

Using ArcGIS to Develop a Dynamic Trail Inventory

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Abstract

The Santa Monica Mountains National Recreation Area, a unit of the National Park Service, is located in Los Angeles and Ventura Counties in the Los Angeles metropolitan region. The recreation area consists of approximately 500 miles of official and unofficial trails and dirt service roads. There are more than 70 local, state, and federal agencies with jurisdiction in the recreation area, each with their own management aims and policies. Additionally, there are thousands of private landowners. Given the jurisdictional diversity and private interests, developing an interagency trail management plan can be a significant challenge. Maintaining an accurate and up-to-date GIS trail inventory is essential for resource planning and management. To create and administer the GIS trail inventory, we are using an ArcGIS™ geodatabase. The geodatabase's ability to maintain data integrity and to dynamically reflect corrections and updates to trail alignments and attributes allows for efficient and effective analysis in a form that is usable to both agency planning staff and the public.

1. Introduction

The Santa Monica Mountains National Recreation Area's vast recreational trail network is subject to the jurisdiction of numerous local, state, and federal agencies. With the advancement and availability of GIS technology, we found it best to utilize a GIS database to effectively manage the vast, complex trail network. Over time, as the demand on the functionality of the database increases and as database managements systems continue to develop, the database may need to evolve to incorporate new functionalities. This paper describes how the GIS staff at Santa Monica Mountains National Recreation Area (SMMNRA) created the GIS Trail Inventory, and how we are currently handling the process of migrating from the coverage to the geodatabase data model.

2. History Behind the Database

The Santa Monica Mountains National Recreation Area (SMMNRA) was established by Congress in 1978. The recreation area boundary encompasses some 153,000 acres, and at the time of creation, only 33,000 acres were in public ownership. Over the years, local, state, and federal agencies acquired public parkland, and today, 75,000 acres are in public ownership. Along with the parkland, agencies inherited many miles of old ranch roads, utility and fire service roads, and informal trails. Additionally, the park agencies are nearing completion of the public right-of-way for the 64-mile regional Backbone Trail that crosses the park from east to west. Now that there is a clearer picture of public land ownership in SMMNRA, the time has arrived to develop a comprehensive trail plan for the recreation area.

The first step toward a trail plan began in 1994 with a three-year public scoping project sponsored by the National Park Service's Recreational Trails and Conservation Assistance (RTCA) program. The scoping project resulted in the 1997 "SMMART" report, the acronym for "Santa Monica Mountains Area Recreational Trails." During SMMART scoping, existing trails and dirt roads were "GPS-d" and entered into an Arc/Info® GIS database. Some trails and roads were also digitized off existing trail maps. The resulting GIS trail database was briefly attributed with, feature type (road or trail), trail name, and use designation, and the database became the foundation for the current GIS Trail Inventory. Meanwhile, the SMMART report was a

compilation of recommendations from the public on how they would like the trail network to be developed and managed. The next step was for the agencies to prepare an official trail management plan for SMMNRA.

In 1998, the three main parkland management agencies—National Park Service, California State Parks, and the Santa Monica Mountains—embarked on completing a GIS-based trail planning inventory to be used to develop the forthcoming Santa Monica Mountains National Recreation Area Interagency Regional Trail Management Plan (TMP). The first step was to integrate several separate GIS data layers into just one trail database. Then, descriptive fields for existing conditions and proposed conditions were brainstormed and put into place. Over the next several years (owing to staff funding limitations), the GIS trail inventory attribution was expanded to address planning queries, official documents for proposed new trails, ADA opportunities, and to document various sources for trail information. During this time, National Park Service staff and a consistent core team of volunteers collected physical trail condition data using Beneficial Design's Universal Trail Assessment Process (UTAP) for over 285 miles of trails and dirt roads. The "UTAP-d" trails were related to the GIS trail inventory via trail name. Initially, staff used the Arc/Info® routes functionality to digitally locate various UTAP data values in the GIS. Such data included trail grade, maintenance features, trail or road width, and recreational use obstacles.

TMP development is an action being undertaken by both federal and state agencies, and as such, requires compliance with the National Environmental Policy Act (NEPA), and the California Environmental Quality Act (CEQA). The interagency TMP planning team is now using the GIS Trail Inventory to develop and illustrate conceptual alternatives for the NEPA/CEQA document, a joint Environmental Impact Statement/Environmental Impact Report (EIS/EIR). The GIS Trail Inventory has been an indispensable tool for not only illustrating existing conditions, but also for quickly querying and analyzing multiple future visions of the SMMNRA trail network necessary for developing three conceptual alternatives.

3. Developing the GIS Trail Inventory Database Structure: Can the Database Answer Questions?

With such a large network of trails and the many different agencies managing these trails, the database had to be set up in a manner that could handle the diverse trail planning situations that generate planning questions. Example questions include: What is the current trail use designation, i.e. hikers, bikers, equestrians, etc., and what use designation is desired for the future? Are dogs allowed on this trail? Does the trail meet ADA standards? How does this trail relate to previous plans? Where are new trails proposed? What do we have planned for this trail under the different planning alternatives for the Trail Management Plan joint Environmental Impact Statement/Environment Impact Review (EIS/EIR)?

Appendix A describes each of the planning fields within the database. The planning fields were created in 1999, and the majority of the fields have remained current and are effective in answering most trail-related questions and analyses. On occasion new attributes need to be added to each of the fields in order to meet some unforeseen circumstances.

4. Demands for Improved Trail Database Management Efficiency

Initially the GIS Trail Inventory was managed with the coverage data model that utilized coverage topological relationships to maintain its spatial integrity. Over its life, the trail database has seen many users and editors and has, for the most part, remained fairly stable. However, increasing user demands on the database for analytic purposes, increasing time requirements for

updates, and stiffer standards on maintaining data integrity all led to the need to migrate the trail database to a more versatile data model.

In addition to the need for a more efficient database, the old route-system, originally created to implement the UTAP data via linear referencing and dynamic segmentation, was in desperate need of an overhaul. The route-system had been stored in a separate coverage and had not been maintained, so many of the trail alignments were out of date. The route-system needed to be recreated and incorporated within the database to be used effectively, especially with the continuous editing of trail alignments that would cause inconsistencies between the trail database alignments and the route alignments.

Because of the demands placed on the database and the time it would take to rebuild the route-system, we realized it would be easier and more effective to manage the database if the database were migrated to the geodatabase data model. ArcGIS™ 8.3 offered the capability to customize topology, to easily maintain relationships within the database, and to allow a vast number of feature classes. Additionally, those capabilities coupled with the extreme ease of editing in ArcMap™, solidified our decision to use the ArcGIS™ 8.3 geodatabase model as the definitive tool for managing the GIS trail inventory.

5. Advantages of the Geodatabase for Trail Data Management

Impromptu Data Editing during Map Making

There were several advantages in using ArcGIS™ 8.3 and the geodatabase data model to maintain the GIS trail inventory instead of the coverage database. The advanced cartographic capabilities of ArcMap already made it the primary software that the SMMNRA GIS Lab uses for cartographic purposes. Generally, data discrepancies tend to appear in the final stages of map making, making it extremely beneficial to be able to do edits without disrupting one's workflow. Maintaining the data in a manner that was compatible with ArcMap™ (ArcGIS™ 8.3 coverage editing is not possible in ArcMap™) would allow for editing as problems surfaced.

Using Complex Symbology for Quality Control

The same cartographic capabilities that make ArcMap™ an indispensable map making tool also allow for easier quality control over the database. When maintaining a large network of arc features, it is easy to miss small segments that were not attributed properly during the editing process. Utilizing the symbology properties of ArcMap™ makes it easy to find these errors. In addition, the ability to symbolize data with up to three different attributes makes it easier to maintain consistency and data integrity among different fields. In the SMMNRA GIS trail inventory, many of the fields are interdependent. The fields representing Current Use (CU), Current Status (CS), Proposed Use (PU), and Proposed Status (PS) are designed in a way that, by looking at the attribute value for one field, the values of the other three fields can be inferred or narrowed

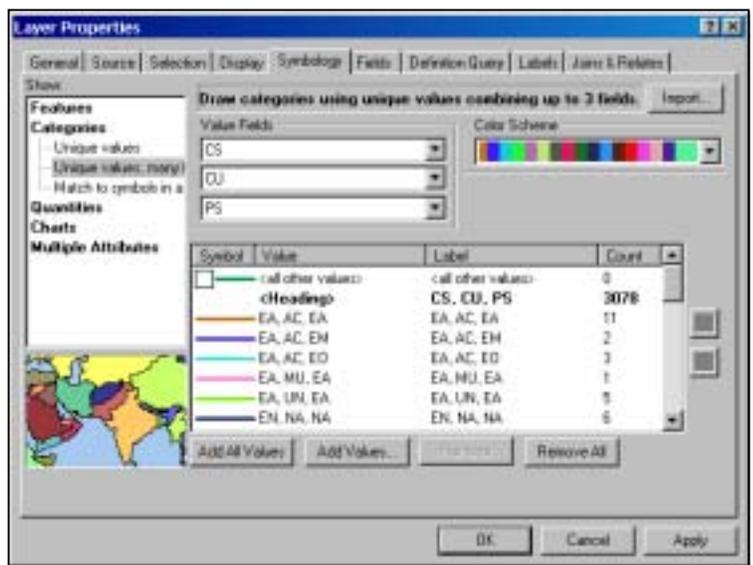


Figure 1

down. This concept also applies to the other EIS/EIR alternatives depicting Proposed Status – High Use (PS_High) and Proposed Use – High Use (PU_High), and Proposed Status – Low Use – (PS_Low) and Proposed Use – Low (PU_Low) respectively.

Symbol Combination					Problem
#	CS	CU	PS	PU	
1	EU	HO	EM	HO	An unofficial trail cannot have a use designation.
2	EN	NA	EO	MU	A proposed trail's "PS" must be equal to "proposed new".
3	EU	UN	EO	HO	An unofficial trail must have "existing official" attribute even if it proposed to have "existing official" status, it must be "make official".

Table 1

An example follows of using multiple field symbology to facilitate data quality control on a proposed new trail. The trail's CS is "Exists Not" (EN), because the trail does not exist but the proposed alignment can be illustrated. A non-existing trail is obviously not available for recreational use, and thus, making its CU value "not applicable". The proposed trail's PS value should be "Proposed New" (PN) and its PU value should address the public need. If there are inconsistencies among the values caused by data entry errors, the inconsistencies can easily be discovered by using ArcMap's "symbolize by categories, unique values, multiple fields" option (Figure 1). One can find these errors simply by doing a count on the number of features that match these criteria, similar to a frequency analysis in Arc/Info® Workstation, but without having to go through exporting tables and other data manipulation, and then correct these errors while viewing this complex symbology. Table 1 goes through a few more examples of inconsistent data.

Centralized Storage of All Related, Interchangeable Trail Data

Example Database

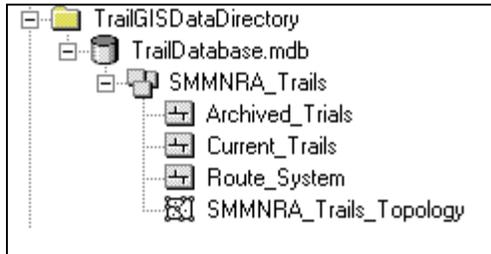


Figure 2

The geodatabase also allows for multiple feature classes—mainly polylines in the trail database—that should not be stored with the main feature class to be archived in a separate feature class within the same featured dataset. This allows for a more diverse centrally located database, which can store the main trails feature class, the routes, the UTAP datasets, as well as easily allowing archived data to be located and reincorporated into the main feature class. When the trails database was initially created, it contained many of the trails were digitized from a variety of sources. Some of these sources improperly designated private roads and driveways as trails. These pathways needed to be removed from the main trail database so that they would not be included in planning discussions, statistics, etc. However, it is still important to keep an inventory of these pathways as another

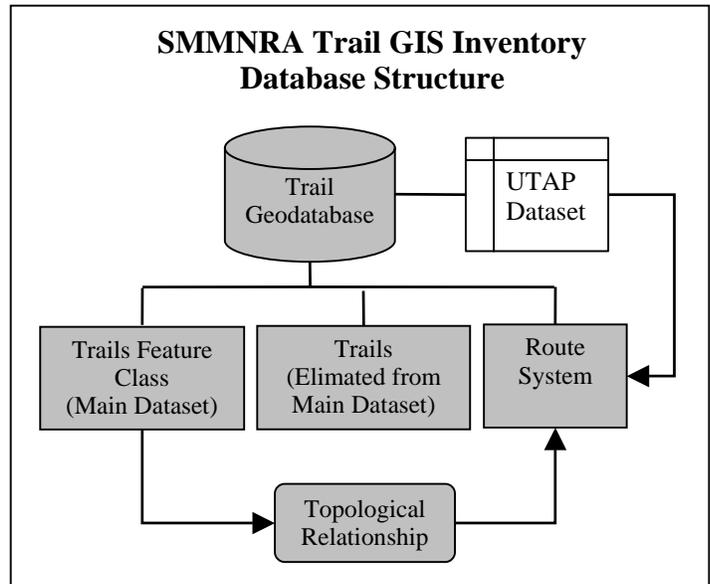


Figure 3

SMMNRA GIS data layer illustrating all access routes, i.e., not just the recreational network, and to maintain a history on the progression of the database.

Simplified Multi-User Editing through Established Topological Relationship Rules

Utilizing the geodatabase topological relationship rules functionality to maintain the spatial integrity of the data takes much of the burden off the editor. Once a set of topologic rules have been established, editors can make changes without concern over the possibility of damaging route or spatial relationships. The database administrator can then track major changes within the database without actually having the benefits ArcSDE™. Backups of the database can always be maintained and restored if any serious damage occurs.

Ease of Route System Management

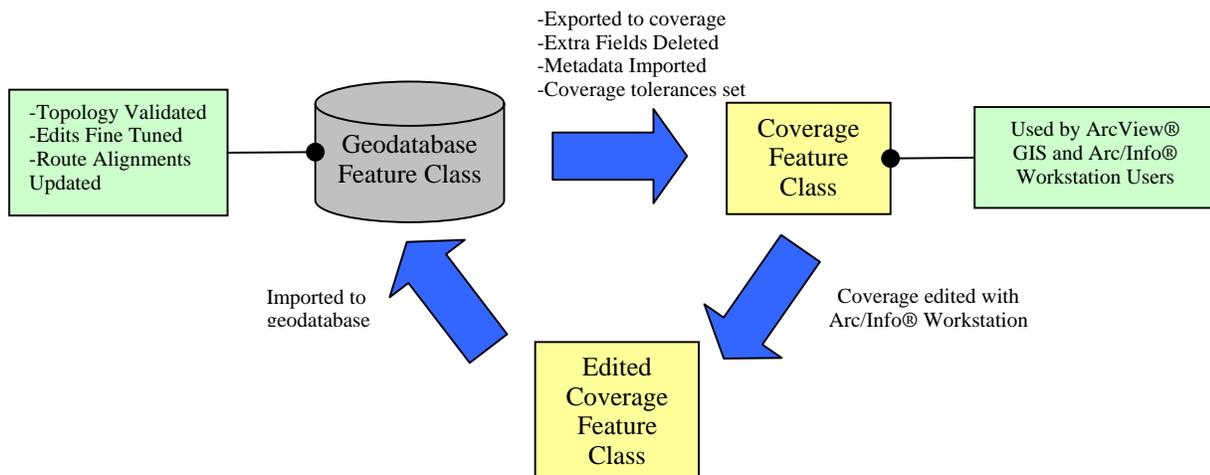
The route system was much easier to generate in ArcGIS™ than in Arc/Info® Workstation because of its more intuitive editing. Creating a route-system only required dissolving the “UTAP-d” polylines from the GIS trail inventory, then assigning both length and directional values to each route. ArcMap™ also has the capability of Arc/Info® Workstation for the user to detect errors after dynamic segmentation such as segments that overshot or undershot their route measure. The original route system, though created in Arc/Info® Workstation, was mainly used in ArcView® GIS, which did not have the capability of detecting these errors. ArcGIS™ combined the ease of use from ArcView® GIS and the reliability of Arc/Info® Workstation.

More Accurate Length Analysis through 3D Feature Classes

ArcGIS™ also allows for the easy calculation of arcs in 3D space, making it possible to get a more accurate representation of the trail lengths for analytical purposes. This can be quite easily done by creating a feature class that contains Z values. The Z values can be generated by the 3D Analyst™ extension to create a new feature class with assigned elevation values based off an elevation layer. To generate trail elevations for our database, we used a DEM with 10 meter resolution. The 3D lengths were then calculated using an equation provided by ET Geowizards for ArcGIS™ (<http://www.ian-ko.com>). Incorporating the 3D length calculations into our database allows us to use these lengths to get a more realistic representation of trail lengths for statistical purposes.

6. Database Migration

Data Transfer Flow Chart



The switch from the coverage to the geodatabase data model was not without its problems. At the time that we were making the switch, our park had not completely moved over from Arc/Info Workstation and ArcView® GIS to ArcGIS™. Without ArcSDE™, ArcView® GIS users could not use geodatabases and the Arc/Info® Workstation users were required to be able to access and edit the data in ArcEdit™. The intermix of older and newer software suites made it important to create a standard procedure for the gradual migration from coverages to geodatabases, while still being able to take full advantage of the geodatabase.

To maintain database efficiency, the easiest solution was use the geodatabase as the primary management tool for the trails database, thereby taking advantage its capabilities. Then, to accommodate the users of older software suites, the trails feature class was exported into a coverage. ArcView® GIS users could continue to use the data as they always had. Those who still used Arc/Info® Workstation could do their edits just as they had always done. After completing their edits to the trails coverage, the coverage would then be imported back into the geodatabase, the previously established topology rules were then loaded, the data would be validated, and corrections would then be made. Finally, the geodatabase trails feature class would then be once again exported to coverage and the process would start over.

Each time the feature class changed data type, (i.e. coverage to geodatabase and vice versa) the new data format would contain extra fields that were irrelevant for the new data type. When changed from coverage to geodatabase, the coverage pseudo items become fields within the geodatabase and could be not easily deleted. However, so long as the data is primarily being utilized in coverage format and the geodatabase is where the data is managed, these fields are irrelevant. When the geodatabase feature class is exported to the coverage data model the previous pseudo items are imported in addition to the previous geodatabase OBJECTID field, and SHAPE_LENG field. These fields should all be deleted from the coverage prior to importing the metadata to alleviate these potential problems and confusion. Table 2 shows the fields that we removed from the finalized exported coverage.

Unnecessary Fields	Source
OBJECTID	Geodatabase
FNODE_	Coverage
TNODE_	Coverage
LPOLY_	Coverage
RPOLY_	Coverage
COVER#_	Coverage
COVER-ID_	Coverage
SHAPE_LENG	Geodatabase

Table 2

It is extremely important to note that after creating one's coverage, the properties of the TOL file must be correctly set. The default values tend to not have the resolution that is required for the data. If the database is edited in Arc/Info® Workstation, it is very likely that it will loose resolution and the data will become corrupted. (See Section 7 for more details.)

ArcGIS Topological Rules to Facilitate Migration

To ensure the data would be easily transferred between the different database models, the topological feature relationship rules of the geodatabase were set up to emulate coverage rules. The polyline rules that we used for the trail database were:

Topology Rules

- Must Not Overlap
- Must Not Intersect
- Must Not Self Overlap
- Must Not Self Intersect
- Must Not Intersect or Touch Interior
- Must Be Single Part

The geodatabase topological feature rules are much more sophisticated and allow for many more circumstances than the coverage model. By attempting to model the coverage topology rules, a more seamless data migration that avoids potential data translation errors. Ultimately, through using these rules, it did not matter where the data was edited; the outcome would essentially remain the same.

Route System Migration

To maintain the integrity of the route system a separate set of rules needed to be implemented. These rules included:

Route-System Rules

- Must Be Covered by Feature Class of “Trails Database”
- Must Not Self Overlap
- Must Not Overlap
- Must Not Self-Intersect
- Must Not Intersect

The most crucial rule behind maintaining the route system was the “Must Be Covered by Feature Class of 'Trails Database'.” Utilizing these rules helps keep the route system aligned with the trails.

7. Problems Encountered and Lessons Learned

It should be noted that the following steps are not necessary if the newly created coverage exported from the geodatabase is not cleaned or does not have its topology built on it while used in Arc/Info® Workstation. Coverages that are created using ArcCatalog™ seem to be fully functional without the need of additionally cleaning or building of topology on it in the traditional way. It is only after editing has been done in Arc/Info® Workstation and the coverage is cleaned or built that these problems occur.

Coverage Precision

Coverage precision was a problem that we encountered when we imported our coverage, edited in Arc/Info® Workstation into the geodatabase. By default, the precision for a coverage is set to single. Users trained recently in ESRI® GIS software generally have never heard of the term “precision” used in GIS, and current shapefiles and geodatabase feature classes don’t have anything less than double precision. In order to make sure the coverage created in ArcCatalog™ have double precision, one must set the precision under the options menu in ArcToolbox™. Here another problem presents itself. Once the precision is set in ArcToolbox™, it is not guaranteed that ArcGIS™ will remain in that precision with each time that ArcCatalog™ is launched. Therefore, it is always a good idea to set the precision prior to creating the coverage.

According to research on the ESRI® support website the best way to maintain a double precision conversion is to do conversion in Arc/Info® Workstation with double double precision the utilizing shapearc command (Article ID 15441). We found the easiest way to make certain that your coverages were being created in the proper precision is to simply make a habit of loading ArcToolbox™ and making sure the precision is set correctly. A possible future solution to this problem is to create a custom “UIButtonControl” for exporting to coverages that makes sure the precision is set properly prior to the export.

Coverage Tolerances

Possibly the most important consequence and easiest to overlook, is the fact that, when converting from one format (either shapefile or geodatabase) to the coverage data format, all tolerances for the coverage are set to their default values. If edits are made in Arc/Info® Workstation and the editor then proceeds to either clean or build the coverage without first properly setting the coverage tolerances, the coverage will lose resolution. Thus, it is extremely important to ensure that the tolerances are properly set prior to a clean or build. According to the Arc/Info® Workstation help file “the fuzzy tolerance is an extremely small distance used to

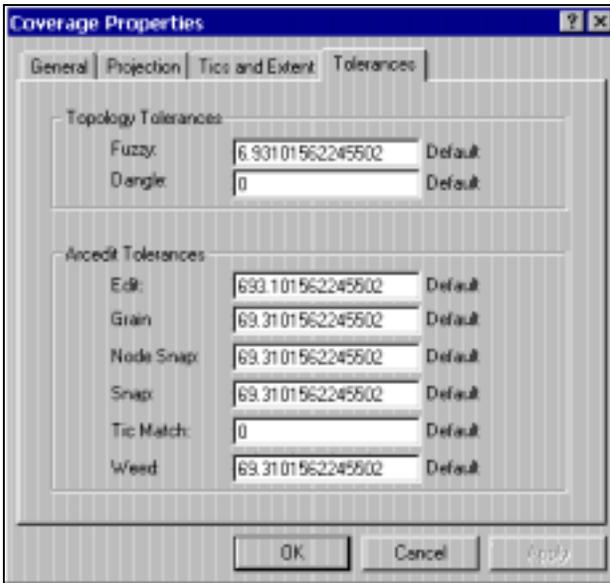


Figure 3

resolve inexact intersection locations due to limited arithmetic precision of computers. Fuzzy tolerance values typically range from 1/10,000 to 1/1,000,000 times the width of the coverage extent defined in the coverage BND file.” The trail database coordinate system is in Universal Transverse Mercator, Zone 11, NAD 27, and has an X extent between 306441.343709363 m and 375751.499933913 m, creating a total extent of 69310.155629767 m. This extent creates a default fuzzy tolerance of 6.93101562245502 m. If you use this default fuzzy tolerance, vertices with a resolution less than the set default tolerances would be merged together, severely damaging the original data. The default tolerance values should be checked and corrected immediately after exporting the coverage. Default values can be checked and edited in ArcCatalog™ by right-clicking and selecting the tolerance properties of the coverage (Figure 3). When we were first piloting the migration of data between geodatabase and coverage models, we were struck by this resolution loss. Fortunately, through backups, we were able to recover lost data, and in the process increase overall resolution of the data by correcting some previously undiscovered mistakes. Unfortunately, the tolerance reset occurrence is not something the geodatabase or the coverage user would anticipate, and is something that should be set in the interface of the “convert to coverage” tool. Geodatabase users don’t even have the option to set tolerances. Arc/Info® Workstation users that are used to setting this property once and not having to worry about it again also might not take the extra time to double check the TOL file to make sure that all the tolerances were set correctly.

8. Conclusion

Trail GIS Inventory and the Trail Management Plan EIS/EIR development continues to be a complex, sophisticated undertaking spanning a number of years. It has been an ongoing challenge to stay abreast of and take advantage of the ever-evolving ESRI® GIS software suites throughout TMP development. The trial-and-error exploration of migrating the SMMNRA GIS Trail Inventory between the geodatabase and coverage models has been a valuable experience. There are clearly benefits to maintaining the trail database in the geodatabase model. Expecting all users to immediately switch to ArcGIS™, however, is not feasible in the short-term. Currently, staff is beginning to use ArcGIS™ 8.3 as their primary GIS application, although staff perform most data analysis in Arc/Info® Workstation and ArcView® GIS.

Our future work on the trail database would ideally involve using ArcSDE™ to set up a fully functioning versioned multi-user geodatabase. As yet, we have not had the opportunity to utilize ArcSDE™. When SMMNRA GIS data is fully switched over to the geodatabase model and we have ArcSDE capability, we will reassess and expand the structure of the GIS Trail Inventory to fully take advantage of the geodatabase's capabilities.

Acknowledgements

Santa Monica Mountains National Recreation Area GIS Lab, for all their help and advice.

Appendix A: GIS Trail Inventor Field Description

Attribute	Description
<i>Unique Identifier Fields</i>	
Name1	Most Commonly used name for a trail
Name2	Second name used to reference a trail
NameUTAP	Relational field to connect trail data to UTAP data
<i>Physical Trail Network Feature</i>	
TYPE	Type of pathway, current and proposed in TMP "Hybrid", High-Use, and Low-Use Conceptual Alternative:
TYPE_high	T = Trail
TYPE_low	R = Dirt Road P = Paved Road N = Not applicable because trail is not constructed yet
<i>Physical Presence of Trail</i>	
<i>Trail's Presence (or non-presence)</i>	
CS	Current Status of trail condition EO = Existing official trail on public lands (may include non-park public lands) trail network. Trail and right of way are established EU = Existing unofficial trail EN = Exists not (planned trails) EA = Existing administrative access or service road, may or may not have general public right of way
PS	Proposed status, TMP "Hybrid", Low-Use, and High-Use Conceptual Alternative
PS_high	EO = Existing official, to remain official
PS_low	EU = Existing unofficial trail, to remain unofficial EA = Existing administrative access or service road, may or may not have general public right of way EC = Existing trail, proposed to be closed EM = Existing unofficial trail, make official PN = Proposed new trail UM = Unmaintained trail - recognized and signed by agency as present, but unmaintained by agency

Allowed Use(s) on Trail

CU	Currently officially designated use of trail way MU = Multi-use HO = Hiker only HE = Hiker-equestrian only UN = Undesignated DA = Disabled access - assumed also hiker only NA = Not applicable, trail does not exist AC = Administrative access only
PU	Proposed Use, TMP "Hybrid" Conceptual Alternative, Low-Use, and High-Use Conceptual Alternative
PU_high	MU = Multi-use
PU_low	HO = Hiker only HE = Hiker-equestrian only UN = Undesignated DA = Disabled access - assumed also hiker only NA = Not applicable, trail does not exist AC = Administrative access only

Dog Policy

CURRDOG	Current dog regulation for trail: 1 = Yes, dogs allowed 0 = No, dogs not allowed
PLANDOG	Planned dog regulation for trail - "Hybrid", High-Use, Low-Use Conceptual Alternatives:
PLANDOG_high	1 = Yes, dogs allowed
PLANDOG_low	0 = No, dogs not allowed

SMMART Report "Missing Links Team"

Proposed needed trail connections

MISLINK	Trails that match the 50 Missing Links recommended by the SMMART Report 1 = TMP to recommend implementation. 2 = TMP recommends not implementing at all (link had been totally deleted in GIS, or is still present and can be illustrated by querying the mis_no field) 3 = TMP recommends the local community work to realize missing link 4 = Implemented already 5 = TMP Team &/or Team Leader haven't made a decision
MIS_NO	Missing Link number referenced to the SMMART Report

Trails Addressing Special Needs and Americans with Disabilities Act

ADA	1 = Existing ADA access to trail that primarily meets ADA standards and is currently used by physically challenged, but isn't necessarily only open to ADA users. CU field is not necessarily "DA" 2 = Potential trail to either begin promoting as an ADA opportunity, retrofit to ADA standards, or to construct the trail opportunity
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3 = "Advanced Opportunity" trail that can potentially be navigated with individual strength and possibly also with assistance. Little or no retrofitting or reconstruction is planned to improve access.

Source Information Fields

NOTE: Trail arc may have more than one source

COSCA	1 = Trails digitized from COSCA maps
LACMTRPL	1 = L.A. County Master Trail Plan digital cvg from Milan Svitek
RSIMI	1 = Trails digitized from Rancho Simi Rec & Parks Dept
HARRISON	1 = Trail digitized from Tom Harrison Maps
GPS	1 = Trail GPS'd as part of SMMART Report trail inventory &/or Trails Illustrated
TECHNAME	1 = Trails incorporated by GIS Technicians from aerial photos or GPS'ing
ONSCREEN	1 = Trails incorporated by onscreen digitizing
BURTGPS	1 = Trails GPS'd by Burt Elliot

Trail System Fields

Systems made up of several independently named trail segments

BBT_SYS	Backbone Trail
NOTE: Route options are prioritized	1 = BBT
	2 = Alternative Route
	3 = (Unused value)
	4 = Mountain Bike bypass option 1
	5 = MB bypass option 2
	6 = MB bypass option 3
	45 = option 1 and 2
	46 = option 1 and 3
LOSR_SYS	1 = Los Robles Trail
JBDA_SYS	1 = Juan Bautista de Anza National Historic Trail
CCRK_SYS	1 = Cold Creek Trail
ZRT_SYS	1 = Zuma Ridge Trail (aka Simi-to-the-Sea Trail)

Municipal Trail Plans

CALTMP	1 = City of Calabasas Trail Master Plan
MALIBUGP	1 = City of Malibu General Plan
AGOURAGP	1 = City of Agoura Hills General Plan

Other Data Management Fields

TEMPDELETE	Temporary field used to group trails that will be removed from database
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References:

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“ESRI Support Center”. 2004. <http://support.esri.com>

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