

As staff and budgets shrink and environmental requirements grow, facilities managers face a critical need for more timely access to geographic-based information to achieve regulatory compliance. An integrated Geographic Information System (GIS) can successfully satisfy this need for a large municipality. But for managers at smaller facilities, a full-function GIS often exceeds what is needed and affordable. Such managers can derive similar benefits with minimal staff, budget, and equipment investments by developing a microcomputer-based system, using CAD/CAM software as a mapping package linked with third-party database management software. This paper describes how a military installation in Hawai'i successfully built such a system using *AutoCAD* and *dBase III+*.

Facilities managers need geographic-based information to make wise management decisions — especially in the area of environmental compliance. Siting facilities in environmentally sensitive areas, investigating former dump sites, tracking noise impacts, identifying historic properties, detecting leaks from underground storage tanks, developing site-specific spill contingency plans and assessing development impacts on protected wildlife populations are just some of the decision-making processes which require geographic-based information.

This need is often difficult to fulfill because while a great deal of environmental data may be available it may be scattered about in a variety of places and formats such as reports, maps, field sketches, photographs and engineering drawings of disparate sizes, scales, levels of complexity and accuracy. Staff and funds are often not adequate for timely data consolidation and evaluation to satisfy permit requirements, auditors, lawmakers, and the affected public.

An integrated Geographic Information System (GIS) can help address this need for a large facility or municipality; however, a different approach is needed for a smaller facility with an overextended staff, limited computer infrastructure, and modest budget resources. This paper will illustrate one approach to meeting this need: the development of an affordable microcomputer mapping system using CAD/CAM software linked with third-party database management software. The system was constructed in the context of a modest budget, colleagues with little or no computer literacy, and a large, slow-moving government bureaucracy.

This project evolved at the Marine Corps Air Station (MCAS), Kaneohe Bay. This military installation is located on Mokapu Peninsula on the northeast (windward) coast of the Island of O'ahu, Hawai'i (Figure 1). Facilities managers there are responsible for an inventory of over 2,000 structures and work spaces, more than 1,900 housing units, and many recreation areas, in support of military personnel assigned to numerous air and ground units of the tenant organizations. Although the Air Station itself occupies less than five square miles of land, it supports a resident population of approximately 16,800 military personnel and their families, 1,800 civilian employees, and about 3,000 retirees who have access to its community facilities. The Station also contains, and is surrounded by, an

Computer-aided Mapping for Facilities Management and Environmental Compliance

A Case Study

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PROJECT AREA

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incredible variety of land and water resources which must be carefully managed.

The attraction of these resources has encouraged development of adjacent communities right up to the Station's gate. Responsible facilities managers must contend with increasingly intense user pressures, environmental constraints, and conflicting cultural values attributed to the

surrounding air, land, and water spaces — the very resources upon which the Marines depend to accomplish a variety of military missions. They must ensure that all Station activities are carefully sited so as to meet not only military requirements, but also those of all federal and pertinent state and local laws in such areas as environmental compliance. Their job is complicated further by the fact that approximately 25 percent of the peninsula is environmentally constrained by steeply sloping terrain, unsuitable soils, endangered wildlife habitats, historic sites including an ancient Hawaiian burial ground, fragile coastlines, and surrounding air and waters zoned with some of the most stringent air and water quality standards in the state and nation. Additionally, aircraft flight paths are constrained by noise impacts and accident risks otherwise imposed upon the adjacent communities, and by bird/aircraft strike hazards due to nearby protected waterfowl

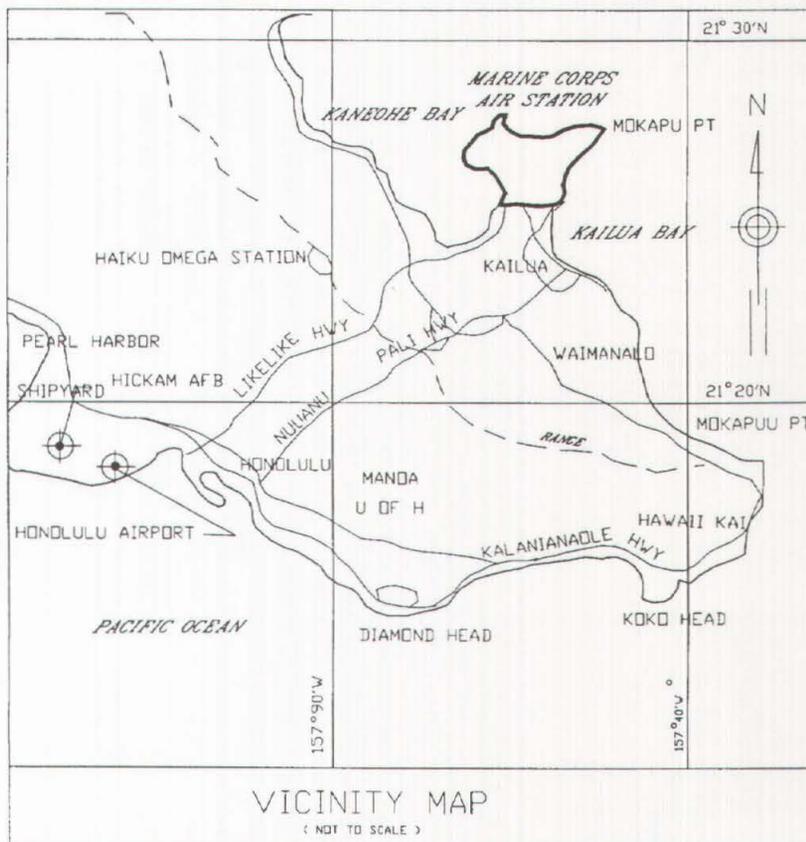


Figure 1: Plan of the Marine Corps Air Station, Kaneohe Bay, Hawaii

sanctuaries and migratory flyways. Also, marine water training space is limited by public boating, fishing, and swimming, and by protected species such as live coral reefs, endangered humpback whales, and threatened green sea turtles. On land no digging can take place without planning for the possibility of disturbing archaeological artifacts and/or ancient Hawaiian burials. Any change in activities or facilities invariably affects or is affected by one or more of these constraints, making quick access to environmental data, both graphic and non-graphic, essential for immediate use to support the decisions of facilities managers.

SPECIFIC OBJECTIVES OF THE PROJECT

When this project started in 1986 we considered it of critical importance that the system be developed and tested in phases, starting with one manageable data set for specific applications and building to include other data sets, one application at a time, to ultimately cover all areas of facilities planning and management.

Since environmental factors frequently constrained facilities planning in so many areas, the project team decided to pilot-test the new system in the environmental arena and later expand it to cover all areas of facilities planning and management.

Although abundant environmental data were available to Station

managers, most of it was dispersed in various contractor reports, engineering drawings, paper maps, field sketches, aerial photos, and field notes. All were at different scales and formats. During time-critical periods of planning or decision-making it was extremely difficult to gather these scattered data sets, then synthesize, analyze, and redisplay the important environmental information that they contained. This situation was aggravated by the frequent turnover of military managers who were required to make critical and far-reaching decisions without the benefit of having the data readily available.

We also felt strongly that the system should be very easy to learn and use, since there were no desktop computers readily available and very few environmental or other facilities staff who had any experience with computers could afford the time for lengthy training sessions.

The system should also be compatible and translatable to/from the existing computer-aided mapping system used by "sister" agencies — in this case *Computervision* — and with the Marine Corps-wide planned future computer-aided mapping system known as Land Use Management System (LUMS) which uses the *ARC/INFO* GIS format.

For real-time decision support, the system should allow interactive manipulation of both graphic and associated non-graphic data so that simple queries of the non-graphics can be made and their results displayed in the graphic environment. For example, a real-time environmental compliance requirement is the ability to locate and leak-test all underground storage tanks within certain deadlines set by the U.S. Environmental Protection Agency (40 Code of Federal Regulations, Part 280), based on tank age, in-use status, and other specified criteria. A typical request requiring graphic and non-graphic data manipulation would be to locate underground storage tanks constructed before 1965 and indicate whether they are still in use, contain less than 25,000 gallons capacity, and have been tested for leaks within the past calendar year.

The system should support multiple geographic coordinate systems to allow selection of user-defined, state plane, UTM, or latitude/longitude coordinates. Support of these multiple geographic formats satisfies reporting requirements as diverse as engineering survey reports, military training plans, and historic preservation documents.

The system should not require extensive commitment of environmental staff for actual data input although it would need the staff's close guidance in the database development for their knowledge about resource distribution and environmental compliance requirements on the Station.

The system should store and display data in a way that is comfortable for professionals from any number of disciplines — engineering, environmental sciences, architecture, planning, archaeology, etc. — since all will use the system to support their various decision-making processes.

The system should be suitable for continuous improvement and enhancement as monies become available, yet be self-contained and productive even in the earliest stages of development in order to gain management support for these future phases.

The system should be able to generate prints and plots suitable for inclusion in various scales and sizes, in black and white or color formats, to accommodate the requirements of diverse uses such as formal and informal presentations. These prints and plots should be easy to photocopy and take into the field at a moment's notice, such as in responding to the report of a hazardous substance spill.

The system should be readily compatible with the most common and accessible software packages used by architectural and engineering firms

A typical request requiring graphic and non-graphic data manipulation would be to locate underground storage tanks constructed before 1965 and indicate whether they are still in use, contain less than 25,000 gallons capacity, and have been tested for leaks within the past calendar year.

that, as consultants, would be hired to work with and add to the database in the future.

DEVELOPMENTAL APPROACH

Given the challenging objectives, constraints, and phasing requirements associated with this project, a unique developmental approach was required which would allow tangible results throughout the life of the project. The steps followed to implement this approach are summarized below:

Evaluation of user requirements

Knowing the environmental requirements of the Station was an essential prerequisite to the actual design and development of the proposed computer-aided environmental mapping system. The project team's knowledge in this area streamlined discussions and fostered early agreement on requirements and desirable features of the proposed system.

A contractor was hired to work in-house to help the project team pilot-test the new system as it evolved. Due to a modest budget, the team utilized a student contractor who was not experienced with the chosen computer system. However, she had a strong environmental knowledge-base as a geography graduate student at the University of Hawai'i, had excellent cartographic skills, some computer proficiency, and previous military experience. While awaiting development of the system and arrival and installation of the equipment, this student became a contractor-in-residence, asked to observe and document the daily program requirements associated with the environmental/natural resources program. Thus she acquired first-hand familiarity with the types and timeliness of environmental data needed for critical management decisions.

Assessment of technology

While user requirements were being analyzed, a survey of mapping technology options was accomplished. This involved extensive review of the technical literature and hands-on evaluation of systems at technical trade shows and vendor locations.

Selection of the Preferred System

Following this technology assessment, an IBM-compatible 80286 microcomputer system was selected as the basic hardware platform for the environmental mapping system, with *AutoCAD* Release 2.52 as the basic software program. The total funds invested in hardware and software at this point was about \$10,000.

AutoCAD was selected over other options for several reasons, including ease of use, abundance of third-party software, potential for customization, likelihood of long-term product support, compatibility with *Computervision* and *ARC/INFO*, support of neutral file formats and so-called standards, and popularity among architects and engineers in both the public and private sectors.

Development of the base map

As earlier indicated, the computer system developed for this project was required to be compatible with *Computervision*. To demonstrate compatibility, the base map was digitized in *Computervision* for later translation to *AutoCAD*. An existing photogrammetrically-derived facilities map at 1" = 400' was used as the source of information for the digitization process. Initially a small portion was digitized to determine the

feasibility and accuracy of the translation approach.

Translation of the base map

Translation from *Computervision* to *AutoCAD* was performed for the test area using Initial Graphics Exchange Specifications (IGES). Following successful translation, remaining areas of the Station base map were digitized and translated. Numerous other methods of translation were explored including DXF, Personal Designer, and third-party direct translator software.

Initial development of thematic overlays

Following successful translation of the basemap to *AutoCAD* format, a few thematic overlays were digitized to determine the suitability of *AutoCAD* for map layering.

System delivery and installation

The prototype system was then packaged and delivered to MCAS Kaneohe Bay for installation, on-site training, and further database development.

Basic system training

Since very few of the project sponsors had any prior experience with microcomputers, an introductory training course was provided which reviewed the fundamentals of DOS as well as *AutoCAD* functions and capabilities. Additional training was arranged later when the contractor-in-residence became familiar with the new system. She developed customized operations manuals for use of the system and conducted individual sessions on a tutorial format using real-time decision needs as the basis for training.

On-site development of thematic overlays

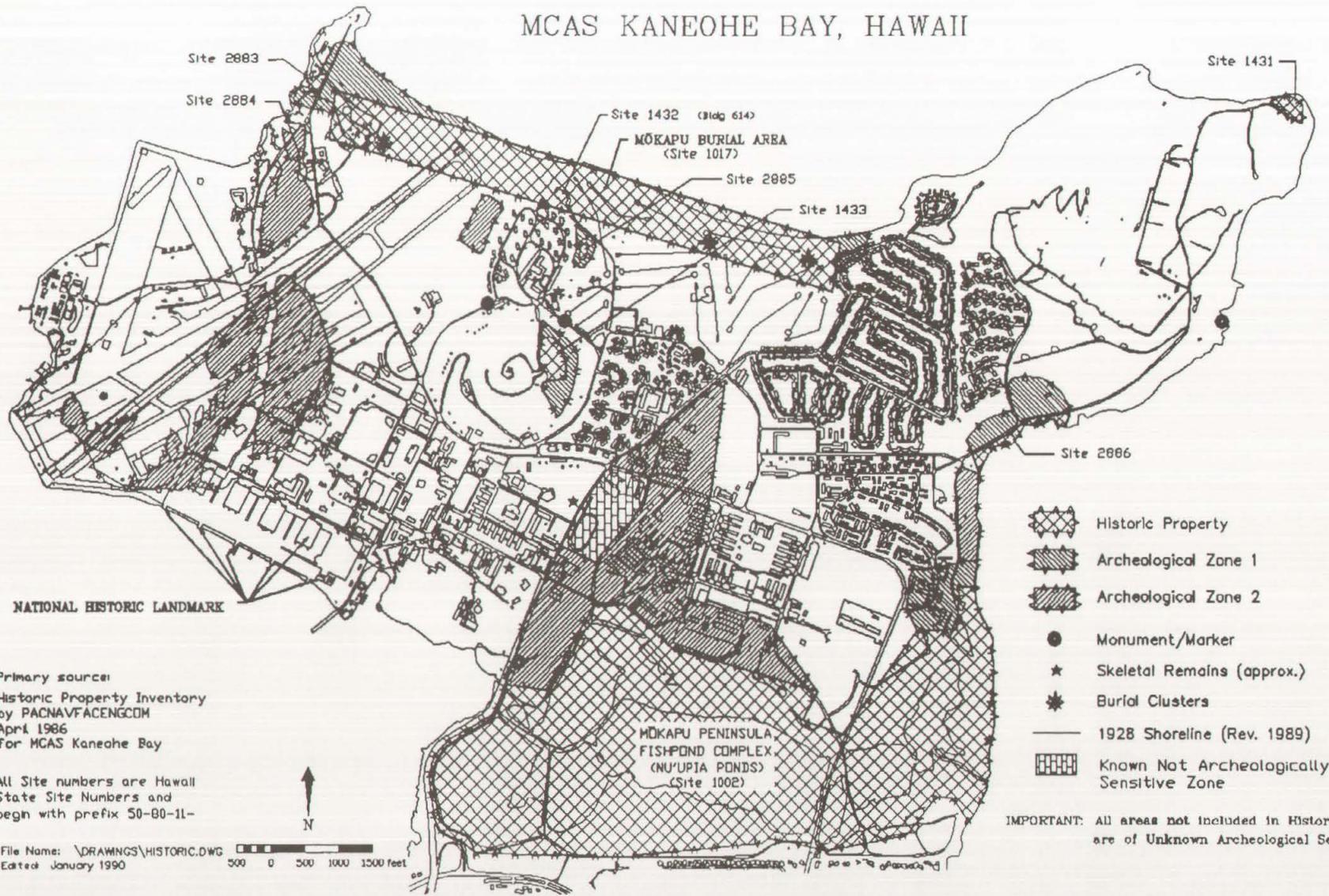
Additional thematic overlays were developed on-site by the contractor-in-residence. Subsequently, the contractor's status changed from that of student to full-time consultant. The on-site availability of this resident contractor greatly facilitated mapping of data contained in scattered locations and formats. Clients who would eventually use the system were encouraged to learn by example and to add their ideas and desires into the creation of the system as it was being developed. This generated a pride of ownership in the product and promoted motivation to learn and use the system.

Generation of graphic products for environmental planning and decision support

Almost immediately following the initial development of thematic overlays, simple graphic products were generated for management application. Early graphic products were often time-consuming to develop due to the inexperience of the users. However, they were widely reproduced and distributed to serve an immediate need. They thus demonstrated the tremendous potential of the system for real-time decision support needs.

As users gained more experience on the system, increasingly complex graphic products were generated. An important early example was the development of a historic properties/archaeologically sensitive areas map (Figure 2). Whenever a site is sought to construct a facility or perform a military training exercise on Station, this map is consulted by project planners, engineers, and military commanders to help plan sites

STATION HISTORIC PROPERTIES MCAS KANEHOE BAY, HAWAII



Primary source:
Historic Property Inventory
by PACNAVFACENGCDDM
April 1986
for MCAS Kaneohe Bay

All Site numbers are Hawaii
State Site Numbers and
begin with prefix 50-80-11-

File Name: \DRAWINGS\HISTORIC.DWG
Edited January 1990

Figure 2

and routes in such a manner as to avoid impacts where possible or plan mitigations where impact is unavoidable. This map can be modified readily as new information becomes available.

A more advanced application of graphic outputs to serve a real-time decision support need involved determining the site for a new family housing project on the Station. Off-Station housing and rental units in Hawai'i are among the most limited and costly in the nation and there is a concerted push to provide more attractive on-Station housing options for the military to preserve the morale and retention time of this all voluntary force.

A low-cost housing development project was proposed with tight deadlines for implementation mandated by the enabling legislation (Section 802 of the FY84 Military Construction Authorization Act, as amended, 10 U.S.C. 2821 note). This computer-aided mapping system was utilized to take into account the environmental considerations that would affect the siting of the proposed project. Twelve potential housing sites were chosen.

Starting with a "blank map," thematic overlays were employed to illustrate the various disadvantages of building at all of the potential sites such as flooding and tsunami hazards, abandoned underground storage tanks, former disposal sites, archaeologically sensitive zones, endangered wildlife habitats, noise hazards, soil suitability, distance from existing support utilities, and safe distance from potentially explosive munitions storage areas (Figure 3).

Planners narrowed their search to three potential sites and then took a closer look at environmental and other constraints at each. Eventually, this "weeding out" process led to the decision to build on a parade ground/recreational field (Area 8 of Figure 3) instead of other areas that may have met more project criteria but were less desirable because of environmental factors. The decisions were made by managers who lacked detailed knowledge of the environmental constraints on the Station and had little computer experience, yet the availability of the maps and accompanying non-graphic data explaining the pros and cons of development at each site influenced their final decision.

Development, testing, and evaluation of third-party software for database links and coordinate conversion

Recognizing the need for non-graphic as well as graphic data manipulation, we began to explore various options for integration of *AutoCAD* graphics with external database files. Off-the-shelf, third-party software alternatives were explored and evaluated. Most of the third party integration software available at this stage was determined to be powerful, yet too inflexible to meet the project sponsor's requirements.

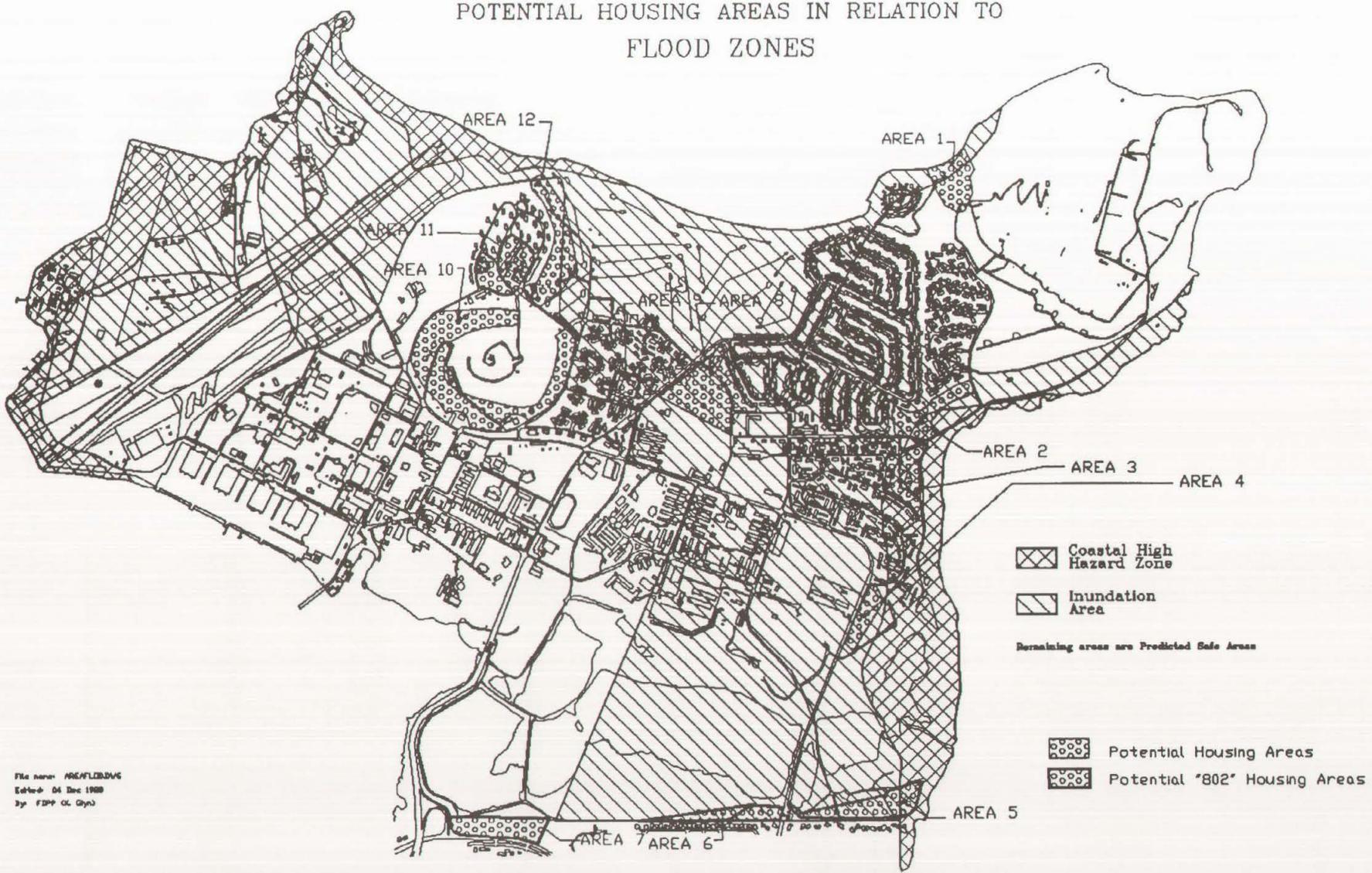
Design and development of non-graphic database management systems for integration with the graphic system

Using *dBase III +* and taking into consideration sponsor guidelines and recommendations, some very specific non-graphic database management systems were developed for Underground Storage Tank (UST) management, oil/water separator management, and hazardous waste/material tracking. These non-graphic databases were developed to facilitate stand-alone use in a *dBase* environment or integration with graphics in an *AutoCAD* environment.

Integration of graphic and non-graphic database management systems

Functions were developed and customized to facilitate linking of graphic

POTENTIAL HOUSING AREAS IN RELATION TO FLOOD ZONES



File name: AREAFLOOD.DWG
 Edited: 04 Dec 1989
 by: F3P4 GK Gyn

Figure 3: Sample use of thematic overlay in evaluating environmental constraints impacting alternate potential housing areas

and non-graphic database management systems with *AutoCAD*. Probing of graphics in the *AutoCAD* environment could result in display of *AutoCAD* attribute data or external *dBase* data, depending on user preferences. For example, one could call up the map on the computer screen showing underground storage tank (UST) locations, then zoom in and display an enlarged view of one UST and query the data base on the detailed attributes of this tank (Figure 4). Likewise, simple queries in the *dBase* environment could result in graphic highlighting in *AutoCAD*. For example, one could ask for a subset of all active USTs built before 1965 then easily edit the map in *AutoCAD* to highlight the sites with a special symbol or "target." This visual depiction would expedite identification of potentially deteriorating tanks which are located closest to environmentally-sensitive areas. For managers with a large inventory of tanks and limited funds to identify and remove the "worst offenders," the ability to sort priorities on tank condition with graphic and non-graphic data integration assistance is critical.

Although highlighting functions appear rather simplistic when compared to more powerful GIS systems, they greatly enhance the utility of *AutoCAD* for environmental mapping applications. Recently they served a real-time function during a formal audit of the Station's Underground Storage Tank (UST) program by the Government Accounting Office of the U.S. Congress and were used by contractors in implementing a UST leak detection program on Station.

Since these early stages of development of our project, a number of third-party software products have emerged which perform similar linking functions.

Upgrade and enhancement of the Kaneohe mapping system

Since the beginning of this developmental effort, the Kaneohe environmental mapping system has been upgraded and improved several times. The system now runs on an 80386 microcomputer with *AutoCAD* Release 10. An internal 20 Mb Bernoulli cartridge system facilitates data storage and backup of important files. Numerous thematic overlays have now been added to the system, and for the sake of efficiency, have been stored separately from the base map file. The system is currently providing the foundation for numerous other facilities-related applications.

Training and technology transfer

Training and technology transfer, although continuous and always critical, received even greater emphasis during the last several months of this project as the system progressed from developmental to operational status. Personalized training sessions on the customized user manuals were conducted with all members of the environmental staff using real project requirements as the basis for training.

Operational use of the integrated system for planning and decision support

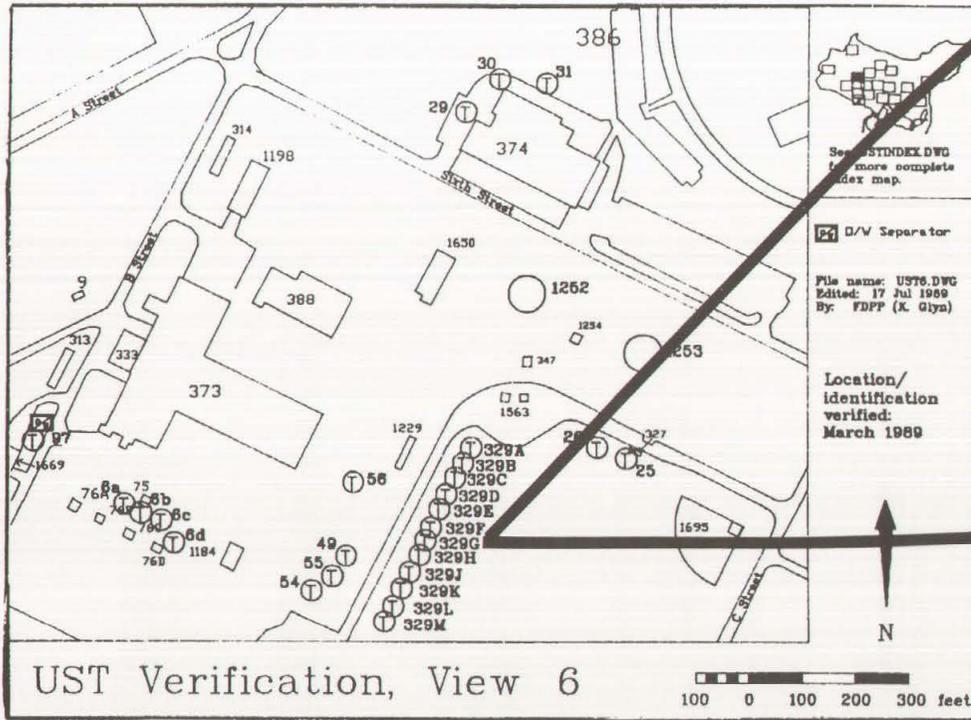
Today, the customized system serves as an operational workhorse for planning and environmental decision-making. Numerous applications, including many previously unanticipated applications, have already been documented and appreciated by the project sponsors.

During the course of this developmental effort, several positive and negative factors emerged.

With respect to initial base map development, file translation techniques were found to be neither simple nor straightforward.

Probing of graphics in the AutoCAD environment could result in display of AutoCAD attribute data or external dBase data, depending on user preferences.

CONCLUSION



Layer 0 -10710'-0", -2894'-8" INSIGHT MENU

LAYER: AREA: ID: LIST: STATUS: TIME: COLOR:

Edit Text

TANK NUMBER.....	329C
YEAR TANK INSTALLED.....	1941
TANK STORAGE CAPACITY.....	25000
PRESENT MATERIAL STORED.....	GASOLINE
LEAK DETECTION.....	STOCK INVENTORY
LAB DATA.....	UNK
ACTION.....	UNK

OK Cancel

C:DDENT
Command: ddent
Select an object.

INSIGHT INTERNATIONAL TANK MGR
TANK MANAGEMENT & GRAPHIC RETRIEVAL SYSTEM
DATA SCREEN

TANK NU.	329C	ABOVE\BELOW GND	UNDRGRND
YR INSTALLED	1941	PIPING FLOW	SUCTION
CAPACITY	25000	CATHPROT	SACRIFICIAL ANODE
PRESENT MAT	GASOLINE	LEAK DETECTION	INVENTORY\SENSOR
PREV. MAT	UNK	DATE FIELD CHK.	/ /
EXTERNAL LINING	UNK	CONTRACT NO.	
INTERNAL LINING	UNK	PROJECT NO.	

CONSTRUCTION MATERIAL	CARBON STEEL	DATE SRV. FORM	08/08/85
STCONSTR	WELDED	STATE FURM	YES
PRCONTAIN	0.31	DATE STATE FORM	05/05/86
WIDTH DIA	10.00		CLOSED YES
LENGTH	43.00	VAULTED	F
HEIGHT	0.00	IN SERVICE	NO
FACILITY ID	329C	BUILDING NO.	
FILE NO		ACAD UU. NO.	10
PLANS DWG NO	NUFC 7006157	LAB DATA	UNK
		DATE REMOVED	
		ACTION	UNK

Figure 4 Sample of interactive capability between AutoCAD (graphic) and dBase III+ (non-graphic) database queries on underground storage tank locations and attributes.

The various methodologies available for *Computervision* to *AutoCAD* translation were poorly documented and required much trial and error and experimentation to achieve successful and satisfactory results.

Despite her lack of previous computer experience, the presence of an on-site contractor-in-residence was critical to the success of this project. It was more important for her to be a dedicated, full-time worker who, working in close cooperation with other Station personnel, would help develop and teach others about the system.

Despite the simplicity of the system and the widespread interest it generated, initially it was often difficult for in-house personnel to find the time to learn and use the system. Ironically, the early presence of an on-site contractor tended to be a "crutch" which fostered procrastination in those who needed to become familiar with the functions and characteristics of the system. Only later in the project, when it became apparent that the on-site contract would eventually end, did efforts really begin to focus on training and technology transfer.

Numerous decisions were made along the way regarding continued development of the customized system versus purchasing and adopting a third-party commercial mapping package. In retrospect, the developmental approach of a customized system, while characterized by extensive trial and error, offered much more flexibility and adaptability to the Marine Corps sponsor.

The mapping system offered, at relatively low cost, far more benefits and applications than were anticipated in the early stages of project conception. Over a four-year time span from 1986-1989, approximately \$200,000 was invested in this project, for both services and equipment, which averages to about \$50,000 per year.

The developmental approach taken by the Marine Corps Air Station proved to be very effective in fulfilling user objectives and requirements despite formidable bureaucratic constraints often encountered in large government organizations.

The use of an *AutoCAD*-based computer-aided mapping system has advantages and disadvantages. While it has proven to be very effective for general site planning and for rapid feedback, identifying environmentally-sensitive zones, it cannot replace a detailed site survey which is still required once the general area of concern is identified in the initial analysis.

Others interested in developing user-friendly, entry-level, low-cost geographic information systems may benefit from an approach similar to that taken at Kaneohe. Careful thought must be given, however, to both user requirements and constraints to determine the optimal approach. With careful analysis, it may be determined that an expensive solution is not appropriate, even if funding is abundant and available. Functionality, ease-of-use, and flexibility must all be balanced judiciously to insure acceptance and appreciation of any GIS. ☐

The authors wish to acknowledge the staffs of the Facilities Department at MCAS Kaneohe Bay, Headquarters Marine Corps (Code LFL), the Naval Civil Engineering Lab, and the environmental engineers, natural resource and archaeological staff at the Pacific Division, Naval Facilities Engineering Command, without whose expertise, moral and/or financial support, this project would not have been possible. We also acknowledge the forward-thinking military commanders we have worked with who understand and support the importance of environmental compliance as a critical element in carrying out their primary military mission.

The presence of an on-site contractor-in-residence was critical to the success of this project.

RECOMMENDATIONS FOR OTHERS

ACKNOWLEDGEMENTS

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Un Sistema Cartográfico para el
Consentimiento y la
Administración de el Medio
Ambiente

Extracto

Translation by Juan José Valdés
National Geographic Society

Con el aumento de requerimientos para el mantenimiento del medio ambiente y la reducción de personal y provisiones en las oficinas, administradores afrontan la necesidad crítica de obtener acceso rápido a los Sistemas de Información Geográfica (SIG) para satisfacer estas demandas. La integración de un SIG puede satisfacer, con buen éxito, los requerimientos de una municipalidad grande. Pero para los administradores de oficinas pequeñas el uso de estos sistemas frecuentemente excede sus requerimientos y gastos. Tal administradores pueden obtener beneficios similares a esos obtenido de un SIG completo con un mínimo de personal, gastos, y la inversión de equipo. Esto puede ser ejecutable con la formulación de un sistema de micro-computadoras que utilizan software CAD/CAM como un paquete cartográfico enlazado a un database management software de un tercer partido. Este resumen explica como una instalación militar en Hawaii, usando Auto CAD y dBaseIII+, construyo con suceso cierto sistema.

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