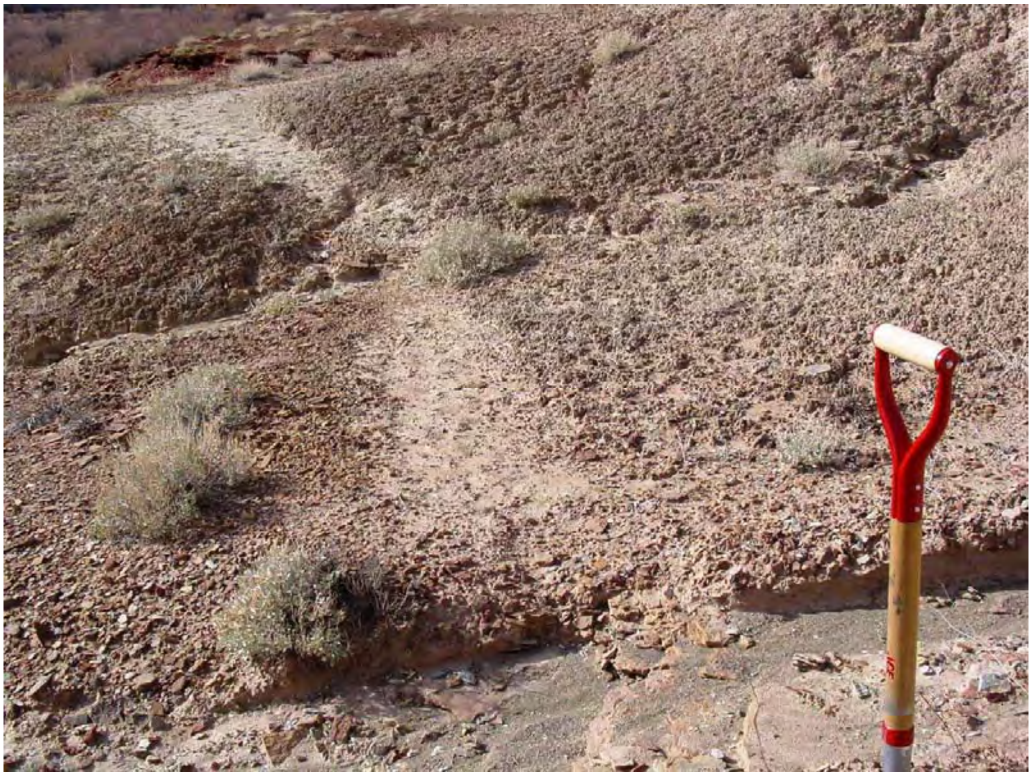
Trail Inventory: Sensitivity and Condition

Representative trail segments were reviewed in the field. Appendix One contains the GPS track and field review data. Observed trail segments were rated for "sensitivity". This term is defined as the synthesis of landscape and soil properties that affects the response of a trail to user impacts. It is generally separate from "condition" which rates the existing trail properties.

Trails having "Low" sensitivity require little maintenance. They are relatively stable (either on bedrock, mechanically stabilized, or in relatively-stable colluvium).

A trail having "Low" sensitivity. Slopes are gentle, and soils have a stable matrix of mixed materials.

Trails with "High" sensitivity are unstable even with low use, and are likely to become very erosive if subjected to high, sustained use. They have potential for actively damaging resources, both on-site (soils, vegetation), and off-site (sediment, trail widening). They should be stabilized along their entire length, given additional maintenance, or closed.



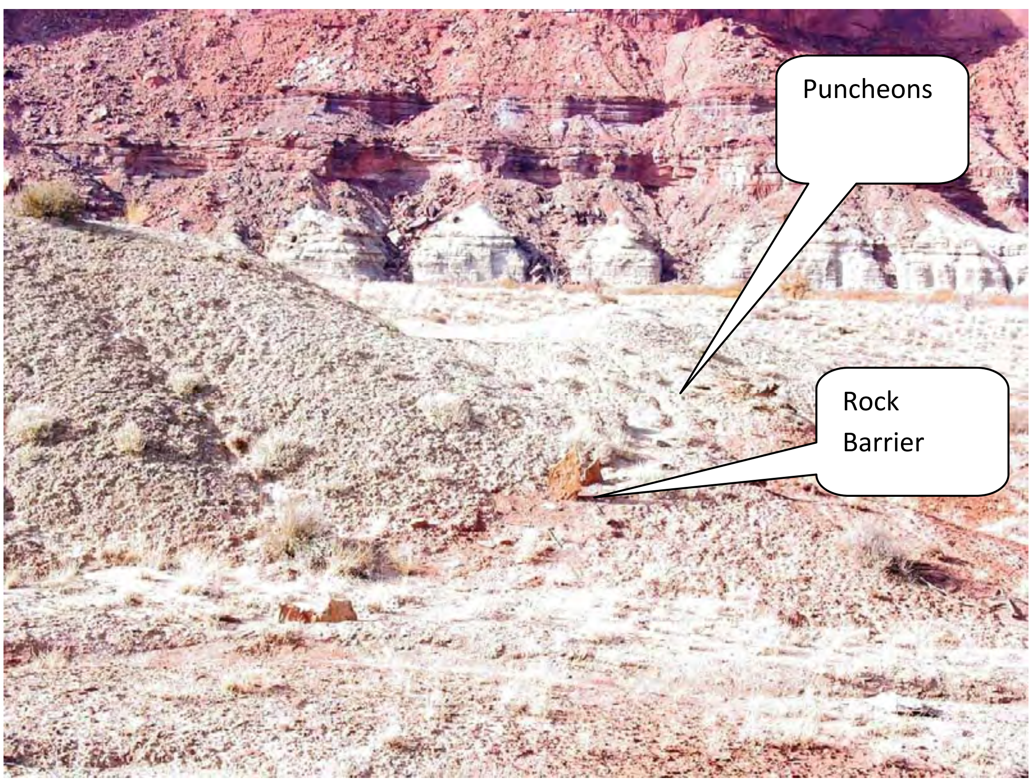
Trail having “High” sensitivity.

An existing inventory of the Fort Bottom Trail segments shows trail condition. This inventory was completed by NPS staff (K. Carpenter). Present condition was rated from “Poor” to “Good”.

Stabilization Methods

Observed stabilization methods include rock borders to define trail tread and reduce off-trail use, rock barriers to discourage social trail use, and “puncheons”, which are small holes excavated in the tread, probably to discourage use and to reduce erosion.

Rock Borders



Trail Barriers.

Results and Discussion

Figure 4 graphically displays results for results of the sensitivity field review and the existing trails inventory. Figure 5 shows the trail sensitivity and condition overlaid on slope and geology. Figure 6 shows a perspective view of the trails.

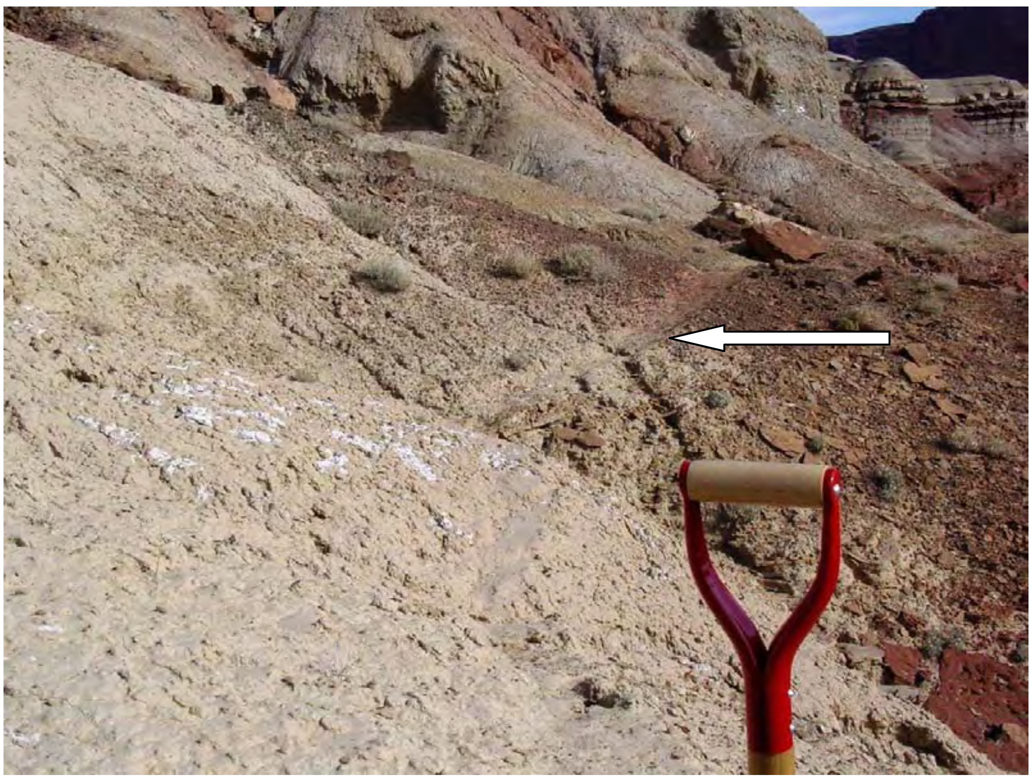
The Fort Bottom Main Trail is generally in good shape (low erosion, tread is stable, little trail widening) and is also in less sensitive material (primarily sandstone with some siltstone). It was apparently an old 4WD road which has been converted to a trail. It has rock borders in places and waterbars on steep slopes. Though it appears to be located on steep slopes (Figure 5), it actually stays primarily on a narrow, flat ridgetop, on sandstone. Where on steep sideslopes, the trail follows an excavated 4WD road. This road is significantly eroded, but the trail itself has been stabilized with waterbars.

The Spur3 trail is also relatively stable, and is not being widened, but is located in erosive material. It is highly visible, and appears to be located on steep slopes (Figure 5) but actually "snakes around" on gently-sloping benches.

Spur3 Trail

Cirque 3 and Cirque trails both are rated as being in “Poor” condition, as well as being highly sensitive. They are both on very steep slopes, and are in the erodible Moenkapi formation (Figure5, 6).

Spur4, Spur5, and Cirque 2 trails are rated as being in “Fair” condition. This is probably correct, as they are in a truly “badland” landscape. The trail itself was actually difficult to find in some places (Appendix One has the GPS track). The trail prism is probably covered by eroding material every year. It was hazardous to traverse in places, especially above steep washes.



Fort Bottom Trails Cirque 2 Trail prism on badland area.

The lower trails (Cabin to Bushwhack, Spur6, and Fort Bottom Spur2) appear to be relatively stable, since they are located in alluvium rather than on the Moenkopi formation (Figure 5). However, Fort Bottom Spur1 goes through a transition zone between the two geologic types, and is probably eroded on sloping segments. It is of lower sensitivity than the trails near Spur4. One un-named spur near Spur5, however, appears to climb steeply from the river, and is in “Poor” condition.

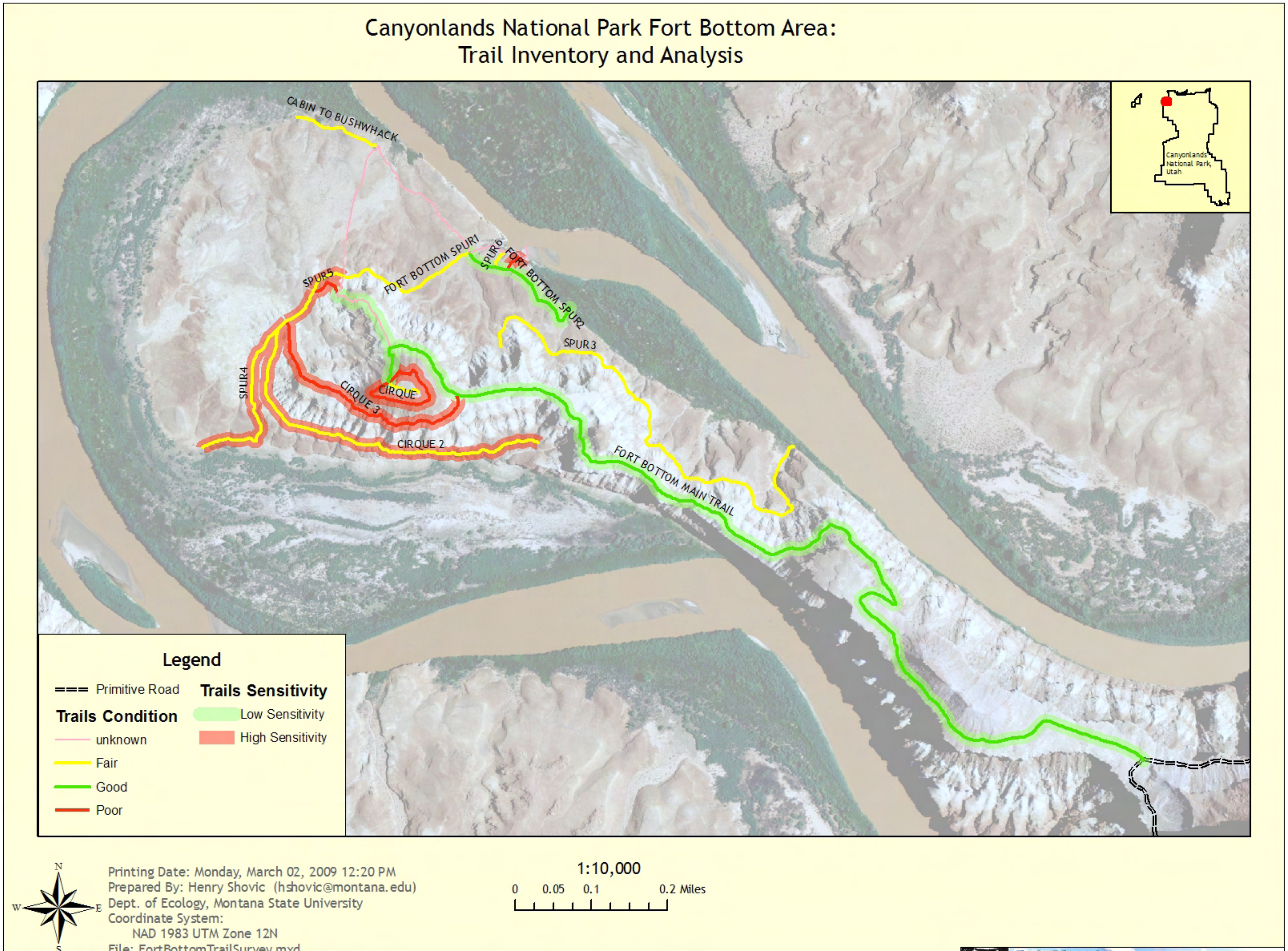


Figure 4. Trail Condition and Sensitivity for Fort Bottom Trail

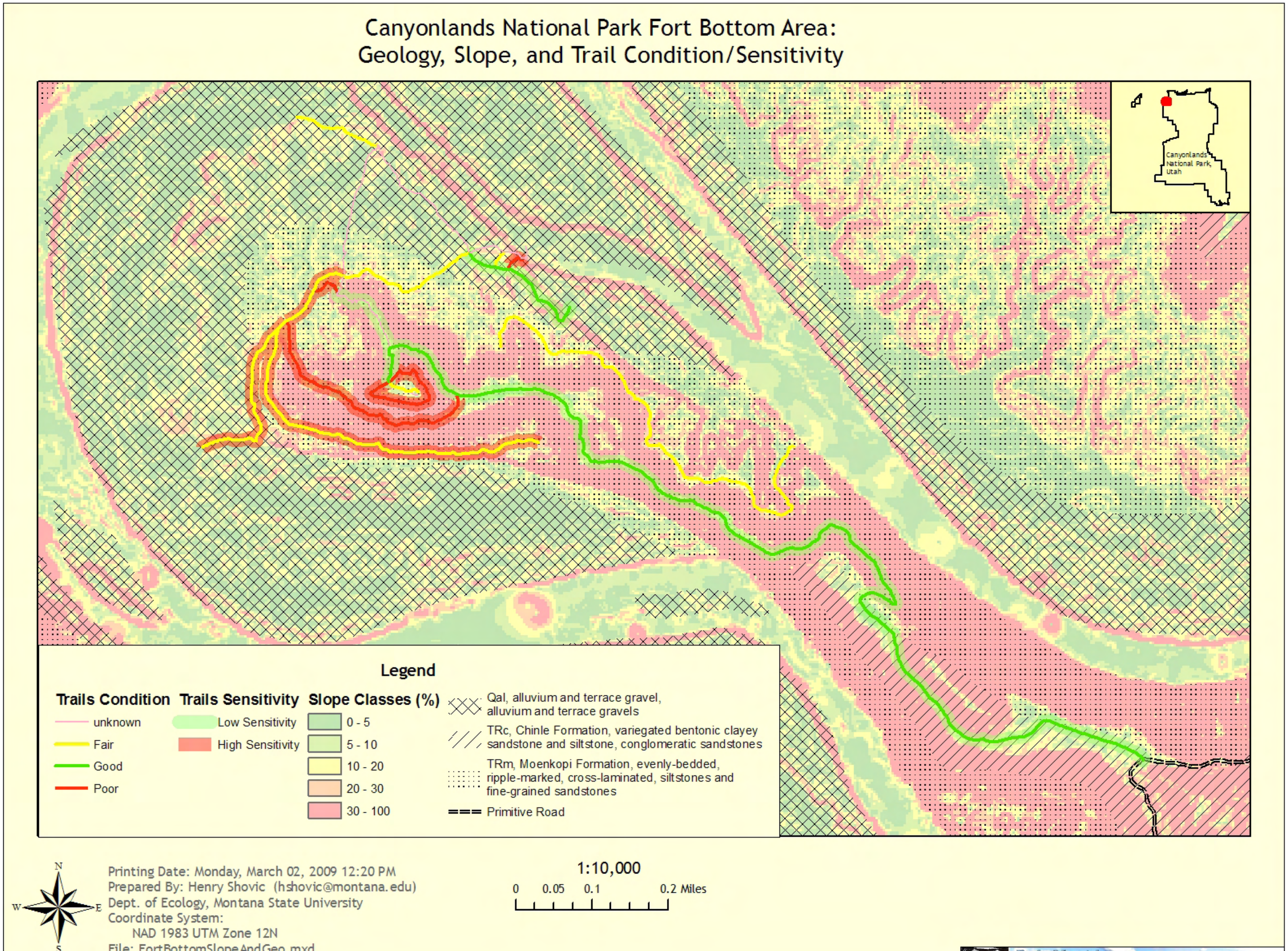


Figure 5. Geology, Slope, and Trails in the Fort Bottom Area

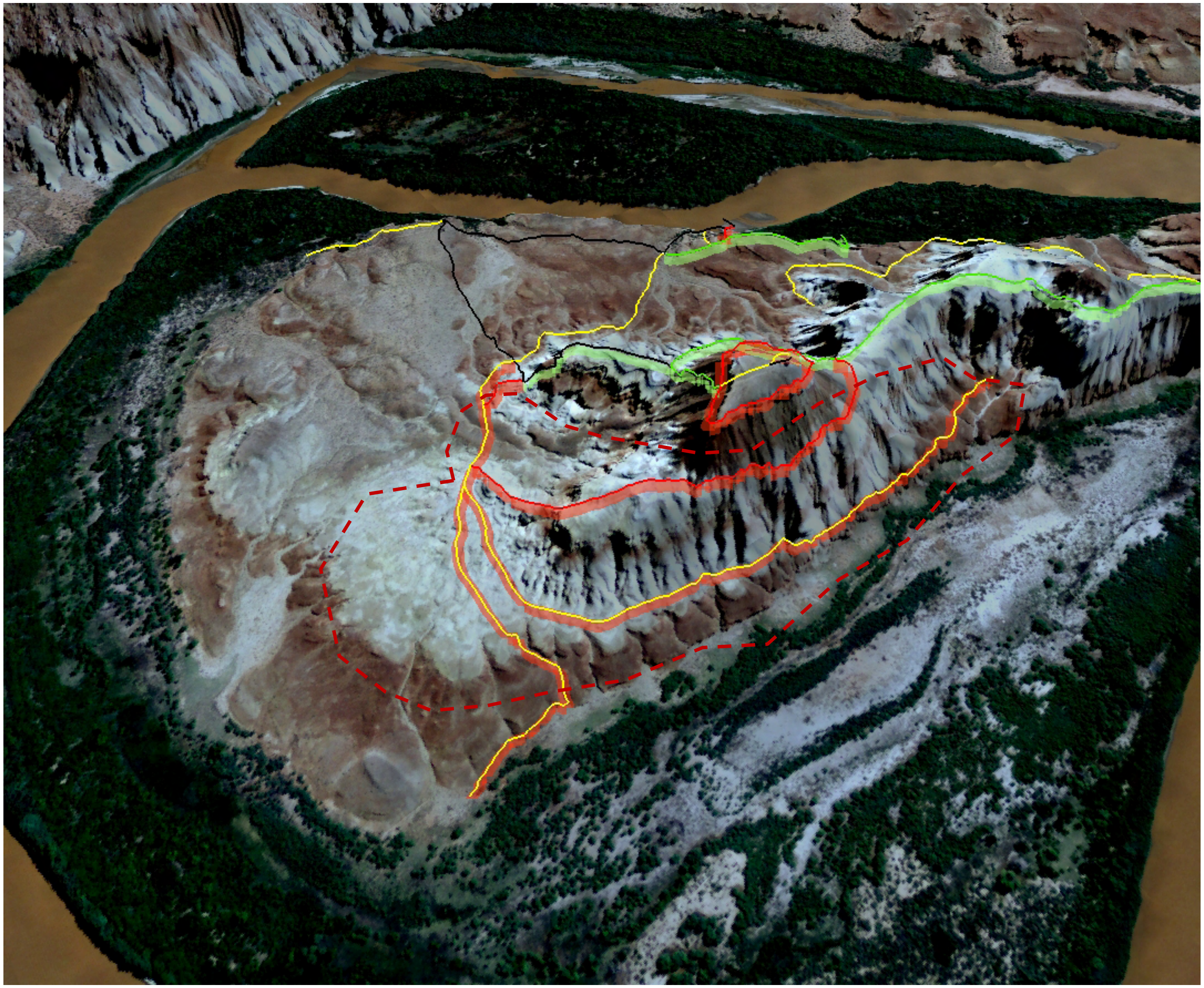


Figure 6. Perspective view of the Fort Bottom Trail (highly erodible area in the red-dashed polygon)

Conclusions and Recommendations

Based on this sample and the trail inventory, the steeper, erodible parts of the Moenkopi formation appear to have the highest hazards for resource protection and visitor safety. Figure 6 contains a dashed polygon which shows the approximate extent of the area.

Soil conditions identified in this field review compared with the San Juan Soil Survey show that the Survey is not very accurate in this area. Trail limitations presented in the Survey are probably too conservative, and do not reflect the actual character of the area. Geology and Slope (Figure 5) offer a better correlation with condition/sensitivity. Trails in the Moenkopi formation and on slopes greater than 10% appear to have higher sensitivity and poorer condition.

If the management objective is to reduce resource impacts the use and creation of social trails should be discouraged. Because of the nature of the underlying soil, social trails on the north side are highly visible (Spur3 and Fort Bottom Spur1). On steeper slopes social trails can be hazardous, and contribute to destruction of bio crust as visitors wander looking for the trail prism or slip off the tread.

Rock borders are effective at keeping visitors on the Fort Bottom Main trail. On other trails rock barriers are generally small and ineffective (probably because of the "primitive" management goals in the area, and absence of readily-available rock). Puncheons, though an effective way of deterring use for some visitors, are probably not very effective since tread erosion is not a large factor here and side-slope slough probably will cover them in a short time.

However, if use is reduced trails on the southern side (Cirque 2) may "self-heal" as rapid side slough covers the tread. Trail markers and frequent enforcement may also reduce impacts.

Appendix One

Field Notes
Fort Bottom Trail System
Canyonlands N. P.
H. Shovic
Nov 22 and 23, 2008

Waypoints are from GPS and are shown on the map (Figure 7 below), using the field COMMENTS. Pictures are shown by reference number.

There is a quarry on Mineral Bottom Road; mostly weathered shale with some poorly-indurated sandstone. Soils on this mesa are clayey. Just west of this quarry, there is a sandstone butte, with potential crush site, but material is likely to have poor durability.

WP 1 is the beginning of the trail. Pictures 188, 189

Between WP 1 and 2, pictures 190, 191 in shale

WP 2 Panoramic picture 192

WP 3 has no data.

WP 4   looking down at social trail Pic 193
Shows trail in crumbly shale – highly visible, but little erosion evident.

The main trail is in good shape and stable from 4 to 5

WP 5   trail east of 5 that shows rated "unknown" on the map is good shape, eroded 2 inches on sandstone/shale; pic 194 shows a representative segment

WP 5 – 6 Short Red trail segment; Social trail puncheoned (small shovel holes to break up trail); inch of erosion

WP 6 – 11 Yellow trail below the red segment is in weathered shale, easily eroded. Some puncheons, some small rock barriers; Soils are silty with some fine sand.

In this area, desert pavement is common on redder rock types, but on light-colored shales, soil is barren.

WP 6, 7, and 8 are at the same location.

WP 6-9 trail is very difficult to follow; poorly marked, eroded, sloughed. Note GPS track is off trail. Soils are silty with some fine sand.

WP 9 desert pavement, pic 195, 196   fragile area, friable sandstone over erodible weathered shale. Soils are silty with some fine sand.

WP 12 on contour; trail has almost disappeared due to slough. Sideslopes up to 40%; hazardous to walk on; in friable, erodible weathered shale (silty); soil is nearly barren.

WP 10 soil is silty with desert pavement, except for trail tread; very silty weathered shale; pics 197, 198

On the N side, much more gravel, pavement, stones in matrix; S side erodible weathered shale.

On the darker colored rock layers, vegetation, pavement, sandstone fragments; less erodible;
It is where light colored shales occur; there is erosion problems; badland topography

WP 11 end of social trail with a small barrier; at least three social trails lead away from here. Pic 199

At WP 11 continuation of social trail, but well maintained, and a series of rocks have been placed to keep people on the trail. Eroded up to 6 inches, but now relatively stable; Pic 200

Picture looking back at the red-rated trail near WP 12; close to WP 4; pic 201 Hard to see tread, because highly erosive soils have covered it.;   self recovering; no recent use this year; possibly should be barricaded or signed.

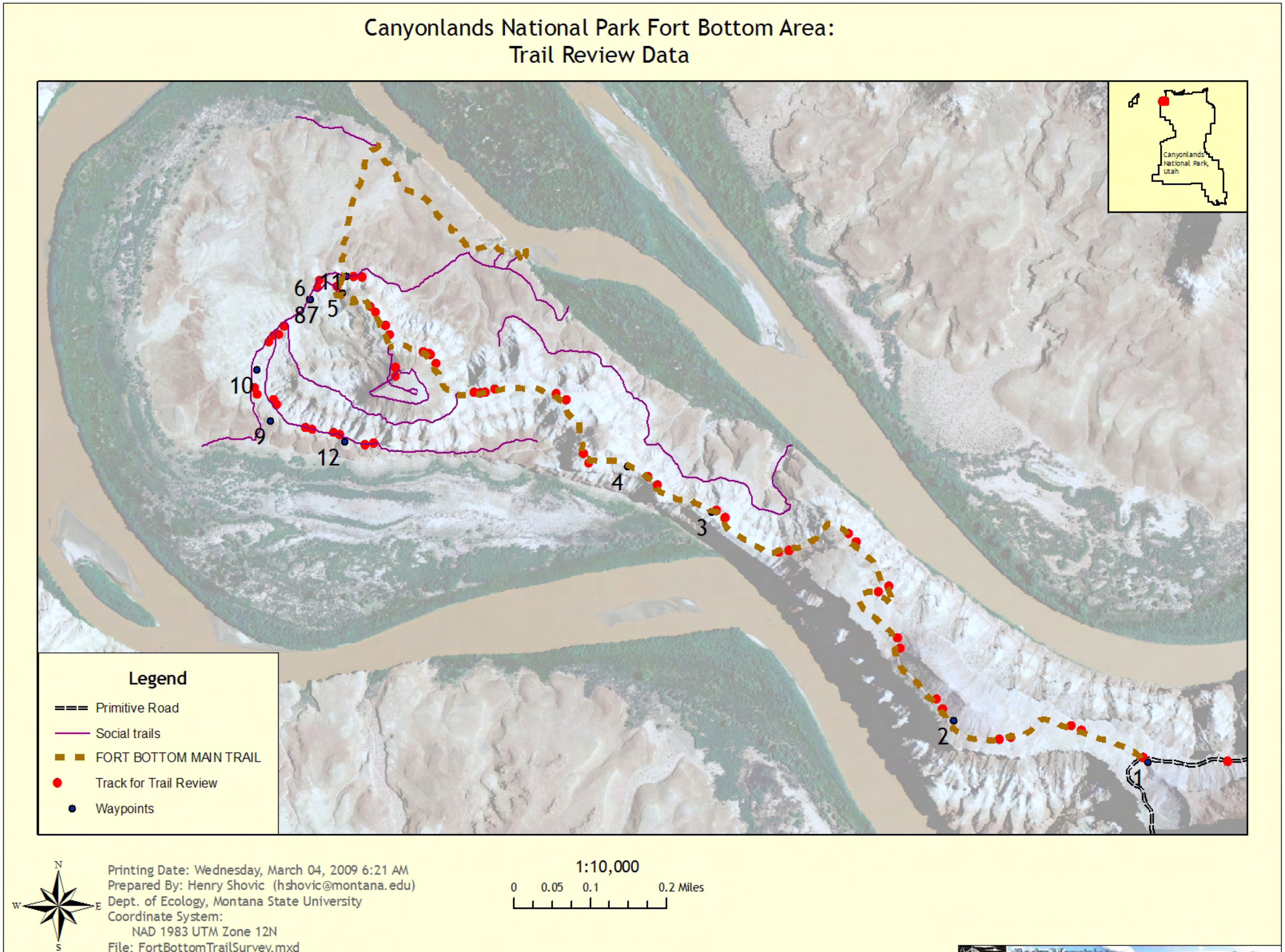


Figure 7. Fort Bottom Trail Review Data Locations

Photos

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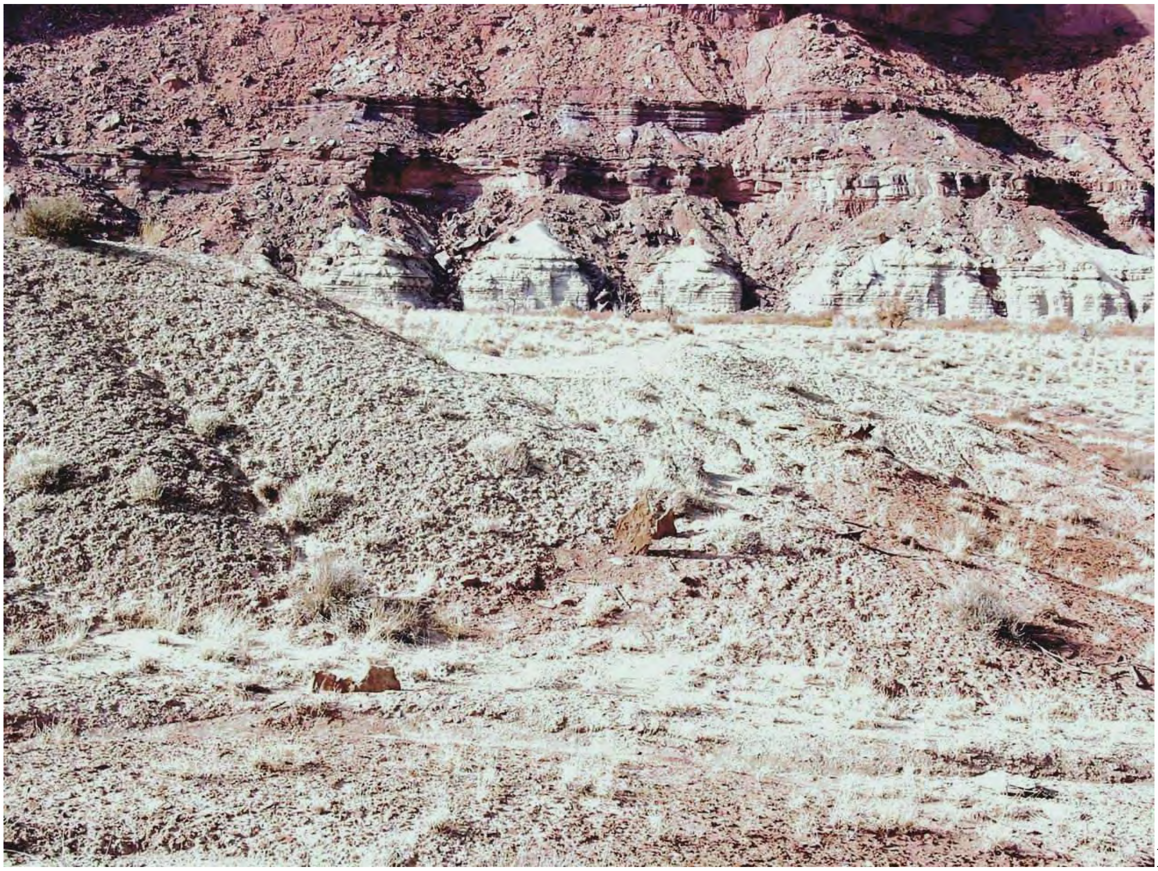
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Appendix Four: Canyonlands Salt Creek Road Review

Project Report: Canyon Lands Salt Creek Road
Field Review, Analysis, Conclusions, and Recommendations
Henry Shovic, PhD
Rocky Mountain Cooperative Ecosystems Study Unit
May 3, 2009

Objectives

This report is part of RM-CESU Cooperative Agreement Number: H1200040001 (IMR) titled "Technical Support for Trail Restoration and Maintenance for Arches and Canyonlands national Parks". It is designed to be a pilot project to support a larger effort to increase road and trail sustainability in these National Parks, responding to growing visitor use, increasing resource damage, and climate change.

This document addresses Objective Two in the agreement "to provide alternative development analysis and support" for three project areas as designated by NPS staff. This report focuses on the Canyonlands Salt Creek road.

Specific objectives for this review included:

1. Review the Horse Canyon reroute area for impacts and potentials.
2. Review the entire road from the gate to Peekaboo Campsite for impacts and potentials
3. Review the proposed reroute for feasibility and potential improvement of resource protection.

Methods

This set of trail interpretations is based on a synthesis of data from a field review using GPS and photographs (Appendix One), maps, spatial data, and interviews with Canyonlands National Park staff.

Analysis

Landscape Description

Figure 1 shows the landscapes of the Salt Creek valley (looking from South to North). Slopes are gentle to steep, with the main road following a following a vegetated stream course and associated flood plain. Uplands are derived from the Cedar Mesa Sandstone with very sandy regolith, and most of the lowland is composed of very sandy alluvium and wind-deposited sand with some river gravels. The road itself is about 3 miles long. About 80% is in the active stream channel of Salt Creek. Flooding is apparently common and significant.

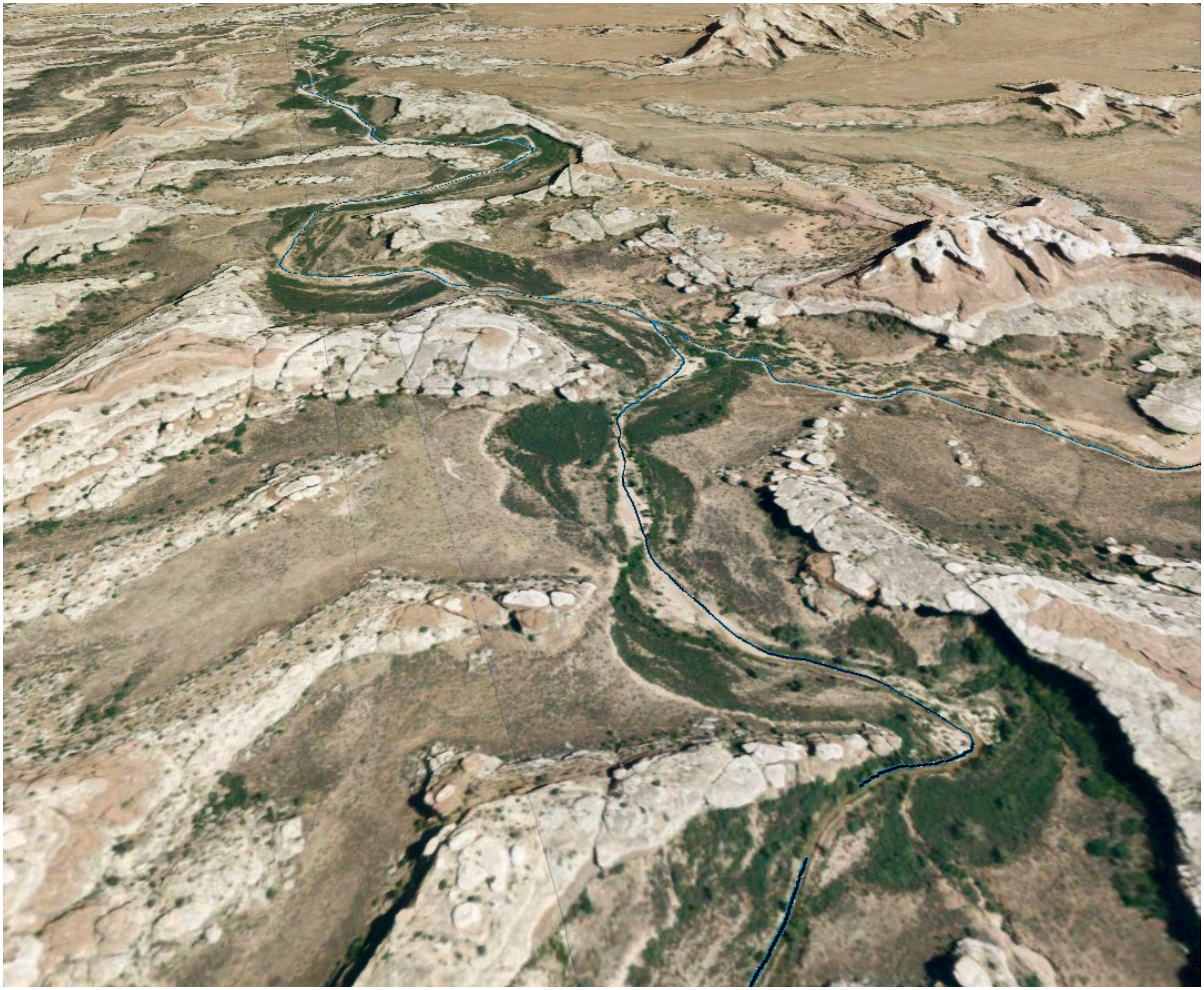


Figure 1. Landscapes of the Salt Creek Road Area, looking from south to north.

Soil materials in the vicinity of the stream are primarily alluvium and wind-deposited sand, modified by floodwaters (Appendix One). All soils are extremely sandy with occasional cobble or gravel layers. These kinds of soils have low productivity and fertility, and low resistance to erosion.

Sandy soils at Peekaboo Campground

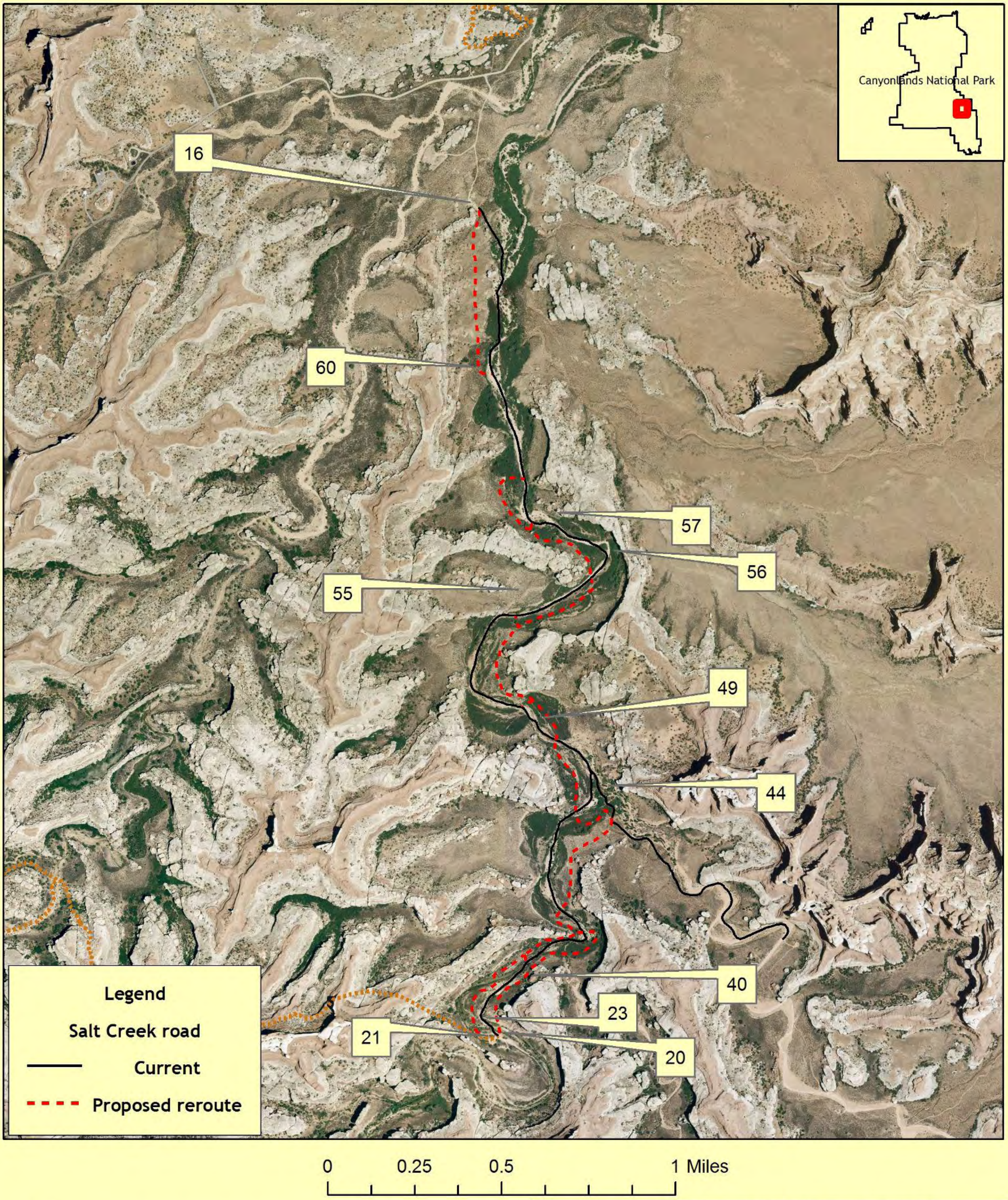
Evidence of flooding below the campground in Salt Creek

Resource Analysis

Figure 2 shows the project area and salient review analysis by location. It is based on the data in Appendix One. See the following discussion for each marked point or area.

Figure 2 is below.

Canyonlands National Park:
Salt Creek Road Review



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Printing Date: Sunday, May 03, 2009 9:59 AM
Prepared By: Henry Shovic (hshovic@montana.edu)
Dept. of Ecology, Montana State University
Coordinate System:
NAD 1983 UTM Zone 12N
File: CANYSaltCreekMap.mxd

This map is designed to support a field trails investigation of the Salt Creek road in Canyonlands National Park. Points are referenced in the report text.

Rocky Mountains Cooperative Ecosystem Studies Unit

Stream Characteristics

Salt Creek was flowing as of April 12, 2009 from Point 23 to 57 (about 2 miles of a total of 3). It is apparently one of only two perennial streams in Canyonlands National Park (the other is the Colorado River). The floodway's upper channel (from Point 20 to 44 or about one mile) has a substrate of gravel and cobbles with a well defined and incised channel, and is sandy with a well-defined channel to 57, then a poorly defined channel occurs below point 57. This may indicate stream scour is likely the primary flood erosive mechanism above Point 57 with deposition occurring below that point and most occurring below Point 57.

Gravel and cobble stream bed on upper channel

Sandy stream bed midway on lower channel

Sandy, poorly-defined stream bed on the lower channel.

Three stream terrace levels were observed in this study.

- The Floodway (including the active channel) has no vegetation and probably flows every year.

Floodway

- The Low Terrace (represented by Point 49) is about five feet above the Floodway. This terrace shows evidence of occasional flooding and has a very sandy substrate.

Low Terrace

- The High Terrace (represented by Point 55 and 60) is about eight to thirty feet above the Floodway and shows no evidence of recent flooding. It has a very sandy substrate.

High Terrace

Impacts to Stream and Riparian Vegetation

Vehicle impacts appear to be significant in the flowing part of the stream (Point 23 to 57). Disturbance is significant from even a very slow traverse (less than 1 mph), with apparent erosion of side banks, exposure of roots, and turbidity. These are all probably detrimental to bank vegetation and invertebrate health.

Erosion, turbidity, and root exposure from low velocity vehicle traverse

Large holes occur in the active channel. These are apparently related to vehicle use, similar to the formation of potholes or washboards on other native surface roads. These holes can be large enough to affect stream flow (Point 40).

Pothole probably caused by repeated vehicle traverse

Stream channel characteristics appear to be different in areas without the impacts of vehicle traffic. At Point 56, a segment of stream channel shows no evidence of vehicle use. The channel is significantly different than the nearby road/channel. No large holes or unconnected pools occur in the un-driven area. In nearby stream channels with no apparent vehicle use, vegetation is present in the channel and it is less disrupted by large holes.

Stream character with vehicle use

Stream character with vehicle use (bathtub ring area)

Stream character without vehicle use

Stream character and vegetation without vehicle use

Stream character and vegetation without vehicle use

Potential Recovery

Removing vehicle traffic from channels or roads was observed to be enough to initiate vegetative recovery. At Point 20, past the gate closure, cut banks are sloughing towards a stable slope. At Point 21, an unused road has vegetation and incipient biological soil crust.

Natural sloughing and filling of unused road

Natural revegetation and biologic soil crust formation on unused road

Road Reroute

The current road follows the active stream channel in the Floodway for 80% of the project area from the gate (Point 16) to the closed gate near Peekaboo Campground (Point 20) (Figure 2). A proposed re-route of the road is shown in Figure 2 (red dashed line). The re-route follows terraces surrounding the current road, with at least four intersections with the stream channel/current road.

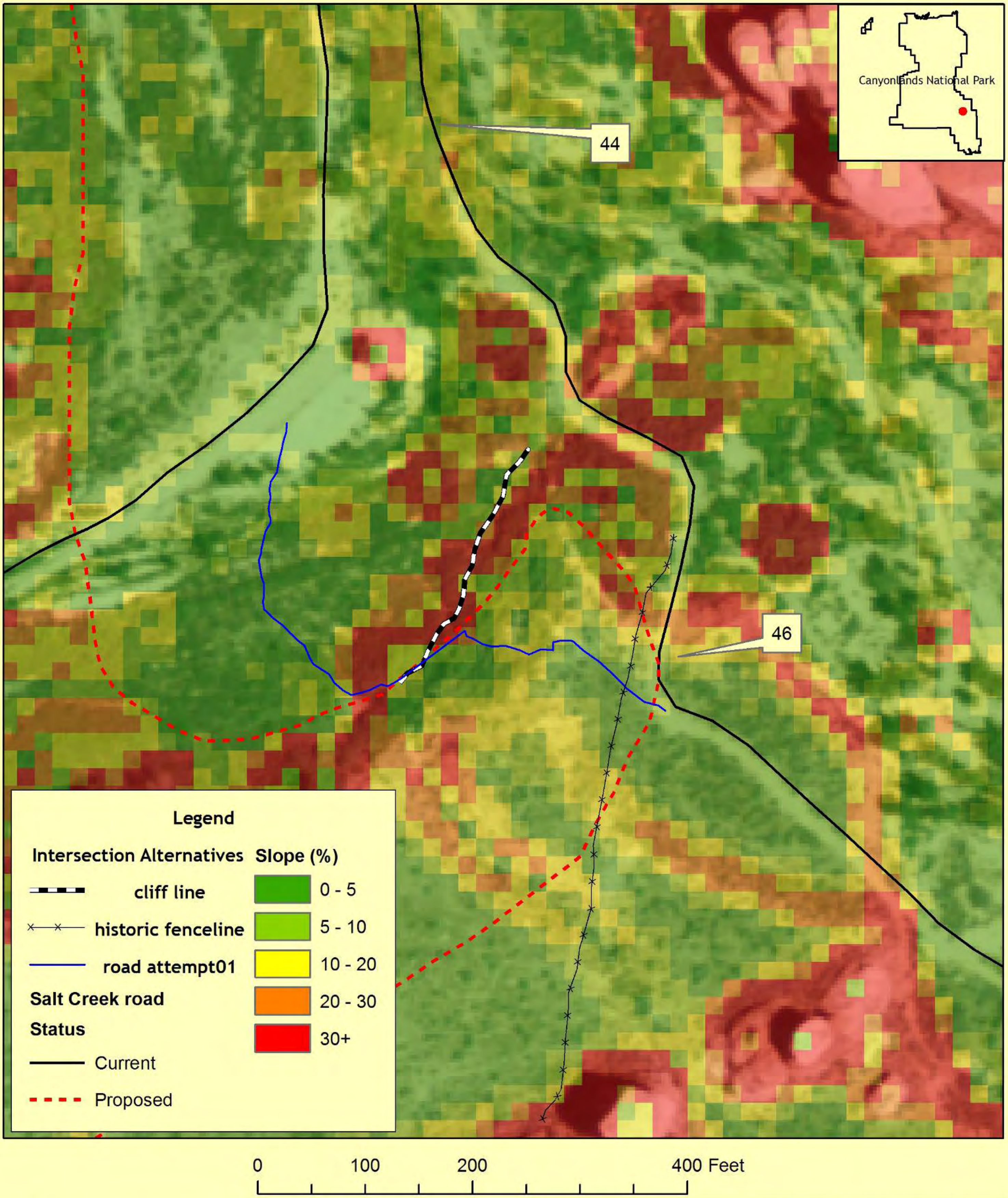
This re-route track was not marked on the ground (with exception of the Horse Canyon intersection discussed below), but its location was well enough defined to review in the field and on digital aerial imagery. Generally, the upper ½ of the re-route (south of Point 57) is on or near the Low Terrace. Below that point it is primarily on the High Terrace. Re-route/current road intersections as specified on the map are almost all on the Low Terrace.

The Horse Canyon reroute area

A particular potential problem area was identified on the Horse Canyon road (Point 44 on Figure 2).

Figure 3 (below) shows a closeup of the area.

Canyonlands National Park: Salt Creek Road Review



This map is designed to support a field trails investigation of the Salt Creek road in Canyonlands National Park. Points are referenced in the report text.

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Prepared By: Henry Shovic (hshovic@montana.edu)
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NAD 1983 UTM Zone 12N
File: CANYSaltCreekMapHorseCanyonArea.mxd

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Horse Canyon road transects a series of steep banks (Point 44 to 46) in extremely sandy material. It has been eroded by vehicles and by intermittent stream flow down the road. Where slopes are gentle, little erosion has occurred.

Erosion on Horse Canyon road on steep sections

Erosion on Horse Canyon road on gently-sloping area

Two potential reroutes have been identified (blue and dashed red in Figure 3). Each appears to have potential to avoid the current road location, but both come very close to an observed cliff line, which probably extends south past the symbolized location on Figure 3, based on the aerial imagery. Both also appear to traverse steep sandy bluffs (slopes > 30%).

Overview showing steep, sandy bluff and Horse Canyon road below

Therefore, both bedrock and steep, erosive slopes are likely to be potential problems for any road re-route through this area. Though it appears feasible, it will probably require engineering analysis and road mitigation measures such as surfacing, drainage structures, and grade control.

Conclusions

The above analysis of the field review data can be used to make some conclusions about the Salt Creek road system.

The Salt Creek riparian system is a rare resource in Canyonlands National Park. It is likely the only example of a small perennial system in the entire Park. The surrounding upland is an arid, infertile, and erosive environment, and the valley produces significantly different vegetation and probably associated wildlife from that upland. Increasing aridity from climate change will only make this resource more rare. The stream system is flood-prone and any mitigation measures will need to take this environment into account.

There are significant impacts to the hydrologic system from vehicle use. About 2/3 of the system is impacted. Effects include deterioration in the nature of the stream bed, nearby vegetation, and water quality. However, local observation indicates removing this vehicle use will probably result in significant natural recovery.

The proposed re-route has potential to reduce stream impacts. However, it is not optimal. The upper 2/3 of the stream is probably the most likely to contain affected resources but, its present location is probably not effective in that upper 2/3 of the road system, because of flooding potential on the low terrace and channelization of intersections. The re-route location on the lower 1/3 is probably more effective since it is primarily on the upper terrace, but the channel is poorly-defined there and may not benefit much from removal of use.

At Horse Canyon, the road re-route will probably be effective at reducing erosion. However, because of bedrock, the steep slopes, erosive soils, and arid environment it will be significantly more expensive to design and build than roads on less-sloping ground.

Overall, it appears that other options should be considered to protect this resource. These might include re-designing the re-route to take advantage of higher terraces (with significant increases in costs due to probable excavation of bedrock). A second alternative might consider a re-route to Horse Canyon and Peekaboo campground on the uplands surrounding the Salt Creek valley rather than within its perimeter.

Appendix One – Salt Creek

Field Notes
Salt Creek Road
Canyonlands N. P.
H. Shovic
April 13, 2009

Waypoints are from GPS and are shown on Figure 4. Pictures are in a separate folder.

Point 016 pic 41, at gate

Point 018 is campsite Campground is on sand dune material (loose)
Pic 42 - 46

Closed road,Pic 47, 49 sand starting to reclaim itself

Pic 50 shows banks starting to slough.

Point 021 closed road incipient cryptogamic soil at the base pic 51, 52, 53

Point 022 Salt Creek appears not driven on; rocky bed pic 54

Salt Creek above campground trail is dry

023 bank from Salt Creek to Campground; relatively stable bank (cobbles)
Bank is 5' high. Pic 55
024 dry channels present, prob recent flooding on this terrace
025 other side of reroute, going east. Goes up a steep (20%) bank; a dry terrace above it (gravelly)

The lower terrace is relatively stable, in sand, older flood plain, 4 feet above road; no evidence of overflow; soils probably have developed from sand (wind-blown), because of uniform grain size and no alluvial patterns seen other than on stream banks.

028 flood debris in tree (picture); reeds are bent over. Pic 56

040 disturbance in creek; gravel bottom ; There is vegetation on bank; medium textured stream bed.; Entire width of stream bed is disturbed every vehicle. Water was turbid; pic 57 And active erosion and disturbance by vehicles pic60, 61, 62, 63 even when driving 1 mph….

042 1.5 ft. deep pools probably created by vehicles; There is bank vegetation.
(related to driving because don't exist where no vehicles drive) pic 59

043 Confluence area to Horse Canyon   very sandy banks; rocky stream bottom pic 64

044 confluence of Salt and Horse Creeks picture deeply eroded Horse Canyon road; streams come down this road; 7 ft. high banks pic 65

Pit blocking off the road.

045 Erosion not evident here. Upland bench (all sand) pic 66

046 Reroute beginning from road (stakes) pic 67

047 steep bank (sand) above active flood plain; but stabilizing a new road cut in this material would be difficult (reference existing erosion and rilling by stream) pic 68

This reroute will be expensive; existing materials poor; veg poor; needs engineering.

048 in main stream channel (there is water, drive through most of the way); gravel base but sandy banks and upper flood terrace.

049 on reroute area; on a terrace with an active channel; appears no better than in channel.

S of 049 needs removal of large boulders to get it out of the flood plain.

Other side of 049 is a wide flat terrace, sandy, will need surface but high out of floodway. No flood evidence. 9 feet above floodway.

Pic 69 and 70 around here on un-disturbed area where road not in stream.

050 road leaves stream channel. 3 ft bank   pic 71

051 back in stream channel, now a sandy channel.

052 back in stream channel

5 ft. bank where reroute might enter stream again.

053 bathtub ring rocks no quicksand today; sand bottom; banks are eroded. Pic 72, 73

054 picture; sandy, well vegetated bench, could be used for reroute; excellent cryptogamic soil crust here. Pic 75

055 across road, medium terrace which has no obvious flood evidence, but 30 ft. lower than the bench on which I am standing. Reroute around 55 is on the south site, not here, bathtub rings indicate floods almost to the level of that terrace, so potentially floodable; where creek crossing, reroute is in the medium term flood terrace, so crossings could become channels; also slope is variable. Suggest reroute at 054. Pic 76, 77

At cutoff between 55 and 57: walked undriven part of stream; shows effects of no vehicle use; pic 79 is undriven; pic 78 is at corner of cutoff

057 comes out of wash again, completely dry and sand filled; up on a low bank

058 back into the wash; come back in 20 ft later form a low bank; back into wash.
Dry channel; sandy flood deposits.

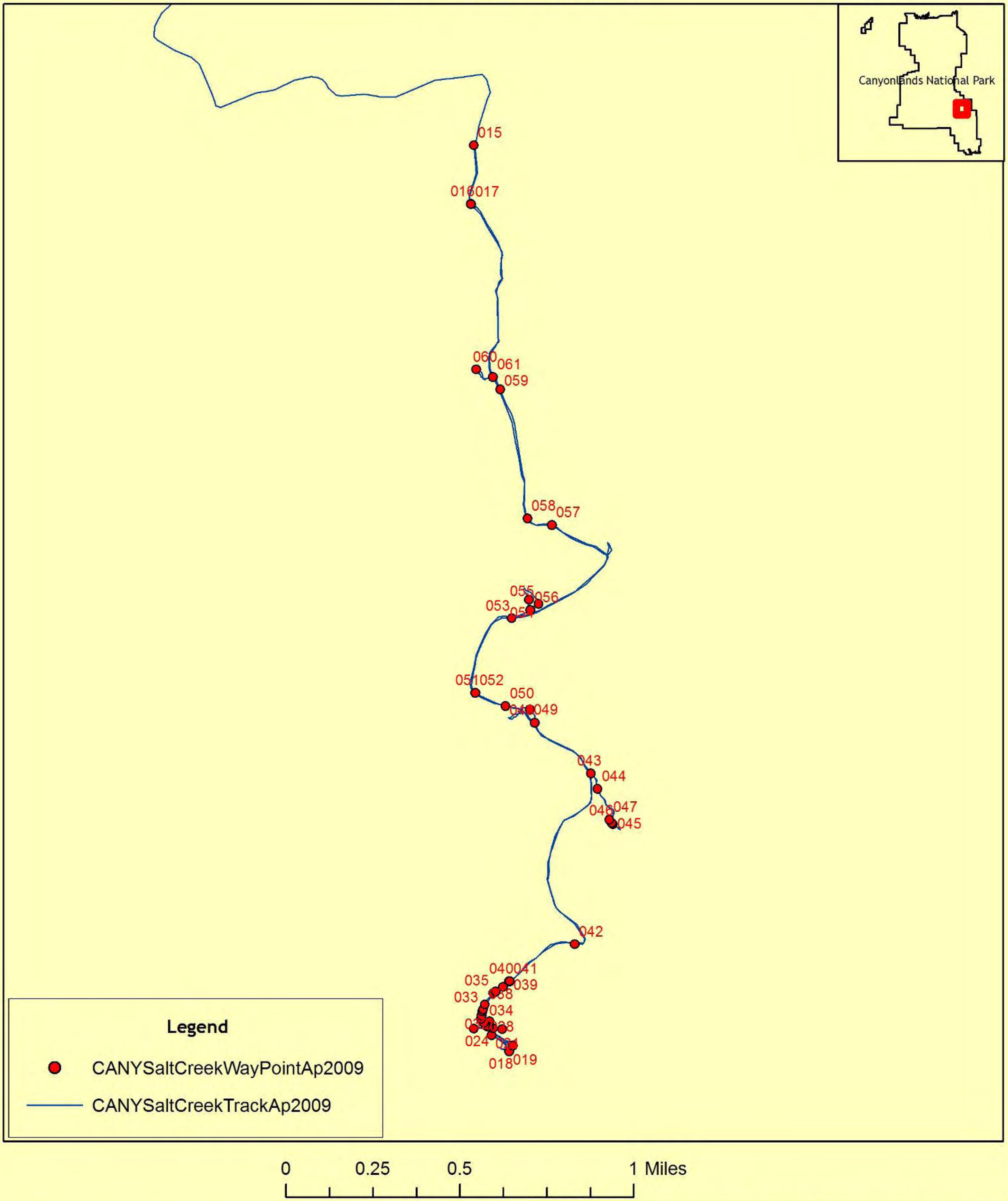
059 From here out, the reroute is not very far above the wash; very dispersed channel here, dispersed flow; multiple floodways pic 80

060 sandy, flat, sagebrush terrace for reroute pic 81

061 very dispersed flow;, no channel, some wind erosion; final 400 ft of road before gate is out of the wash.

Figure 3 is below.

Canyonlands National Park:
Salt Creek Road Review



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File: CANYSaltCreekMapGPSPoints.mxd

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Rocky Mountains Cooperative Ecosystem Studies Unit

Appendix Five: Annotated Bibliography of Trail Maintenance

Annotated Bibliography
Canyonlands National Park and Arches National Park Technical Support Project
Henry Shovic, Rocky Mountain CESU
May 5, 2009

In the Forest Service, roads are never encouraged in riparian zones or in streams. Best management practices (BMP's) always discourage placing any part of the road components (including fill, and end-haul) in the stream management zone, in designated wetlands. See page 52 for examples of regulations.

U. S. Forest Service. 2000. Water quality management for forest system lands in California: Best Management Practices. USDA, Pacific Southwest Region

Native plants have become a standard for revegetation even in highly disturbed and artificial environments, such as highways. These two publications are a technical planning guide and a manager's guide developed by the U. S. Forest Service for the Highway Administration.

Steinfeld, D., S. Riley, K. Wilkinson, T. Landis, L. Riley. 2007. Roadside revegetation: an integrated approach to establishing native plants. Federal Highway Admin. West. Fed Lands Highway Division, 610 E. 5th St. Vancouver, WA 98661 http://www.wfl .fhwa.dot.gov/td/.

Steinfeld, D., S. Riley, K. Wilkinson, T. Landis, L. Riley. 2007. A manager's guide to roadside revegetation using native plants. Federal Highway Admin. West. Fed Lands Highway Division, 610 E. 5th St. Vancouver, WA 98661 http://www.wfl .fhwa.dot.gov/td/.

Trail development, construction, and maintenance are discussed in the Forest Service manual. Those subjects are contained in the folder "USFSTrailManualDirectives2309.18". Following are relevant files. These can be viewed in MS WORD.

2309.18,1.rtf – trail planning
2309.18,2.rtf – trail development
2309.18,3.rtf – trail preconstruction and construction
2309.18,4.rtf – trail operation and maintenance

These are dated, but are useful for reference. An up-to-date guide is included below. This is a very detailed handbook on trail planning, preconstruction, construction, maintenance, and reclamation techniques. It is oriented to the Rocky Mountains, but techniques do not vary all that much.

Hesselbarth, W., B. Vachowski, and M. Davies. 2007. Trail construction and maintenance handbook: 2007 Edition. USDA. Forest Service. Missoula Technology and Development Program, Missoula, MT.

The National Park Service has a recent guide on trail management. It is oriented to mountainous terrain, but contains some guidance on Pinyon Juniper woodlands (p. 44) and some matrices for trail sustainability (p. 50).

National Park Service. 2007.Guide to Sustainable Mountain Trails: Assessment, Planning & Design Sketchbook, 2007 Edition. Denver Service Center.

There are many methods of trail monitoring and evaluation. However, they all emphasize trail erosion as the main impact. This is a synthesis and evaluation of methods, including both sampling and census concepts.

Jewell, M. C. and W. Hammitt. 2000. Assessing soil erosion on trails: a comparison of techniques. USDA Forest Service Proceedings RMRS-P-15-VOL-5. 2000

More trail evaluation methods are discussed in this paper, applied to the National Park Service. In particular, condition classes are described (page 39) which might apply to arid lands.

Marion, J., Y. Leung, and S. Nepal. 2006. Monitoring trail conditions: new methodological considerations. The George Wright Forum.Vol 23 (2).

An unpublished document discusses trail evaluation near riparian areas. Jeff Marion is involved in this work. Quantitative measures are described.

Lanehart, E. 1998. Backcountry trails near stream corridors: an ecological approach to design. Thesis, Virginia Polytechnic Institute and State Univ. Dept. of Architecture and Urban Studies.

There are many publications on the effects of vehicles on stream sediment and turbidity. Here is one that relates ATV use to increased levels of stream impacts.

Guldin, James M., tech. comp. 2004. Ouachita and Ozark Mountains symposium: ecosystem management research. Gen. Tech. Rep. SRS–74. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 321 p.