A BOEMRE and Esri® White Paper
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Management of Marine Resources through the Development of Marine Boundaries and Offshore Leases

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Synopsis

Establishing marine boundaries can be a daunting exercise. Where there is no feasibility or practicality to establishing a physical boundary, the establishment of a reproducible and legally binding boundary holds value. In areas where making physical observations is impractical, boundaries along the earth's ellipsoid can serve a similar purpose.

The solutions presented are not intended to arbitrarily determine a boundary but rather to provide the tools to come to an equitable distribution of responsibility for overseeing the protection and management of marine resources. Solutions involve inputs that are generated from physical features and established agreements. As with many legal descriptions, boundaries change over time due to interpretation and the forces of nature and man and may be ambulatory in nature unless immobilized by law. The purpose of this paper is to provide a vision and introduce tools to support marine boundary development and management. The complexities of existing boundaries, changing water levels, accretion, reliction, revisions to baselines, the location of the continental shelf, and other factors can each play a part in forming this boundary and can be utilized with the tools discussed. Whether the interest is in the application of the Law of the Sea (LOS) or simply the definition of the boundaries internally, this paper provides an approach.

The Bureau of Ocean Energy Management and the Marine Cadastre

The Bureau of Ocean Energy Management, Regulation, and Enforcement (BOEMRE), formerly the Minerals Management Service (MMS), is the bureau within the US Department of the Interior (DOI) that is responsible for the management and development of energy and mineral resources on the US Outer Continental Shelf (OCS). The OCS is defined as the submerged lands, subsoil, and seabed lying seaward of the states' jurisdiction, encompassing the seaward extent of federal jurisdiction. BOEMRE also collects, manages, and disburses revenues from federal offshore mineral leases, such as oil and gas, and from onshore mineral leases on federal and Indian lands.

Under the Office of Management and Budget Circular A-16 (as revised in 2002), BOEMRE has the primary responsibility for administering the official marine (offshore) cadastre for the United States. The marine cadastre extends from the official baseline of the nation's coastline to the full extent of the US OCS, which in some areas is coincident with the boundary of the Exclusive Economic Zone, lying 200 nautical miles seaward from the baseline.

Prior to the creation of the MMS in 1982, the mapping of offshore oil and gas areas was the responsibility of the Bureau of Land Management (BLM). In 1954, BLM published the first leasing maps and issued the first leases off the shores of Texas and Louisiana.

These first maps were based on the local state plane coordinate system (SPCS) for those states. Offshore leasing maps were also produced for Southern California using the local SPCS. BLM decided to switch to the universal transverse Mercator grid system in 1974 when using the SPCS for mapping the OCS proved problematic. It was also decided to continue using the North American Datum of 1927 for the Gulf of Mexico area.

MMS was renamed the Bureau of Ocean Energy Management, Regulation, and Enforcement in 2010 after the Deepwater Horizon oil spill in the Gulf of Mexico. The reorganization process will divide BOEMRE into two separate bureaus: the Bureau of Ocean Energy Management (BOEM) and the Bureau of Safety and Environmental Enforcement (BSEE). BOEM and BSEE will function separately beginning October 1, 2011. The OCS mapping responsibilities will remain with BOEM, which will continue to provide mapping support for BSEE.

Within BOEM, the Offshore Energy and Minerals Management (OEMM) offices contend with all aspects of offshore federal leasing and renewable energy projects. This includes the preparation and administration of all oil and gas lease sales in federal waters. The primary authority for OEMM comes from the OCS Lands Act (43 USC 1344) (1953). The OCS Lands Act directs the secretary of the interior to manage the OCS in a manner that considers economic, social, and environmental factors as well as the potential impact of oil and gas exploration on the marine, coastal, and human environments.

Official Blocks and Boundaries

Within BOEMRE, the Mapping and Boundary Branch (MBB) develops and maintains the marine cadastre, which includes the OCS lease block grid and various boundaries. The resultant map products depict precise boundaries and blocks for the purposes of lease sales.

Specifically, the MBB produces boundaries that reflect the following:

- The Submerged Lands Act (SLA) of 1953, which defines the limit of a state's jurisdiction—The jurisdiction of most states ends at three nautical miles seaward of the national baseline.

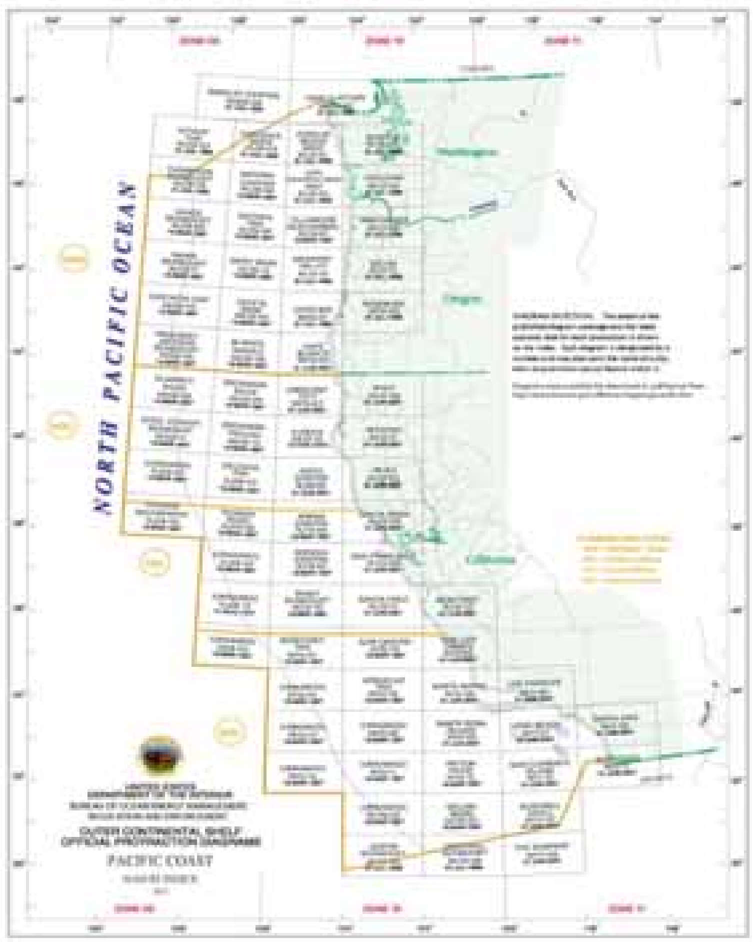
- The limit of the 8(g) zone, which refers to section 8(g) of the OCS Lands Act as amended in 1985—Lying three nautical miles seaward of the Submerged Lands Act boundary, the 8(g) zone defines the limit of revenue sharing between the state and federal governments.

Both of these boundaries are mathematically derived from the baseline and are required to be as accurate and current as possible.

The OCS blocks and boundaries are displayed on the official protraction diagrams (OPDs) and lease maps. An OCS block is an approved subdivision of the OCS that is intended for leasing purposes. A typical OCS block measures 4,800 by 4,800 meters and contains 2,304 hectares (approximately 5,693 acres). The OCS blocks are the true BOEMRE "parcels." Supplemental official block diagrams (SOBDs) are created for individual OCS blocks that are intersected by the SLA and 8(g) zone boundaries. The OCS blocks and boundaries provide the base for nearly all BOEMRE offshore maps and leasing processes. This information gives BOEMRE the means to define, describe, analyze, and account for every hectare of federal offshore submerged lands.

The MBB has developed OPDs of the US OCS for the Gulf of Mexico, Atlantic Ocean, Pacific Ocean of the contiguous United States, and most of Alaska. OPDs have not been developed for Puerto Rico, the US Virgin Islands, Navassa Island, Hawaii, Guam, Northern Mariana Islands, American Samoa, or the smaller island possessions of the Pacific Ocean. The potential for development of energy resources will dictate if and when the remaining OPDs and SOBDs will be generated. Currently, a wind farm is being proposed for Hawaii, which has prioritized the creation of OPDs for the eight principal Hawaiian Islands.

Figure 1
OPD Index Map



This index map shows the OPDs for the Pacific Ocean areas offshore of the contiguous United States.

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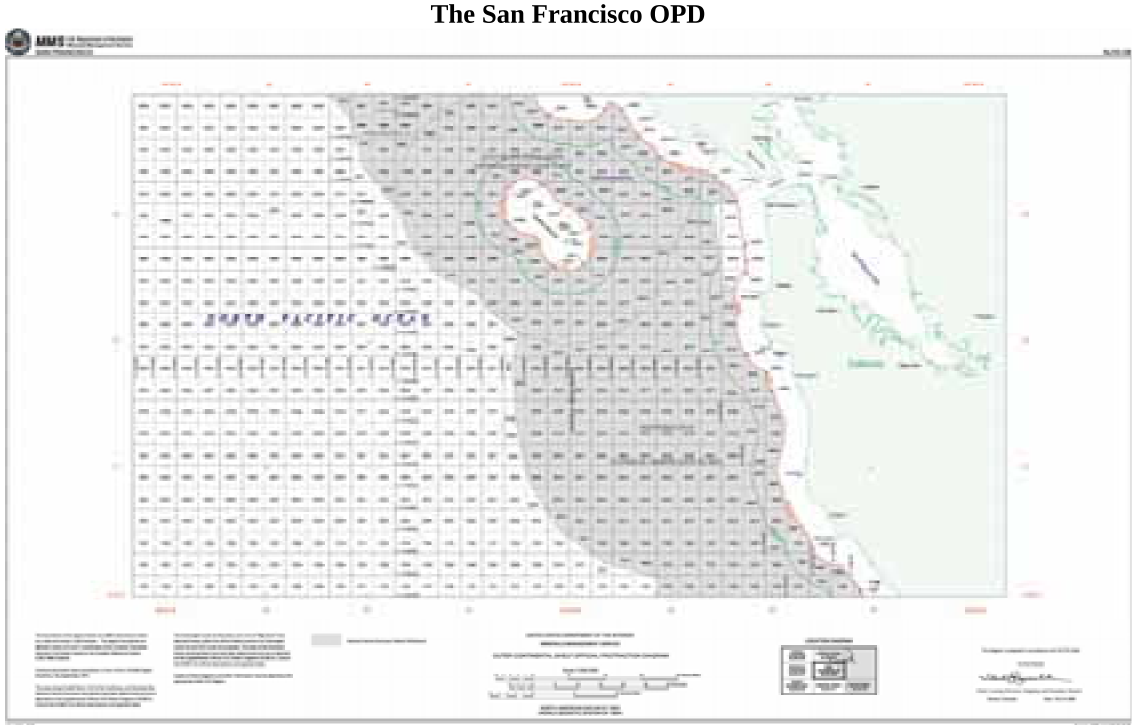
Figure 2
The San Francisco OPD



This map reflects the OCS blocks, Submerged Lands Act boundary (red line), and 8(g) zone revenue sharing boundary (green line).

Mapping Production and the Need for a New System

The mapping computational software used by MMS to create the marine cadastre was developed in the 1970s, before the advent of the personal computer and geographic information system (GIS) technology. The software, which was based on the FORTRAN programming language, was manual-labor intensive and required days and sometimes months to perform tasks such as projecting boundaries and creating block grids. Limitations of the software included the inability to project a line seaward beyond 12 nautical miles or generate blocks/boundaries in the Southern Hemisphere or west of 180°. In 2007, MMS decided to pursue a GIS solution to create and maintain the marine cadastre.

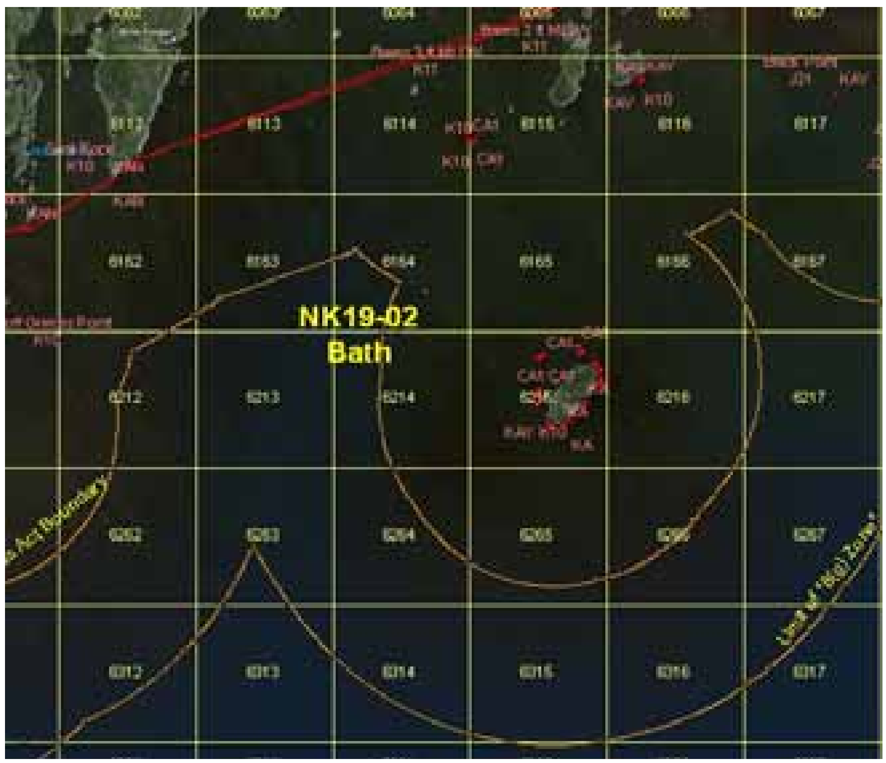
Solutions Require an Understanding of the Problem

Given that a marine boundary generally cannot be seen, it is difficult to understand where the boundary is, how it was determined, and how to reproduce it. Unless immobilized by law, the most common solution is to determine what observable factors contribute. These factors may be in the form of the natural geology of the seabed, but in most cases, they are influenced by the coastline. Since this is something that most people can get their heads around, it's a good place to start.

Interpreting the Coast

Regardless of the ebb and flow of the tide or other natural forces that change a coastline, the physical features that define a coast can be observed. The final boundaries are likely to be impacted by the same prominent features as those seen by the eye. Combined with established boundaries, the most protruding and prominent features along water bodies play a role, which are surmised as being a series of baselines. The word *baseline* is misleading in the fact that a baseline can comprise both points and lines without the need for connectivity between all points. Rules for determining the validity of a specific input are beyond the scope of this paper, although establishing contention point criteria within a system will help gauge the impact of such points. In general, salient points with spacing in relation to the projected boundary that is influenced by line of sight play a role. Additionally, the incorporation of closure lines is frequently used for features such as bays or archipelagos. Properties such as line type should be noted, since a closure line that is based on direct, line-of-sight observations will interact differently than a closure line generated through geodesic calculations. In this document, the concern is handling these points and lines.

Figure 3
Baselines in Relation to Projected Boundaries



Interpreting the Seabed

Physical land formations don't stop at the waterline, and prominent underwater features can influence the environment and how water resources develop and are used. For boundary purposes, one of the most critical features is the foot of the continental shelf for its contribution in defining the farthest extents of a nation. What constitutes the foot of the continental shelf is more of a geophysical question, and for the purposes of this paper, the interest is in consuming the resultant isobaths. The same rules and applications used with baselines can be applied to isobaths when they are used as a reference. The combination of projections from both isobaths and baselines can contribute to determining the farthest extents of a nation under the Law of the Sea criteria.

Immobilized Boundaries

Representation of fixed boundaries can be handled by adding the boundary extents. Whether the boundary is described by a series of fixed points, lines drawn on a map, legal descriptions, or historic agreements, the inputs may be entered directly or through digitizing methods into the survey network.

Getting Started

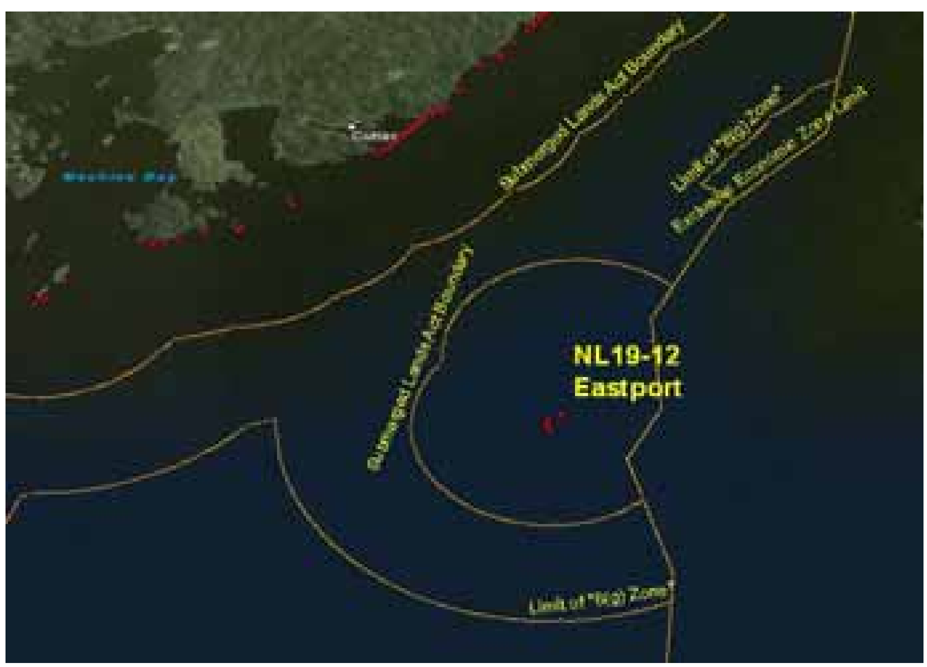
The physical data is only one component. Understanding the relationships that exist and maintaining them in a GIS are critical to obtaining meaningful results. A common model employed has a basis built on corners, which contribute to boundaries and subsequently support parcel generation and display. The approach discussed below will focus on this idea by building a strong survey network that will allow the base components to feed into and build up the larger marine cadastre. This logical approach allows components to inherit attribution from parent features and spatially relevant features.

Survey Data Concepts in a GIS

While being input into the database, the data needs to become survey aware to effectively integrate with a marine cadastre. At a high level, the data can be approached as either record or COGO data types. In this context, the term *record* refers to survey measurements that have been directly observed or have fixed positions through jurisdictional agreement or court decree. Fixed points in space and baseline points and closure lines that are generated through line of sight fall into this category. COGO data types cannot be directly observed and are generated through calculations such as bearing distance, equidistant, or intersection type.

The basic idea is that a point can persist by itself; a line will have a beginning point, endpoint, and line type; and an arc will have a beginning, end, and radius point. Combining a number of points, lines, and/or arcs of a shared property forms a boundary. This boundary may be composed of various data types and does not rely on connectivity.

Figure 4
Boundaries in Parts



In essence, baselines are a form of a boundary in that they are a collection of points and potential lines depicting the most seaward points of land along a coast. Graphic connectivity between points will not necessarily exist, and it is important to manage the sequence of the baseline to project offshore boundaries. Isobaths are similar but are only composed of points. Baselines and isobaths may be referred to as *fixed* or *ambulatory*. There are cases where it will be required to mix solutions. An example of this can be seen in the Gulf of Mexico, where Supreme Court decrees in certain states require that fixed boundaries be incorporated into a resultant solution that includes an ambulatory baseline that is redefined every few years as the coastline changes.

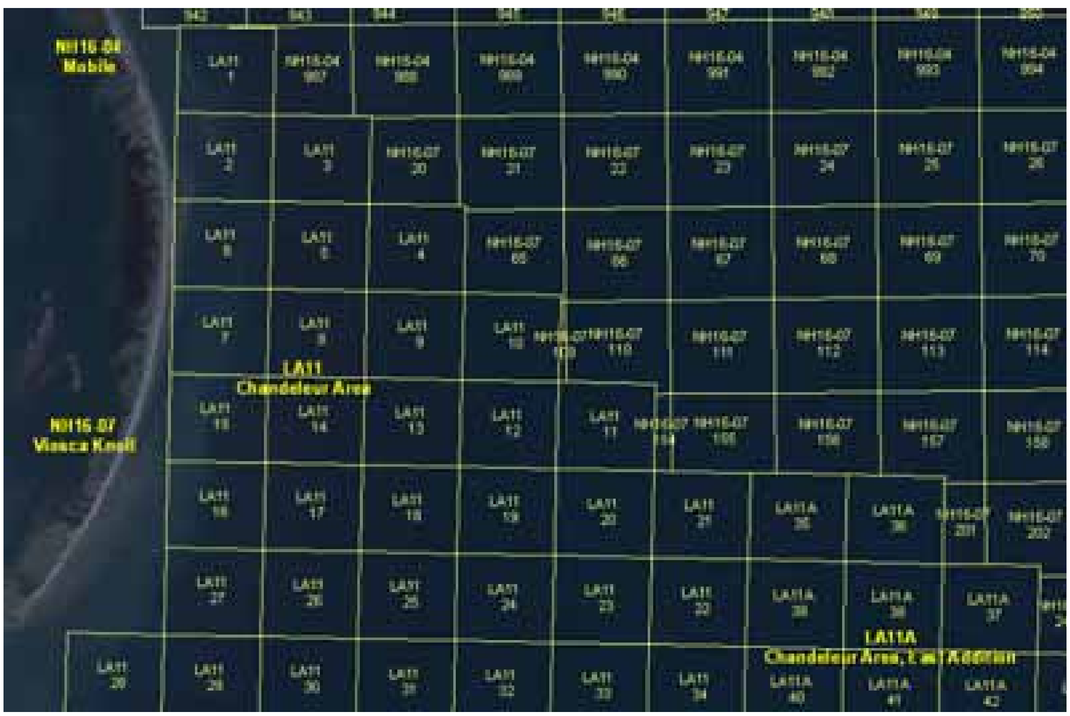
Working with and Getting Marine Cadastral Data into a GIS

A key requirement for any solution is the ability to enter and modify contributing data. Techniques for dealing with baselines will be critical to the solution, but examining additional data at this stage is also necessary.

Parcels

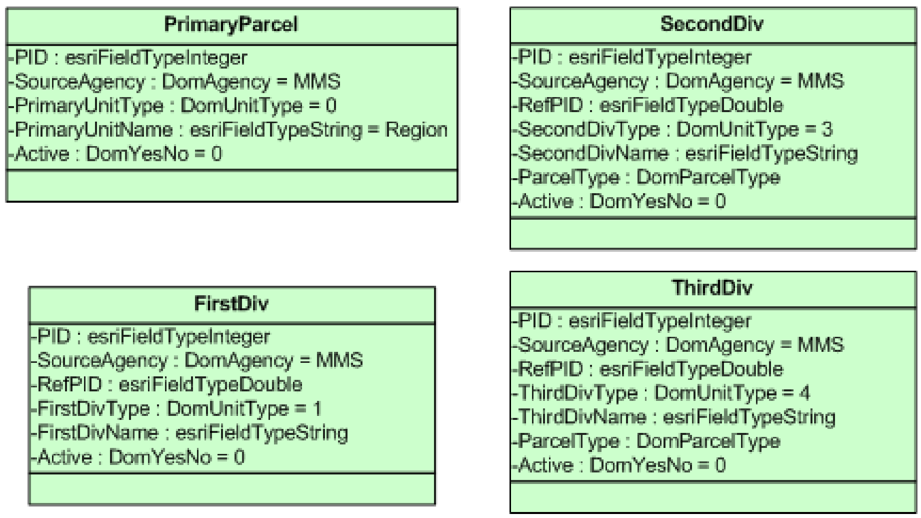
For practicality, the marine cadastre should be based on a logical network. This network will frame the attributes assigned through various processes. By way of an example, the United States utilizes five cadastre systems offshore, which use either the lease map or official protraction diagram as the base unit. These units are then further divided into lease blocks; in the newer cadastres, these emulate the Public Land Survey System (PLSS), a rule-based system that subdivides parcels into smaller parcels in the western United States.

Figure 5
Two Cadastres Intersecting That Represent Lease Maps and OPDs



The approach shown in figure 5 employs a generic four-tier system that allows various parcel types from one or more cadastres to be incorporated into a database. Legal positions are stored in separate tables.

Figure 6
Generic Polygon Feature Classes



This system may be employed with features such as planning areas or marine sanctuaries, allowing relationships between hierarchical features to be maintained. A common containment relationship exists between regions, OPDs, blocks, and block subareas, as seen in figure 7.

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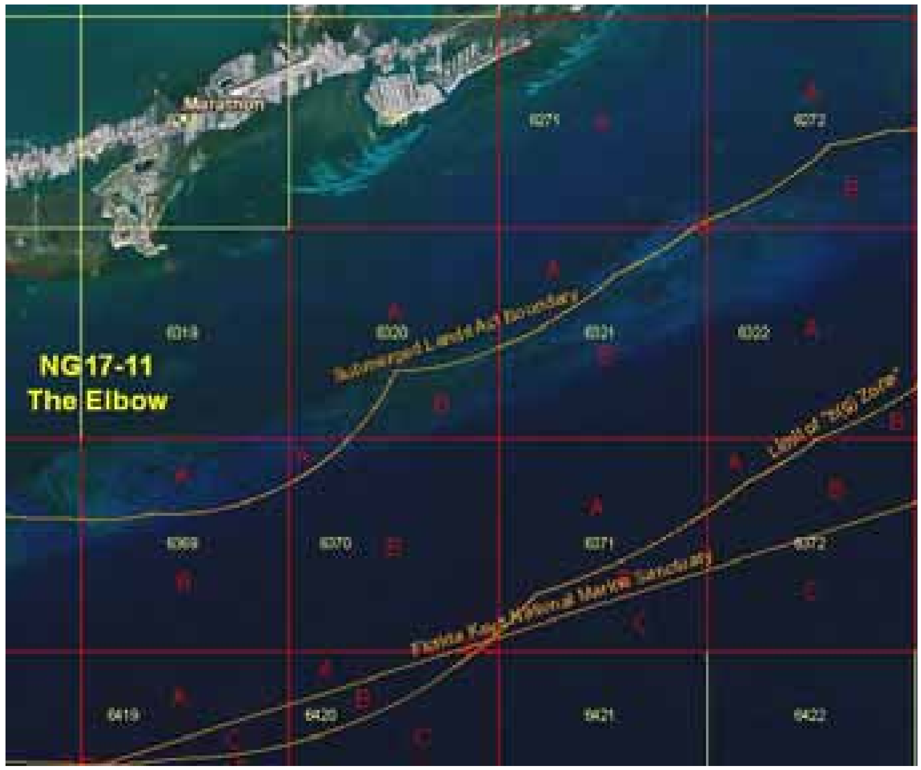
Figure 7
Illustration of Polygon Relationships



Legacy Parcels

Existing parcels may not conform to a common model. For parcels that are located along a defined boundary, one approach is to take the parcel, reverse engineer the lines and points, and then enter the data into the marine cadastre. Where line and polygon features intersect, an alternative approach is to establish the sequence of vertices on the polygon and apply known properties along the edges. This will reduce the features in the systems and provide a method by which to establish intersections along the boundary.

New Blocks

The most common parcels used to form leases in the marine cadastre are blocks. The OPDs and respective block leases used by the United States are loosely formed using a United Nations (UN) grid that covers the planet, minus extreme polar regions. This means that the model can be quickly adapted to apply to other jurisdictions if the UN grid is put into use.

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Figure 8
Quick Adaptability for World Coverage

New Block Subareas

Block subareas are slightly different in that they inherit properties from both the parent block and supporting survey network. This maintains the survey network's integrity by aligning new block subarea features to known boundaries. By basing the block subareas on known corners and defined boundaries with known line types, not only will edgematching be more consistent but the attributes that are required in writing a proper legal description for the area of interest will be satisfied.

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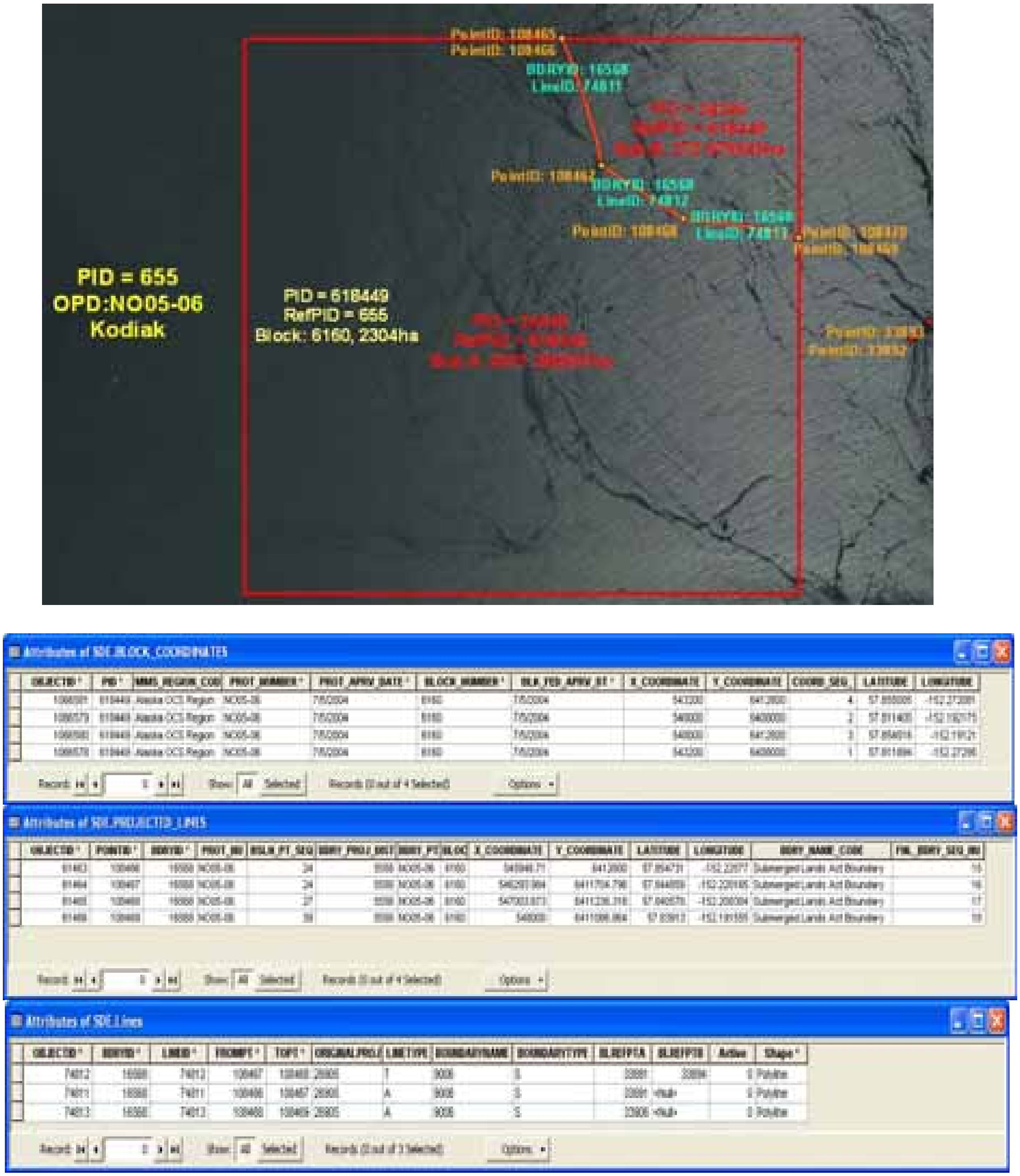
Figure 9
Using a Unique Identifier to Relate Features and Data



Legacy Data

Most implementations will involve the integration of legacy data. If this data is in electronic form, analysis will be required to integrate the data into the current data model. This step will involve applying general assumptions to the practices used during data acquisition and separation of data types. Legacy datasets can be of mixed quality, and it should be anticipated that a percentage of the data presented will be unsuitable or require additional filtering. Treating the migration of legacy data as a separate task will help users focus on the overall implementation of a marine cadastre. This type of development can be addressed through generic importers or custom batch processes that are designed to deal with specific data concerns or data volumes to be most cost-effective. This migration will help populate the initial data for the database. Alternatively, some users prefer to use historic data as reference material and enter new data only as required.

Digitized Data

GIS is equipped to accommodate various forms of media, such as satellite imagery, aerial photography, and digital charts. Georeferencing, or aligning the media with the projected data, will allow spatial feature acquisition in defining baselines and boundaries. This method may be appropriate where existing survey networks are sparse. GIS tools for maritime boundary and cadastre creation, for use by BOEMRE, provide a solution for this kind of data entry. At a minimum, these tools will integrate digitized points and lines into the data model with the ability to add attribution related to quality and special conditions. These features will form parts of a baseline or fixed boundary for use in the marine cadastre.

Manual Entry

For minor updates where positioning data and conditions are clearly defined, adding data manually may make sense. These tools are part of the solution that enable the user to enter known coordinates of points for baselines or implement COGO instruction. The COGO tools generally fall under the classification of nonprojected or fixed boundaries and involve functionality to generate points using bearing and distance as well as lines through inverse or trim-and-delete functionality. Nonprojected boundaries are generally static in nature and edited internally once created. Standard routines apply internally to automate the creation of the survey network.

Looking at the bearing distance calculation, the user identifies the origin, bearing, distance, and line type to generate a new point. The solution will allow attribution to be inherited from both the origin point and spatial location of the resultant point. At the same time, an inverse call is applied to form the line. This triggers analysis to determine valid intersections along the line segment. Intersects are created as required and the inverse call is applied again while maintaining the current active status of the line segments. The bearing distance call ends by allowing the continuation of the line segments to participate in a larger boundary.

Baseline Editing

Once the data—particularly the baseline data—enters the marine cadastre, the editor is required to maintain and correct poor data. Projections from a baseline can be highly dependent on the sequencing and breaks along a baseline, and over time, modifications to ambulatory baselines will be required. The baseline editor will allow access to the structure of the baseline to ensure that the calculations are applied as intended. Special conditions may exist with the data, such as contention points, a common one being a point that may be the result of human interference. When applying the projected boundary, it must be decided whether to include or exclude the man-made baseline modifier. Visualizing the effects on the solution will help users determine appropriate courses of action.

Projecting Boundaries

The projected boundary is an automated COGO process. The process uses one or more baselines as inputs. Allowing multiple baselines will provide a combined solution if required under law. Similar to using nonprojected lines, saving a boundary signifies ramifications on legal descriptions. Therefore, the recommendation is to form a new boundary if the baseline inputs change and to archive the previous boundary as required. Both grid and elliptical solutions are being improved. Using the elliptical solutions will become more critical as the projections extend farther from the baselines being referenced. Similar to using other COGO tools, projecting boundaries incorporates the creation and maintenance of the survey network to support other operations in the marine cadastre.

Geodetic Engine

So far, the discussion has involved the creation and modification of boundaries. Missing from the discussion is how to handle the intersections between boundaries and, to a greater degree, the construction of boundaries. Behind the scene, a solution must support intersections. To address this, a geodetic engine supports the most common intersections that are encountered offshore. These include combinations of planar lines, loxodrome lines, geodesic lines, simple arcs, and elliptical arcs.

Note that the calculations providing corner information that feed into the legal description can be separated from the cartographic representation. Although it is important to have the underlying survey network and parcels in alignment, it is not always critical to display the graphics to the accuracy of a calculation, nor is it practical in many cases. The approach in this paper consumes the official coordinates through the geodetic engine and provides a new coordinate based on a mathematical solution. This provides the accuracy required to support the legal description. Cartographically, this approach employs a number of algorithms to best display the data. Elliptical curves are of particular interest. Additionally, the COTS projection engine is used to provide a better cartographic representation of the data.

The overall approach reuses the geodetic engine throughout many applications and implements a number of intersections behind the scenes. The COGO tools mentioned above use the intersection models every time a line crosses another line or parcel.

Conclusion

Implementing a marine cadastre to support marine boundaries and offshore leases can be as daunting as implementing a land cadastre. The components are similar, although the emphasis on applying COGO on the ellipsoid and focusing on baseline maintenance is critical to the solutions required. In summary, a solid survey network is required to support the activities employed by experienced GIS professionals.

Appendix A: Glossary

Accretion—The gradual and imperceptible increase to land-boarding water through the deposit of alluvium on the banks or shore or through the withdrawal of water

Article 76—Definition of the continental shelf under the United Nations Convention on the Law of the Sea (UNCLOS), part VI, Continental Shelf

BLM—Bureau of Land Management

BOEM—Bureau of Ocean Energy Management

BOEMRE—Bureau of Ocean Energy Management, Regulation, and Enforcement

BSEE—Bureau of Safety and Environment Enforcement

COTS—Commercial off-the-shelf

DOI—United States Department of the Interior

GIS—Geographic information system

LIS Team—Land Information Systems Team

LOS—Law of the Sea, in reference to UNCLOS

MBB—Mapping and Boundary Branch, the leasing division of BOEMRE

OCS—Outer Continental Shelf

OEMM—Offshore Energy and Minerals Management

OPD—Official protraction diagram

PLSS—Public Land Survey System

Reliction—The increase of land by the retreat of the sea or river

SLA—Submerged Lands Act

SOBD—Supplemental official block diagram.

SPCS—State plane coordinate system

UN—United Nations

UNCLOS—United Nations Convention on the Law of the Sea

Appendix B: Contact Information

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