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ODOT'S SALMON RESOURCE AND SENSITIVE AREA MAPPING PROJECT: A HIGH-TECH PROCEDURE FOR OBTAINING BIOLOGICAL RESOURCE DATA FOR RESOURCE PROTECTION AND REGULATORY COMPLIANCE

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Abstract: In response to increasing environmental concern and regulation, the Oregon Department of Transportation (ODOT) hired Mason, Bruce & Girard, Inc. (MB&G) to develop a Geographic Information System (GIS)-based sensitive resource inventory along nearly 6,000 miles of state highway. The inventory was named the Salmon Resources and Sensitive Area Mapping (SRSAM) project. The primary purpose of the SRSAM project was to provide accurate resource protection maps to roadway maintenance crews so that their activities (e.g., mowing, pesticide applications, etc.) do not harm these resources. Some of the high-technology features used to expedite the development of a comprehensive resource inventory for such a large geographical area included: 1) ortho-rectified, color infrared digital imagery with 2-foot pixel resolution, 2) on-screen digitizing of obvious sensitive resource features, 3) road-side capture of sensitive resources using laser rangefinders linked to vehicle-mounted real-time Global Positioning System (GPS) units, and 4) sophisticated GIS modeling. We were able to accurately determine the locations and attributes of twelve sensitive resource categories or "fields" with an error rate of less than one percent. Resource data gathered through this project were tied to ODOT's Linear Referencing System (LRS) and converted to easy-to-read straight-line maps showing resource features for use in ODOT's maintenance and planning activities. A second series of straight-line maps was produced identifying Restricted Activity Zones. These maps are used to facilitate better management of sensitive resources located within Oregon's transportation corridors.

Introduction

In the wake of Oregon Governor Kitzhaber's 1995 Executive Order to Oregon state agencies to protect and recover salmon and steelhead populations state-wide, and following the listing of numerous such fish stocks as "threatened" under the Federal Endangered Species Act (ESA), the Oregon Department of Transportation (ODOT) realized that it had both an obligation and an opportunity to contribute significantly to the protection and enhancement of aquatic ecosystems. To carry this out, ODOT's Maintenance and Operations, Environment, and Transportation Inventory and Mapping Sections identified a need for the following:

- An inventory of sensitive natural resources, and
- A set of maps that describes the resources and the restrictions to maintenance activities needed to minimize impacts to them.

ODOT recognized that a traditional field-intensive natural resource inventory along the thousands of miles of highway under its jurisdiction would be tremendously expensive and time-consuming. Not having the resources available in-house, ODOT sought a contractor to acquire the needed natural resource information in a more expedited fashion.

ODOT contracted with Mason, Bruce & Girard, Inc. (MB&G) in 1999 to collect biological resource information inside the state transportation corridor along nearly 6,000 miles of highway across four ODOT regions (Regions 1, 2, 4, and 5). The methodology developed by MB&G for the SRSAM project utilizes the latest spatial data collection techniques to maximize efficiency. The project employed digital aerial orthophotography, GIS, and GPS and laser surveying technology.

Pilot Project

ODOT's first large-scale attempt at collecting natural resource data along transportation corridors occurred in 1998 with mixed results. This effort occurred along approximately 1,200 miles of highway in Region 3 (southwest Oregon), and involved biologists driving the state highways and visually assessing the presence or absence of numerous environmental features (e.g., streams, wetlands, riparian zones, sensitive species habitat, etc.) for each 52-foot (i.e., 0.01-mile) highway increment. Data were attributed directly onto ODOT's

LRS and used to generate Resource Maps showing the locations of sensitive resources that ODOT maintenance crews needed to avoid.

While these data were useful, the collection process proved problematic. The two-person crews averaged less than 20 miles per day. Additionally, since the inventory was done visually, classification of resource features that varied between the 0.01-mile markers (e.g. land cover) became a subjective interpretation of the data recorder. Indeed, quality control checks conducted by ODOT biologists found a high degree of variability among the Region 3 data, necessitating follow-up fieldwork to correct the errors. Finally, since the data were recorded in such an unconventional format, their utility and application beyond this particular project was extremely limited.

Methods

The approach employed by MB&G for the SRSAM project in Regions 1, 2, 4, and 5 was to use the latest imagery, spatial modeling, and surveying technologies to maximize data quality and collection efficiency. ODOT identified 12 natural resource features, or "fields," that MB&G was required to map for the SRSAM project. These fields varied from streams, wetlands, or other resource features that could be readily observed, to those that were dependent upon the spatial relationships of two or more variables and thus required GIS modeling to delineate. A multiphase process involving digital aerial orthophotography and GIS guided the fieldwork and the GPS verification and collection of base layers. This, in turn, supplied the spatial data used to generate more complex modeled fields.

Imagery

The acquisition of digital high-resolution imagery was integral to the approach used for this project. Imagery acquisition was subcontracted to Space Imaging, and was achieved using fixed-wing aircraft. Color infrared imagery (red, green, near infrared) was chosen for this project for its ability to clearly highlight vegetation and water. Each image consisted of 2000 x 3000 pixels, with a single pixel representing two feet on the ground. As the digital camera acquired the imagery, GPS and inertial measurement equipment on the aircraft collected exact location, attitude, and altitude information. The images could therefore be orthorectified, or geometrically corrected for terrain variation. The individual images were merged to create a geo-referenced mosaic, and incorporated into the GIS. Imagery extended a minimum of 1,000 feet out from both sides of the centerline of the highway to ensure adequate coverage for photo interpretation.

This digital imagery was used throughout the various stages of the natural resource inventory process. Primarily, the imagery allowed the team to assess the project area before going into the field. Existing features were confirmed and spatially reregistered and previously unmapped features were identified, attributed, and flagged for confirmation by the field team. Imagery was also used in the post-field processing phase to confirm and delineate new features identified by the field team.

Spatial Modeling

Base Data Generation

The SRSAM project utilized existing digital databases as a base for the mapping. ODOT maintains 1:24,000 Computer-Aided Design (CAD) files for the state. These contain detailed information on rights-of-way, landmarks, hydrology, and wetlands, among other features. Stored in quadrangles, appropriate features were extracted from these CAD maps, converted to ArcInfo GIS coverage format, and mosaiced together for each of the four ODOT regions. Recognizing that more recent and detailed resource inventories had been conducted across the state, the project team gathered all other relevant and available GIS data for the state. For example, hydrology and wetland data were acquired from the National Wetlands Inventory, Bureau of Land Management, U.S. Forest Service, and U.S. Geological Survey, among others. The data acquired through this outreach effort were collectively referred to as "auxiliary data."

After compiling the hydrology and wetlands data into GIS coverages, they were overlaid on the digital orthophotography for photo interpretation. The hydrology and wetland features were verified and reregistered to match the imagery. Features apparent on the imagery but not shown on the auxiliary data were digitized on-screen and attributed. Existing features in question were flagged for later verification by the field team.

Transportation Network

The existing GIS transportation network (i.e., the digitized highway system) was originally mapped by ODOT at a scale of 1:100,000. While the network had since been positionally corrected in most of the urban areas to a larger scale, the 1:24,000 base data still did not match properly. Consequently, GIS analysts reregistered the transportation network to match the digital orthophotography. It was crucial to duplicate the topology of ODOT's highway centerline to maintain the proper routing used for determining mileage and side of road (i.e., left or right).

As some environmental features were differentiated by their proximity to the road, the project also required detailed coverages of the "transportation corridor" and "clearzone" for modeling purposes. The transportation corridor is defined as the area extending out 500 feet on either side of the highway centerline. By contrast, the clearzone is the area along the highway where vegetation is actively managed (through mowing, spraying, etc.), and has a narrower but highly variable width.

Sensitive Species Information

One of the project's goals was to provide data that would minimize impacts to sensitive, threatened, or endangered species. To meet that goal, data from the Oregon Natural Heritage Program (ONHP) were spatially enabled from sighting records and converted into an ArcInfo coverage. ONHP maintains the state's largest database of threatened and endangered species. It contains over 20,000 records of endangered plants and animals, including historical sightings. This ONHP-derived GIS coverage of sensitive species locations was then augmented with current project-specific sensitive species information as obtained from interviews with state and federal biologists with local knowledge of the four ODOT regions. Information obtained from interviews was compared to the ONHP GIS data, and any new data were digitized into the GIS and attributed according the biologists' records.

Field Data Collection

A two-person team performed the fieldwork. The field vehicle included a laptop computer loaded with both the imagery and GIS data derived from the pre-field effort, a GPS unit, and a laser rangefinder. Using a real-time GPS feed and a customized ArcPad interface, the vehicle location could be continuously displayed on the computer screen and superimposed on the GIS data and imagery. This allowed the field crew to focus their efforts on verifying the on-screen display of GIS data that had been developed during the pre-field processing stage rather than collecting all features in the field. Thus, rather than the traditional and time-consuming role of data capture, the field crew for this project focused on data verification. Those few natural resource features that had been missed during the pre-field process were captured by the field crew using the GPS unit and the laser rangefinder. The field crew averaged more than 50 miles per day using this approach.

Feature Modeling

Prior to the project's inception, ODOT planners and biologists defined 12 specific fields of information that were to be collected for this project (Table 1). These fields were identified as being critical for determining whether ODOT's maintenance and construction activities would adversely affect sensitive natural resources. While these 12 fields were distinct, many were highly correlated. In addition, several of the fields were dependent upon the spatial relationships of one or more resource features, or upon the spatial relationship of resource features relative to the transportation system. As a result, the project team's approach was to collect and map a few key fields and derive the remaining fields through GIS modeling.

Project GIS analysts developed a preliminary set of algorithms to derive the modeled fields. These were reviewed by ODOT biologists, refined, and finalized. Ultimately, 7 of the 12 fields collected for the project incorporated GIS modeling.

Table 1
Method of Capture for the 12 Sensitive Resource "Fields", SRSAM Project.

Field Name	Method of Capture
Dominant Land Cover Type	Imagery
Fill Slope in Riparian Zone	Model
Riparian Overstory Condition	Model
Late Successional Habitat	Imagery
Riparian Zone Integrity	Model
Riparian Zone Boundary	Model
Salmonid Presence	Auxiliary Data
Sensitive Resource Areas	Auxiliary Data + Model
Spawning/Rearing Areas	Auxiliary Data + Model
Tributaries	Imagery + Field Data + Model
Wetlands	Imagery + Field Data + Model
Wildlife Trees or Snags	Field Data

Dynamic Segmentation

After deriving the 12 fields, presence/absence values for each field had to be related back to ODOT's routed transportation network. Utilizing custom programming in combination with ArcInfo's Dynamic Segmentation model, point, line, and polygon features associated with each field were related back to ODOT's routed transportation network in 0.01-mile increments. Presence/absence values for sensitive resource features were generated separately for both the transportation corridor and the clearzone. Data were exported in an ASCII format for use in ODOT's custom straight-line mapping program to produce the Resource Maps and Restricted Activity Zone (RAZ) Maps.

Accuracy/Quality Control

The project team conducted field tests throughout the course of the project. Accuracy was assessed at two levels: whether or not features were missed, and the positional accuracy of recorded features. Presence/absence determinations of sensitive resource features were at least 99 percent accurate. Actual positional accuracy of features in the GIS was within 10 feet at least 95 percent of the time. This far exceeded the contract requirement of ± 52 feet (i.e., 0.01 mile).

Project Deliverables

Resource Maps

ODOT's Inventory and Mapping Section converted the ACSII text files into Resource Maps, which utilized the standard straight-line presentation format. These maps indicated, by 0.01-mile segments, where sensitive resources were present and whether they were on the left and/or right side of the road. These maps were prepared for ODOT biologists, planners, and maintenance managers.

Restricted Activity Zone Maps

ODOT's Inventory and Mapping Section also converted the ACSII text files into RAZ maps. These maps also utilized the straight-line presentation format. However, as opposed to the Resource Maps, the RAZ maps used a simple color-coding scheme of green and red to indicate, for each major -class of maintenance activity (e.g., surface and shoulder work, vegetation management, snow and ice removal, etc.), whether or not that activity should be restricted along the left and/or right side of a given 0.01-mile segment of highway. These maps were prepared for the ODOT maintenance crews and did not require any biological understanding to interpret.

GIS Data

The final GIS data generated from this project included coverages of hydrology, wetlands, land cover, old growth, wildlife trees/snags, and sensitive species locations. These GIS data were corrected with respect to position using the high-resolution imagery, and were field-verified. Additional GIS fields were generated thorough modeling of the spatial relationships of the fields to each other or to the transportation system. The resulting library of GIS data is a detailed environmental inventory of ecological resources throughout four of ODOT's five regions. In addition to their use in generating the Resource and RAZ Maps, these GIS data serve as a tremendous resource available to ODOT biologists, engineers, and planners who can more easily consider and address sensitive natural resource features when planning and designing transportation system improvements.

Imagery

The imagery acquired for this project consists of a series of ortho-corrected, high-resolution, color infrared images mosaiced together to create a region-wide network. This imagery has wide utility within ODOT for project planning and environmental scoping purposes. For example, from their computers ODOT biologists will be able to access the imagery and GIS data for a given highway segment 300 miles away and perform "virtual environmental scoping" to assess the extent to which various environmental resources or permitting requirements may affect a certain project.

Conclusions

The data and ancillary products from the SRSAM project have enabled ODOT to minimize the potential for violations of the Federal ESA and the Clean Water Act. Agreement to produce the Resource and RAZ Maps was key to ODOT negotiating a programmatic ESA permit for standard maintenance operation activities with the National Marine Fisheries Service (NMFS). Specifically, ODOT received an exemption under 4(d) of the ESA allowing crews to perform routine road maintenance without having to consult with NMFS on individual actions.

For approximately the same cost as a traditional field-intensive natural resource inventory, ODOT has used a more modern, high-tech approach with numerous benefits over the traditional approach, including:

- Better Quality Data: Compared to the pilot project, the SRSAM project resulted in fewer classification errors. The method is repeatable and much less subject to individual interpretation.
- Larger Analysis Area: The imagery provided the project team with a lookdown view. Sensitive resources could therefore be assessed as far as 1,000 feet from the centerline without concern for access/trespass issues.
- Ancillary Products: As described in the preceding section, the GIS data and imagery will have many uses to ODOT beyond the scope of the SRSAM project.
- Easy Updates: With the imagery now in hand, the GIS base data already compiled, and the modeling routines written, future updates can be easily made.

The limits to this high-tech approach to natural resource inventory are still being explored. Already in development by MB&G and Space Imaging is an Internet-based application to deliver these data to the desktop. A likely future application is the integration of these data into maintenance vehicles where, for example, herbicide application would be controlled by a computer accessing the SRSAM data with a real-time GPS feed, which would automatically turn the spray boom on and off as needed to avoid impacting sensitive resources such as streams, wetlands, or rare plant populations.

As these technologies continue to improve and become integrated into everyday life, the call for improved data will only increase. Endangered species, wetlands, and other environmental permitting issues continue to drive the need for better resource data. With constrained budgets, agencies will be called upon to do more with fewer resources. The adoption of innovative techniques and emerging technologies will only aid in meeting mission statements.

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Jason Neil is the manager of the ODOT Project Coordination Unit, which is responsible for NEPA compliance and environmental permitting for ODOT projects statewide. Prior to his current management position, he served as a senior environmental project manager for ODOT. Jason has also worked for the U.S. Forest Service and the Colorado Division of Wildlife. He received his Bachelor of Science degree in Natural Resource Management, and has over eight years of natural resource management experience.

Robert Kirkman has nine years of experience in GIS and Remote Sensing in both Environmental Sciences and Urban Planning. He has his Bachelor of Arts degrees in Geography and Environmental Science. Prior to joining MB&G, Robert was a GIS Specialist at the Metropolitan Regional Government (Metro) in Portland, Oregon. He has also conducted wetland research for the National Wetlands Research Center in Lafayette, Louisiana. Robert currently serves as GIS analyst and manages the GIS department at Mason, Bruce, & Girard, Inc. He provides expertise on integrating GIS in field efforts, database development, and environmental modeling.