

Creating, Sharing, and Using GIS for the Salinas River Headwaters

David I. Yun, GISP

Tom Mastin, PLS

Douglas D. Piirto, Ph.D., RPF

ABSTRACT

“Dreaming The Salinas [a project of Ecologistics] is an innovative and collaborative region-based restoration and conservation initiative to reconcile nature and cultures.” The Salinas River provides water to cities and highly productive agricultural lands along its corridor. Once a mighty river that supported many life forms, it is now degraded due to heavy water use and non-point pollution. Managing the Salinas River is complex given the wide variety of stakeholders and issues. Resolution of these issues requires better geospatial data and interpretation which will improve communication and trust between stakeholders and lead to better informed decisions. Students, faculty, and staff from the Natural Resources Management and Environmental Sciences Department at California Polytechnic State University in San Luis Obispo performed a pilot study to create, share, and use GIS for the Salinas River headwaters. GIS provides facts to make informed decisions, gain concurrence, resolve conflicts, and “Dreaming The Salinas.”

INTRODUCTION

Managing the Salinas River Watershed is complex given the wide variety of stakeholders and several different regulating agencies trying to resolve many issues that collaboration is required. The lack of factual information creates assumptions that often leads to false beliefs and creates divisions among stakeholders. Lack of communication among stakeholders further

divides stakeholders and hinders collaborative efforts. A management plan based on factual information, scientific analysis, and logical decision making is needed. Geographic Information System (GIS) is a tool to create geospatial data, perform spatial analysis, and share information.

Students, faculty, and staff from the Natural Resources Management and Environmental Sciences Department at California Polytechnic State University in San Luis Obispo performed a pilot study to create, share, and use GIS for the Salinas River headwaters. This study presents geographic approach method to collect data, design and create geodatabase, and share the information.

GEOGRAPHIC APPROACH

Geographic approach is “a way of thinking and problem solving that integrates geographic information into how we understand and manage our planet.” It has 5 major steps: ask, acquire data, examine data, analyze data, and Act. (ESRI, 2012) Although the term may appeared in recent years, the concept is very old. For example, if road needs to be built from point A to point B, many geographic information is needed such as terrain, property ownership, soil, easements, archeological sites, etc. Collected data is carefully examined and recollected as needed to meet the quality standard. Then, information is analyzed to create a route that is based on informed decision. Finally, it is shared with others for approval and road is built.

The key component of the geographic approach is the geographic information. The primary objective of this project is to create quality geographic information for the management of Salinas River headwaters.

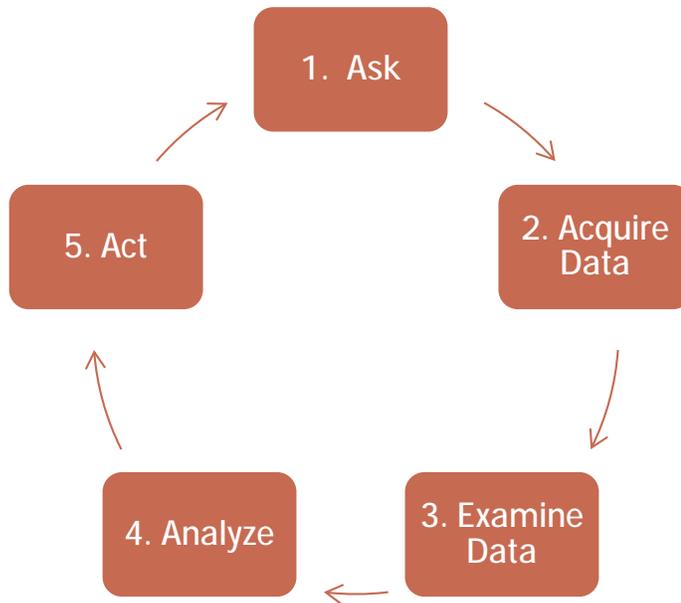


Figure 1, Geographic Approach steps

MATERIALS AND METHODS

Cal Poly already had necessary materials and staff to perform all required tasks. The ArcGIS Desktop was the primary GIS software for designing and creating the Geodatabase. ArcGIS Desktop software is the most widely recognized GIS software in the world. Virtually all governmental agencies, educational institutions, and GIS service providers use this software.

Mr. Mastin and his crew used survey grade GPS unit and classical survey equipment for establishing control points and grid system. Using survey equipment requires formal training to be effective. Mr. Mastin is a certified Professional Land Surveyor and his students, Mr. Ryan Gee and Ms. Eva Pong are well trained on using the equipment,

Mr. Yun and his crew taking the NR 418 (Applied GIS) course used mapping grade GPS units with ArcPad software for capturing features. Six students, Kristen Reichardt, Kaleigh

Morgan, Sam Rossi, Dean Chapman, Trevor Seck and Colleen Mooney spent significant time on this project working often on weekends to collect field data. Unlike surveying equipment, mapping grade GPS units are easy to use with few hours of training. Most students can learn how to use it simply by viewing a tutorial video or completing few hours of tutorial exercises. Students learned how to use the ArcPad at the Cal Poly campus before starting the field data collection. Students also used digital camera to take many photographs of features while collecting the data with GPS. Mr. Kevin Howen joined the project in April 2012 to complete his senior project requirement.

The knowledge and experience of NRES and BRAE Department staff played key role in completing the project.

Spatial Reference

Spatial reference contains coordinate system, tolerance, and resolution of a spatial data layer. A coordinate system is a reference system that locates a position in space. It allows different spatial data layers to be placed in correct spaces and be spatially related to each other. There are many different types of coordinate systems. Two most broadly categorized coordinate systems are geographic coordinate system and projected coordinate system. Geographic coordinate system uses angular measurements (longitudes and latitudes) to locate the position on a sphere or ellipsoid.

Projected coordinate system uses linear measurement unit on flat surface. Although most GIS data is in two dimensional flat surfaces as X and Y coordinates, GIS data can store 3 dimensional information using X, Y, and Z coordinates. Projected coordinate system depends on geographic coordinate system often described by the datum. Most projected coordinate systems

are identified by coordinate system name, zone, datum, and coordinate unit. There are hundreds of projected coordinate systems; however, only some are applicable for a particular location.

The study site is in San Luis Obispo County, California. GIS layers created in this study are using the California State Plane Coordinate System in zone 5 using North American Datum (NAD) of 1983. It is most commonly used coordinate system for GIS data in San Luis Obispo County. It is currently used by the County, CALFIRE, and other local GIS services group.

Mr. Mastin used same California State Plane Coordinate System Zone 5 in U.S. Survey Feet; however, he used NAD83 with 2007 North American adjustment in order to establish accurate control points. This adjustment is known as National Spatial Reference System 2007 (NSRS2007). Table 1 lists most commonly used projected coordinate systems in San Luis Obispo County.

Table 1

Commonly Used Projected Coordinate Systems in San Luis Obispo County.

Name	Zone	Datum	Unit	Notes
California State Plane Coordinate System (SPCS)	5	NAD83	U.S. Survey Feet	Current coordinate system. County of San Luis Obispo and most local agencies use this coordinate system.
California State Plane Coordinate System (SPCS)	5	NAD83 (2007 adjustment)	U.S. Survey Feet	Used for survey work.
California State Plane Coordinate System (SPCS)	5	NAD83 HARN	U.S. Survey Feet	Used by City of San Luis Obispo
California State Plane Coordinate System (SPCS)	5	NAD27	U.S. Survey Feet	Old coordinate system. Most data in this coordinate system was converted to NAD83 datum. Some historical data may be in this coordinate system.
Universal Transverse Mercator (UTM)	10	NAD83	Meter	This coordinate system is typically used by federal government agencies
Universal Transverse Mercator (UTM)	10	NAD27	Meter	Old coordinate system. Most data in this coordinate system was converted to NAD83 datum.

GIS data in different coordinate systems may not align properly unless correct geographic transformation setting is used. One of the most common geographic transformation is between WGS 84 and NAD 83. Data collected with GPS unit set to WGS 84 datum will not align properly onto NAD 83 unless proper geographic transformation setting is used. For San Luis Obispo County, the correct transformation option is “NAD_1983_To_WGS_1984_5” setting.

Mr. Mastin’s control and grid system which is in NAD 83 (NSRS2007) requires use of “NAD_1983_NSRS2007_To_WGS_1984_1 = NAD_1983_To_WGS_1984_5” setting to be properly aligned with GIS data. There is loss of positional precision with any transformation, as all transformations are mathematical estimations.

Geodatabase

Much of the GIS Database is stored as a feature class in a geodatabase. It is the preferred data model for the ArcGIS Desktop application. Although shapefiles are still very widely used, more and more GIS users are converting to geodatabase. Data stored in a geodatabase allows ArcGIS Desktop to perform more advanced functions such as topology editing and performing geometric network analysis. Topology editing uses set of rules to detect and fixes errors that are very difficult to detect visually. Geometric network allows modeling of connected network such as transportation, utility, and stream networks. More detail descriptions of geodatabase are well documented in *Modeling Our World, The ESRI Guide to Geodatabase Design* by Michael Zeiler (1999) and *Designing Geodatabases, Case Studies in GIS Data Modeling* by David Arctur and Michael Zeiler (2004).

Workflow

The first step was to explore and gather existing available GIS data. This included data from the County of San Luis Obispo, CALFIRE, USDA, and environmental consultants. In many cases, educational institutions such as Cal Poly State University host many GIS data. For example, aerial image and elevation data for the County was already available at the Cal Poly's GIS data server. It also contained many of the County's GIS data needed for this project. Once available data was compiled, students assessed what additional data will be needed.

Field data collection was carefully planned to reduce number of field trips and minimize data entry errors. For example, creating a form for data collection simplified and reduced time for capturing data and eliminated data entry error. Students also divided study site into zones for more efficient data collection.

Spatial adjustments were made to remove any errors such as polygons overlapping or having gaps. Features having "zig-zag" lines due to GPS signal loss are corrected from field notes and other reference information such as aerial images and elevation data. Additional information about the feature is entered into feature's attribute table. Metadata describing the feature is also entered into each GIS layers created by students.

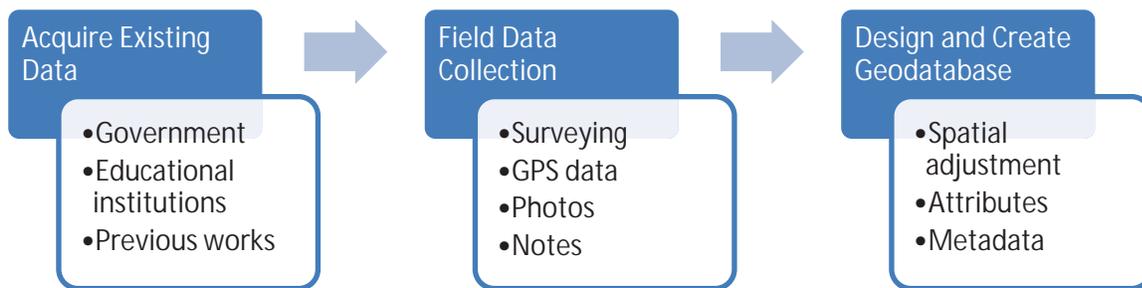


Figure 3: General project workflow

GIS LAYERS

All newly created data is saved as a feature class in ESRI's file geodatabase format. The GIS data from other sources are archived "as is" on a separate folder.

Control Points and Grid System

Mr. Mastin and his two students established controls points and local grid system to provide framework for mapping positions in study site with better accuracy and reliability. The baseline survey followed existing main road entering the study site. The areas of interest such as near the lake and potential research project sites are identified for control and grid point establishment. If grid intersection location was too dangerous due to extreme slope, it was offset to a safer place. The control and grid survey was used immediately in mapping other GIS layers such as parcels and roads. A separate survey report was created by Mr. Mastin describing details of baseline and control points.

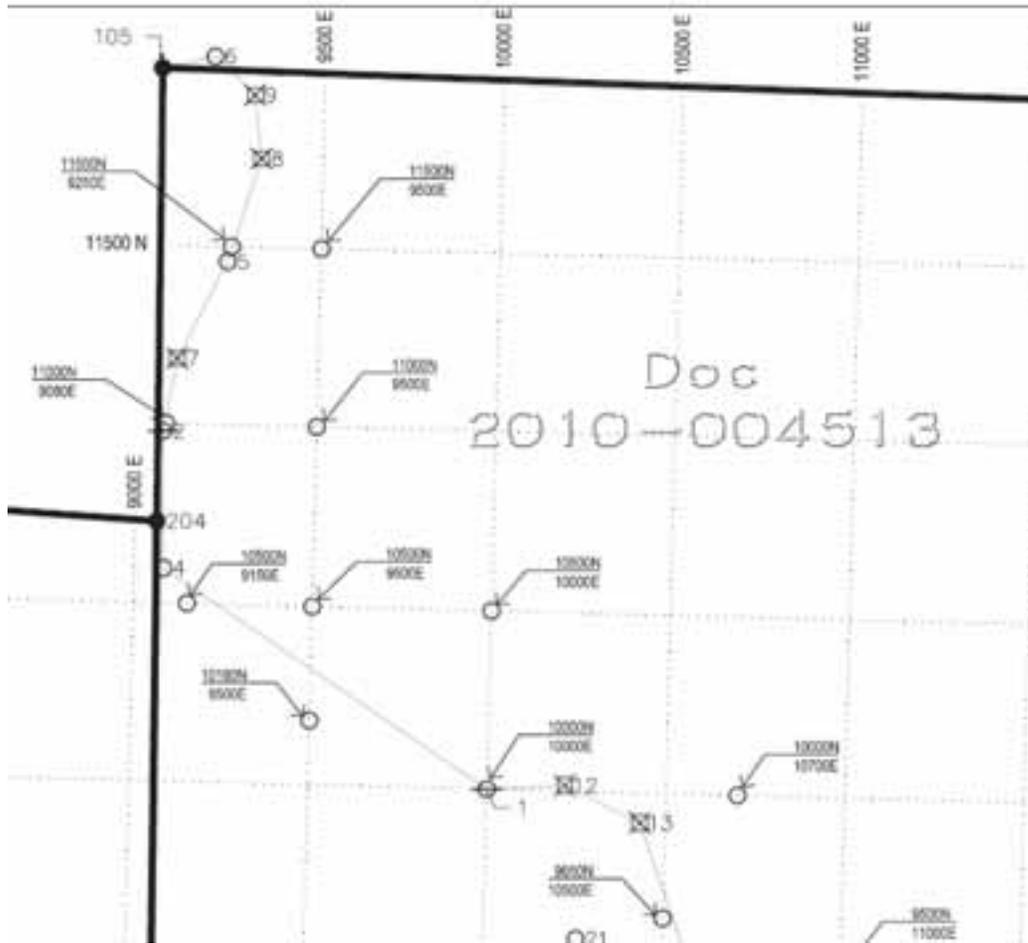


Fig. 4. Control and grid points.

Aspect

The aspect represents the direction a slope is facing. Aspect information is important for natural resource management since it has significant influence on vegetation distribution. Spatial Analyst extension in ArcGIS Desktop software calculates the aspect information in raster data format with cell values ranging from azimuth of 0° to 360°. Input data source was SLO County elevation data. Aspect cell values are azimuth directions of the slope faces. Cell value of 0° or 360° is facing due north. Cell values of 90° is facing due east, cell values of 180° is facing due south, and cell value of 270° is facing due west. For generic usage, initial aspect layer is

classified to show four general directions: north, east, south, and west. The table 2 shows the ranges of cell values used for creating four general direction aspect layer.

Table 2

Four general aspect directions and cell values

Direction	Aspect Cell Values (Azimuth in degrees)
North	0-45 and 315-360
East	45-135
South	135-225
West	225-315

GIS user can change the cell value ranges to create customized aspect layer. For example, one can find the exact azimuth bearing of sun location from 10 AM to 3 PM and create an aspect layer showing areas where sun light shown during that time. Graphical representation of four general aspect layer is shown on figure 5.

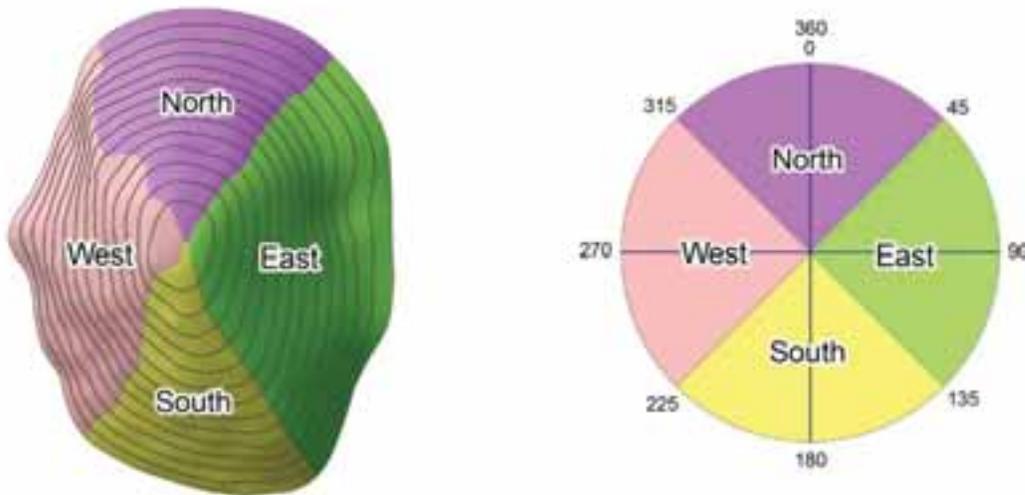


Fig. 5. Four general aspect directions.

Contour Lines

Contours are lines that connect locations of equal value that represents continuous information such as elevation, temperature, or atmospheric pressure. In this project, the contour lines represent locations of equal elevation derived from SLO County elevation data using Spatial Analyst extension in ArcGIS Desktop software. Contour interval is set to 20 feet. Although ArcGIS Desktop can create smaller contour interval, the SLO County elevation data is not appropriate to make more detailed contour interval lines.

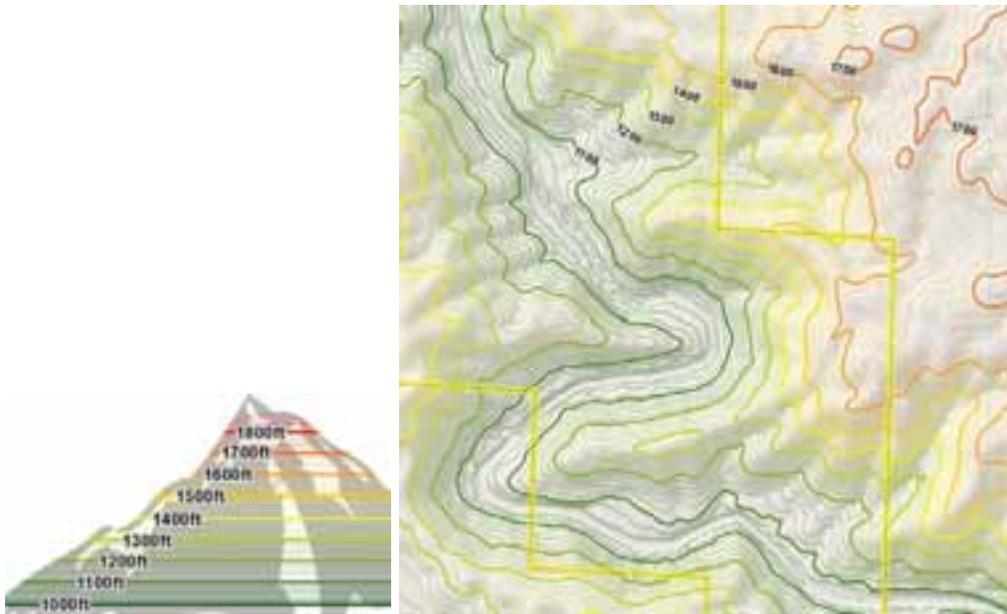


Fig. 6. Elevation contour lines.

Fire History/Frequency

The initial information for the fire history layer (CF_FIRES_HISTORY) was obtained from SLO County. The attribute table contains information such as the date the fire started, the reason for the fire, the response, and the method of collection for the fire data. Fire history data

was then analyzed to find locations where multiple fires occurred over time. Fire history data was combined using “Union” tool to identify overlapping areas. Overlapping areas are then dissolved using “Dissolve” tool to merge all overlapping polygons into one polygon with information showing how many overlapping polygons were merged in that area. The result is a fire frequency layer showing number of fire occurrences.

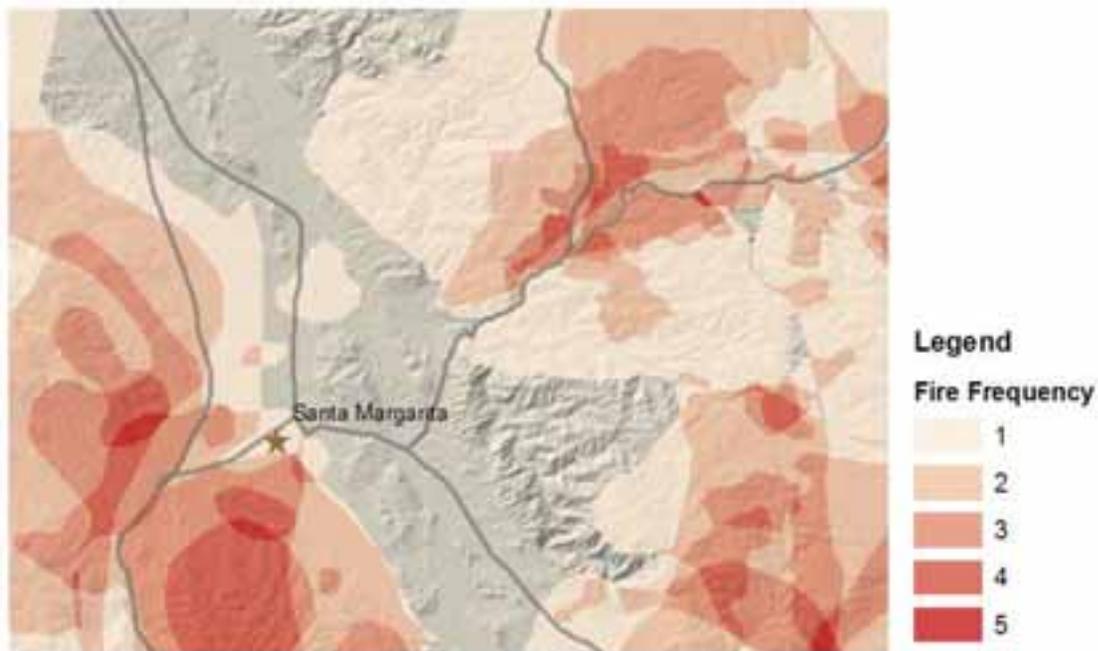


Fig. 7. Fire occurrences near Santa Margarita.

Geology

San Luis Obispo County geologist, Lew Rosenberg, created geology layer with intention of showing relative liquefaction susceptibility of sediments in San Luis Obispo County. The layer is described in its metadata.

“A common type of ground failure associated with moderate and large earthquakes is liquefaction in which water-saturated fine-grained cohesionless sediments lose strength

and may fail during strong ground shaking. Liquefaction susceptibility depends on the age and type of material, relative density of the material, and the depth to first (shallowest) water. Generally, younger sediments (especially latest Holocene that are less than 1,000 years old) such as loose fill, river channel, and flood plain deposits are more likely to liquefy than older Pleistocene terrace deposits. This map database depicts the relative liquefaction susceptibility for San Luis Obispo County.”



Fig. 8. Geologic units.

Parcels

The parcel information was obtained from the San Luis Obispo Assessor’s Office. The parcel maps were obtained from SLO County Assessor’s website. They were georeferenced using the Public Land Survey System (PLSS) layers from the United States GIS Data Repository, the 2011 Imagery, ESRI online basemaps, and Mr. Mastin’s survey information.

Parcels were digitized using bearing and distance information when available. If bearing and distance information was not available, lines were drawn to visually based on georeferenced assessor's parcel maps. Assessors Parcel Numbers and other information are entered in the associated attribute table.

Many counties in California already have the parcel data in GIS data format. San Luis Obispo County has the data; however, they do not own it and cannot distribute it. This study demonstrated parcel data can be created from scanned paper map.

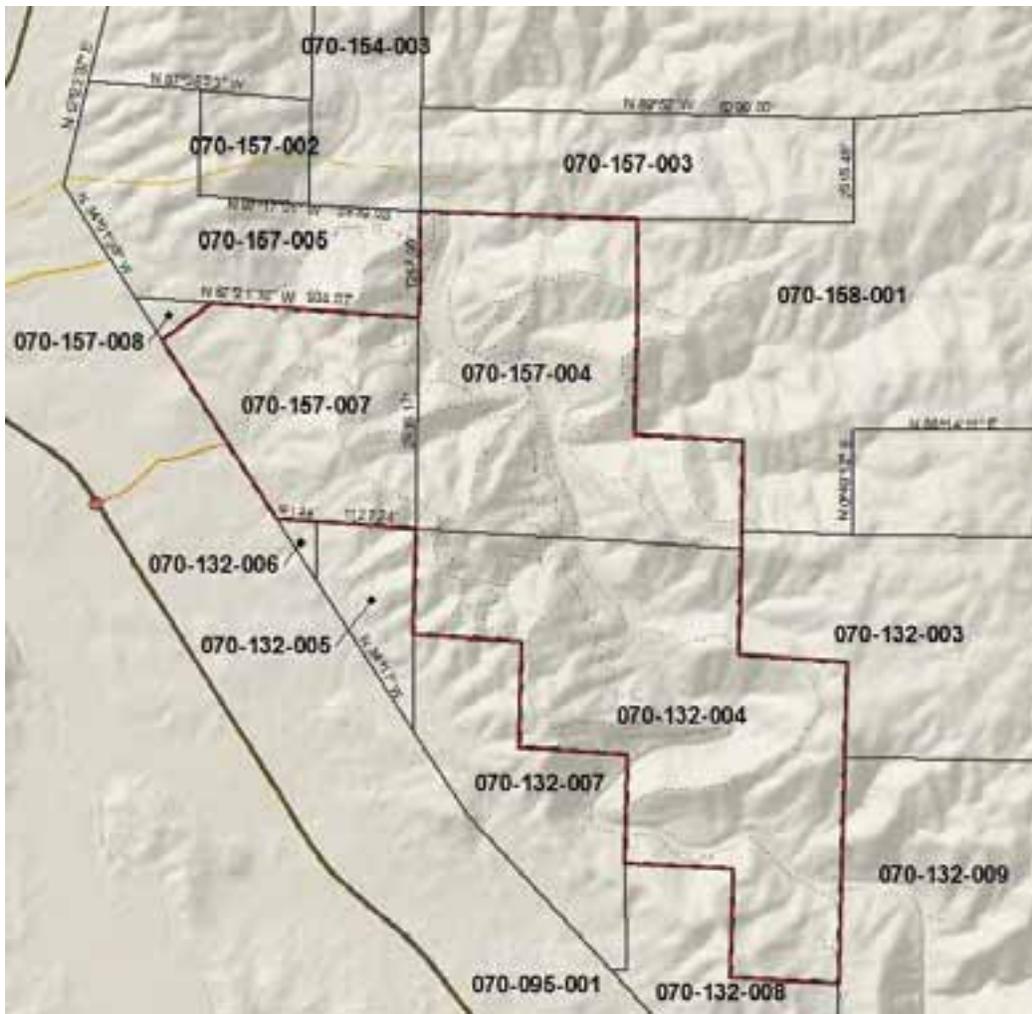


Fig. 9. Parcel layer.

Roads and Trails

Student reviewed San Luis Obispo's countywide road layer, but it did not contain roads in the study site. Students decided to recreate the road layer to improve the spatial accuracy and add missing roads and trails in newly acquired parcel. Student used Topcon GPS units with ArcPad software designed to perform mobile GIS analysis and collect field data. ArcPad also has form builder to create custom forms to expedite data collecting process. Students built a form that automatically assigned type of roads and erosions using predetermined values. This simplified data collection with fewer data entry errors. Ms. Colleen Mooney and Mr. Trevor Seck are credited for most of the roads and trails information.

Roads feature class had two road types: Roads and ATV. Roads are drivable by regular vehicle on dry conditions. ATV type is for All Terrain Vehicle (ATV) or four-wheel drive vehicles. ATV used in the study site is small enough to maneuver on narrow ATV roads by most people; however a driver needs to be experienced in driving on narrow, steep, windy road if Four-Wheel drive vehicle will be used on ATV roads.

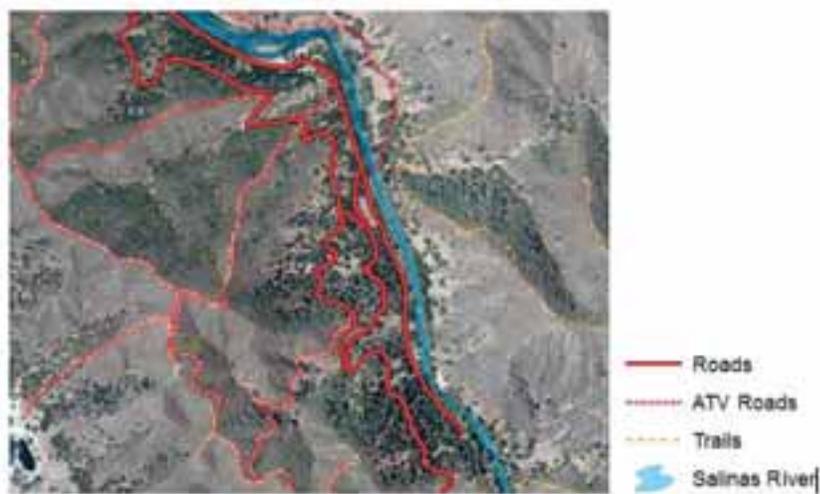


Fig. 10. Roads, ATV roads, and trails.

Slope

Similar to creating aspect layer, slope layer was created by using the slope tool in ArcGIS Desktop's Spatial Analyst extension. The "slope" tool had option to create the slope layer using degree slope or percent slope. The "percent_rise" option was selected for creating slope data. The figure 11 shows slope information

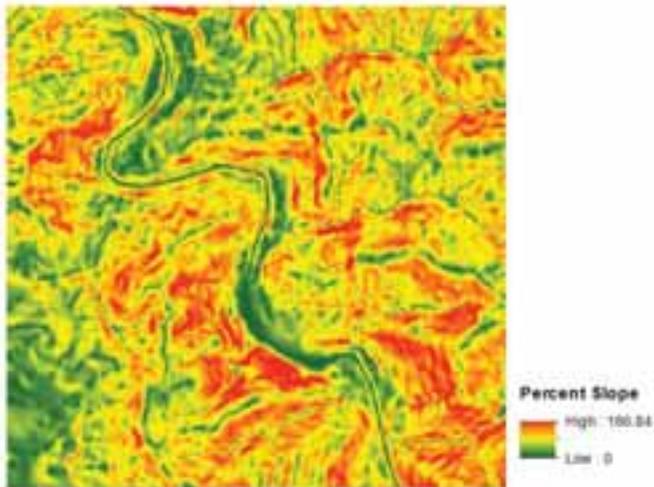


Fig. 11. Percent slope raster data.

Soil

Soil data was downloaded from USDA, Natural Resources Conservation Service (NRCS) Web Soil Survey website. Any user can specify the location and create a customized soil report containing detail description of soil map units for that area.



Fig. 12. Soil Map Units.

Watershed and Sub-Watersheds

Watershed is the upstream areas that contribute surface water flowing to a common outlet. Watershed can also contain smaller watershed called subwatershed. Watershed was created using the hydrology tools in the Spatial Analyst extension of ArcGIS Desktop. SLO County elevation data provided input elevation information for all of the watershed and subwatersheds. A pourpoint, a location where all of the water will flow out, was the Salina River exiting the study site. The calculated watershed for this study was 147 mi² including the Santa

Margarita Dam and the lake. Watershed was divided into two parts: before and after the Santa Margarita Dam. The Santa Margarita Dam controls surface water flow from areas above the dam, and it also slow the water allowing heavy sediments to settle on lake. The watershed before the Santa Margarita Dam is approximately 112 mi² and watershed after the dam is approximately 35 mi². Subwatershed layer was created for smaller drainage areas that flow into study site. Any subwatersheds less than 5 acres were not mapped. The largest subwatershed (SW-6) flowing into the Salinas River in study site was approximately 493 acres. Figure 14 shows the locations and sizes of 16 subwatersheds.

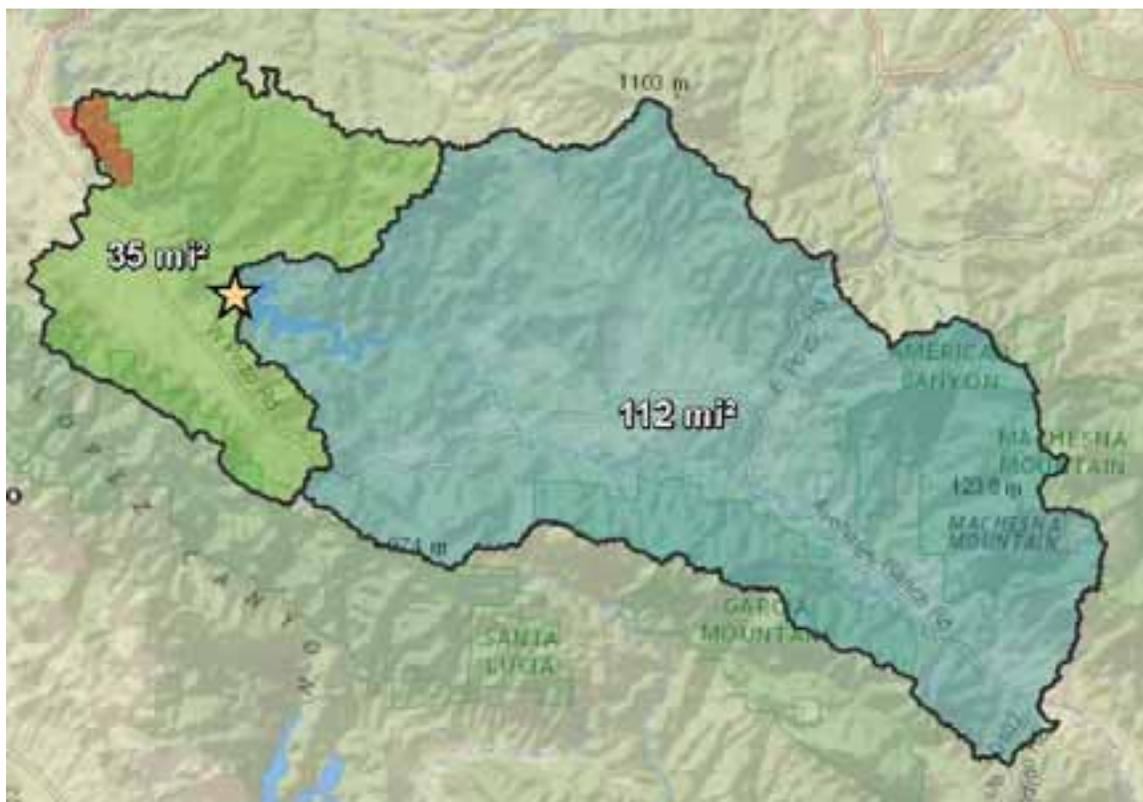


Fig. 13. Watershed above and below Santa Margarita Dam.



Fig. 14. Study site subwatersheds.

Vegetation

The habitat layer provided by Althouse and Meade contained some vegetation information; however, decision was made to find more detailed vegetation layer. Students downloaded USDA's CALVEG (Classification and Assessment with Landsat of Visible Ecological Groupings) GIS layer for the study site area. The CALVEG data is used for National Forest planning and other natural resources applications. It is a polygon layer showing existing

vegetation using Forest Service regional and national vegetation mapping standard. Polygons are derived by automated systematic procedures, remote sensing classification, photo editing and field based observations. However, due to large geographic extents, not every polygon is field verified. Although CALVEG data gave more detailed vegetation information, NRES staff decided that it would not be good enough for this project.

San Luis Obispo County performed countywide survey of Oaks in 2007. In doing so, they captured other vegetation information. County's vegetation layer had better spatial accuracy; however, it lacked the detail vegetation information.

NRES Department decided to create new vegetation layer that will have both spatial accuracy and detailed vegetation attributes. The USDA CALVEG and San Luis Obispo County vegetation data was used as a reference when creating new vegetation layer. Aspect information along with digital stereoscope was used during digitizing new vegetation layer to improve spatial accuracy of vegetation boundaries. The information was field verified. The resulting layer had far better spatial accuracy and more detailed information than the USDA CALVEG or the San Luis Obispo County's vegetation data. The figure 15 shows comparison of three vegetation layers for same geographic area. It demonstrates the spatial inaccuracies of CALVEG data, generalized attributes of SLO County data and the new vegetation data created by NRES students with improved vegetation delineations and more detailed vegetation types. The table 3 shows complete listing of vegetation types created by NRES students with areas calculated in acres.

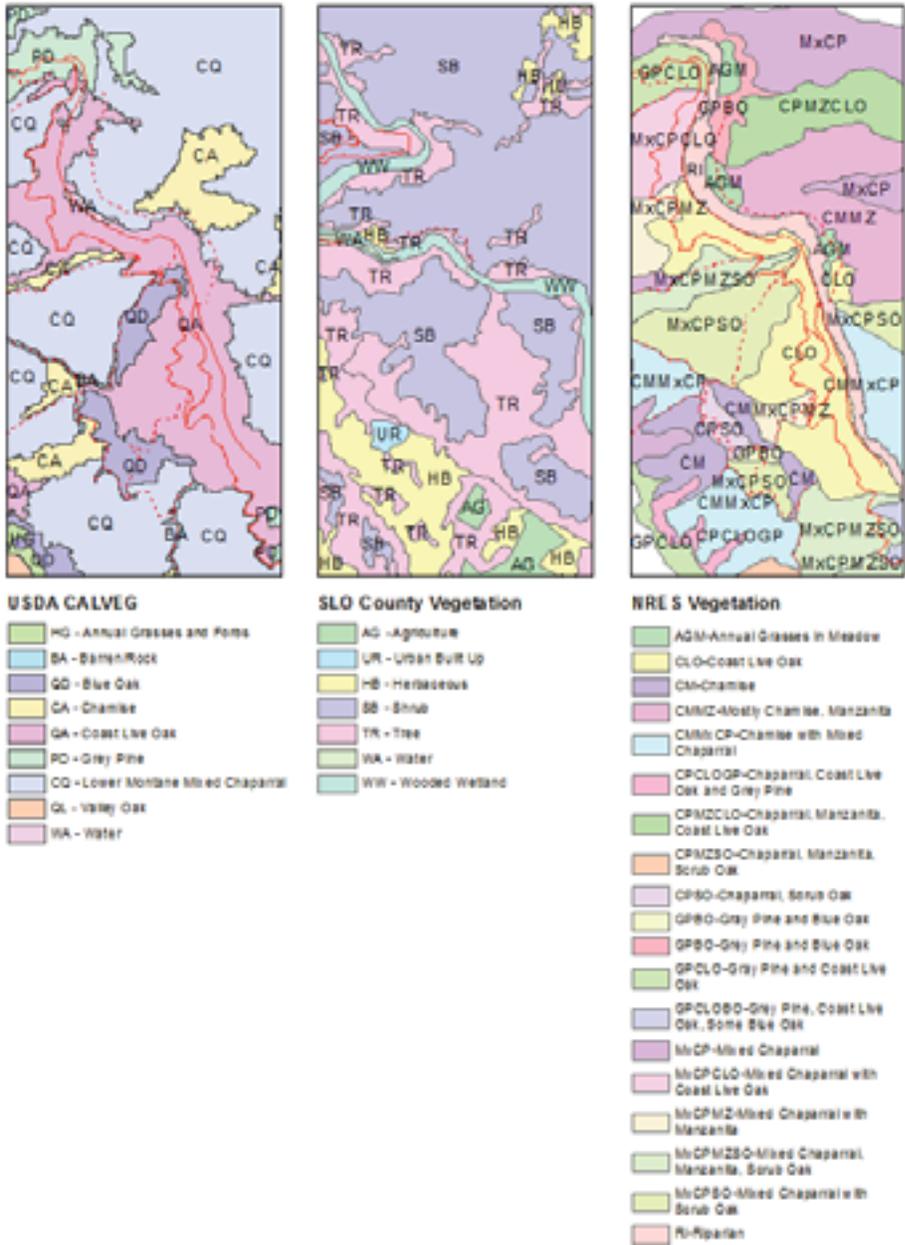


Figure 15, Comparison of USDA CALVEG, SLO County Vegetation and NRES Vegetation.

Table 3

NRES Vegetation Area Summary

Vegetation	Area (Acres)
AGM-Annual Grasses in Meadow	10.6
AGR-Annual Grasses in Range	23.7
CLO-Coast Live Oak	81.5
CM-Chamise	131.8
CMMxCP-Chamise with Mixed Chaparral	65.2
CMMZ-Mostly Chamise, Manzanita	51.5
CMSO-Chamise with Scrub Oak	2.7
CPCLO-Chaparral with Coast Live Oak	18.0
CPCLOGP-Chaparral, Coast Live Oak and Grey Pine	0.8
CPMZCLO-Chaparral, Manzanita, Coast Live Oak	29.9
CPMZCLOGP-Chaparral, Manzanita, Coast Live Oak, Grey Pine	12.1
CPMZSO-Chaparral, Manzanita, Scrub Oak	0.4
CPSO-Chaparral, Scrub Oak	5.5
GPBO-Gray Pine and Blue Oak	1.8
GPBO-Grey Pine and Blue Oak	6.7
GPCLO-Gray Pine and Coast Live Oak	39.3
GPCLO-Grey Pine and Coast Live Oak	13.2
GPCLOBO-Grey Pine, Coast Live Oak, Few Blue Oak	1.9
GPCLOBO-Grey Pine, Coast Live Oak, Some Blue Oak	12.7
MxCP-Mixed Chaparral	32.7
MxCPCLO-Mixed Chaparral with Coast Live Oak	19.9
MxCPMZ-Mixed Chaparral with Manzanita	20.0
MxCPMZSO-Mixed Chaparral, Manzanita, Scrub Oak	42.7
MxCPSO-Mixed Chaparral with Scrub Oak	81.7
RI-Riparian	40.1
VO-Valley Oak	9.9
Total	756.5

PROJECT MANAGEMENT

It is common to find many people storing the the information in email system, personal computer or as a hardcopies in filing cabinets. Storing data with these methods are not reliable and access is very limited. Problems in email system will prevent access to those files. Personal computers fail for variety of reasons, and there is good chance that files stored in personal computers may get corrupted. Hardcopies can be misplaced easily. There is no search option for hardcopies whereas digital files can be searched in various ways: file name, date, size, location, type, etc. A Project document management system was needed to provide quick retrieval of information in variety of ways as well as relate information from one project to another. Project Management System will also be used for planning, implementing, and documenting future projects.

Project reports will be converted to Portable Document Format (PDF) which can be opened by most computers and mobile devices. Project report PDFs will be placed on a webserver to be available on internet. A separate copy will be saved in NRES internal server as a secondary reliable and secure storage.

If project contains any features with specific location information, they will be converted to GIS layer with associated project information. Once mapped, it can used along with all other GIS layers to understand the relationships between features as wells between projects. Mapped features can also be shared with public for education and other outreach purposes.

ESRI's ArcGIS Online was chosen as a platform for creating and managing the online map for projects. First step is to extract the necessary information out of the project report and create project features in GIS. Information such as GPS points of interest, geotagged images,

features shown in the map and any data that are associated with location are good candidates for converting to GIS layer. When creating the project features, standard set of attributes need to be added. These attributes are essential for proper retrieval of project information. Following attributes are added to all project related GIS features.

Table 4

Required attribute information for project features

Field Name	Field Type	Description
ObjectID	Short integer	A unique identifier for the object.
Date	Date	The date that the object was collected.
Name	Text, 50 spaces	Generic Name for Object.
ProjectID	Long integer	The ID of the source project.
ProjectName	Text, 100 spaces	The name of the source project.
ControlGrid	Text, 20 50 spaces	Grid Polygon ID in column letter with row number.
Latitude	Double	Latitude in decimal degrees.
Longitude	Double	Longitude in decimal degrees.
Category	Short integer	Feature subtype categories.
Link	Text, 250 spaces	Hyperlink path for document retrieval. If needed, Link2 and Link3 can be added for additional information hyperlinking.

The next step is packaging and uploading the project features to ArcGIS Online. Project related features with necessary information will be packaged as zipped shapefiles or layer packages and sent to ArcGIS Online hosted server.

Finally, the webmap is designed and created on ArcGIS Online. ESRI is investing heavily on ArcGIS Online to make it more functional for all desktop and mobile devices. This is the stage where customized information bubble can be added to map when user clicks the feature. Once online maps are created, few simple settings will allow it to be shared with everyone or just a certain group. Another few click of button will automatically generate a code to embed the map within any website.

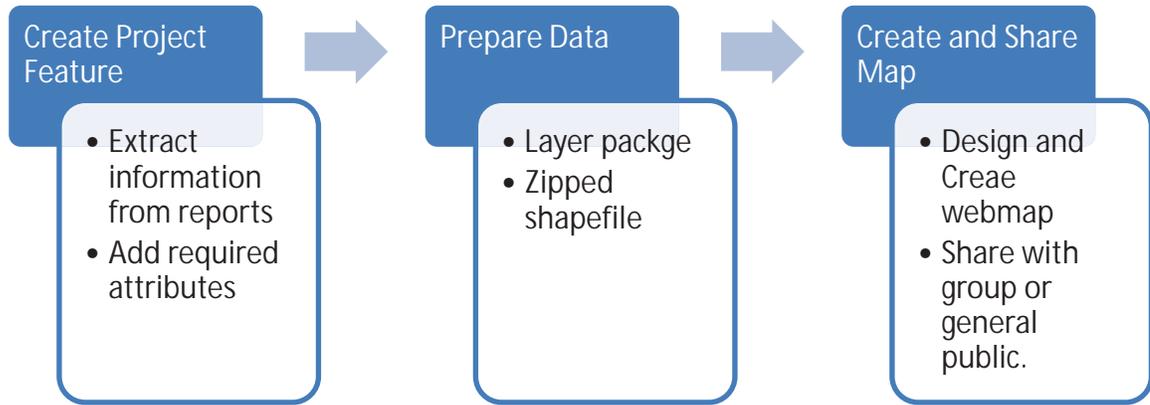


Figure 16, General workflow for providing project information as a webmap..

CONCLUSIONS AND RECOMMENDATIONS

GIS revealed spatial relationships between features. The slope, aspect, soil, elevation combined with human activities explains why certain areas are different from others. Once certain site characteristics such as aspect and elevation are understood, we could now search for all other places with same characteristics.

GIS enables users to see the entire landscape and the specific location. GIS is dynamic. We could see the entire study site or even surrounding properties to get the large landscape perspective as well as zoom in close to see each specific feature. GIS allows user to “see the forest and the trees.”

GIS is essential for relating past, present, and future studies and monitoring efforts. The control and grid points will ensure that we can map projects of past, present, and future. Geographic information is associated with time (when) and space (where). For example, the

Calf Fire data is associated with where the fire was when it happened. Similarly all activities on site can be recorded in GIS database and retrieved by location or tabular query.

GIS enabled us to identify future work related to land and resources management. We know more about the study site. The recent Calf Fire on the study site provides many opportunities for post-fire studies. Will there be new species growing in burned area? Will certain erosion measure work better than other?

GIS is a tool for users to make more informed decisions.

Following recommendations are given to anyone wanting to manage resources using GIS:

1. Continue to update and maintain GIS database. GIS is evolving quickly as technology is advancing. Keeping up with current technology and updating associated GIS data and software is very important.
2. Collaborate with educational institutions. Using university students prepares our future generation to be more efficient in natural resource management using GIS. Educational institutions also have many experts in variety of fields and necessary resources to start most GIS related projects.
3. Establish protocol for mapping all future projects. Using the control points and existing GIS database, all future projects could be mapped very accurately. A meeting with GIS Coordinator could save many work hours as he would know the time saving techniques, best practices.
4. Share GIS data on internet. This will promote sharing information with everyone. ArcGIS Online mapping services are easy to set up and most people can create one with one day of training.

5. Create a management plan based on factual information.

GIS has been used by organizations for many years. It is expected that GIS will be much easier to use on browser based application. Although there will always be need for GIS Specialists, general public will be able to do much of the GIS analysis work in near future. Using geographic approach to solve problems and understand our environment is efficient and practical.

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