EVALUATING A FIELD AUTOMATION GEOGRAPHIC INFORMATION SYSTEM FOR ENVIRONMENTAL AND FACILITY MANAGEMENT UTILIZING MOBILE COMPUTING, VIDEOGRAPHY, AND THE GLOBAL POSITIONING SYSTEM

by

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EVALUATING A FIELD AUTOMATION GEOGRAPHIC INFORMATION SYSTEM FOR ENVIRONMENTAL AND FACILITY MANAGEMENT UTILIZING MOBILE COMPUTING, VIDEOGRAPHY, AND THE GLOBAL POSITIONING SYSTEM

ABSTRACT: Field Automation is an evolving set of geographic information system (GIS) technologies, including mobile computing and the global positioning system, addressing operational and environmental applications in the field. This research involves designing, developing, implementing, and evaluating an environmental and facility application field automated GIS. The Camp Rilea National Guard base, located on the northern Oregon coast, provides a testing ground for this new technology. A variety of environmental and facility data collection and management applications make Camp Rilea an ideal study site.

SITE OVERVIEW

Site Location

The Camp Rilea National Guard Training Facility is located on the Clatsop Plains along the northern Oregon coast. It is situated in the town of Warrenton, Oregon, approximately ten miles south of the city of Astoria, Oregon, and approximately 91 miles west of Portland, Oregon (Figure 1). Camp Rilea is bordered by the Pacific Ocean on the west, Highway 101 and the Burlington Northern Railroad on the east, Delaura Beach Road on the north, and private land on the south (Figure 2).

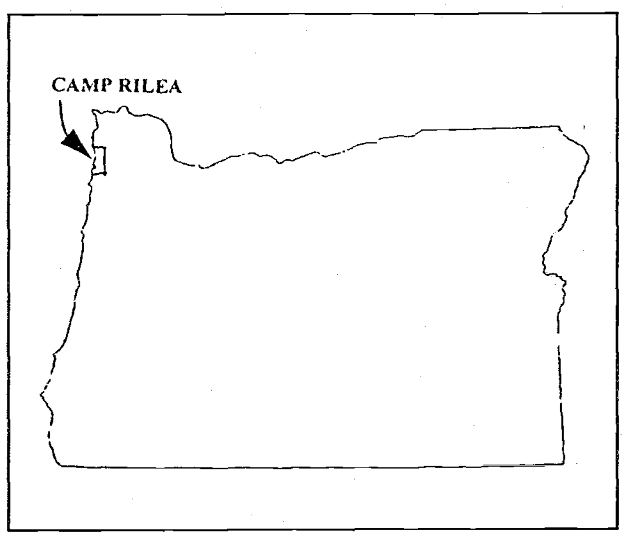
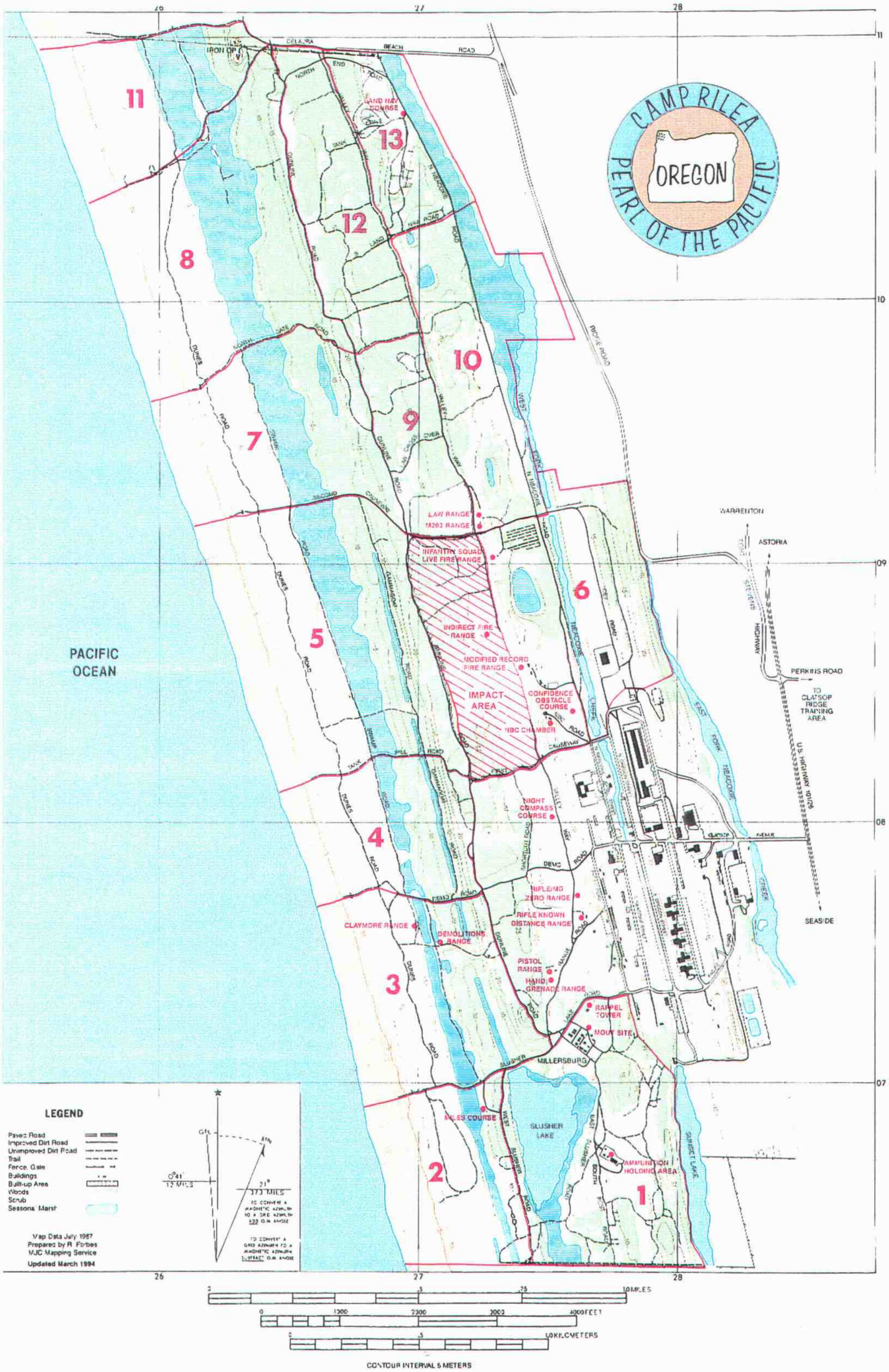


Figure 1: Oregon reference map

Figure 2: Camp Rilea reference map



Source: Rosenfeld, 1996a

Site Description

The Camp Rilea site is centrally located on the Clatsop Plains, which extend from the mouth of the Columbia River south to Tillamook Head, Oregon. The Clatsop Plains are a Quaternary sand dune deposit which overlies the Astoria formation at depths of 125-400 ft . The dunes are prograding due to deposition of erosion sediments from the Columbia River. The dunes are characterized by a series of sand ridges running parallel to the coast, a feature unique to the Clatsop Plains. Approximately nine dune ridges have been identified in the Camp Rilea area. Camp Rilea dune ridge heights do not exceed 80 ft. Camp Rilea is a uniform conditionally stabilized dunal area with little to no soil development. Some stabilized dunes and the majority of mature dunes have developed soil horizons, primarily composed of Waldport and Gearhart soils, respectively (Oregon Military Department, 1982, Carlson et al., 1991).

A dune stabilization program, beginning in 1934, initiated by the Soil Conservation Corps dramatically changed the campsite environment. Prior to the 1930's, vast areas of the Clatsop Plains became active when natural vegetation, which had stabilized the dune ridges, was destroyed by human disturbance. Under the dune stabilization program, the Civilian Conservation Corps planted approximately 3,000 acres of European beach-grass (*Ammophila arenaria*), Scotch broom (*Cytisus scoparius*), and shore pine (*Pinus contorta*) along the Clatsop Plains. Shore pines were planted in orderly blocks running parallel to the coast, which are readily apparent on current Camp Rilea maps. The overall Clatsop Plains stabilization program is considered, "the most successful dune management program on the Pacific Coast and one of the most successful in the world" (Carlson et al., 1991, 13).

Camp Rilea Background Information

Historically, Camp Rilea has been in continual operation as a military training facility since 1927. The early campsite environment dramatically changed following the dune stabilization program. Due to proximity to north Willamette Valley population centers, Camp Rilea annual use has increased dramatically since the early 1970's.

The mission of Camp Rilea is to provide a realistic environment for annual training and inactive duty training exercises. Currently, Camp Rilea is used as a training facility for units of the Oregon Army National Guard, the Air National Guard, United States active duty forces, and civilians. The base is owned by the State of Oregon and operated by the Oregon Military Department. The base includes a variety of training areas, such as firing ranges, demolition's ranges, light anti-tank ranges, mine ranges, obstacle courses, grenade ranges, artillery ranges, forced march routes, compass courses, military housing, administration and support buildings, warehouses, vehicle and equipment maintenance facilities, and large areas of open space. Major facilities also include an armory, a motor pool, sewage treatment plant, and a Unit Training Equipment Site. Tracked training vehicles do not operate on base and off-road vehicle traffic is primarily limited to human treading and occasional jeep traffic on the foredune areas. Overall, Camp Rilea is a full-service facility with a population varying from less than 50 to almost 1500 per day depending on time of year and training schedules (Mitchell, 1995).

One concept often overlooked by environmental proponents is the perception of a military base acting as an ecological reserve. Camp Rilea serves as a sanctuary for a variety of wildlife, encompassing more than 400 acres of wetlands and endangered species habitats (Rosenfeld, 1996a). The base also provides protection for a variety of archaeological and cultural resources.

The Oregon Military Department has realized the potential of Camp Rilea to provide a quality training and housing site for a variety of government services. The base is located close to major North Willamette Valley population centers and base usage has been steadily increasing. 1973 base usage was estimated at only 3,000 person days, compared to 1982 estimates of 70,557 days, and a projected 1996 total of 177,000 person days (Oregon Military Department, 1982, Rosenfeld, 1996b). The Oregon Military Department hopes to optimize efficiency, economy, and environmental compatibility, while striving to provide a realistic environment for annual training and inactive duty training exercises (Oregon Military Department, 1982).

Integrated Training Area Management / Geographic Information System Program

The Army National Guard Integrated Training Area Management (ITAM) program is designed to ensure that training areas are maintained and available for long-term, continuous military training. A major component of the ITAM program is initiating a Geographic Information System (GIS) for environmental and facility management. As defined by Antenucci et al. (1991, 281), a GIS is a, "computer system that stores and links nongraphic attributes or geographically referenced data with graphic map features to allow a wide range of information processing and display operations, as well as map production, analysis, and modeling." Three fundamental geographic principles, georeferencing, geocoding, and topology, accompanied with new advances in information technology serve as a paradigm for GIS. Data management principles, technology, and the organizational setting dynamically influence the implementation of a GIS and the overall GIS paradigm (Huxhold and Levinsohn, 1995).

RESEARCH OBJECTIVE

The objective of this research is to test and evaluate the applicability of a new stage of GIS computerization called field automation to environmental and facility management. Field automation promotes a GIS shift from an office to a field environment, ideally increasing efficiency and accuracy for data collection and management. Field automation is an evolving set of technologies which has found recent widespread use in utility applications, though has experienced limited environmental and facility applications. This technology integrates a variety of state of the art geographic tools, including videography, mobile computers, and the Global Positioning System.

The Camp Rilea military installation provides a proving ground for this new technology. Camp Rilea planners perceive field automation as an efficient data collection and management tool and a relatively simple and easy to use information system. My research included designing, constructing, and implementing the digital field data collection forms, compiling spatial data and producing digital map layers, integrating associated ground and aerial imagery into the GIS, and performing field testing and data collection utilizing this new GIS technology.

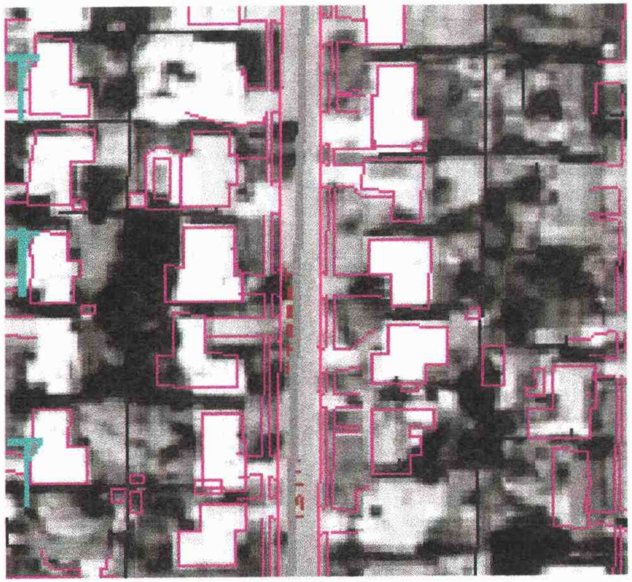
Software and Hardware

GIS software selection was a critical factor to the success of this project. A GIS data collection and management software system must meet a variety of criteria to satisfy project needs. Several key software selection criteria were determined during the design phase of the project, including:

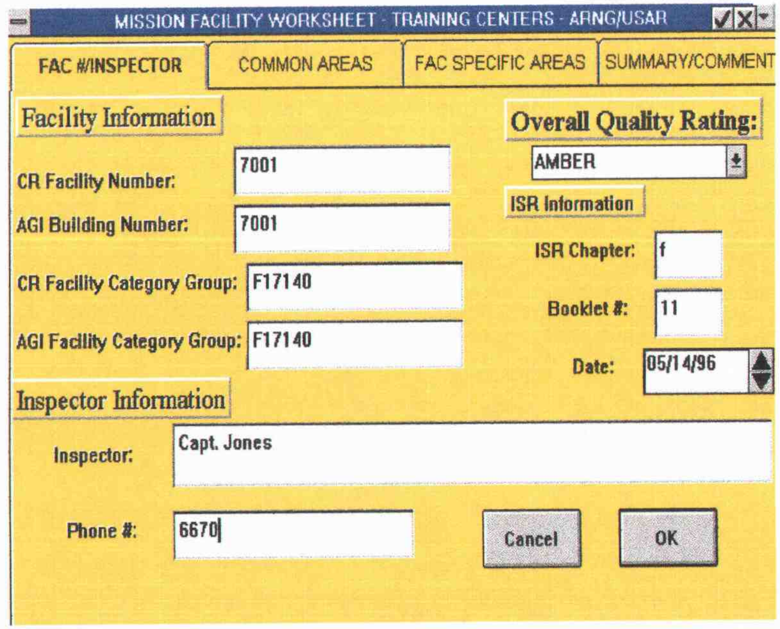
- Provide easy to design, customizable data entry forms for a variety of applications.
- Provide direct compatibility with pre-existing AutoCAD files.
- Be a PC Windows and PC Windows for Pen Computing application.
- Provide direct compatibility with dBase formatted files.
- Offer full compatibility with ArcView (potential future military GIS package) (Skarret, 1996).
- Provide image display compatibility.
- Offer a good selection of built-in attribute and spatial querying tools.

The FieldNotes (Penmetrics, Inc.) software package fit the criteria. The FieldNotes software package is designed primarily to ease data collection. FieldNotes provides an efficient and accurate system for timely data capture. Direct digital data capture is crucial to maintaining an up to date GIS. The essence of the Camp Rilea GIS relies on designing digital data collection forms which replicate the pre-existing standardized paper forms. Users only need to "click" on the desired feature, fill out the associated digital data collection form, or FieldForm, to save all data in a readily accessible database (Figure 3). Ideally, digital data conversion time will be minimized by implementing FieldNotes.

Figure 3: FieldForm demonstration



To query, update, or retrieve data, the user begins by clicking on the spatial feature of interest.



After selecting a feature, the associated FieldForm is displayed for viewing and editing.

INSPECT_NM	PHONE_NU	DATE	FAC_NUM	AGI_NUM	CR_FCG	AGI_FCG	OVERALL_Q	MAJ_IT_RAT	CRIT_IT_RA
Capt. Jones	6670	5/14/96	7001	7001	F17140	F17140	AMBER	AMBER	AMBER

All data is stored in dBase IV file format.

Nathaniel Whelan, 1996

The FieldNotes package utilized in this project includes four main applications: FieldNotes, FieldForms, FieldNotes GPS, and FieldPack. FieldNotes, the main application, provides for display and editing of databases, drawings, and images, and queries of drawings and databases. The FieldForms applications allows users to create custom database forms to use for data collection. The FieldNotes GPS module allows users to collect spatial and attribute data simultaneously by integrating GPS with FieldNotes functionality. Database modifications, such as querying, modifying structure, and editing, can be accomplished with the FieldPack application.

The project primarily utilized AutoCAD version 12 (Autodesk, Inc.) for digitizing and drawing layer editing. Adobe Photoshop version 2.5 (Adobe Systems Inc.) was used for editing digital images. Microsoft Excel was also relied upon for database merging and minor editing.

Primary GIS development was conducted on a 100 MHz Pentium computer and a 120 MHz Pentium computer, both located in the Geoscience Department at Oregon State University, and also a 33 MHz 486 located at the Oregon Military Department Headquarters in Salem. All workstations are loaded with Windows 3.1 except for the 120 MHz Pentium which has Windows 95. Two laptop computers, a GRiD model 2260 386 loaded with Windows 3.1 for Pen Computing and a Compaq Concerto 486 loaded with Windows 1.0 for Pen Computing, were also utilized for database development, fieldwork, and demonstrations.

Aerial videography was taken utilizing a Hi-8 millimeter videocamera mounted on a Cessna 182. Video was shot at a scale of approximately 1:12,500 from an altitude of

5000 feet. Computer Eyes (Digital Vision) image capture software was utilized to save still images from the video.

An eight channel Garmin 55 and a five channel Magellan NAV 5000DLX Global Positioning System (GPS) receiver were utilized for field mapping. The Magellan Differential Beacon Receiver was utilized to accept broadcast differential corrections, demodulate the signal, and relay the corrections to the Magellan GPS receiver. An external four foot Ireland antenna also improved differential signal reception. All GPS data was input to the FieldNotes GPS module.

Literature Review

Growing environmental concerns and technological advances have promoted the need to transform and use information about the earth in a two dimensional and three dimensional digital context.

"Environmental resource managers and training planners face complex problems in land use planning, maintenance, and protection of valuable natural and cultural resources. The amount and complexity of geographic information available to assist in the management of resources is becoming overwhelming" (Maris, 1991, 38).

GIS offers a powerful means to manage voluminous amounts of spatial and attribute data. Antenucci et al. (1991) provides a comprehensive discussion of GIS technology, issues, and concepts. Officials at Camp Rilea have consulted with other military installations utilizing GIS for technical and organizational guidance.

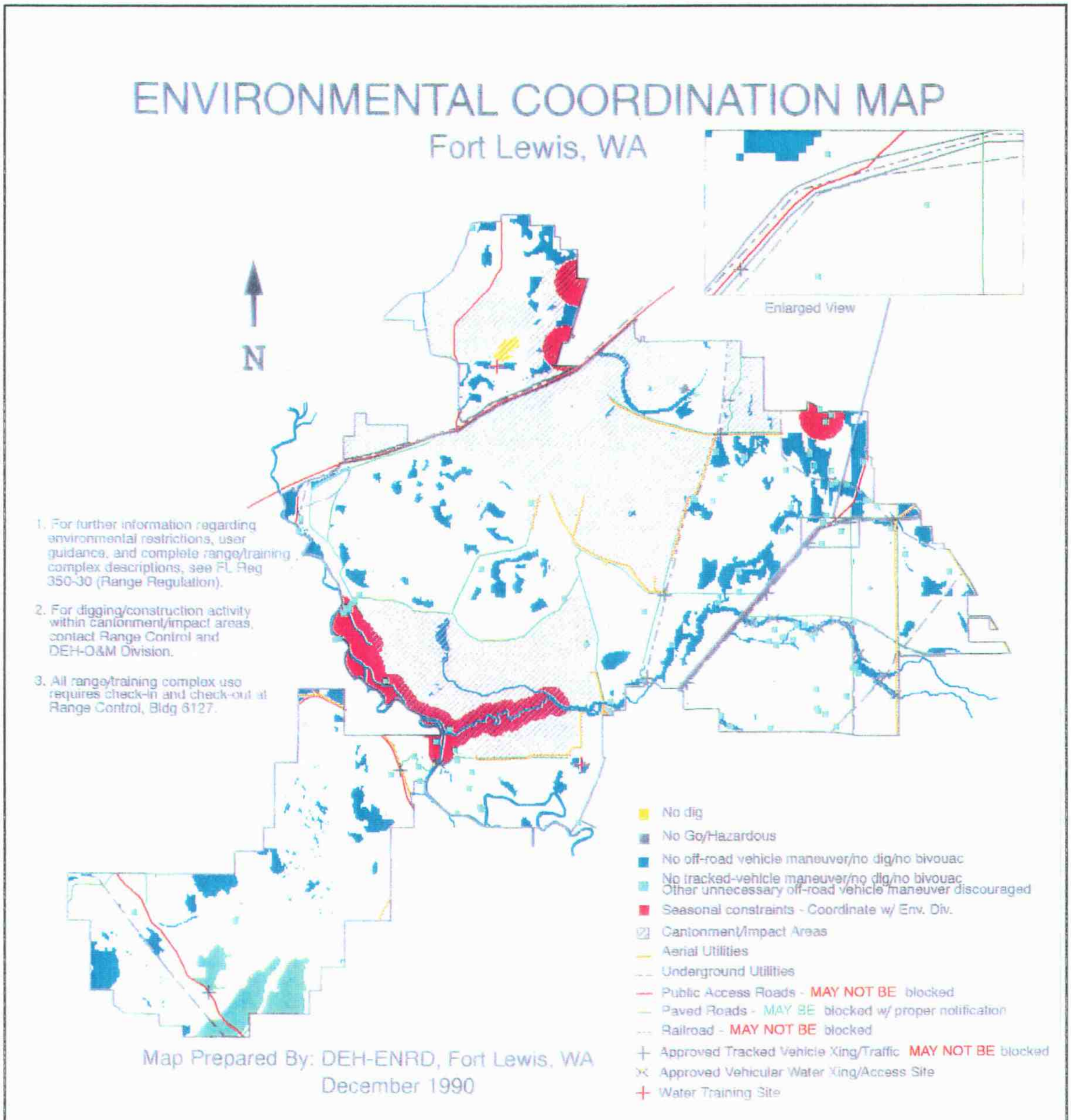
Officials at the Fort Lewis Military Reservation, located in the west central portion of Washington, have discovered the advantages to a cartographic database. Beginning in 1984, Fort Lewis implemented the Geographic Resources Analysis Support System

(GRASS) to assist in making environmental management decisions. Developed by the Army Corps of Engineers, GRASS is a GIS and a image processor capable of integrating satellite imagery and aerial photographs. The Fort Lewis GRASS system is a relatively state of the art environmental management GIS, incorporating hundreds of vector and raster data files (Ft. Lewis ENRD, 1990). Many of the Fort Lewis GIS applications can be incorporated in the Camp Rilea GIS.

The Fort Lewis GIS base layer data is composed of aspect, elevation, slope, soils, and landcover files. Many base maps are further delineated on a temporal scale; for example, land cover change can be analyzed by comparing the 1995 land cover base map to a digitized 1870 land cover map. Temporal analysis can depict trends over time, such as changes in forest distribution. A cartographic digital depiction of areas continually forested, lost forest, or have gained forest, can be integrated with GIS statistical analytical capabilities to provide a detailed map in a clear and efficient manner.

The Fort Lewis Environmental Coordination Map (Figure 4) is an example of a practical cartographic utilization of a military GIS database. The Environmental Coordination Map is a dynamic mapping system comprised of many data layers. From temporal investigation, a stand age map layer is used to determine the age of various stands in ten year increments. A forest stand age layer can then be correlated to assist in the management of endangered or threatened species by assessing potential habitats or monitoring current populations and nest sites of species, such as the Northern Spotted Owl or the Marbled Murrelet. Wetland data layers, compiled from the National Wetlands Inventory, are also correlated to many other species, such as the Western Gray

Figure 4: Ft. Lewis Environmental Coordination Map



Source: Ft. Lewis ENRD, 1990

Squirrel, Bald Eagles, and the Pileated Woodpecker. The wetlands and stand age data layers are further overlaid with heavy use maneuver areas, including cantonment/impact areas. Old Government Land Office (GLO) Map Series or County Assessor Notes were digitized to also analyze cultural resource and historically significant sites. Historically significant sites, such as homesteads, roads, and railroads, may be protected by the National Historic Preservation Act and needed to be identified and preserved. These various data layers; endangered species habitat, cultural resources, wetlands, forest stands, and cantonment/impact area, are combined to form the Environmental Coordination Map (Ft. Lewis ENRD, 1990). Training planners can utilize this clear and concise map to make a variety of logistical and organizational decisions in an environmentally educated manner.

The Pt. Mugu Naval Air Weapons Station located along a coastal area south of Los Angeles, California, has also established a GIS to aid in managing over 125,000 sq. miles of ranges. The Pt. Mugu GIS has been a cooperative effort between the National Biological Service, University of Arizona, and the Department of Defense. The newly developed GIS presents environmental constraints in a manner to effectively educate military decision makers. The Pt. Mugu military base provides a protected area for a variety of cultural and natural resources. The site's lagoons, tidal bays, and sensitive coastal area, provide valuable habitat for a variety of threatened and endangered species. For example, seal breeding on the site's beaches often conflicts with military maneuvers. In order to effectively utilize the ecosystem, military officials need to perceive the GIS as an avenue for understanding environmental dynamics (Kunzmann, 1996).

Designers of the Pt. Mugu GIS have placed primary emphasis on database development. Field laptops utilizing ArcView and GPS equipped GeoLink (GeoResearch, Inc.) software are used for field data collection. This setup allows for quick and efficient training of data collection personnel and easy integration with ArcInfo (ESRI) software equipped workstations. The base map layers include 70 mm or 25 mm GPS referenced videography backdropped with one foot interval digitized elevation layers. Base facilities, species locations, and various ecosystem components comprise the GIS layers which overlay into a decision management surface. Pt. Mugu military officials can readily access the decision management surface to determine how, when, and where military operations can take place (Kunzmann, 1996).

Pen based digital field data collection applications have in the past primarily targeted utilities companies. Toronto Hydro's ongoing pen based initiative exemplifies the advantages of streamlining the data collection and validation procedures of a pre-established automated mapping/facilities management (AM/FM) GIS project. Paper forms previously used to collect utility pole and transformer attribute and positional data were replicated in a digital environment. The FieldNotes software package's built-in capabilities allowed designers to improve on the forms and implement validation checks. Various form improvements improved end user acceptance and productivity. FieldNotes ease of use permitted minimal training time for end users. Toronto Hydro's AM/FM GIS technicians would collect the field units and download the data in the pre-existing database (Thompson et al., 1994).

The benefits of Toronto Hydro's pen based system over the previous paper forms are dramatic. Field crews productivity levels increased 67% and form validation checks virtually eliminated incomplete and inaccurate forms. The field crews training time was decreased by 25% and eliminated the reams of paper products previously wasted. Data conversion from the paper based system to the AM/FM GIS was also eliminated, which alone cost justifies the implementation of pen based computers. Overall, the pen based system was more complicated to implement than the paper based system. However, once in place the new system increased efficiency and simplified the entire data collection process (Thompson et al., 1994).

Technological advances have dramatically increased the options available for building a large scale GIS. These GIS applications are indicative of the potential for timely and practical utilization of a variety of data by decision makers. The proposed GIS for Camp Rilea has the potential to provide an abundance of spatial and attribute information to assist in environmental and facility management.

TECHNIQUES

GIS design and development efforts have focused on the three primary components: map layers, databases, and imagery (Figure 5). My research involved identifying and prioritizing a variety of pre-existing spatial and attribute data, some already in digital format, then inputting the data into the GIS for future updating, retrieval and analysis.

Figure 5: Camp Rilea GIS Components

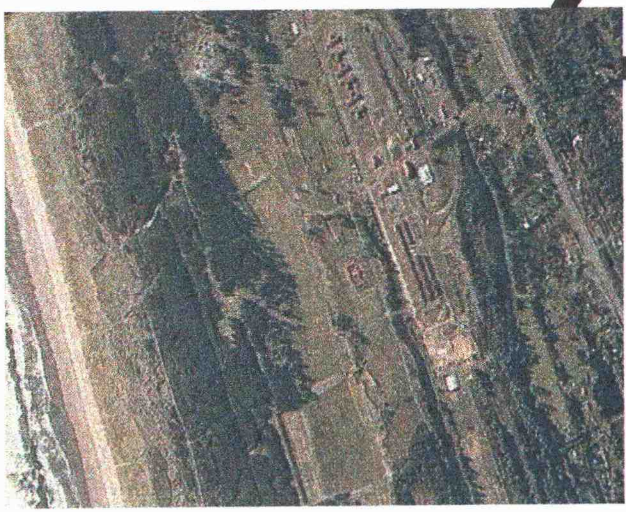
dBase IV files

	1st Qtr	2nd Qtr	3rd Qtr
East	20.4	27.4	90
West	30.6	38.6	34.6
North	45.9	46.9	45

Representative attribute database file

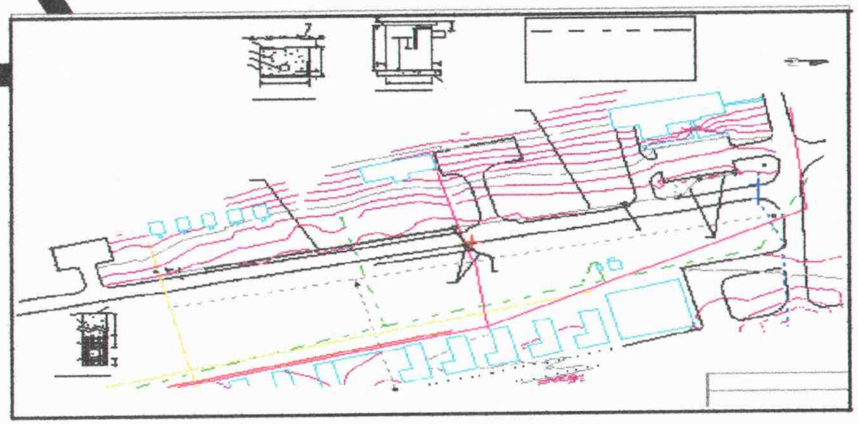
Databases, map layers, and imagery are the three primary components integrated in the Camp Rilea GIS.

Videography images



Aerial image of Camp Rilea

AutoCAD files



Representative map layer file

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Map Layers

The AutoCAD drawing (DWG) file is the primary drawing format utilized. Except for topography, all drawing layers were manually digitized into the GIS. Data layers were digitized from a variety of pre-existing sources, including 24 by 36 inch mylar sheets, National Wetland Inventory maps, and maps produced from a variety of resource oriented studies conducted on-site. Source map scales vary widely, from extremely large scale maps focusing on one structure to 1:24,000 United States Geological Survey quadrangles. Mapping standards were preset, such as the Universal Transverse Mercator (UTM) coordinate system, the North American Datum of 1983 (NAD83), and a standard scale of 1:24,000 or larger. Attribute data for map layers should, at a minimum, include base map name, year, projection, and source. Currently (September, 1996), approximately 75 layers have been digitized into the GIS.

Digital scanning was also relied upon for layer compilation. One mylar sheet depicted Camp Rilea's uneven stabilized dunal environment with relatively dense one to three meter interval topography contours. A local blueprinting company, Fox Blueprinting in Salem, was subcontracted to scan the mylar sheet and convert the raster digital image to vector format. The conversion produced a two layer DWG file consisting of high quality and low quality vector lines. Following minor editing, text entry, and moving contours to appropriate elevation coordinates, the topography layers will be available for a variety of uses, from slope analysis to 3D visualization.

GPS receivers were utilized in conjunction with the FieldNotes GPS module to produce map layers. GPS allows users to create dynamic maps which allow for detail and specificity required for certain and diverse applications. UTM position data, including elevation, can be down loaded real-time to FieldNotes equipped laptop computers to map point, line, or area features and record attribute data. This proved to be an efficient layer production system capable of immediate integration into the GIS.

Advanced GPS hardware provided the capability to use broadcast data from United States Coast Guard Differential GPS (USCG DGPS) beacons to calculate and display differentially corrected positional data. The USCG Differential Service is based on reference beacons that determine position error and broadcast this error continuously to differential beacon receivers. The Magellan Differential Beacon Receiver unit accepts the broadcast differential corrections in RTCMSC-104 format, demodulates the signal, and relays the correction to the differential-ready Magellan NAV 5000DLX GPS receiver. Compared to non-corrected GPS accuracy's of roughly 100 meters, a differentially corrected GPS can increase positional fix accuracy to ten meters or better (Taggert, 1996).

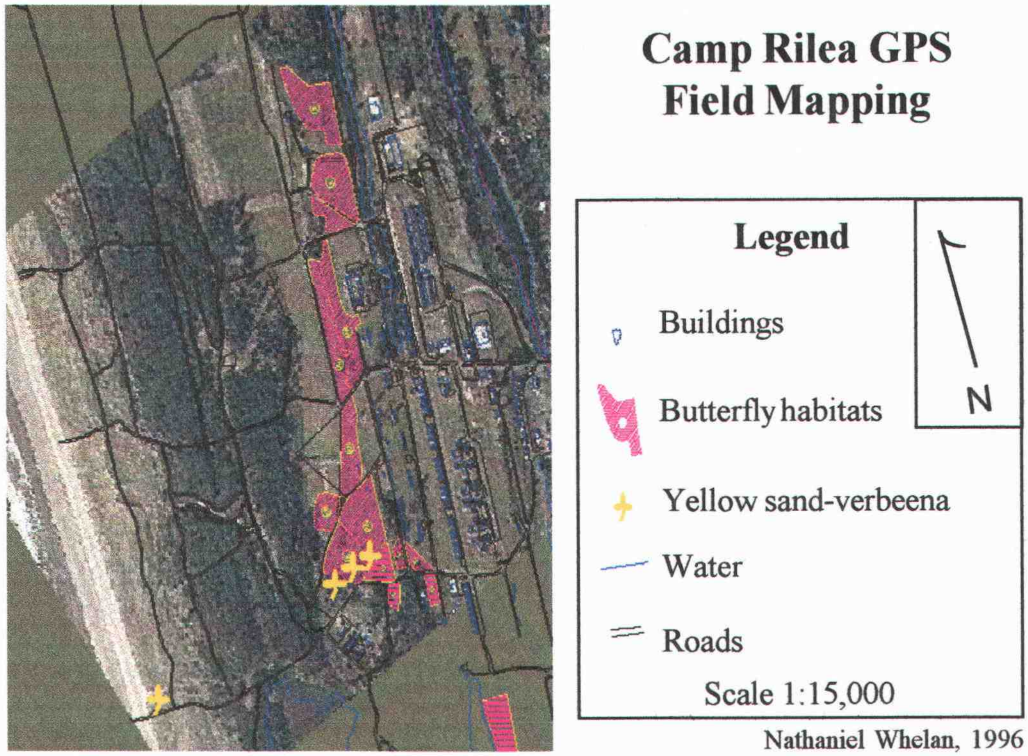
The USCG DGPS corrections are only accurate for an area within broadcast range of beacon, which varies from 30 to 350 miles. The USCG DGPS system is targeted for maritime vessel traffic and buoy positioning, but the signal also reaches coastal inland areas and is available for civilian use. Camp Rilea GPS mapping exercises relied on the Fort Steven's, Oregon, USCG DGPS beacon, broadcast at 287 KHz, located approximately 15 miles north of the base (Taggert, 1996).

***GPS Case Study*: Inventorying and mapping Camp Rilea's rare, threatened, and endangered plant species.**

In 1993, the Oregon Natural Heritage Program (ONHP) was contracted by the Oregon Military Department to inventory and identify the locations of rare, threatened, and endangered species at Camp Rilea. Among other species, ONHP identified two rare plant species currently on the ONHP Review List at Camp Rilea. Both honkenya (*Honkenya peploides*) and yellow sand-verbeena (*Abronia latifolia*) were located along the Camp Rilea beach and were roughly plotted on a 1:12,500 base map (Kagan, 1993).

My research included fieldwork conducted in early September, 1996, which attempted to locate the ONHP sensitive species, GPS the positions, and enter attribute data on the pre-assembled FieldForms. The GPS point data collected during the fieldwork was overlaid on pre-existing raster and vector layers, consisting of an aerial image, roads, buildings, water, and butterfly habitats (Figure 6). These pre-existing layers represented a scaled down application-specific version of the larger GIS database due to laptop data management restrictions. A concurrent beach closure due to artillery range testing limited accessibility to the honkenya plant patches previously identified by the ONHP study. One of the four ONHP yellow sand-verbeena plant patches was located, as well as nine sand-verbeena plant patches not previously inventoried. Differential GPS fixes were averaged for approximately a five minute interval centered on each plant patch. UTM coordinates are displayed as fields within each corresponding FieldForm. Plant and locational attribute data, such as area, percent cover, height, flowering remarks, disturbance comments, and surrounding vegetation, are also saved in the FieldForms. A yellow sand-verbeena map layer displays each plant patch with a point symbol as each

Figure 6: GPS/GIS map display



The GPS/GIS map display utilizes a yellow sand-verbeena symbol to illustrate the real time GPS positional fixes for each patch. The user has application specific vector and raster files available for reference in the field.

positional fix was marked. Future GIS users merely need to double click on the sand-verbeena point symbols to access the corresponding attribute data.

The GPS fixes proved relatively accurate in relation to the pre-existing vector layers and on-screen coordinate display. Differential two-dimensional GPS accuracy was tested at two known surveyed benchmarks located on base. Both point fixes were averaged for approximately five minutes centered on the benchmark. The following is the comparative results:

	Survey	GPS
BM #1	5107697 N 428070 E	5107697 N 428068 E
BM #2	5108763 N 427366 E	5108758 N 427365 E

Although not statistically conducive, the comparative results seem to confirm the USCG DGPS accuracy estimate of ten meters.

Databases

The Camp Rilea GIS presently stores all data in dBase IV format. Data sources include files from popular database programs and a variety of military specific databases. Many popular database software packages convert files to dBase format. Following conversion, files are copied into the pre-existing database fields within the FieldNotes environment. Initial database building is eased by the FieldNotes merge feature. Providing all fields between FieldNotes and the pre-existing dBase formatted database are labeled consistently, matching records for one field will control data placement.

One primary research task was constructing digital FieldForms for application specific data collection. Two FieldForm case studies are presented illustrating an environmental and a facility application at Camp Rilea. Each study includes a background on the feature and the accompanying data collection attributes. An overview of the present standardized Camp Rilea data collection schemes for each application is also discussed. Finally, the customizable features of FieldForms is described. Application success, potential problems, and practicality issues are discussed in the System Analysis section.

***FieldForms Case Study #1* - Environmental Management**

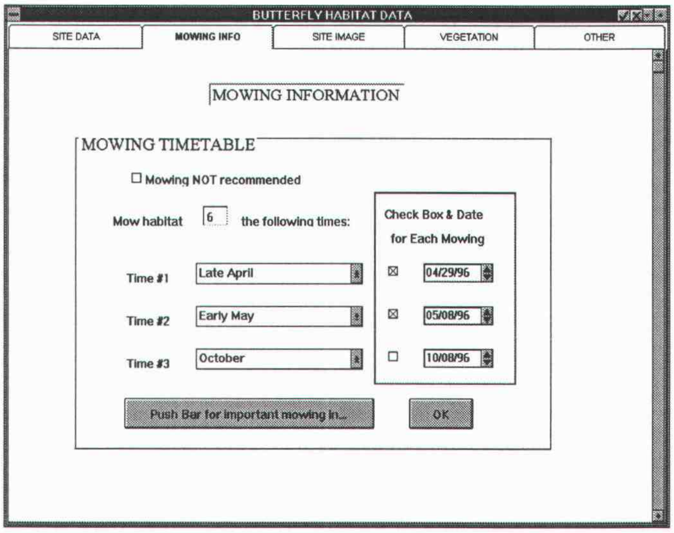
The Oregon Silverspot butterfly (*Speyeria zerene hippolyta*) is a federally-listed threatened species which occupies the sand dunes of the Clatsop Plains. Beginning in the early 1990's, Camp Rilea in cooperation with the United States Fish and Wildlife Service, under the Endangered Species Act, began actively managing approximately 65 acres of butterfly habitat. Concentrated areas of the Common Blue Violet (*Viola adunca*) are known to be important habitats for the Oregon Silverspot butterfly to oviposit and rear its young. For management purposes, ten concentrated violet areas have been divided into numbered management units. Except for scheduled habitat mowings, all base activity is restricted from the habitat areas (Hammond, 1994).

The Camp Rilea Butterfly Habitat Management Plan outlines various data collection methods utilized for habitat assessment and monitoring. Habitat total area measurements, including prime vs. degraded and renovated area breakdown, and off-road construction easement areas, provide baseline habitat data. General habitat vegetation data, including plant species listing, total number of species, percent of native vegetation, and average vegetation heights, are included for the individual habitats. Specific vegetation data, such as number of blooming violets and blooming goldenrod colonies, and quality analysis, are recorded along transects. Silverspot butterfly observations and population estimates are also included. Mowing management timetables, including management schedules for controlling Scotch broom, are presented on a year specific basis for each habitat (Hammond, 1994).

The corresponding digital FieldForm folder constructed during my research is organized into pages by the general habitat data collection realms, pages include spatial data and site condition assessment, vegetation, a mowing timetable, a digital image, and other linked monitoring databases (Figure 7). The first page is composed of site spatial data, inspector information, and logical check boxes for assessing habitat condition. The method of study choices, varying from a quick walk to a detailed transect analysis, are picklisted for efficient and consistent data recording. The second page includes the mowing timetable on a habitat basis and an accompanying logical and date field for recording each mowing. The third page includes a digital image captured from ground videography of the habitat, potentially displaying varying views or specific habitat sections of note. The fourth page includes a listing of non-native and native plants in the habitat management areas. A logical answer check box is included for each species denoting absence or presence. Summary vegetation data, such as total number of species and percent of native vegetation, is also included. The fifth page contains push button links to related databases containing monitoring and transect data.

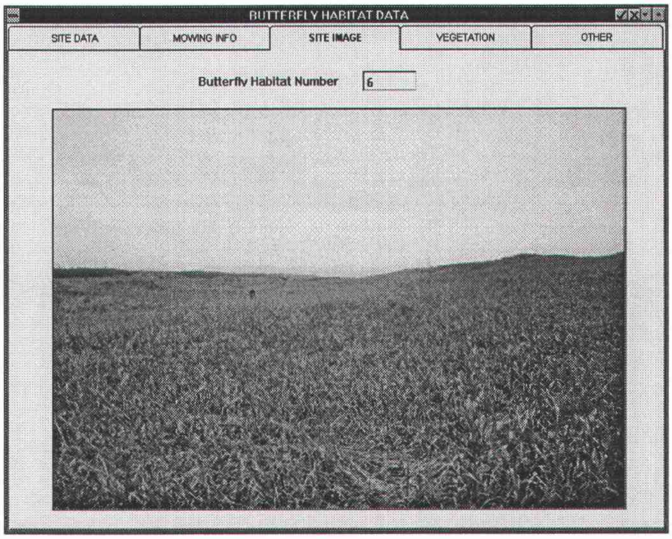
A FieldNotes project file for butterfly habitats is saved targeting two end users: maintenance personnel responsible for base mowing and wildlife biologists conducting habitat monitoring. Data not applicable to either end user is marked as read only fields. Project files for mowing personnel are limited to the butterfly database and drawing files for the butterfly habitats and roads to serve as orientation points. Wildlife biologists' projects include databases and drawing files for the butterfly habitats and survey data for

Figure 7: Sample pages from the Butterfly Habitat FieldForm



The mowing information page displays a mowing timetable for butterfly habitat #6. Users can check and date the FieldForm following each scheduled mowing.

The site image page displays a profile view of butterfly habitat #6. The user can select a variety of images, such as an aerial view or a specific area of note, for display within a FieldForm.



Nathaniel Whelan, 1996

all site vegetation. An aerial videography backdrop image can also provide the biologist with field available remote sensing data.

The FieldNotes environment is customized for this environmental application. Settings for the tool and icon bars are minimized for only the essential functions, such as opening and closing a project, zooming, the pointer, and the database icons. Upon entering FieldNotes, the user has only to push the large open project icon and select butterfly project file to begin work.

***FieldForms Case Study #2* - Facility Management**

The Camp Rilea wastewater treatment plant, located in the southeast corner of the base, was designed to put treated domestic sewerage to beneficial use. The primary components of the plant are: two aerated lagoons, a chlorine contact chamber, an irrigation pump and sprinklers, and a 15-acre irrigation field. The Department of Environmental Quality (DEQ) outlines operating standards for the treatment plant and determines plant effectiveness through analysis of data on the volume of wastewater flow and on various monitoring parameters. The wastewater treatment plant provides a large scale, relatively complex facility application for FieldForms.

The primary plant sampling points are: influent samples at the lagoon intake structure, the lagoon ponds, effluent samples near the chlorine contact chamber, and four monitoring wells surrounding the irrigation field. Influent monitoring includes influent flow, pH levels, Biological Oxygen Demand (BOD) levels, Total Suspended Solids (TSS), and temperature. Lagoon monitoring measures water depths of the primary and secondary ponds, and precipitation levels. Similar to influent, effluent sampling monitors flow, pH, BOD, TSS, but also samples Chlorine, Coliform, Nitrate, Ammonia Nitrogen, and Total Kjedahl Nitrogen. A daily log, remarks, date, DEQ permit number, file number, inspector name, title, and signature are also recorded for influent, effluent, and lagoon datasheets. Influent and effluent monitoring frequency varies from a daily basis to a monthly basis. Effluent data is only collected when flow is released onto the irrigation field. The four monitoring wells surrounding the irrigation field are sampled on a bimonthly basis for groundwater surface depth, volume of water in well, and monitoring of Ammonia Nitrogen and Nitrate levels. A four well average is calculated for each sampling time. All chemical samples are sent to a laboratory for analysis (Mitchell, 1995).

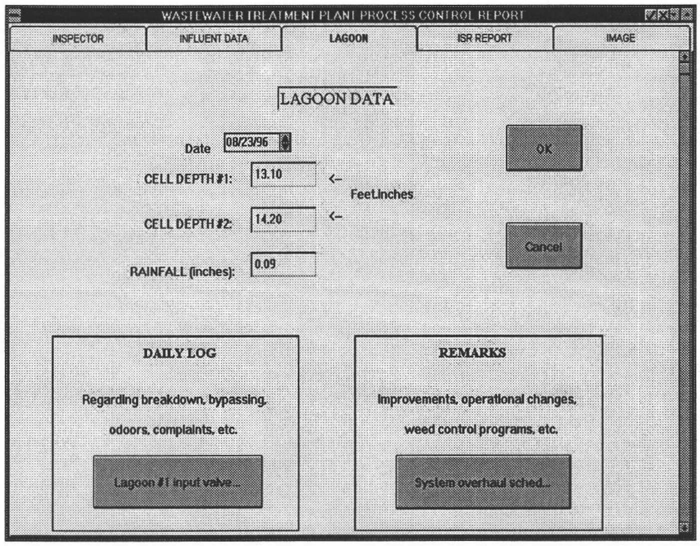
Presently all data collection is performed on paper worksheets in spreadsheet format structured by a monthly basis. The wastewater plant operator is primarily responsible for all facets of data collection. All data collection forms are sent to the Oregon Military Department`s Natural Resource Specialist for compilation into an annual report on operations submitted to the DEQ. The annual report includes tables, charts, and graphs summarizing monitoring data and conclusions and recommendations addressing accomplishments and concerns.

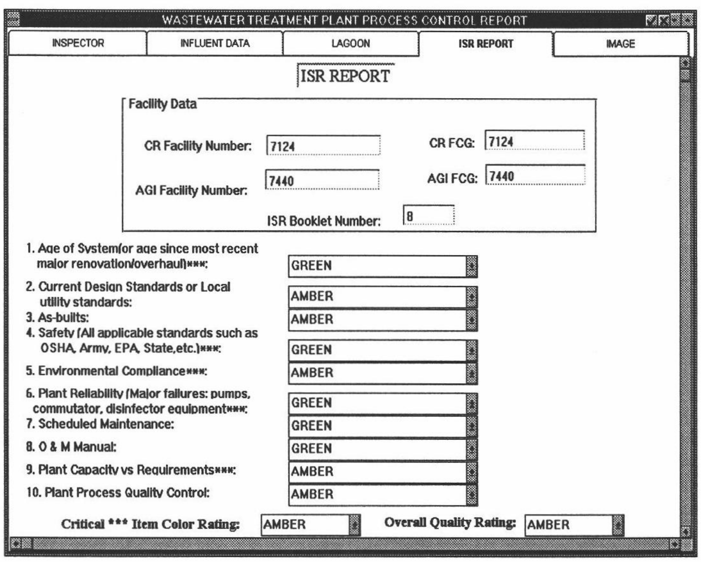
FieldForms constructed during my research attempt to replicate the paper worksheet data collection process. Three separate FieldForms target the primary sampling points: influent, effluent, and the groundwater wells. Lagoon data is included in the influent dataform. The influent and effluent forms are linked spatially by symbols designating in and out, positioned north and south of the plant, respectively. The four groundwater wells are linked through well point features numerically labeled on each side of the irrigation field.

Each wastewater treatment plant FieldForm folder is subdivided into pages. The effluent form is comprised of three pages, the well form has four pages, and the influent form has five pages (Figure 8). The first page for all forms includes a large font form title and requests inspector information. Inspector information includes name, title, date, and signature. The second page varies for the differing forms. The influent/lagoon data form has flow, temperature, pH, TSS, and BOD, included on the second page. The second page of the effluent data form has the same criteria, and Chlorine, Coliform, Nitrates, Ammonia, and TKN levels. The second page for well data includes fields for DEQ required measurements used in calculating groundwater surface elevation. The third page for influent monitoring focuses on lagoon monitoring, including fields for cell depths, precipitation, and memo fields for remarks and a daily log. The third well monitoring page includes fields for analysis of chemical parameters. Following off-site laboratory analysis, all chemical readings are to be entered on the FieldForm corresponding to the date of original data collection. The fourth page for influent data includes criteria for the Installation Status Report (ISR) for Sewage Treatment and Disposal facilities. Similar to other facility ISR forms, the facility specific predetermined criteria are rated on green, amber, red, or not available scale, and are easily selected by utilizing preset pick lists. The eleven ISR criteria for the wastewater treatment plant are evaluated on an annual basis and include topics such as the availability of as-built

Figure 8: Sample pages from the Influent Wastewater Treatment Plant FieldForm

The lagoon data page displays fields for depth measurements of lagoon cells #1 & #2, and daily rainfall measurements. Push button memo bars save daily log and remarks data.





The ISR report page collects facility classification data. The ISR page also utilizes preset pick lists for rating ISR criteria on a green, amber, red, or not available scale.

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drawings to rating environmental compliance levels. All ISR data is currently available on the influent data form. The final page for databases includes a digital image of the associated structure, such as the lagoons for influent and the irrigation field for the effluent FieldForm.

A wastewater treatment plant project file includes only GIS data necessary for the application. The project file was minimized to the influent, effluent, and well databases, and drawing layers of the wastewater treatment system, including the lagoons, chlorine chamber, irrigation fields, monitoring wells, and infrastructure piping, and no aerial backdrop was utilized. Similar to the Silverspot butterfly application, the FieldNotes environment was also simplified for the wastewater treatment plant application.

Imagery

The Camp Rilea GIS is currently composed of six aerial and 28 ground videography images. All current imagery was saved utilizing video image capture software. FieldNotes is capable of supporting BMP, TIFF, GIF, and JPG image files, and can directly interface with TWAIN-device-specific software for digital cameras. FieldNotes does not accept 24 bit imagery.

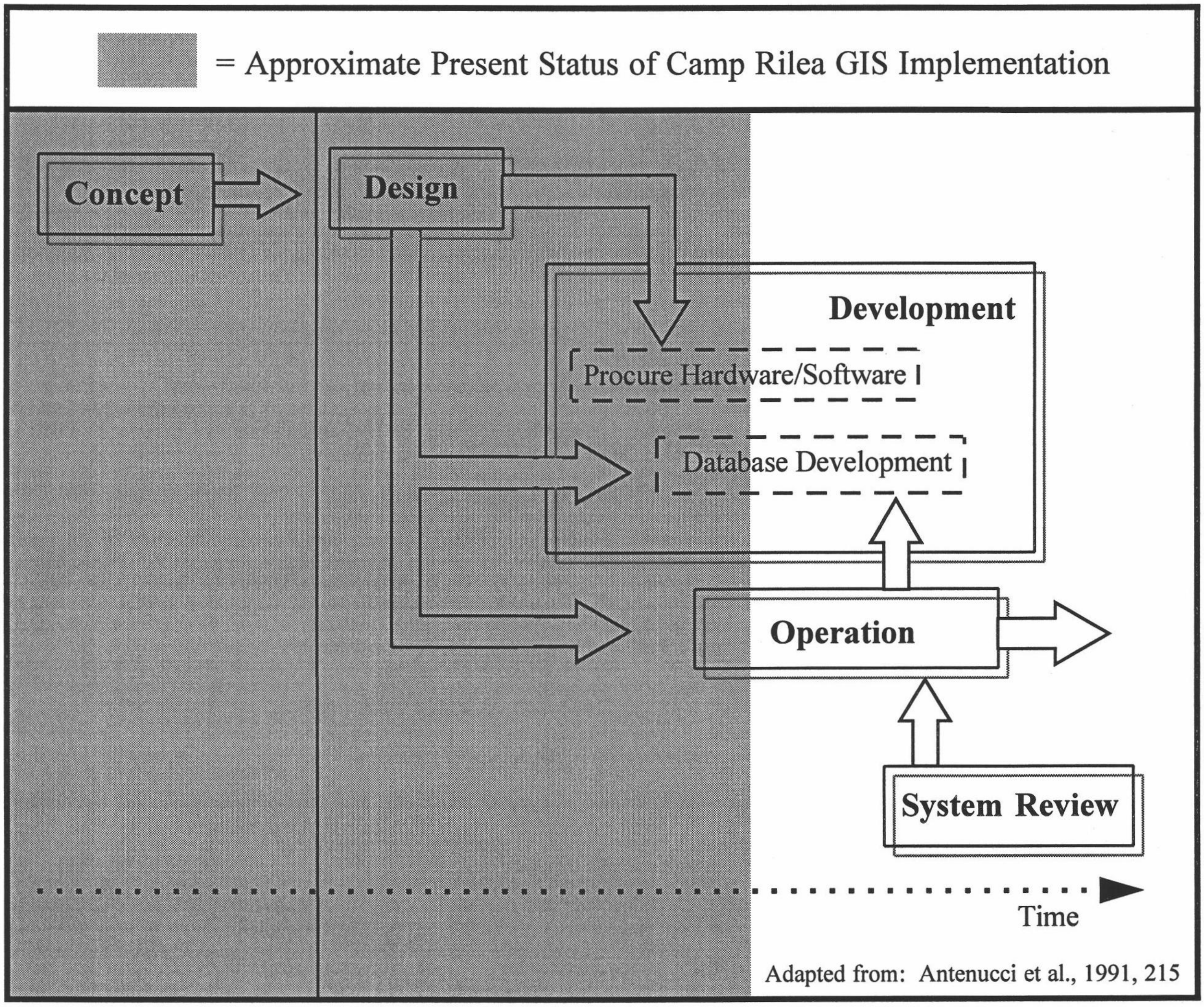
The six current aerial images were captured from Hi-8 millimeter color videography flown along two north-south flightlines at approximately 5000 ft. The images overlap and cover the entire base. The captured 8 bit images are saved as 1.1 Megabyte BMP files. The aerial images were mosaiced utilizing Adobe Photoshop software, then rectified in FieldNotes with the drawing layers.

The 28 ground images were also captured from Hi-8 millimeter color videography taken at ground level. The images are profiles of various buildings and structures on base. The 8 bit images are saved as 750 kilobyte TIFF files. Each image is incorporated into that building or structure's associated FieldForm.

SYSTEM ANALYSIS

The Camp Rilea field automation GIS is continually being tested and evaluated. Figure 9 illustrates the current status of the Camp Rilea field automation GIS on a

Figure 9: GIS implementation stages



flowchart depicting five broad stages of GIS implementation. My research has outlined many issues during the initial phases of GIS design, development, and operation critical to the project's future success. These issues are interdependent and encompass a variety of topics, including system practicality, security concerns, data communication linkages, and data standards. Early feedback from the Camp Rilea experience provides guidance for future directions of field automation for other GIS applications.

The digital FieldForms have proved flexible and easy to construct to address a variety of Camp Rilea applications. Early feedback from military planners expressed interest in "fine-tuning" the FieldForms to create linkages to other software utilized for military applications. Future work in this direction would involve more advanced programming, requiring a greater resource investment. Similar to other field automation GIS projects, military planners have perceived a greater potential for facility applications of the FieldForms rather than environmental applications. Facility applications, such as maintenance logs, place an emphasis on regular record keeping involving spatial features. The higher the frequency of data collection will allow for greater opportunities for debugging the field automation system and work to reinforce the technology to regular users. Due to limited environmental database updating, applicability for environmental features has emphasized the use of the customizable FieldForms as an informative, easy to read interpretation of the database file, rather than as a tool for methodical data entry.

Utilizing the FieldNotes package integrated with a GPS receiver has proved to be an accurate and efficient data layer compilation process. The USCG DGPS positional accuracy's accompanied with the attribute data collection possibilities of FieldForms provides an efficient system for point, line, or polygon map layer and database production. GPS layer and database compilation applications are especially evident for the environmental realm, where sub-meter accuracy's are rarely required and FieldForms can be tailored for various applications.

The use of field technical equipment presents potential problems. Equipment durability and portability is tested by varying weather and environmental conditions, and by users unfamiliar with proper handling and operational procedures. A certain degree of field durability is required of all field equipment. Laptop memory restrictions limit the amount of data available to field users. Also, battery management is a significant concern for all field equipment.

Data communication addresses the data transfer linkages between technical equipment, and networking between Camp Rilea and the Oregon Military Department Headquarters. An efficient and consistent system needs to be accepted for data transfer between field units and office workstations. This will allow for effective uploading of data for fieldwork and for downloading the data back into the primary database for accurate updating. For this application, a network also needs to be established between the Headquarters facility and Camp Rilea. This will allow for real-time data updating for decision makers at either location.

Security concerns for spatial and attribute data is an important issue. Data editing must be controlled by the needs of the given application. Control functions within FieldNotes allow for data fields to be set as read only, effectively limiting potential erroneous editing. Graphical objects composing the various map layers can also be set to not permit spatial editing. Decisions concerning security clearances are subject to change in accordance with user recommendations provided during project implementation.

Data standards throughout will provide for efficient data sharing and a benchmark for GIS data quality. Although there is a wide variety of data conversion possibilities available, feasibility of data sharing will increase with preselected standard file formats. Standardized file formats may ease potential future GIS integration across jurisdictional boundaries, such as the need to collaborate with the Bureau of Land Management and the United States Department of Agriculture databases for ecosystem management applications. Data quality controls within the GIS will set limits of mapping and attribute data accuracy.

This project relies heavily on user acceptance of the field automation GIS as a tool for data collection and as an accessible information source. As previously stated, the value of the Camp Rilea GIS is determined by accurate and timely spatial and attribute data; therefore, a total usage committal is necessary for each project phase. This type of GIS will be rendered valueless if pertinent data fails to be integrated in the overall database.

CONCLUSION

The variety of complex environmental and facility management issues present make Camp Rilea an ideal test site for field automation GIS. Military planners have realized the potential of this system, even though it is still relatively in its infancy. Field automation has provided an efficient and accurate attribute data collection tool for widespread Camp Rilea facility applications. Integration with GPS and customizable FieldForms has provided convenient tools for initial environmental spatial and attribute data collection, though applicability of consistent database updating has not been tested during the early stages of the Camp Rilea project. Many topics, including focused, realistic planning directives and financial and human resource allocation issues, remain as questions which need to be resolved for future project success. Following successful implementation at Camp Rilea, other Oregon military facilities can benefit from similar databases. The variety of applications for this user friendly system potentially signify a techniques shift from office workstations to a field emphasis and extend across the gamut of spatial and attribute data collection and management.

REFERENCES

Antenucci, J.C., Brown, K., Croswell, P.L., and Kevany, M.J. 1991. Geographic Information Systems: A Guide To The Technology. London: Chapman and Hall.

Carlson, J., Reckendorf, F., and Ternyik, W. 1991. Stabilizing Coastal Sand Dunes in the Pacific Northwest. Washington, D.C.: United States Department of Agriculture.

Fort Lewis Environmental and Natural Resources Division (ENRD). 1990. Ft. Lewis Environmental Coordination Map. Washington, D.C.: Defense Mapping Agency Topographic Center.

Hammond, P.C. 1994. Habitat Management Plan for the Oregon Silverspot butterfly (Speyeria zerene hippolyta) at Camp Rilea, Clatsop County, Oregon. Oregon State Military Department, Oregon Army National Guard.

Huxhold, W.E., and Levinsohn, A.G. 1995. Managing Geographic Information System Projects. New York: Oxford University Press.

Kagan, J.S. 1993. Inventory for Rare, Threatened and Endangered Species and Significant Habitats at the Oregon Military Department's Camp Rilea Training Area. Oregon State Military Department, Oregon Army National Guard.

Kunzmann, M. 1996. GPS/GIS for Natural Resource Management at Point Mugu Naval Air Weapons Station. Paper presented at the conference on GPS/GIS '96: Mapping to Manage, Billings, Montana.

Maris, J. 1991. State of the environment report at Fort Lewis and its sub-installations. Department of the Army, Environmental and Natural Resources Division, Directorate of Engineering and Housing. Fort Lewis, WA: The Directorate.

Mitchell, G. 1995. Wastewater Treatment Plant Report for Camp Rilea, Oregon. Oregon State Military Department, Oregon Army National Guard.

Oregon Military Department. 1982. Camp Rilea Master Plan. Oregon State Military Department, Oregon Army National Guard.

Penmetrics, Inc. 1995. FieldNotes User's Manual. Corvallis: Penmetrics, Inc.

Rosenfeld, C.L. 1996. GPS-Equipped 'Pen' Computer for Facilities/Environmental Management of Military Training Areas. Paper presented at the 5th Annual LRAM/ITAM Workshop, Lacrosse, Wisconsin.

Rosenfeld, C.L. 1996a. interview by author, Corvallis, Oregon, October 1.

Skarrett, S.K. 1996. interview by author, Corvallis, Oregon, July 15.

Starr, RM., Marston, R.A., and Hall, M. 1977. Environmental Sensitivity of Oregon's Coastal Sand Areas. Department of Geography Resource Paper 7. Corvallis: Oregon State University.

Taggert, D. 1996. Maritime Differential Global Positioning System. Paper presented at the conference on GPS/GIS '96: Mapping to Manage, Billings, Montana.

Thompson, C., Podgorski, J., and Campbell, M. 1994. Pen Based Computing Eases Field Data Collection. GIS World, 3: 36-8.