Modeling, Designing and Developing a Multidisciplinary Geodatabase GIS with the physical Implementation of RDBMS in conjunction with CAD and different GIS applications for the development of Coastal /Marine Environment

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Thesis submitted to obtain the Academic Degree of Doctorate in Sciences

(Spatial Information Science)

Geography Department, Faculty of Sciences, Vrije Universiteit Brussel

Pleinlaan 2, 1050 Brussels Belgium

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Dedicated to:-

To my family who were exceptionally kindhearted and endlessly tolerant …. !

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Abstract

The prime significance of Geographic Information System as a multidisciplinary data integrating, analyzing and visualizing tool depends on the organization of data encompassed within the system. This notion calls for the indispensability of structuring diverse raw data with the intention to establish a functional and robust Geodatabase model that safeguard the consistency and integrities of spatial information management.

This research work deals with the process of Georelational GIS data modeling, designing and implementation of a wide spectrum coastal-marine measurement data.

To let the research task set in motion; raw coastal related issues have been discussed under the perspective of Coastal Zone Environment. GIS building block entities were selected. Their conceptual interrelationships have been diagrammatically illustrated. SQL's DDL applied to execute the physical creation, determine dimension, storage and constraints of the entities in an ODBC compliant RDBMS. Likewise, GIS geographic elements were produced applying spatial programs and their integration with attribute database led to the hatching of the object relational GIS.

Topologic operations pertaining to gap detection, segmentation, removal of redundant geographic elements was performed using topology clean up spatial and editing tools.

Georefrencing of the coastal maps have been performed using a provided ellipsoid and datum (PSAD56) of a case study area (Guayaquil estuary, Ecuador).

Interoperability tests among variety GIS applications show feature-transfer-related lose of spatial features properties but successful regeneration of spatial pointers. The process shows the possibility of producing or transforming a functional spatial database from a specific GIS application into another one.

Generating object-relational and spatio-temporal queries related to the developed GIS objects resulted in disclosing thematically visualisable spatial maps. The output of the spatial analysis enables us to perform possible spatial correlation of multidisciplinary results and perceive effects associated to certain marine events.

Preface

One of the essential appealing factors of Geographic Information System (GIS) in the field of coastal environment management and decision-making is that the data dealt with is georeferenced and can be spatially analyzed and visualized.

Heterogeneous disciplines data can be incorporated into the system for the purpose of querying and retrieving the spatial information assets. With this regard as the data are the prime assets; their embedded value in could be more appreciated when appropriate structuring and design process of the GIS database is carried out. The result directs to the effective utility of GIS and enhances the spatial data processing.

The principal task associated with this research work comprises of modeling, design and implementation of available coastal-marine GIS database geodata (raster and vectors and attributes).

The research theme is partitioned mainly into eight chapters. Chapter 1 focuses on an over view of the GIS subject matter and includes motives and research objectives, conceptual definitions, and outline of coastal problems which could be challenged with the application of spatial technology (GIS). It emphasis on why GIS is elected to be principal spatial tool to tackle coastal/marine environment aspects.

Moreover, a brief rationalization of the application of GIS in disaster management (Environmental, economic, societal, hazard) is illustrated to pinpoint some of the possible environmental application and methodologies of exploiting the System. Eventually, background information (GIS case study) on the estuary of Guayaquil Estuary is elaborated diagrammatically.

Chapter 2 centers mainly on the processes of constructing the geo-relational GIS database. The process incepts by a brief description of the main coastal entities and stresses on the suitable method of organizing and structuring of the GIS database. The conceptual representation and constraints of the building block entities is based on certain propositions of the geodatabase data-modeling rules. The possible relationship among the GIS building block entities is constrained grammatically. The data model is generated according to the established design rules of the established cardinal relationship information-structure diagrams (ISD). The constraints are defined to maintain and ensure object relational integrity. The ISD were eventually transformed into definite objects.

Their physical creation executed using the data definition language (DDL) and programming procedures (DAO). Likewise, data manipulation language (DML) was harnessed to manipulate the data stored in each GIS building block entities. Moreover, macro programs that automate the manual process of loading were developed.

Chapter 3 concentrates mainly on the issue of combining the GIS building block entities. A compatible data source (ODBC) has been defined to achieve it. System generated special working files and user defined and structured GIS building objects are integrated within the GIS project.

Within the GIS project, a number of steps are employed. This includes the generation of the workspace, populating the project Geodatabase (by categories and feature) and creating spatial relationships.

This phase of the research work also shows the implementation of macro programs (MBE) to create features. In most cases, the process of organizing the building block entities is described hierarchically (explained in the feature setup interfaces) as follows. Every category is affiliated to specific features and every feature contains its own properties and symbology. The categories are (a) coastal geology category (b) estuary category and are further refined, at the feature level as lithology, tectonic structure and measurement-locations and estuary morphology respectively. This sequential process leads to the integration of the system generated special working files and user defined and structured multidisciplinary attribute database as a main building blocks of the GIS project.

The result of this process demonstrates that integrity and consistency of the information depends on a clearly defined migrating spatial key (s) of the geo-data source table. Furthermore, it has been discovered that the visualization of spatial features associated to attribute database records thematically can be implemented only if the one to one relations of a centroid feature to the attribute database record maintained. Otherwise, a process of aggregation of the many side is binding.

Chapter 4 commences with an introduction to the basic database models and ascends to the object relational model. Highlights of each model's differences, advantages and disadvantages are described. Eventually, the essentiality of object relational database structure is paraphrased.

Furthermore the issue of spatial operations (superimposing and creation of map layers) is illustrated, for instance the importance of having a commonly georeferenced maps for overlay analysis. This has been ensued by a process of assimilation of the geographic objects.

The relationship among geometric elements influences the process of spatial analysis. Inappropriately created geometric elements may hamper the possibility of displaying thematical maps and visualization of the area of interest. Thus, taking into account the importances of topology clean up for appropriate spatial analysis, experimental exercise on removal of line fragments, overlapped polygons, splitting and reconstruction of geometric objects was executed.

The work in chapter five mainly reveals the essentiality of GIS maps construction. It includes the process of registering new maps. A registered satellite image (datum PSAD56) depicting the Guayaquil Estuary has been used as a base map for discrete measurement point within the estuary. Furthermore, an extended experiment has been made to illustrate on how a scanned map is vectorised and cleaned, projected and incorporated into the coastal GIS system. Besides, a process of generating features by developing application macro shows more advantages in generating geographic elements with less undesired line woks.

Based on the processes stated, coastal GIS maps (Lithology, tectonic-structure, estuary and measurement) were produced for the purpose of integrated multidisciplinary spatial analysis;

correlate the spatial distribution of the lithological composition and stratigraphic distributions and the tectonic structure maps for depicting zones dissected by faults lines of different trend in the coastal area and estuary channels. Furthermore, coordinates (x, y and z) values of the estuary were used to model the estuary and produce 3D maps that enable visualization of the Guayaquil estuary environment.

Chapter 6 focuses essentially on the process of spatial exploitation of the developed Georelational GIS database. Spatial queries were formulated to extract location-oriented inquests.

Construction of the spatial queries is based on two important requirements. These are: - (a) the matching of two object's spatial pointers (b) objects commonality/cohesion of being referenced. (Sharing of characteristics with other individual features) To accomplish this undertaking, the objects were subjected to topology cleanup and registered under the same georeferencing datum.

Associated specific related feature have been utilized with their existing feature linkages in a different GIS application to test interoperability among GIS applications (MicroStation Geographic, MapInfo and ArcView and ArcGIS). The outcome shows preservation and loss of some information characteristics, such as projection, shapes and linkages. The loss of the objects spatial property is more pronounced when the test is performed between non-open GIS complaints and v.v.

Correlation of features among measured objects (SedResults, BioResult, PhyResults…etc.,) associated to bottom sediments and bio-diversity distribution variation has been performed based on spatial operators and statistical inbuilt packages of ArcGIS, MapInfo …etc. Thematic outputs related to temperature vs. salinity, sediment type and distribution, sub marine erosion zones were also demarcated.

Chapter 7: Emphases on spatio-temporal information analysis have been covered on chapter seven. Although the utilized GIS has not been equipped with tools that store time within the spatial engine coordinates, it was possible to challenge the analysis by storing the temporal parameters within the attribute database and georeferenced it by a migrating feature identifiers. The analysis is not straight forward, i.e., it requires reshaping of the data by means of aggregating functions, so that the M: 1 relationship of record-to-centroid is adjusted to 1:1. Temporal analysis focused on the measured water current magnetic direction (magN) and the water current speed ($cm.S^{-1}$) has been executed. The combined analysis, of a thematic and linked linear graphic display of the value of magN and speed (cm-1) as function of time (F (t)), discerns variation of direction and speed in the same measurement point but at different times. Furthermore, the interpretation has been carried out by comparing and contrasting the results out of the measured ebb and flood tidal velocity and ebb and flood tidal velocity direction across different depths in different times in the same station. Generally, the result has disclosed the lower current velocity at the surface or close water surface, higher at deeper water column and again low velocity at deepest measurement points (x, y, and z). Such effects are possibility attributed to the variation of the tide generating forces related to the syzygy and quadrature positional effects of the moon-earth-sun system and to the possible frictional effects on the surface water and morphological change of the estuary channel in which the data were collected.

Aspatial data are bundle of attributes describing an entity, relationally structured and connected to spatial features. Chapter 8 focuses on the importance of aspatial data analysis. To facilitate browsing and analyzing the geodatabase aspatially, an interface has been developed. As a result, it was possible to explore the geodatabase using developed user-friendly interface. The last chapter (9) outlines the possible conclusions and suggestions on possible further research works.

Contribution of this work

The capability of GIS in integrating, spatial analyzing interdisciplinary data and executing holistic and important spatial decisions is a promising development in its application for the welfare of human beings. Although GIS and its applications are evolving very rapidly, this work will provide the GIS community a practical approach of designing and implementation of a Georelational data model, widen their horizons and enable them develop and utilize this kind of application within their own environment.

Therefore, the different issues emerged, illustrated and tests carried out in different development phases are key launching pads for a self-motivated quests. Thus, contributions of this work are outlined briefly as follows:

- A stable and robust multidisciplinary Georelational database system has been constructed during a sequence of development processes, i.e. parallel to an active marine/coastal environment GIS project.
- An important point of the developed system is its implement-ability in a multidisciplinary GIS project. The design of the object relational geodatabase is geared up to accommodate redundancy free data, retrieve efficiently, and perform spatio-temporal correlation on incorporated interdisciplinary data.
- The designed system is connectable to several spatial engines (SE); and geographic objects created in a specific GIS application are interoperable with other spatial engines. This enhances the applicability of a single Georelational data model in various spatial engines simultaneously.
- Multi-purpose mission critical and executable object relational retrieving and analyzing SQL statements are developed; and are available to the user to be used in his/ her environment.
- A user-friendly aspatial interface that facilitates the process of extracting information from underlying geodatabase reservoir intelligibly has been developed.
- Visualization of GIS information is one important output of spatial information mining. With this regard, certain procedures have been established to extract 3d tabular data to be generated and viewed as a georeferenceable spatial object layers with 3D maps.
- Digitizing raster files generates features. However, this is laborious task. A relatively simple method has been developed to generate associatable spatial features with minimum topological works.

Glossary of Symbols and Acronym

Glossary of Symbols

- ***f*** *: flatness*
- ***a*** *: major axis*
- ***b*** *: minor axis*
- ***abs:*** *Absolute*
- ***1st*** *first*
- *2nd: second*
- ***Pnt:*** *point*
- ***X1, y1****: point 1 coordinate*
- ***X2, y2****: point2 coordinate*
- ***ΔX:*** *difference along the meridian*
- ***ΔY:*** *difference along the parallel*
- ***(ΔX)***$^{\wedge 2}$ *Squared value along the meridian*
- ***(ΔY)***$^{\wedge 2}$ *Squared value along parallel*
- ***PIV:*** *possible intervals*
- *N: observation one*
- *N and N1: upper and lower boundary*
- *Σ: Summation*
- $\sum x(i\_n) / n$ *: X-coordinate of a centroid*
- $\sum y(i\_n) / n$ *: Y-coordinate of a centroid*
- ***M:*** *measured elevation value*
- ***Z:*** *exaggerated value and*
- ***Z:*** *user defined elevation coefficient.*
- ***n:*** *number of occurrence*
- $n\sum x2$ *: Squared Sum of population multiplied by n*
- $-\sum x2$ *: Subtracted Squared sum of population*
- $(n(n-1)$ *: Non-biased method*
- $\sqrt{\frac{n\sum x^2 - (\sum x)^2}{n(n-1)}}$ *: Stand Deviation*
- Z= (Actual depth) (m) = z $\cdot 10^{-3}$
- Flatness: = f = (a-b)/a
- Point X, Y, Y (i): = $(X \pm Xn)/2, (Y \pm Yn)/2, (Z \pm Zn)/2$

- ***G: Universal gravitational constant***
- ***Fg : Gravitational force***
- ***M1, M2 : Masses of two objects***
- ***R: separation between two objects***
- ***d1, d2: distances changes from d1 to d2***
- ***ly: light year (astronomical unit)***

Abbreviations

Acrony	Meaning	Acrony	Meaning
Si	Silica	LST	List Box
. CTL	A Control Point Extension File	M: 1	Many to One Relationship
. DBF	A Database Extension	MAGN	Magnetic North
. DGN	Extension to A MicroStation File	MAPID	Map Id
. GEO	An Extension of The Geology Category	MAPINFO	MapInfo GIS APPLICATION
. MAR	An Extension of The Marine Category	MAR	Category Related to Marine Feature
. SHP	An Extension of an Arc View Shape File	MBE	MicroStation basic Extension
. TAB	An Extension of a Map Info Map File	MMCODE	Measurement Code
1:1	One to One Relationship	MDL	MicroStation development language
1:M	On to Many Relationship	MEASLOC	Measurement Documentation
3D	A Three D	MEAS-NO	Measurement Number
ABS	Absolute	MEARESULTS	Measurement Results
AC	Acidic	MEASTECH	Measurement Techniques
ADO	Active data objects	MeasuredBio	Measured Biology attributes
ADR	Attributes Database Records	MeasudChm	Measured chemistry attributes
API	Application Interface	MeasuredPhy	Measured Physical attributes
ASC	Ascending	Mg	Magnesium
AUB	Statement A Union Statement B	MGE	Modular GIS
AV	ArcView	MI	Map Info
AZ.	Azimuth's Related Parameter	MMID	Measurement Id
BA	Basic	MP	Measured Parameters
BIO	Related To Biology	MSL	Mean Sea level
BIORESULT	Results Of Biology	Mo	Map Objects
BMMID	Biological Measurement Id	Na	Sodium
BS	Bottom Sediment Environment	NDS	Network Data Structure
CAD	Computer Aided Design	NIAM	Nijssen's Info Analysis Method
CAMPAIGNDT	Field Data Collection Date	NIMA	National imagery & mapping agency
CAMPDTCOD	Field Data Collection Date Code	NOLOT	Non Lexical Objects
CBO	Combo Box	NS	North South
BIORESULT	Results Of Biology	NW	North west
CCWISE	Counter clock wise	NE	North East
Cd	Cadmium	OBJ	Object
CENTROIDX	Centroid Of X Coordinate Function	ObjA	Object A
CHM	Chemistry	ObjB	Object B
CNAME	Category Name Related To Features	ObjecteID	Object Id
COLNAME	Attribute Name	OBJID	Object Id
COLDEF	Attribute Definition	OD	Original depth
CU	Copper Measured	ODBC	Open Database Connectivity
CZ	Coastal zone	OE	Departure pt of easting coordinate
DAO	Data Access Object	OLE	Object linking and embedding
DBMS	Database management system	ON	Departure pt of Northing coordinate
DBS	Database	OR	Object relational
DTCODE	Date Code	P1, P2	Parameter 1, parameter 2
DDL	Data Definition Language	P1, P2..	Parameter 1, Parameter 2
DISCPCODE	Discipline Code	PARMUNIT	Parameter unit
DPI	Dot Points Per Inch	PARMVALUE	Parameter value
DXF	Digital Exchange Fmt (Between CADs)	Pb	Measured lead
E1N1	1^{st} Pnts of Easting + Northing Coordinate	PC	Personal computer
E2N2	2^{nd} Pnts of Easting +Northing Coordinate	PHYS	Related to physical measurement

EBB.PARAM	Ebb Related Parameter	PMMID	Physical measurement id
ECHODEPM	Echo Sounding Measured Depth in Meters	PSAD56	Provisional S_American Datum 1956
ECODE	Estuary Data Code	PT.	Point
ENTNM	Entity Number	PHS	Primary hazard site
ER1	Entity Relationship Rule	R.S	Results.Station
EstChannels	Estuary channels	RCV	Representative Class value
E-W	East to West	RDBMS	RD management system
EXP.FILE	Exportable File	RDS	Relational data structure
ϕ	Latitude	REC-NO	Record number (rec no)
F (T)	Function Of Time	REL	Relation
F (t)	A Function of Time	RESULTID	Result Identifier
F.F	Field.Fieldcode	RDS	Relational data structure
F-CODE	Field Code of an Entity	RSE	Relationally structured entities
FEATUREID	A Feature Identifier	S1, R1	Site1, Record 1
FIELDDATA	Field Data	S1, S2	Site2 Site 2
FK	Foreign Key	S1R1	Station 1 record 1
FDCODE	Field Data Identifiers	SA	Spatial Analysis
FMT	Format	SAMPDEPM	Sample depth in meters
FTDESC	Fault description	SAMPTIME-E	End Of Sampling Time
GCOORD	Geocoordinator	SE	South East
GeoLithology	Lithology	SED	Sedimentology
GEOREFNO	Georeferenced Number	SEDRESULT	Results Of Sediments
GeoTectonics	Tectonics	SGE	System generated entities
GIS	Geographic Information System	SILTPERC	Silt Percent
gm/l	Micron Grams Per Liter	SL	Similar line works
GPS	Global position system	SMMID	Sedimentology id
GVAL	Gap Value	SO	Spatial objects
HDS	Hierarchical Data Structure	SQR	Square root
Hevymet	Heavy meta object	SQRT	Square root
Hg	Mercury Measured	STC	Space Time Composite
I.O.C.A	Oceana graphic de la Armada	SW	South West
I: 1 or M: 1	One to One or Many to One	SYStab	System tables
IGIS	Integrated Geographic Information System	T1 (L1)	Layer 1 At Time 1
IMS	Information management structure	TAB	Extension of MapInfo map
INDVALUES	Individual values	TALIAS	Table Alias
ISD	Information structure diagrams	TbA	Table A
In	Information at point	TbB	Table B
JDBC	Java database connectivity	TCODE	Tectonic structure code
K	Potassium	TMS	Temporal Map Sets
λ	Longitude	TOLVAL	Tolerance Value
L1, L2	Layer 1, Layer 2	TSQL	Transform SQL
LAT	Latitude	UDE	User Defined Entities
LATDEGDEC	Latitude Degree Decimal	UDF	User defined function
LATTXT	Latitude In Textual Form	UDT	User defined type
LBL	Label	UG-TAE-CAT	System table compatible to MGE GIS
LCODE	Lithology Code	UMF	Ultramafic composition
LF	Line Fragments	URL	Uniform Resource Identifier
LITHID	Lithology identifier	UTM	Universal Transverse Mercator
LLE	Longitude, latitude elevation	VB	Visual basic
LOCATIONIDX	Location Index	WC	Water Column
LocID	Location identifier	WGS84	World geodetic system of 1984
LOCID	Location Id	WSI	Eater Sediment Interface
LON	Longitude	Z1, Z2	Zone 1 and zone2
LONDEC	Longitude Decimal	ZCODE	Zone Code
LONDEG	Longitude Degree	ZN	Zinc
LONTXT	Longitude Text	LST	List Box
LONTXT	Longitude Text	M: 1	Many to One Relationship
LOT	Lexical Objects	MAGN	Magnetic North

LS	*Line Segmentation*	*MAPID*	*Map Id*
Si	*Silica*	*MAPINFO*	MapInfo GIS application
SOF	*Spatial Query Formulation*	*MAR*	*Category Related to Marine Feature*
. CTL	*A Control Point Extension File*	*MBE*	*MicroStation basic Extension*
. DBF	*A Database Extension*	*MDL*	*MicroStation development language*
. DGN	*Extension to A MicroStation File*	*MEASLOC*	*Measurement Documentation*
. GEO	*An Extension of The Geology Category*	*MEAS-NO*	*Measurement Number*
. MAR	*An Extension of The Marine Category*	*MEASRESUL*	*Measurement Results*
. SHP	*An Extension of an Arc View Shape File*	*LST*	*List Box*
. TAB	*An Extension of a Map Info Map File*	*MDL*	*MicroStation development language*
SYZYGY	*Alignment of the sun, moon and earth during spring tides*	*QUADRATURE*	*In astronomy, arrangement of two celestial bodies at right angles to each other as viewed from a reference point. If the reference point is the earth and the sun is one of the bodies, a planet is in quadrature when its elongation is 90°.*

Chapter 1: General Introduction

1.1. Introduction

The coastal zone is an area at the edge of the oceans, which extends from the continental shelf to the coastal plain [1]. Environmentally, it constitutes diverse habitats, major settlements, and significant resources and socio-economically; it is the center of vibrant activities. It is marked by great environmental instability effects such as sea level rise, geologic, geomorphologic and Sedimentological changes. Moreover, it is a geographic center where a coastal zone shoreline is marked by prolonged fluctuations of high/low tides. Understanding the magnitude and geographic scope of the changes and effects might be difficult due to the cumulative processes of: - (i) Socio-economic activities impacts (ii) Periodic environmental fluctuation and (iii) Intensive interaction among marine forces such as tides, waves, winds, currents, etc.

i) **Socio-Economic Activities Impacts**: At the present time, the coastal ecosystem is being stressed mainly due to higher population pressure compared to inland areas of the world. The related effects are diverse and include polluted runoff (hazardous chemicals) into an estuarine environment ecosystem and indiscriminate fishing (depletion and extinction of species)…etc.

ii) **Periodic environmental Fluctuation:** Although natural hazards have occurred throughout history, their recent impact is becoming increasingly devastative along low lands of coastal zones.

iii) **Interaction of Marine-Coastal Forces:** The back and forth migration of shorelines results in reshaping coastal geomorphology. These changes can pose a threat to the coastal community; and efforts to manage problems associated with coastal resources, environment, population, uncontrolled degradation pertaining to urbanization and their current potential relationship to sustainable development of coastal resources has become wakeful issue [2]. Such changes related to the process can be detected in images acquired through environmental satellites, for instance the Massive Iceberg Peels off from Antarctic Ice Shelf [4].

One way of challenging the problem is establishing well Designed GeoRelational GIS Database pertaining to a multidiscipline marine or coastal environment for an effective and efficient access and managing the data spatially using Geographic Information System (GIS).

GIS is realized as an integrating, analyzing and visualizing tool for heterogeneous multidisciplinary data within a system. This is due to the fact that, multiple information layers can be filtered and analyzed to retrieve geo-referenced information, which are critical for decision-making. Thus, GIS is becoming a vital tool for challenging issues that require spatial identification, interpretation and assessing certain impacts [3] and vulnerability in the coastal zone. The application of GIS is increasing across different disciplines. For instance, satellite images are available at a reasonable price and can be processed adequately to identify the evolution of deforestations or desertification. Further, GIS associated with remote sensing can be exploited in mitigating and minimizing environmental catastrophes (such as natural hazards-cyclones, floods etc) perform integrated coastal zones spatial analysis and visualization of variety problems connected to the above stated issues (i-iii).

1.1.1 Motivation

An important derive behind this quest is ***founding of a functional GIS data model***. The know-how on how it is methodologically organized in space and time is fundamental to the development and implementation of a *Geodatabase*. Without including multidisciplinary raw input data in a model, it becomes rather difficult to reason about the dynamics of the real world spatial objects (SO). Appropriate management and utilization of the miscellaneous data necessitates constructing a data model that enables retrieving relevant information and performing a spatial analysis on multidisciplinary data. Encrusting this notion in mind, the designed model is to be tested and implemented across different GIS applications to assert its flexibility. Furthermore, the goal would encompass performing spatial information analysis on associated GIS building block objects. This would include, discovering the distribution rate of sediments and related anomalous concentration (PCBs and heavy metals), delimitation of abnormal environmental spatial symptoms and impacts discerned on biodiversity distribution across the coastal environment and understanding the process of tide generation and effects on the current's velocity and direction.

Motive: GeoRelational GIS Database Construction and Implementation

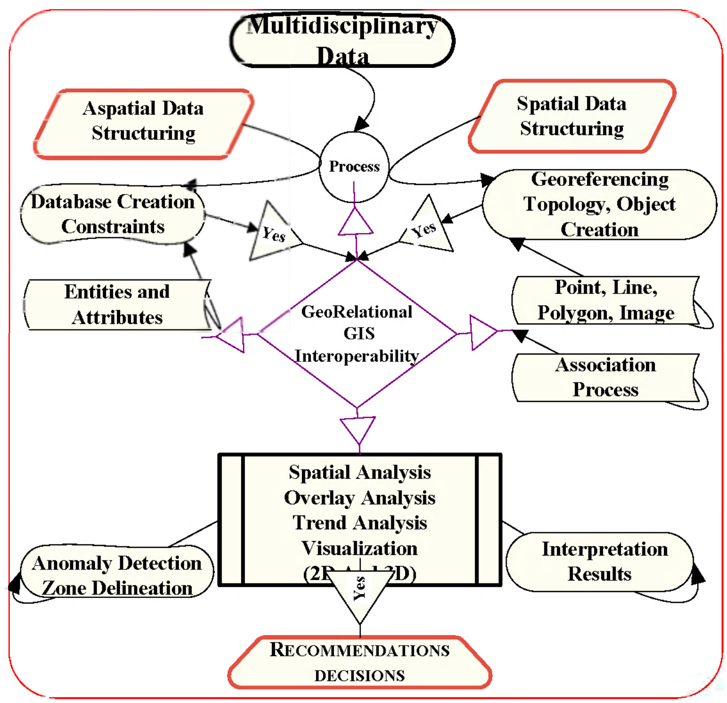


Figure: 1-1 Motive : Georelational GIS Construction

A graphical display of the intended motive of this PhD research work is portrayed, (see figure 1-1).

Moreover, decipher the hydro dynamics, related to ebb and flows (current speed and direction) along estuary channels, perform spatial correlation on the coastal geotectonic and GeoLithology on preexisting data, and thereby understand the origin and relationship of the estuary channels (using a case study) to the coastal geology. Furthermore, perform Spatio-structural analysis on the tectonic trends to deduce tectonic alignment to the regional structures, which is an essential step in assessing seismicity in the coastal zone of Guayaquil.

1.1.2 Problem Statement

Problem statement: The coastal zone is a dynamic environment and is essentially known as a source of interdependent data. Data is powerful asset if managed appropriately by well established geodatabase. Building a robust and implemental GeoRelational GIS data model is rather an overlooked challenged. Connecting with this, implementing one and the same geodata model across different GIS applications is very important, although, that but it requires a persistent efforts and resources to achieve it.

Conceptual Solution: Environmentally the coastal zone (CZ) can be subdivided into, (A) coastal geology comprised of Lithology and Tectonic Structures (B) Main estuary, mainly of surface water, and deep water which are associated different sediment particles. Based on these and other data categories, a vector GeoRelational GIS Data model applicable in coastal zone/marine environment can be devised and implemented. Spatial analysis can be performed to correlate events associated to the main estuary and coastal zone through thematic and spatial coincidence of multidisciplinary geographic objects. This would enhance understanding the relationship of estuary and Coastal GeoTectonics structures play vital role in producing a priority search maps, locating (delimiting) environmental anomalies and assess relevant potential resources.

1.1.3 Research Objectives

Model, Design and Implement a Geo-Relational Multidisciplinary GIS Database for the Application of a Marine / Coastal environment across different GIS applications

Devise a plausible definition and populating methodology for conceptually and realistically structured Multidisciplinary objects.

Integrate and link spatially diverse measurements data (biology, Sedimentology, physic-chemical …etc.) and build up geo-reference-able and topologically cleaned coastal GIS maps which are applicable across different GIS engines.

Validate and evaluate the reliability of graphic and tabular outputs utilizing **O**bject **R**elational **S**patial **O**perators. Develop an aspatial interface that enable process and manipulate the data.

Harness complex sub-queries, spatial analysis akin to buffering, overlay and statistical delimited spatial anomalous zones on the Geo-Relationally interconnected coastal objects.

Visualize the coastal zone via constructed 3d maps and associated Meta data.

1.1.4 Research Questions

Major questions addressed in this thesis work include: -

How to organize, design and implement multidisciplinary data for the development of coastal/ marine Georelational GIS

How to structure /define interdisciplinary entities that converge and share identical dereferencing position

How to assimilate user defined objects, special system generated object; establish cardinality that functions in object relational GIS data models.

How to construct interoperable Geographic objects with or without preserving its object properties

How to synchronize objects with a 1: M relationship in order to achieve thematic analysis results.

How to develop object Relational spatial queries and perform spatial analysis aimed on detecting coastal environment impacts and trends

How to construct a 3D map and integrate with geo-referenced geographic objects

How to create and integrate Meta data (video, images and documents) with spatial objects and employ them during the phase of data mining and thematical visualization

1.1.5 Scope of the Research

Modeling, Design and Implementation of a coastal/marine GeoRelational GIS database

Design Method of Generating and Integrating of multidisciplinary geographic objects

Technical tools development of topological clean up tools

Design of spatial query and analysis for employment among different geographic object types

Practical Interoperability operations and Communication of the model among GIS engines

Object Relational data mining methodology on Objects applying object operators and object Identifiers.

Development of spatial and aspatial interfaces

1.1.6 Methodology

Conceptual Geodatabase design: Conceptual entities design was carried out by establishing rules (proposition) of communications based Nyssen Information Analysis Method [33]. Abstractly, the rules link the entities and the information structure diagram conforms to the communication rules.

Physical implementation: Entities and attributes were physically created applying a Data Definition Language (DDL) and the DAO (data access object). Data types and constraints among the conceptual building block entities established. Graphic representation and cardinality of the structured geodatabase was generated using a case tool (Visio Professional). Data types applicable at this phase were alphanumeric and date and the possible entity pointers were determined.

Objects Definition and Topology: The geometric objects (Points, lines and shapes) executed using MicroStation basic extension (MBE), [12] and Mapbasic, [36] programs. Furthermore, Digitizing process was applied to create geometric features within a geo-reference-able map. Also, spatial update operations on a generated object were applied to create new objects. E.g., a series of x, y coordinate based object points were converted into a Polyline type by updating the point object. Topological operations were performed to clear undesired line works and create shapes required for thematic resymbolisation.

Interoperability: The constructed GIS geodatabase has been set to communicate with different spatial engines. (Geographics [11], ArcView [21], MapInfo, [30] and ArcGIS [89]), Connected via compatible DLLs and ODBC version.

Also, experiment on interoperability among the spatial engines executed based on transforming and employing a specific GIS application feature into another GIS application. (For instance MicroStation Geographic DGN files into ArcView GIS shape file, or MapInfo tab file into ArcGIS shape etc.

The process necessitates an appropriate definition of the original feature and feature translation. The interoperability experiment shows loss and preservation of feature property during the spatial information exchanging process. E.g., object identifier of MicroStation Geographic changed into MapInfo object identifier with certain object id prefix.

Geo-reference: Requires availability of a known ellipsoid, datum and a target map. A grid map that conforms to a target map was generated applying projection application Geocoordinator. It was implemented using a projection system of universal transverse Mercator (UTM) and a datum known as PSAD56.

A satellite image related to the same target area and same datum has also been available. Reregistering it using control points, applying the same datum, and corresponding to known points of reference has proved a successful geo-referencing and superimposition of both types of GIS maps.

Spatial interface and spatial interpretations: Every GIS application presents its own interface to the user. Some are very user friendly and others are relatively not. A customized interface for incorporating spatial layers and connecting to the geodatabase has been developed. This has been done applying ArcGIS and Visual basic (VB6) and Map objects (MO), [70]. Its functionality facilitates adding maps and connecting to the Geodatabase. Since its interface functionality is already in the GIS application, it is skipped.

Spatial interpretation process has been executed by designing object relational spatial queries. This process includes (a) on the objects themselves (b) object identifiers and (c) type of the objects (d) sharing of the same geo-referencing properties. The later has been vital for extraction of the spatial information on the coincidence of the geographic objects boundary and centroids. A hybrid of spatial and SQL operators (contain, intersect, within, overlays…etc.) were incorporated with a SELECT query structure.

Aspatial interface: An object oriented programming environment Visual basic [74] has been applied to develop an aspatial interface using procedures and program codes. The Aspatial interface-building components include - VB forms, controls connected to the underlying procedure program codes and embedded queries. The interface facilitates the performance of visual analysis of the underlying Geodatabase data without writing SQL codes and connecting to different GIS applications.

1.2. Background

1.2.1 Conceptual Definition of (GIS)

In most cases Geographic Information System (GIS) is a computer based information system used to digitally represent and analyze the geographic features present on the Earth' surface and the events (non-spatial attributes linked to geography elements). Every object present on the Earth can be geo-referenced, is the fundamental key of associating any database to GIS. GIS stands for Geographic Information System. Its perception can be paraphrased as follows: -

Geographic: Signify spatial features. Real world objects (features) referenced to a particular location in space [6]. For instance, the different features (lines, points, polygons …etc.) on a map depict graphic representation of real world objects. The spatial objects are represented by different symbology (color, line weight and styles).

Information: It is a processed data converted to meaningful form through analysis [12].

Systems: A term utilized to indicate the systems approach taken by the GIS, where complex systems are decomposed into their component parts for ease of understanding and managing. GIS encompass the storage systems, processing and manipulation of tools, projection systems. In other words, a GIS is both a database system with specific capabilities for spatially referenced data [7]. It is defined as a powerful set of tools for collecting, retrieving, at will, transforming and displaying spatial data from the real world [54].According to [21], a Geographic Information Sys tem is a computer-based tool for mapping and analyzing things that exist and events that happen on earth. GIS Technology integrates common database operations such as query and statistical analysis with unique visualization and geographic analysis benefits offered by maps. These abilities distinguish GIS from other information systems and make it valuable to a wide range of public and private enterprise for explaining events, predicting outcomes, and planning strategy.

1.2.2 Evolution of GIS

The evolution of manual GIS system was derived from the discipline of cartography [7], as site designers and architects required visual comparison and contrast the building plan with the site surveys. These were translucent papers and later plastic sheets upon which maps were drawn or printed. For instance, a map of a drainage site can be overlaid on a topographic map or a street plan. These layers of information could help a site or urban planner to determine whether or not to locate houses or other buildings at a given place. An information layer is mostly like a conventional map, flat drawing indicating the nature, form, relative position and the size of the selected geographic area. A typical overlay map includes several layers. Likewise, overlay layers (see figure 1-4) can be used to interpret different information layers; example, geo-chemical data over mineralized rock super imposed on a satellite images.

1.2.3 GIS System Ingredients

A) Engines: Two main systems are involved in a dual architect GIS database; these are DBMS (database management system) and graphics systems. The database is separated from the spatial engine because the relational database stores the textual information format and the graphic with different format. Textual data are stored and retrieved more efficiently the RDBMS. Further, the data in the database becomes easily available for sharing with other software applications. An API is applied to create the connection, transfer and process of data. However, the retrieving process subsumes migrating spatial pointer to extract spatial information. Typical types of GIS with such architecture are, Modular Geographic Information System (MGE), [20], MicroStation geographic [11], and MapInfo professional Version [30]…etc.

Other GIS alternatives that encompass both engines in a single system are known as integrated GIS (IGIS) system. For instance, some of the currently active integrated GIS management engine types (IGIS) include Oracle spatial cartridge [90], Informix spatial [91], DB2 spatial extender [92].

B) Interfaces: Windows is fundamental for the display of the processed information within the computer.

C) Hardware: machinery on which a GIS operates such as a computer, printer, plotter, scanners and digitizers. Includes workstations and networks for communication with other systems, disks, and tape for storage and digitizers for creating vector objects, see Figure 1-2.

D) People: - The most important of GIS; without people GIS will not work. To be useful and successful it should have people dedicated to it. System user: is responsible for the day-to-day operation of the system, engages with trouble shootings and system hang-ups, train and configure systems, act as system as well as database administrator whereas GIS suppliers: are responsible for the GIS software provision.

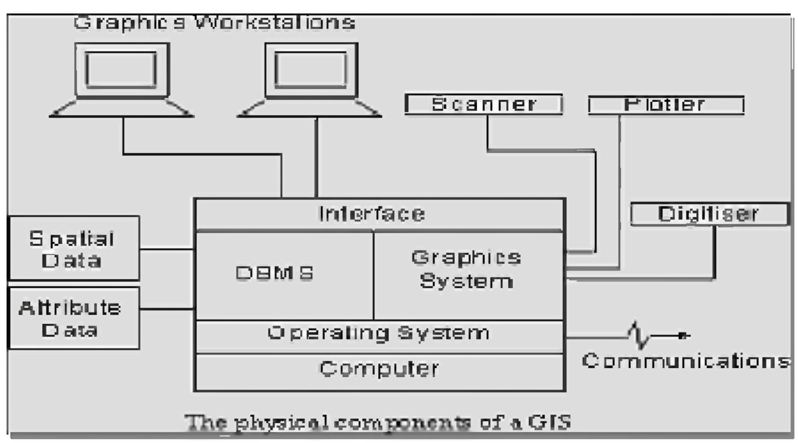


Figure: 1-2 GIS Physical Component

GIS system analysts: are group of people specialized in the study of systems design, professional responsible for determine the goals and objectives of the GIS system within the organization.

E) Data: GIS can use data from a wide variety of proprietary and standard maps and graphic formats, cad files, spread sheets relational database sources.

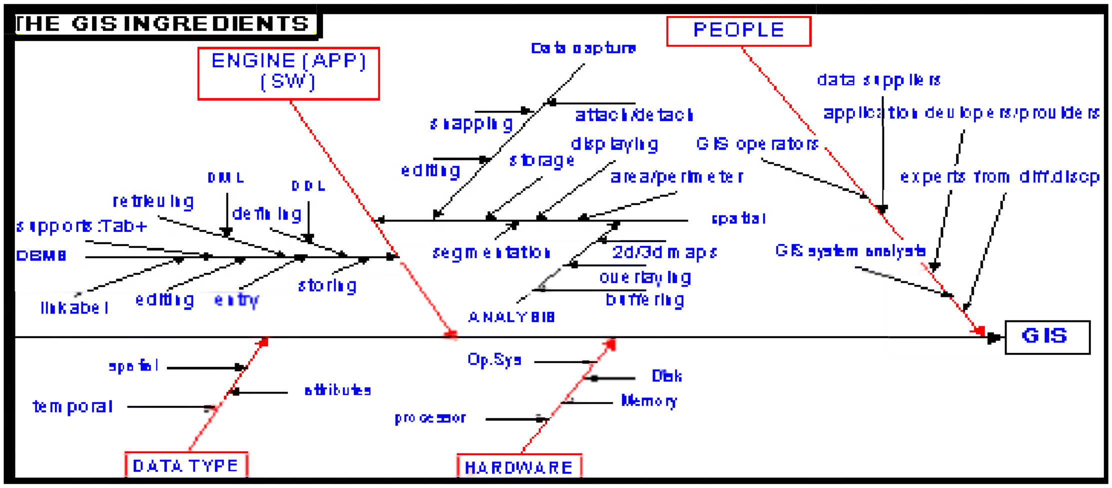


Figure: 1-3 GIS Ingredients

1.2.3.1 Spatial Engine Functions

A GIS engine has the capabilities of data capturing, storage, data editing, management, retrieval, analyses and display. GIS can detect and eliminate (**capturing and editing**) digitized errors, which are one of the essential functions in editing of maps, for example in [19] and [20], a GIS function can snap nodes so that points that are close to each other are automatically placed with identical co-ordinates

Shape Creation: Topological based GIS applications can check for gapped nodes, dangles, and duplicate lines and eliminate unnecessary map elements (see chapter 4). Automated cleaning should be carried out cautiously because the assigned tolerance may eliminate important topological elements.

Choroplethic Mapping: -Choroplethic Mapping is the display of mapped area based on classes of attribute values. A legend acts as a lookup table with each range of attribute values being associated with particular color of the distribution of attribute values, E.g. dispersion rate of Hg (mercury in different areas) in a specified location and depth (see chapter 6). **Spatial Analysis** requires linkage (assimilation) between the spatial features and the attribute data bounded to the same coordinate performed by a process of projection (see chapter 5). Queries on a GIS can thus be **Graphic driven** or **Data Driven**. Graphic driven queries involve spatial features based on searches for objects and retrieval of the associated attribute data, and query functions to select features and retrieve the associated information (see chapter 6).

Buffering: GIS performs analysis based on zonal boundary generation with reference to a spatially associated feature (s) (lines, points or areas) at a specified distance. The distance is set from the original object during a spatial analysis e.g. creation of buffer zone around measurement location to display the concentration of pollutants dissemination intensity 50 meters away from the foci of the geo-referenced point.

Overlay Analysis: Shape features of specific data layer are overlaid onto those of other data layers in order to calculate the areas, which have a certain combination of attribute values or lack of common values.
E.g., overlay of geo-chemical distribution of the heavy metal lead concentration feature display over the underlying geological rocks.

Depending on the provenance of base metals then relationship of the dispersion of the geo-chemical elements can be related and interpolated directly to its main underlying source.

1.2.3.2 Database Engine Functions

Data Definitions, Manipulations and Integrity Checkups: In order to make a GIS useful, the database manager checks the attributes integrity, enforce restrictions on the GIS that specified during the data definition phase of the database construction, (see chapter 2).

The Database management system (DBMS) allows the manipulation and retrieving of information and supports tabular or other list types of output. Much of the power of the GIS software is generated from the ability to manage not just map data but also associated attribute data, stored in the DBMS.

1.3. Measures and Solutions

Many spatial and aspatial problems can be handled if the development applications are known to some extent to the user. The measures should include measurements related to spatial technology for establishing spatial database that lead to appropriate assessment and monitor the environment.

The data (spatial and aspatial must be modeled by incorporating with appropriate geographical coordinates [5] and temporal time-stamp.
Thus, integrated multidisciplinary data modeling is key approach to the possibility of appropriate and holistic geographic analysis to obtain predictable results in order to understand the genesis of natural phenomenon and protection of vital coastal eco-system.

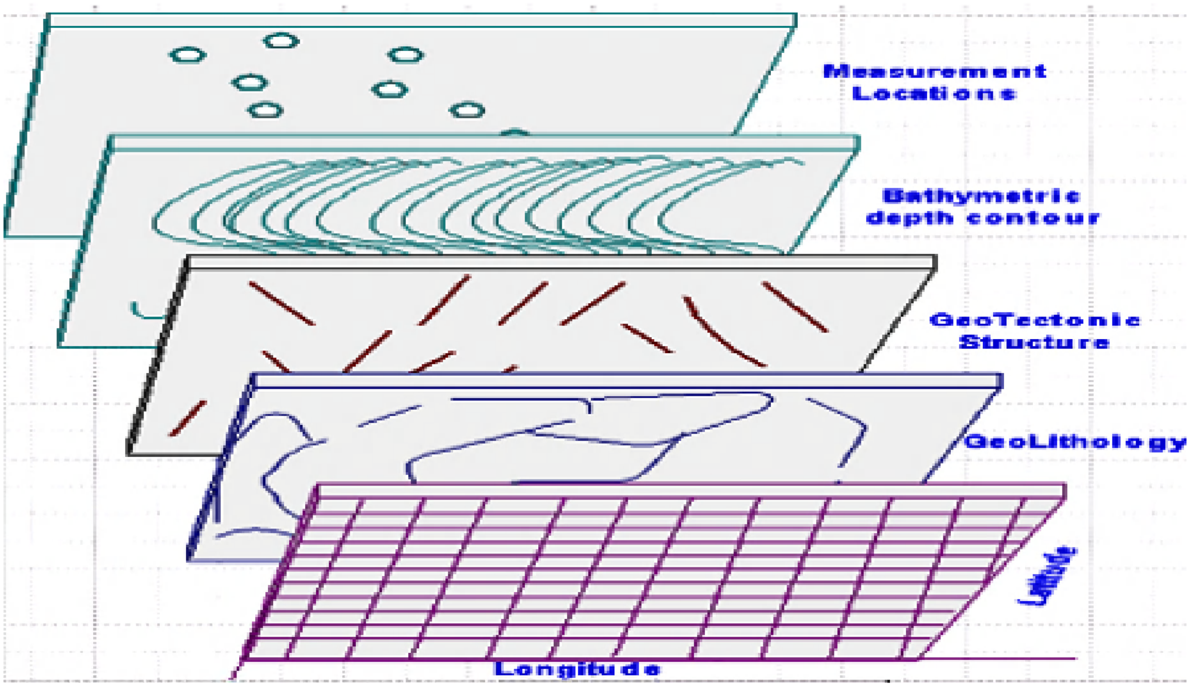
1.3.1 Data Acquisition

Integrated Monitoring: Regular assessments of environmental issues in coastal zones using integrated environmental GIS database management analysis and visualization of the multidisciplinary data sets enhance monitoring effects and response on coastal environment.

GIS related researches aimed on collecting integrated multidisciplinary data set (geological, biological, physical, geo-chemical and digital spatial data) and integrating with pre-existing data using Geographic Information System facilitate the holistic spatial analysis, decision making on monitoring performance of the coastal zone environment.

Analysis and Display: GIS has the power and capability of being queried and display geo-referenced information. Furthermore, it can integrate multidisciplinary data layers and view the extracted information in a holistic perspective, (see figure 1-4). Geolithology (rocks) affected by different magnitude of geotectonic structures, bathymetric contour and measurement stations layers are depicting the processed data layers and all are bound to the same geo-referencing grid. GIS enables not only process the tabular data but also monitor and analyze socio-economic and environments repercussions by means of Choroplethic maps, 3D visualization and integrated statistical trend graphic displays.

Figure: 1-4 GIS Information Layers



1.3.2 GIS Objects Models

The principle of data modeling is based on the concept that all objects should be clearly defined. The first point is how to define an object in a dual GIS database. Two diametrically opposed geographic data models (vector and raster) are available nowadays for encapsulating the aspects of interest of spatial phenomenon. In the vector model, lines link a series of exactly known points and exactly defined lines bound polygons. The raster object based model regards spatial data as a cell grid at a given level of resolution. Figure 1-5 shows a common raster and vector data models where the grid is represented by fixed sized pixels. These two models are abstraction of reality that appeals for their logical consistency and their ease of handling using conventional reasoning [69].

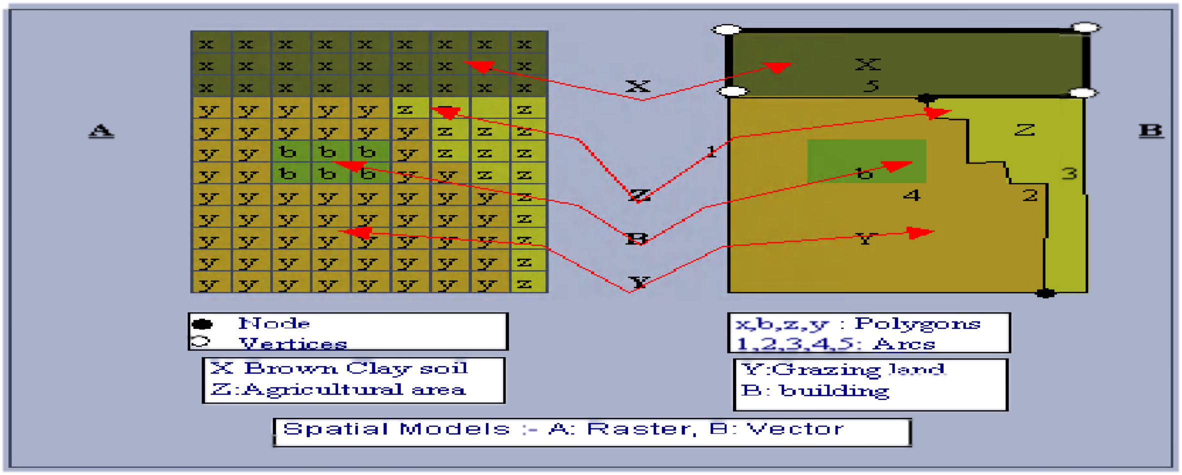


Figure: 1-5 GIS Models (vector and raster)

The advantage of vector (feature) object models is that the topological relationship can be expressed explicitly; however, it lacks the handling of continuous objects. The advantage of a raster lies on its capability to handle the continuity of spatial objects; however, it lacks a definite form of boundary.

Point – (Location site): composed of x and y coordinates, is the simplest graphical representation of an object. Its visibility depends on the viewing scale. A point feature class has been used to represent a measurement site during the construction of the Geodatabase in this research work.

Lines- (Area boundary): - composed of x1, y1 and x2, y2 coordinates, represents one-dimension objects. Lines connect at least two points and are used to represent objects. For the coastal environment, GIS (Guayaquil estuary) line features were applied as bounding geographic features.

Polygon – (An area of interest): composed of a series of x1, y1, x2, y2, x3, y3 and x1y1 coordinates. Polygons represent geographic objects defined in two dimensions. It is represented by at least three connecting lines, each of which comprises of points. In this work, polygons represent the delineated zone of a coastal zone environment and Lithology covered by specific composition. Adding the elevation (z) to an area feature allows us to observe and record information in 3D (see figure 1-6).

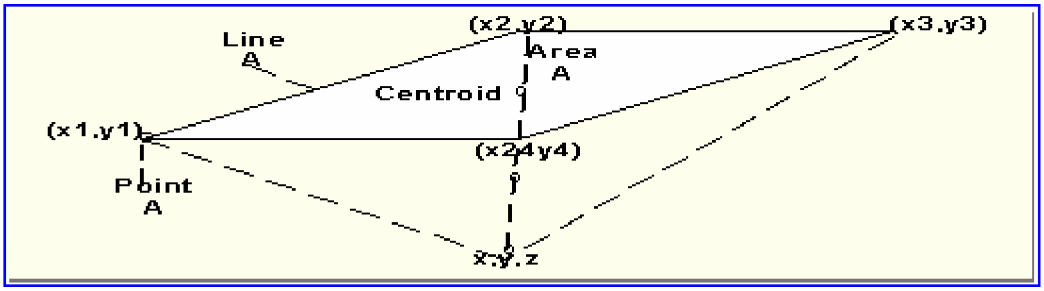


Figure: 1-6 Geometric elements

These (points, line, polygon) are major building blocks of spatial elements of a vector based GIS where their generation depends mainly within the spatial engine and the type of a seed file [7].

Primary type	Data Acquisition	Secondary type
Directly from an object Surveys Sat. images Photogrametry Remote sensing Conventional docs.	Geometry Data	Manual digitizing Scanning Existing digital databases Insitu sampling and measurement Remote sensing ...
Insitu sampling and measurement Remote sensing Interviews Existing Or Historical Data. ...	Attribute Data	Compiled scientific research rep. Existing digital report ....

Figure: 1-7 Type of Data Incorporated

Besides the spatial objects, data available for the case study and research work encompasses data collected insitu during a measurement field works from disparate locations and pre-existing documents. They are classified as primary and secondary type to indicate originates of data acquired as indicated in figure 1-7.

1.3.3 Approaches in the Application of GIS

1.3.3.1 Environmental Approach

The strength of GIS is based on its capability of integrating multiple disciplines and permitting the user to inter-relate and correlate the processed data with respect to a geo-referencing point. However, the complex nature of multidisciplinary data in general and the coastal environment data in particular requires rigors analysis before incorporated into a structured GIS database [7].

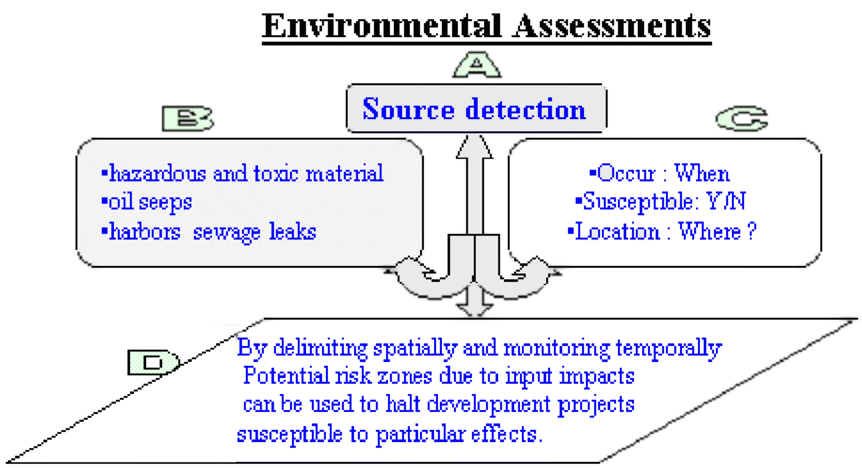


Figure: 1-8 Environmental Assesment

Purpose: - Clearly defined purpose is required to harness GIS as a supportive tool for targeting vulnerable locations and applying for hazard mitigation. Figure 1-8 shows the required general environment assessment.

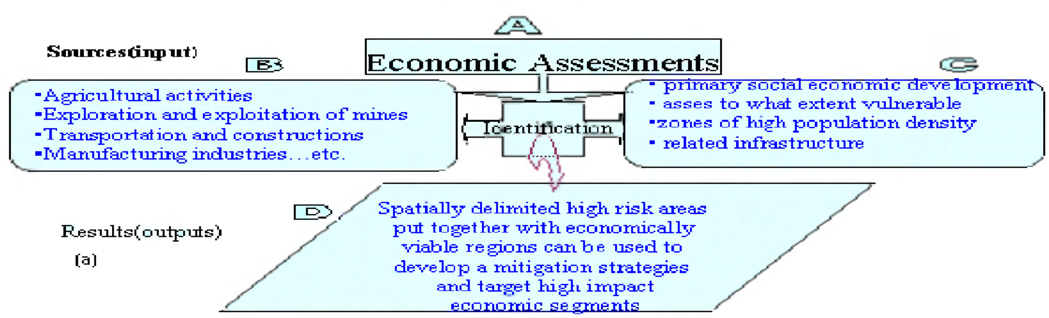
Detection of Sources data: - Identify areas susceptible to primary hazards sites (PHS) in relation to most possible natural hazardous regions and design hypothetical inquire.

Identify key environmental resource: - locations and their proximity to secondary risk sites (prioritize secondary risk sites). Examples: a) after flooding, dams may burst and inflict an adverse environment on areas rich in vulnerable community. In this case, census on a bio-diversity is important in identifying endangered species per area.

Suggested GIS Solution: - Overlay species maps per area may show either flourishing or extinction trend of the flora and fauna.

1.3.3.2 Economic Approach

Identifying economic zones, which are categorized to be potentially vulnerable to hazard impacts? Mapping primary centers of activity and assess major possible impacts on local economy and public properties. For instance, floods cause disasters [42], whenever a river overflows its banks; it dumps sediments and debris on to the surrounding land (see figure 1-9b).



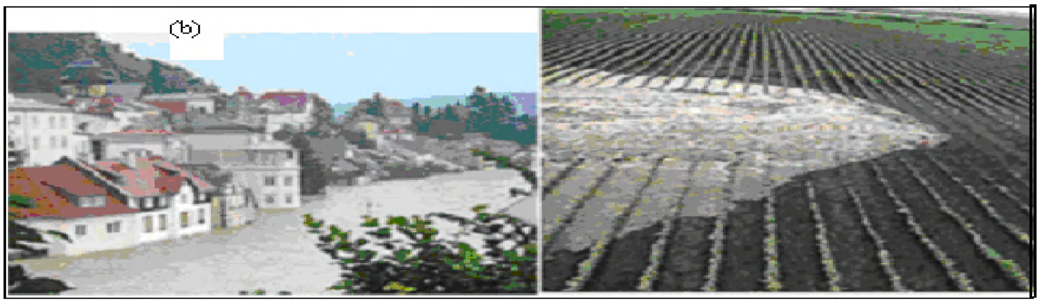


Figure: 1-9 Economic Assessment (a) Flood disaster in Europe (b)

Required considerations include (see figure 1-9a), identify and locate primary economic sectors, which are vulnerable to hazard impacts, mapping primary centers of activities and assessing major possible impacts on public properties and Identify linkages of economic core and high-risk areas.

1.3.3.3 Societal Approach

Identifying inter-relations of special consideration areas with high-risk, such as locations where individual's personal resources for dealing with hazards can be extremely limited.

Figure: 1-10 Societal assessment

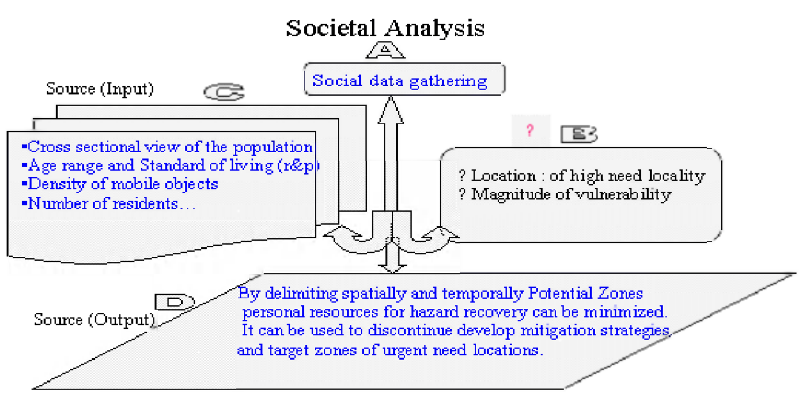


Figure 1-10 illustrates the processes of gathering data and possible outcomes of the process during the application of GIS in finding solutions to social problems. Suggested GIS application Solution: = Spatial Maps supported by ranked values will indicate areas that require prime priority. Use Overlay and spatial analysis methods by taking into account special areas of special considerations

1.3.3.4 Hazard Approach

Extract all possible and best available information to identify higher potential impact areas as a repercussion of each hazard. For instance, locating target areas liable to flooding or storms, burst of polluted fluids; earthquakes on slop stability …etc. and categorize them in degree of different level of risk intensity.

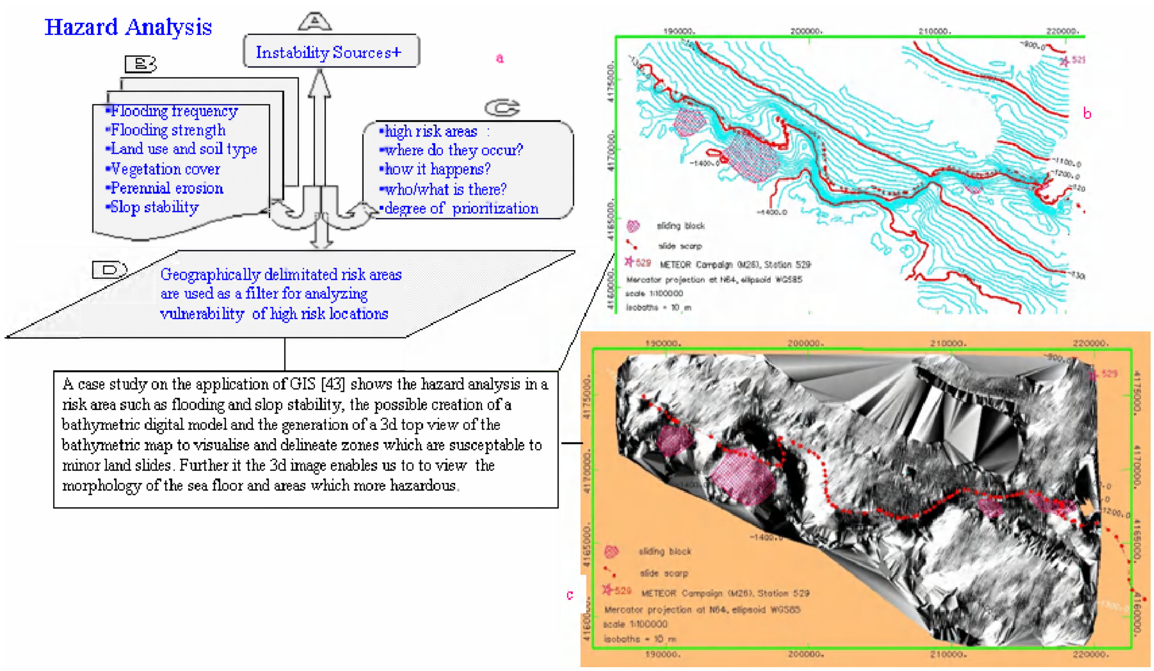


Figure: 1-11 Hazard Assesment : Storegga submarine slide scarp

Unstable slops can be detected from a basic input to GIS 3D graphic displays, which could result in DMT (digital model terrain).

A case study, [43] indicates the result Therefore, mapping different parameters (physico-chemical properties of sediments, tidal variations, and submarine slides and submarine tectonic structures) that enhance the failure of submarine morphologies is a primary step in managing and monitoring coastal environment problems. The process requires a robust GeoRelational GIS data model that allows appropriated storage and performing spatial analysis and visualization of the phenomenon that raises causes of destabilizing factors and increase awareness of mitigating potential risks.

1.4. Study Area: Coastal GIS Data Source

1.4.1 Geographic set up: Guayaquil Estuary

The case study area (figure 1-12) is bounded by longitude and latitude ranging 80°:15" to 79°:45" W and 2°:45" to 1°:8" S. It encompasses the main Guayaquil Estuary, close to the Guayaquil City of Ecuador and an area derived from a scanned previous geological works, covering North and North West of the estuary.

The Estuary expands (southwards) to the Gulf of Guayaquil and is linked to the Pacific Ocean along the coastal zone of the country. The Guayas River estuary and the Gulf of Guayaquil form the largest estuarine ecosystem on the Pacific coast of South America [95], and it is an important sanctuary for habitat and economically important marine invertebrates.

According to [96], the river-dominated estuary of Guayas has a tidal range of 3-5 meters compared to the tidal range of 0.25 to 0.5 through out the Caribbean. This regional setting is classified as allocthonous coasts with strong tidal currents.

Furthermore, the rainfall in the area is seasonal, with more than 95% of the precipitation occurring from December to May causing seasonal river discharge ranging from 200 $m3^{s-1}$ during an average dry season to 1400 $m3^{s-1}$ in the wet season during average year of precipitation [96]. The same literature further indicates that the annual mean temperature varies from 24 to 27 (°C) along the coast resulting a potential evapo-transpiration rate of about 1300 mm^{y-1}.

The estuary acquires water from the perennial rivers that flow into and from the oceanographic processes in the Gulf of Guayaquil, [14]. Two major channels of the Estuary are the Esterio Salado and the Guayas River. The estuary occurs at the junction where the southerly tropical Current from the Panama Bight and the northward flowing Humboldt Current from Peru. This current is what brought Penguins and Fur Seals to the Galapagos [61].

This literature indicates that the dominance of the Panamanian current occurs during the summer causing an increase in seawater temperature and initiates the onset of the rainy season. Years of abnormally warm water temperature and associated rainfall attributed to the EL NINO climate pattern.

A research study reported in [15] depicts that warmer offshore waters resulted to the explosion of white shrimp population off the coast from enhanced spawning and maturation. Geotectonically, a Regional, a major fault system, known as the **Delores-Guayaquil Mega shear**, [97], on the gulf of Guayaquil passes into the Interandean valley.

According to the literature the Delores-Guayaquil Mega shear is similar in scale and seismic activity to the San Andreas Fault system in California. [97]. Such fault system has made the country exposed continually to earthquakes and other geologic hazards, [98].

The north and northwestern part of the estuary is also characterized by multi-direction fault trends indicating the geotectonic of the coastal region. The Progresso Basin in the Gulf of Guayaquil is believed to have formed as pull-apart basins within the strike-slip regime of the Dolores–Guayaquil Mega shear (DGM)

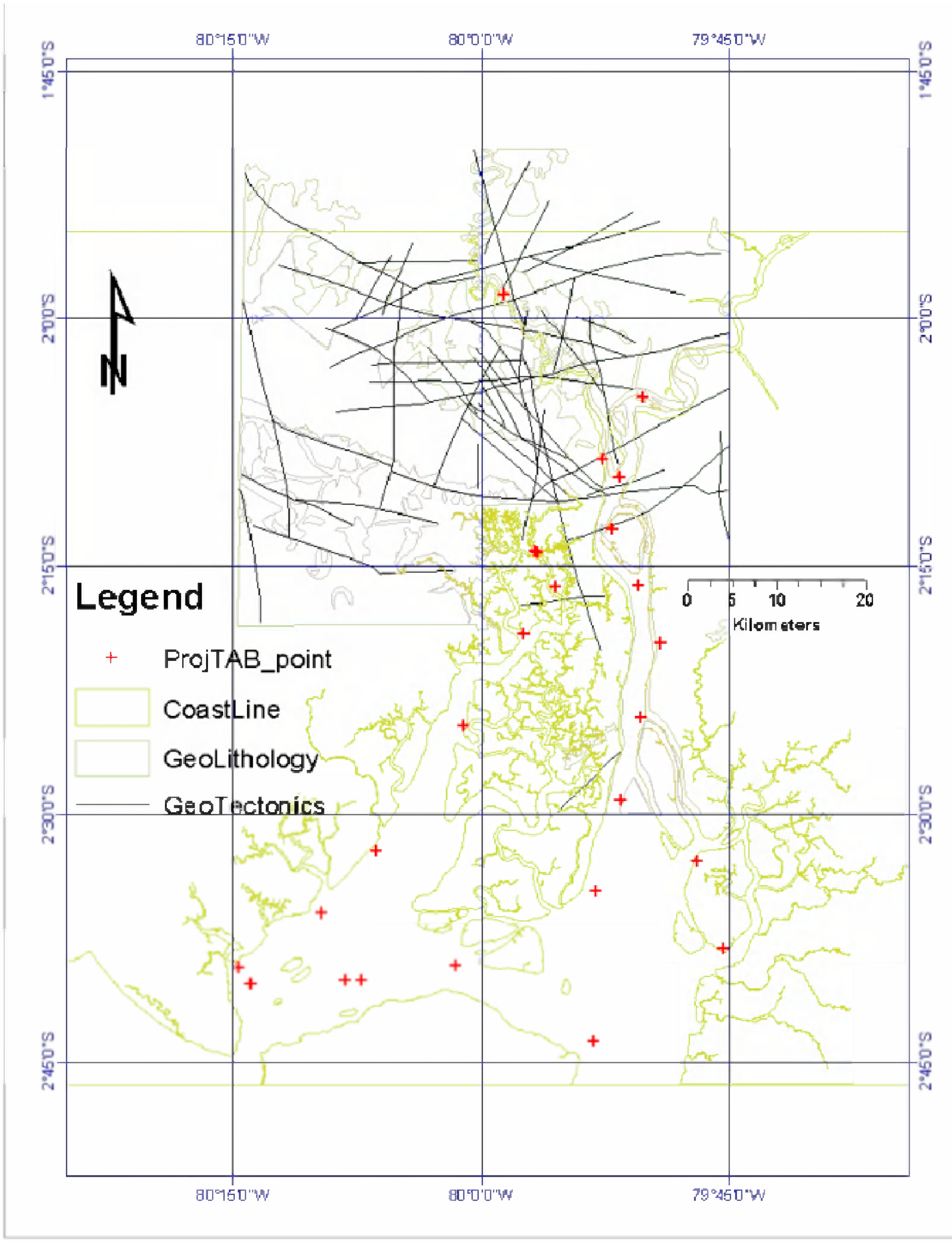


Figure: 1-12 Study area : The GeoData

1.4.2 Estuary

Description: The nature and organizations of facies within incised valley estuary is controlled by the interplay between marine processes (waves and tides), which generally decreases in intensity up-streaming, and fluvial process, which decreases in strength down estuary [101]. Further, the literature also illustrates that an ideal estuary posses a three-fold (tripartite) structures. These facial zones are: - (a) an outer zone, which is a marine process dominated portion and the net bed-load is head-ward; (b) central zone, relatively low energy, where there exist a net bed-load convergence and (c) inner zone: - a marine dominated but river influenced where the net transport is seaward. However, all estuaries may not show the same development mainly due to the availability of sediments, coastal gradients, and the evolution of the estuary. Two distinct but intergradational types of estuaries (waves, and tides dominate) are recognized based on the dominant marine process. The wave dominated estuaries typically posses a well defined tripartite zonation: a marine sandy body barrier, wash-over, tidal inlet and tidal delta deposit; a fine grained generally muddy (central basin); and a bay head delta that experience tidal and saltwater influence. The marine tide dominated sand body consists elongated sand bars and passes head into low-sinuosity or straight channel; equivalent to the central zone is described by a tight meanders where bed-load transport by flood tidal and river currents is equal in the long term. These ideal facies models and their conceptual basis provide means of highlighting the difference between estuaries and the possibility of having a clear definition of an estuary.

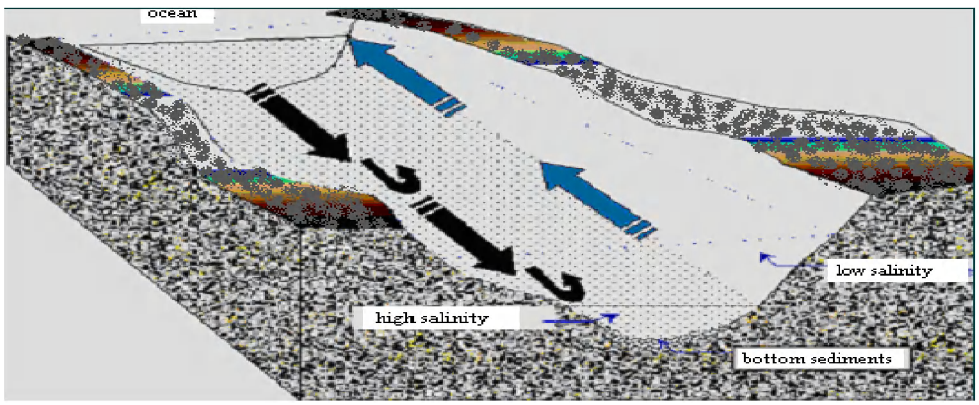


Figure: 1-13 An Estuary's dynamic view

Definition: Estuaries are dominant features along the modern coastlines, are results of Holocene transgressions and some times are associated to tectonic structures filled by undifferentiated sediments. They are strongly influenced by a seaward flow of terrestrial waters and by a landward surge of saline ocean waters. These processes of mixing up of different water masses and different composition create variation in the estuarine environment and Sedimentological depositions as indicated in the sketched figure (see figure 1-13). The facies boundary marking the landward end of the estuary as defined always lies landward of the 0.1‰ salinity value but the facies boundary of the outer end may lie either landward (as shown here) or seaward of the limit of normal marine salinities (32‰), (see figure 1-14). The most widely used definition of an estuary is based on the salinity concentration, with specific requirements and which states "a zone in the seaward river where the seawater is measurably diluted with water derived from land drainage" [102]. This definition implies that an estuary would occupy the mouth of a river where the salinity ranges 0.1 to 30 ppt (see figure 1-14). This definition is useful when dealing with chemical and biological process, in the fluvial–marine transgression. But it is of limited use in the study of ancient deposits because the physical process rather than the salinity determines the distribution of the lithofacises. On the other hand, defintions of an estuary include tides; for instance, according to Fairbridge [104], an estuary is defined as "an outlet of the sea, reaching into a river valley as far as the upper limit of tidal rise " however this definition is argued, if strictly applied would includes delta, barrier and lagoons as part of the estuary.

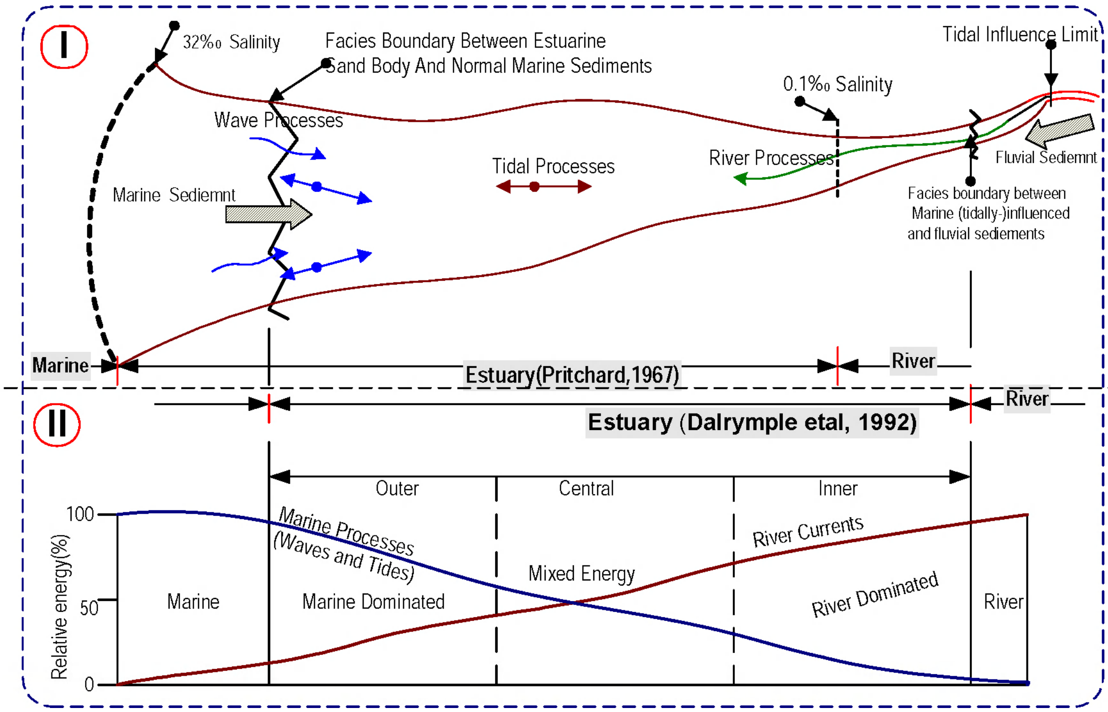


Figure: 1-14 : Ⓘ Estuary's Definiton Schematic Representation (Pritchard, 1967)and Darymple et al., 1992).

Thus, the definition of estuary should include processes such as the river currents and marine process, tides, waves as well salt-water intrusions. Based on these considerations - an estuary is the seaward portion of a drowned valley which receives sediments from both fluvial and marine sources [101] and which contains facies influenced by tides, waves and fluvial process, (see figure 1-14, Ⓘⓘ).

In most cases, the fluvial energy, as given by energy influx per unit cross sectional area, typically decrease downward of an estuary because the hydraulic gradient changes as the river approaches the sea. Marine energy by contrast, generally decreases headword, either because the oceanic energy is dissipated by wave built barriers or tidal speeds diminishes up estuary as a result of frictional damping. Thus, Estuaries (marine influenced, seaward portion of a drowned valleys) are depostionally complex due to the interaction of river and marine (tidal or waves) processes. However, despite this, literature study indicates certain organization of the estuaries environment due to the predictable nature of the fluvial and marine intensities or the river and marine process. Coarse sediments supplied by marine, river processes accumulates in the outer (marine dominated), and inner, (river dominated) portion of the estuary respectively, while finer sediments occurs in the central zone. The nature of the sediments depends on the nature of depositional environments (waves and tides), which are applied for the purpose of classifying estuaries into wave and tide dominated. In an ideal wave dominated estuary, the tripartite facies distribution is clearly expressed. An analogous tidal dominated estuary, clearly defined zone is not possible because tides can penetrate the sediments more than the waves do. Most modern estuarine differ from idealized models due factors such as the mixing influence of waves and tides, variation in the coarse sediment supply by marine or river process and dimension of the valleys.

1.4.3 The GIS's Raw Data Resources

Data employed during this research work have been obtained from a GIS project work conducted during the 1996 and 1997, in the Guayaquil Estuary. The data constitutes a variety of measurement data, temporal, images (scanned / satellite) and vector coastline maps.

Measurement data: multidisciplinary data pertaining to aquatic (extend from the estuary-water-surface to estuary-bottom zone) environment (figure 1-15).

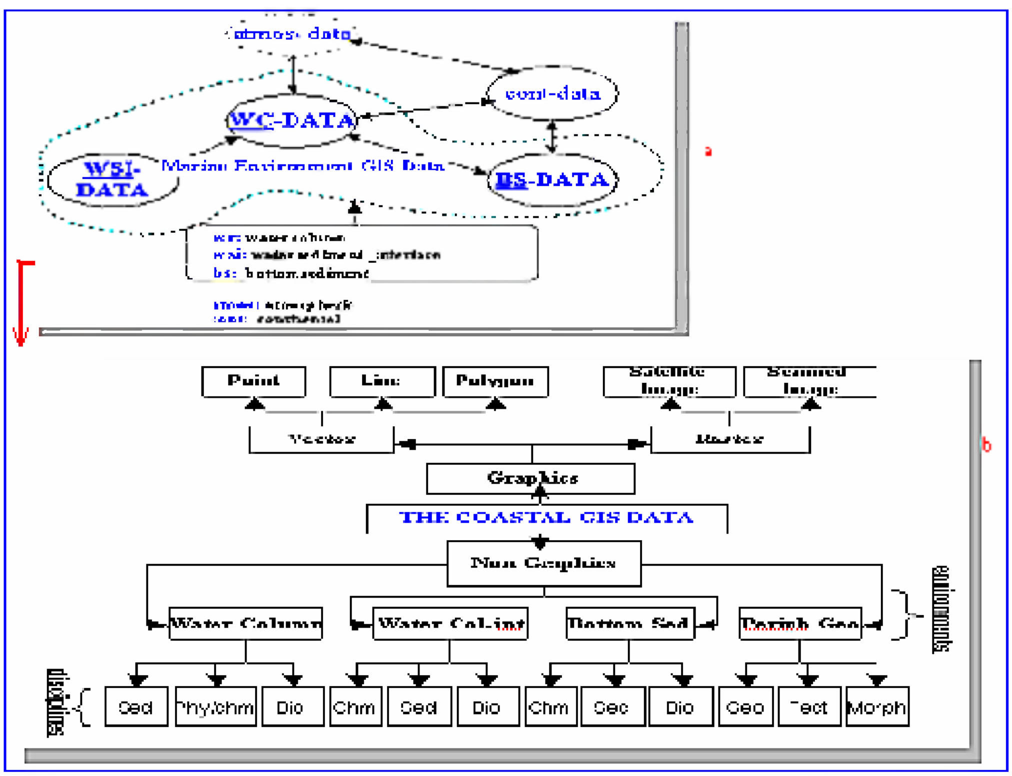


Figure: 1-15 Coastal Zone Environment Data Interaction (a) and GIS Data Input Scheme(b)

The **WC** (water column) data is characterized by direct interaction with atmospheric and terrestrial data, climatic change, coastal degradation and man made impacts respectively. This environment extends vertically towards the (water sediment interface) **WSI.** The WSI is a benthic environment habituated by benthos species and denser sediments particles**.** **BS** (bottom sediments) environment hosts muddy sediments and organic material data, which can grade to undifferentiated bulk sediments, depending on the state of the bottom estuary environment. The WC, WSI and BS are thought to have direct or indirect interactive relationship with the coastal environment medium and coastal peripheral sediments can be deposited within the WC-WSI-BS mediums (see figure 1-15).

The coastal data are complex. Figure 1-15(b) displays multidisciplinary measurement data incorporated in the Geo-Relational GIS data Model of the Marine / Coastal GIS. This complexity necessitates the Construction of Geo-relational data model for the appropriate storage, integration of spatial and aspatial data and enhances analysis of various coastal phenomena.

It becomes evident if one takes into account factors such as the diversity of data resources related to fishing, tourism, transportation, rhythmic motion of marine forces and heterogeneous constructions, land use vs. misuse and consequences of industrial discharges into transitional water mediums (estuaries). Implementing an integrated GIS database on data, acquired on regular span of time, better image resolution and increased measurement density in a dynamic environment like an estuary environment is indispensable to solve critical environmental problems.

Scanned Paper map data: They are maps derived from pre-existing geological reports [16] related to the coastal peripheral geo-set-up (Lithology) and Tectonic structural. They have been registered and vectorised before being incorporated to the geodatabase. The graphic data include bathymetric and satellite images, as described in tables 1-1 and 1-2).

Projection	Utm Zone 17
VD (vertical datum)	Mean sea level (MSL)
Spheroid	International
Horizontal datum (HD)	PSAD1956
Bathymetric contour interval	20 meters
Scale	1:100,000

Table :1-1 Data source

The data has been obtained from the Instituto Oceanographico De La Armada (I.O.A.), 1976, Coastline Ecuador: According to [95]. The Lithology of the coastal periphery is composed of typical coastal deposition such as solidified carbonate rocks-limestone, argillite, greywacke, alluvial and colluvial sediments [16]. The Peripheral Geology and Structural Data depicts that the area is composed of tertiary sediments and the NW tectonic structures.

Table:1-2 Measurement, Images and Coastal Geologic Document

Data Source and Type	Description	Area
Satellite image	Acquired: landsat_5, Sep98 Pixel resolution: 30 meters Path 11 Row 62 Projection: UTM SAD56	Guayaquil region (Ecuador) Sep-1998
	Bands: 7, 4, 1	
Scanned general geology paper map (extracted from the congress of Ecuadorian engineers and geology of mines and petroleum), July 18/22 1983.	Geological map Guayaquil –(Ecuador)	North and North-West of Guayaquil Estuary (documentation, 1983)
	Stratigraphic: formation, groups and members	
	Lithology: intrusives and sediments	
	Tectonics: NE, NW, NS, EW trending	
Measurement data and Location	Integrated Multidisciplinary GIS research project	Guayaquil Estuary) (Documentation 1996-1997
Bathymetric map	Coast lines along the main channels and point of measurement	(Instituto Oceanographico De La Armada) (I.O.A. (1976)

1.4.4 Coastal GIS Data Composition

Various data were collected from the Guayaquil estuary, in different measurement stations with respect to different depths during the 8th month of 1996 and 4th month of 1997 fieldwork by different scientists for GIS related scientific research work. To facilitate the interpretation, the depths pertaining to the data collected per station are categorized as surface water column (depth ranging 0.2 - 1.0 meter), middle water column data (depth ranging 4.0-9.0 meters) and bottom water including the bottom sediments (3.0-19.0 meters). Main components of the data include discipline specific entities such as Zoo and phyto planktons, Bulk sediments, physico-chemical … etc., (see table 1-3)

Zoo plankton		Heavy Meta		Phytoplankton		Bulk Sed		Nutrients		Physico ch		Water Curren	
parameter	unit	parameter	unit	parameter	unit	parameter	unit	parameter	unit	paramet	unit	parameter	unit
Acartia spp.	ind/m3	cadmium	ug/l	Abundance	cel L^{1}	clay	%	Nitrates	µg/l	ph	++	direction	degMag
Acrocalanus sp.	ind/m3	chromium	mg/kg	Abundance	ind.L-^{1}	silt	%	Phosphates	µg/l	salinity	ppt	speed	cms-1
Aegisthus	ind/m3	chromium	ug/l	Abundance	org/^{m3}	sand	%	Silicates	µg/l	temp	°C		
Appendicularia	ind/m3	copper	mg/kg	Abundance net	org/^{m3}	gravel	%						
Ascidian larvae	ind/m3	copper	ug/l	Number of	Count								
Bivalvia	ind/m3	mercury	mg/kg	Number of	ind.L^{-1}								
Egg Pisces	ind/m3	mercury	ug/l										
Foraminifera	ind/m3	zinc	mg/kg										
Gastropoda	ind/m3	zinc	ug/l										
Larvae Pisces	ind/m3												
Medusa	ind/m3												
Mysids	ind/m3												
Polychaeta	ind/m3												
Rotifer	ind/m3												
Tintinid	ind/m3												
Tortanus sp.	ind/m3												
total abundance	ind/m3												

Table: 1-3 Coastal RawData Descriptive Parameters

Bottom Sediments: Data pertaining to the discipline *Sedimentology*, collected during the 1996 and 1997 GIS project field works were composed of bottom sediments, bottom water and surface water environments. The bottom sediments data were approximately 21 samples and are of bulk sample type. They are composed of unconsolidated sediments, organic materials and rock fragments.

The sampling technique applied includes Van Veen 5 kg, (A type of grab sampler for several sizes sediments, especially applicable for collecting bottom sediments, (See figure 1-16 a).

The sampling depth environment of this data ranges between 3 and 19 meters. The analytic technique has been carried out using R. Folk, Schla&Schm, 1969/pipette and R. Folk, Schla&Schm, 1969/sieve. These bulk samples have been analyzed for the purpose of identifying Sedimentological processes, compositions and perform spatial interpretation using GIS spatial applications.

FIELD DATA: 1996 and	*Bottom Sediments ENVIRONMENT*		
	Sample Type	Bulk sediments	Method
	Sampling Method	Van Veen 5 kg	Anchor/ Shipek 70 kg
	Sampling Doc.	Approximately 21 samples	Cable lowered until 3 m
	Analyzed Parameter	Clay, silt, sand and gravel	R. Folk, Schla&Schm., 1969/dry sieve
	Unit	%	Percentile
	Depth (m)	3-19	WSI-BS

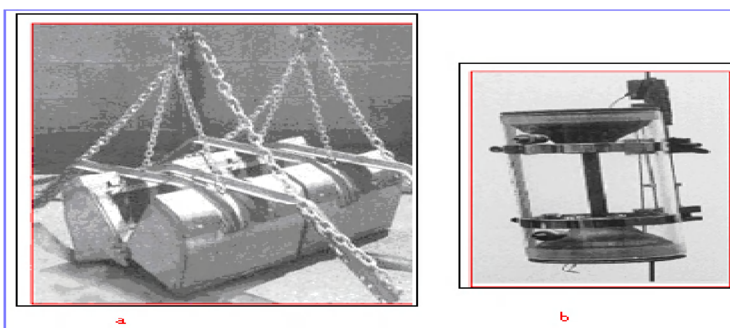
Table : 1-4 Bottom sediments

Heavy Metals: The data related to the discipline heavy metals, collected in the same duration of the Sedimentological data belongs to the bottom water column environment. The data were of bottom water sample type. The heavy metals analysis result is related to possible sources of a local galvanic industry, natural set-up and gold mining environment. The sampling technique applied includes Botella Van Dorn type, (Valve-closing bottle used to collect data), see figure 1-16) and Goulds NPE pump, 2HP, 3450 rpm, 1 1/2 x 2" High Efficiency Impeller (turbine motion). The water samples have been analyzed to gauge and identify the concentration (micro gram per liter) of the heavy metals parameters of mercury, copper, zinc, chromium and lead, (see table 1-5).

FIELD DATA: 1996	*Bottom water column environment*		
	Sample Type	Water	
	Sampling	Botella Van Dorn	Goulds NPE pump.
	Sampling	Ebb tide	Related environment
	Analyzed	Mercury, copper,	Galvanic industry, natural
	Analysis	X	X (not reported)
	Unit	Micro gm /l	
	Depth (m)	3-18	

Table: 1-5 Bottom Water Column Environment

Figure: 1-16 Van Veen Sampler (a) and Bottela Van Dorn Veen Sampler(b)



***Physico-Chemical*:** The physico-Chem. data collected during the same GIS project field works is of water column environment type with a sampling depth environment ranging 0.2 to 15 meters. The sampling technique applied includes Salinometer and CTD-Sea Bird In situ. The measurements have been carried out to determine the water current's speed in cm.s-[1], water current direction in MagN, temperature in Celsius and salinity.

FIELD DATA:1996	Environment	*Water Column*
	Sampling duration	*During Ebb/syzygy*
	Sampling Method	*CTD Sea Bird - In situ*
	Analysis Method	*Salinometer, CTD-Sea Bird - In situ S4lab*
	Analyzed Parameter	*Salinity, temperature, current direction and current speed*
	Unit	*PPT, Celsius, Degree magnetic and cm s^{-1}*
	Depth (m)	*0.2-15*

Table: 1-6 Physico-Chemical

Salinometer - a hydrometer that determines the concentration of salt solutions by measuring their density

CTD *(Conductivity-Temperature-Depth)* Sea Bird - In situ: *an oceanographic research tool for recording conductivity, temperature and pressure, designed for long-term fixed site deployments. As the CTD instrument is lowered through, the water (see figure1-17) measurements of conductivity, temperature and depth are recorded continuously*. (Source http://www.windows.ucar.edu/cgi-bin/tour.cgi/earth/Water/CTD.html)

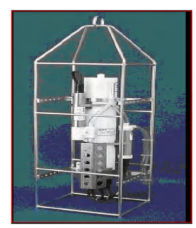


Figure: 1-17 CTD Sea Bird - In situ

BioData: The biological data, collected from the Guayaquil estuary, in the same period were related to water column environment, with a sampling depth ranging between 3.7 to 18.5 meters. The data are composed of diverse biomasses, species related to phytoplankton and zooplanktons diversity. Some of the samples weight ranges 1 – 28 kg.

FIELD DATA: 1996	Environment	Water Column	Tools
	Sample	Diverse bio material, 1-28 kg.	
	Sampling	Net 50 mic, Van Don bottle + net 20u, Plastic	Stereomicroscopy
	Analyzed	Abundance, Coscinodiscus, Protoperidinium	Zooplankton
	Analysis	Microscopic standard	Filtered by Plankton net
	Unit	Org/m3	Ind/m3
	Depth (m)	3.7-18.5	

Table: 1-7 BioData

The sampling techniques applied were of Net 50 microns, Van Dor bottle +net 20u, Plastic Bucket (40) and Stereomicroscopy. Biological species have been counted using standard microscopes and expressed in org/m3 and plankton net filtered zooplanktons where the output is expressed in ind/m3. Net 50 µ: Plankton Nets intended for biological study. Net Diameter Selections include 30, 50, 60, 75, 100, and 200 cm diameters

Geolithology and Tectonics: The lithologic and tectonic data are derived from pre-existing mapping and exploration geo-works in the coastal region of Ecuador (16).

These compiled data are composed of various lihological compositions, stratigraphic names, lithologic units and tectonic structures that dissect the different coastal geology extending towards the main estuary.

Compiled Geological Reports (1983)	Environment	Coastal Periphery
	Data (Sample Type)	Compiled geologic works
	Data acquisition	Scanning, digitizing, topological cleaning and geo-referencing
	Interpreted data	Lithologic composition associated to different stratigraphic and tectonics trends
	Analysis Method	Thematic distribution and relation to tectonic trend
	Unit	Km, km2

Table: 1-8 Geolithology and Tectonics

Some of the extracted lithologic types or parameters incorporated in the modeling of the geodatabase are siliceous limestone relate to the local Pinon formation, oceanic crust described by harzuburgite outcrops, granodioritic intrusions associated with pyrite and rarely copper mineralization, unconsolidated and calcareous sediments related to the Rio river, etc, see table 1-8.

1.4.5 Coastal GIS Data Classification

Primary and Secondary type

Attribute Data	
Sedimentology data: intended to understand the sediments distribution within the estuarine environment and affinity to related measured	o explain the vicinity estuarine sedimentary estuary channels. The atigraphic names and 1 coastal environment s, graywacks, alluvial
Biological data: intended to decipher the species diversity species and spatial distribution across the different environment.	
Physical data: measurement intended to unravel the water's current speed and direction with respect to temporal variation, understand cause and	
Chemistry data: (chemicals) intended to explain the spatial dissemination of chemicals and their relationship with the indicated sub marine	is a structural entity rea, which dissects pick up the fault nd establish the origin
Industrial and Agricultural wastes data entities (Heavy metals and pesticides).	

C) Geometric and images Data	
Primary	Secondary
Satellite Image	Bathymetric maps
GPS coordinates	Scanned paper maps
	Vectorised features

Table :1-9 The data: Attribute (a and b) and Geometric data (c)

1.4.6 Coastal GIS Data Organization and Specification

The increasing amount and inherent complexity of coastal data collected in a multidisciplinary research program requires organization and specification as an onset of the GIS database design.
Such approach requires that the vast amount of data that will be amassed be intelligently catalogued, as well as spatially and temporally co-registered. This procedure permits us to understand the discipline-specific objects as the core building block of the GIS. Table 1-4 depicts the classification of the main estuarine attributes. The vertical dimension (z) or echo sounding measurement (measured sample's depth (case study)) can also be extracted from core sample during sub surface data collection. Figure 1-16 depicts the possible descriptive attributes and entities that could be derived from core samples.

Schematic Geodata specifications

Informative
Speed and magnetic direction pertaining the estuarine water current
Pollutants and PCBs dissemination: indicating the degree of estuarine contaminations
Fraction of sediments (%): indicating sedimentation and flocculation intensity
Species counted: specific location citing biological diversity
Temperature: degree of evapo-transpiration concentrates, water temperature and flow
Salinity: discerning the degree of the estuary dilution or vice versa
Ph: the degree of the water acidity or dissolved ions the enhance acidity

Temporal
Temporal data: used to perform spatio-temporal analysis
Spatial
Spatial, x, y or x, y, z coordinates
Two dimensional co-ordinate values (surface point data, x, y)
Three dimensional x, y and z co-ordinates (x, y, z)
Point feature: generated from xy or xyz coordinate indicating a measurement point position
Line feature displaying a user defined boundary, (series string of x, y)

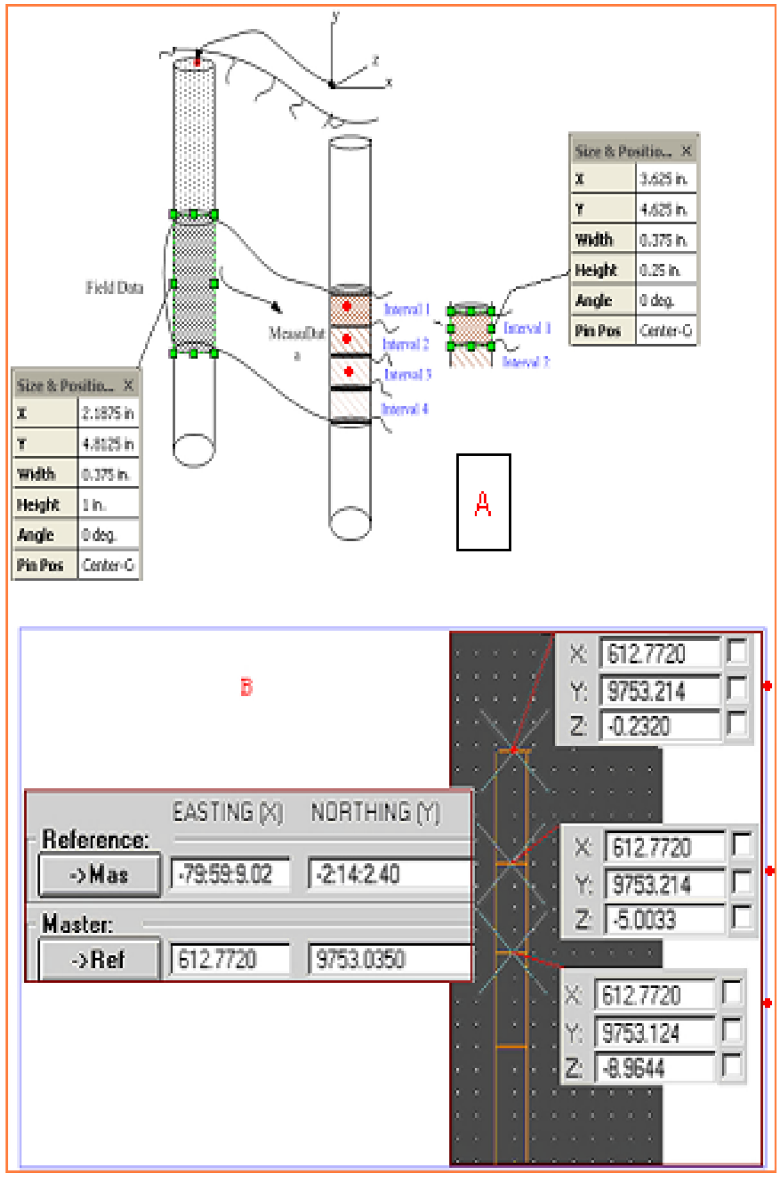
Table : 1-10 Classifying the data as Informative, temporal and Spatial

The data specification can be described using a schematic core sample, assumed to have been collected at a specific location with specific depth or surface level. The objective of such data analysis and specification is to decompose a bulk data and generate possible building block entities and attributes of the GIS database.

In the above example, the bulk data that can be sampled vertically or slanted (core) is coined as Field Data. It is geo-referenced by its locational coordinates (x, y, and +-z) and is assigned to a relevant field identifier and its specific depth interval hooked to a unit. Other environs characteristics included are: - surrounding geo-set-up, field workdays whether, nativity of the measured data such as in situ or allocthonous.

Also, further refinement of the data can be performed depending on the degree of analysis such including or excluding into accounts the display and visualization of the vertical dimension of the data (see figure 1-18)

The locational data are viewed three dimensionally by incorporating the different measurement interval (x, y, z where z extends to Z1, Z2 … while the x and y coordinates remaining constant Visualizing the information, i.e. in the above figure shows the sampling measurement intervals at 0.232,5.00,and 8.964 meters at a geo-referenced point of x, y of 612.772 and 9753.124.



This procedure of decompose and analyze method is vital to refine the raw data into smaller entity sets which could stand as independent interacting GIS building block objects of the Coastal–Marine Geodatabase.

Figure: 1-18 Schematic data specification (A) and elevation based data incorporation (B)

Furthermore, based on the incorporated (z bearing data), the process of spatial analysis to extract multidisciplinary measurements at a spatially referenced point is facilitated by means of the data aggregation tools. Eventually this will enhance the interpretation and extract the relationship of specific disciplines based data spatially.

1.5 Results and Conclusions

According to literature works, the environmental instability of the coastal zone is attributed to impacts pertaining to diverse socio-economic activities and natural processes interactions.

Coastal zone encompasses estuaries, beaches …etc, and is the center of activity such as aqua culture, fishing, marine transportation, agriculture and heavy industry …etc.

It is imperative to suggest that an eventual cumulative effect of the activities would influence the coastal eco system in general and certain biological species in the surroundings.

It would be a recommended necessity to carry out *Integrated Measurements* through spatial application, such as GIS and remote sensing. Besides, incorporating multidisciplinary measured data into coherently and logically structured geodata model would facilitate analysis and visualization the relevant spatial problem.

Such undertaking requires an integrated multidiscipline approach of analysis, with more holistic and broader geographic perspectives to grasp genesis of natural as well human induced phenomenon. With this regard, the complex nature of coastal data requires rigors organization before incorporating into a structured GIS database.

Chapter 2: Building the Geodatabase

2.1 Introduction

Prior to this chapter, an endeavor has been exerted to introduce and explain the fundamentals and possible applications of Geographic Information System as a spatial technology tool in tackling coastal and related socio-environmental problems. Emphasis has also been given to data and its acquisition process. Moreover, possible approaches of utilizing GIS in disaster mitigation, management, and locating and identification environmentally susceptible spots site have been illustrated.

Likewise, the main substance and emphasis of this chapter is the process of ***Building Multidisciplinary GIS Geodatabase*** for a Coastal / Marine Environment. With regard to this theme, modeling and structuring of the coastal data will be discussed. The advantage of conducting a strategic database planning and designing with a phase of an active GIS project study will be paraphrased, and the implementation of the actual procedures and physical designs to specific GIS hardware and software will be elaborated. Subsequently, construction of the geo-relational data model is resumed.

2.2 Development processes

The GIS system design was founded on a PC using Win2000 and WinNT Operating systems and Office2000. Graphic applications applied during this research work include- MicroStation95 [18] as the main plat-form, MicroStation Geographic GIS [11], as a Geo-Engineering GIS package, MicroStation Geocoordinator [22] as a projection application, Terra modeler, as a 3D modeling [19], and MicroStation Basic [12], as a customizing application. On the other-hand, Intergraph's Modular Geographic Environment (MGE) [20] and, at the late phase of the GIS development ESRI's ArcView [21], ArcGIS [70] and MapInfo [30] were implemented.

Oracle database, (version 7.1, NT 3.1) [39] and later an ODBC (.MDB) [34] were also applied to the physical implementation of the Geodatabase GIS schema. Visio professional [71] and the inbuilt MDB's case tools were applied to generate information structure diagrams. Notions of the Nyssen Information Analyses Method [33] have been implemented harnessed to analyze the information construction.

Data model is the heart of any GIS, which is a set of constructs for representing objects and process in the digital environment. The types of analysis that can be undertaken are strongly influenced by the way the real world data is modeled. Thus, a decision about the type of the model to be adopted is vital to the successes full implementation of a GIS project.

In this research work, the strategic database planning and design that encompasses the human-oriented (reality to conceptual model) and computer-oriented (logical model to physical model) have been conducted concurrently with an on going pilot GIS project study (Guayaquil Estuary GIS project). The physical attribute database design depends on the structure and format of a specific GIS special working system entities or objects generated simultaneously during a geodatabase initiation. Figure 2–1 shows a partial view of the spatial system and user data entities, specific to MicroStation Geographics GIS [11].

2.2.1. The Building Block Entities Descriptions

The above information structure diagram (ISD) geo-relational model shows integrated internal and external Entities defined as: -

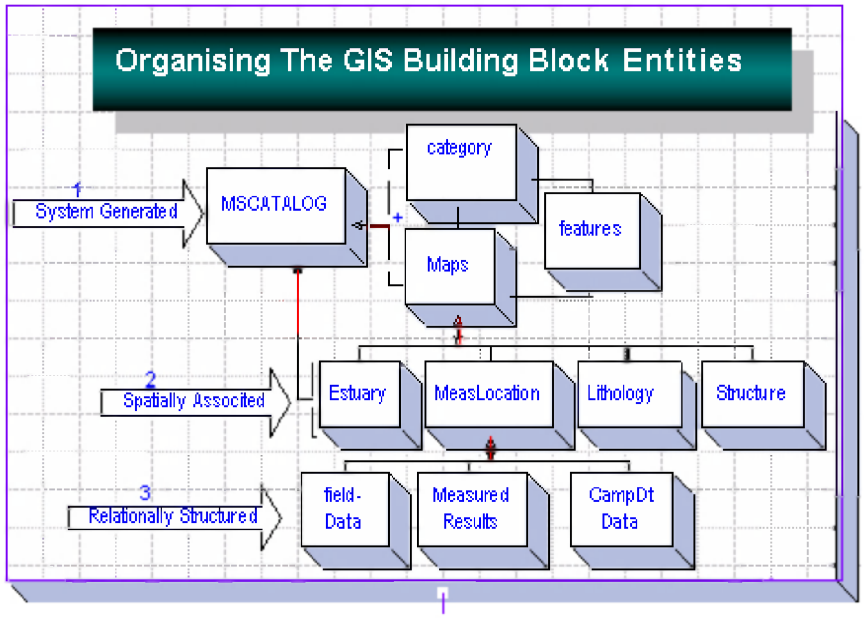


Figure 2-1 Partial view of GIS building block entities

1. Internally generated entities (SGE);
2. Structured objects and spatial migrating pointers and
3. Relationally tied and appended entities (via pointers)

The system generated entities (SGEs) level 1, are special working entities generated at some stage of the GIS project creation. The user's spatially associated objects (level 2) are characterized by a global coordinates (latitude, longitude and +- elevation), are linked upwards and downwards to the SGE and RSEs respectively. Those entities at level 3 are designed to store non-spatial data pertaining measurements and are geo-referenced via the user defined associated entities' identifiers and associated geometric objects. The conceptual formulation and description of this Coastal/Marine GIS geodatabase was based on selected entities according to the needs and assessments such as:

Entities that represent the Estuary (measurements, i.e., *per discipline)*

Entities that pertain to coastal periphery (secondary measurement)

The main Estuary and Coastal Periphery Entities are-

2.2.1.1. Estuary Entities

1. Zone (Zonal Data of the estuary)
Location (multidisciplinary Measurement Locations)
Field Data (Raw Data description)
CampagindateData (data with temporal issues)
MeasuredResults, (measured / analyzed attributes)
Estuary Morphology (features disclose estuary)
Disciplines (main research groups)
Tectonic Data (fault trends description)
LithologyData (rock type and stratigraphic)

Table 2-1 Building block attribute entitie

Zone and Location: Zone: An entity described by zone attributes. It contains different measurement stations in the estuarine channels. Location: The entity Location discerns measurements points belonging to multidisciplinary scientific team performing variety of measurements. A Location's attributes are strictly mandatory.

Field Data and CampagindateData: Field Data: data collected and described in the field by any means of interface. Field data's attributes are those, collected in a site instantaneously. On the other hand, Date Data described the temporal attributes.

Measured Result: is an entity described by the measured attributes.

It encompasses all the discipline objects.

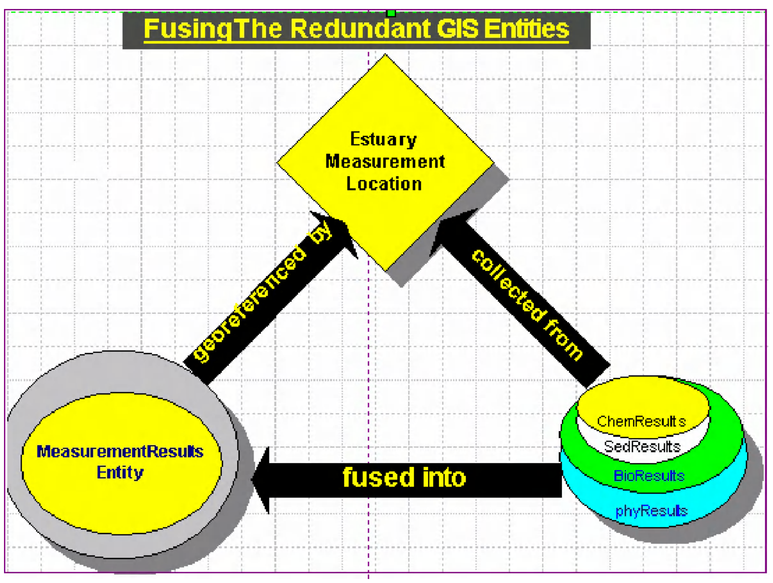


Figure 2-2 Fusing of the GIS Building blocks

It is linked to the main Location object via migrating spatial pointer to geo-reference the measured values residing inside the database and create all the required objects, see figure 2-2, lower left.

Measured Result is an output of amalgamated layers (see figure 2-2, lower left). The process of amalgamating the Measurement Results entities belonging to different discipline was required because of -

(a) The descriptive classification of the attributes was based on mmcode or MMID (identifier) (see figure 2-3)

(b) To avoid repeating informative attributes that creates unnecessary layers of entities and inflates the system

(c) To reduce multiple joins and alias during object relational inquiry on the GIS system.

Normalization has been used to remove redundant attributes.

Thus, normalization is the process of converting complex relations into a larger number of simpler relations that satisfy relational rules [55].

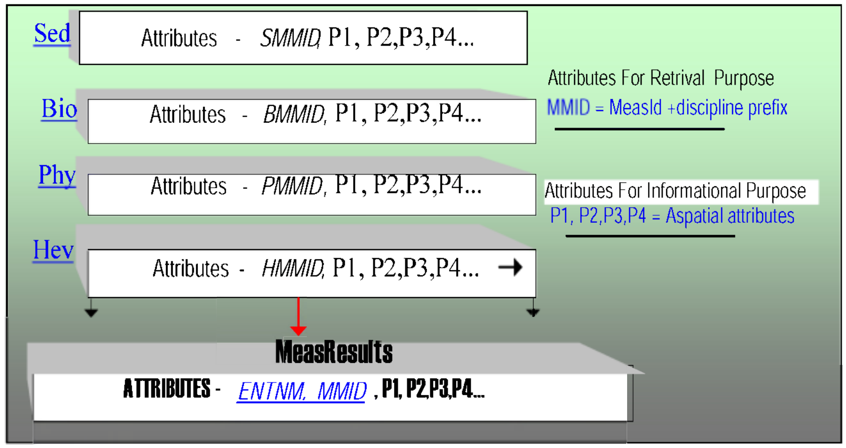


Figure 2-3 Amalgamation of entities

It involves a study of the type, dimensions, interrelations of the data to be stored, handling the one to many relationships, elimination of ambiguous attribute and repeating groups of attributes.

2.2.1.2. Coastal Periphery Entities

Estuary morphology: An entity described by attributes related to tributaries and main estuary channels.

Geolithology and GeoTectonics: these entities were derived pre-existing geological and structural data intended to explain the vicinity geological set up. They are considered as part of the provenance of the estuarine deposits (See raw data description (chap1).

2.2.2. Design Analysis: Conceptual Structure

As one incepts with GIS information analyses, the data (in this case coastal/marine data) that the user desires to exchange with the information system is analyzed and the grammar of the information system is formulated. Representing the descriptive information about the geographic features is fundamental to model the data [24]. GIS is composed of non-graphic data (structured mainly in a RDBMS in the form of a tabular data) and graphic data structure stored within the spatial engine of the GIS application. Thus, understanding the content and context of the two separately before their amalgamation to form Marine /Coastal GIS is prerequisite.

The building block non-graphic data (coastal environment) specific to this work are categorized as classes or NOLOT (Non Lexical Object Type) and attributes or LOT (Lexical Object Type) which describes every measured attribute of each meaningful entity [33]. These Object types can be communicated in the system using a certain manipulation language and an output of information can be extracted. To facilitate the analyses and enhance the understanding of the Geo-Relational GIS data modeling, the data source environment has been divided into three sub-environmental zones (see chapter 1).

During the design and creation of GIS database to store and track all the spatial and non-spatial data processing and management, it can be difficult to think through all the entities. On such circumstance, the database will need a mechanism on how the attributes are related to each other. This is done by establishing specific rules about the interaction of the data and information stored in each GIS database. Eventually, this process leads to the development of the information structure diagrams (ISD) by establishing and considering certain propositions or rules as: -

Information that would be stored in an entity must be explained grammatically.

Rules stated for every entity structure and proposed phrases must reflect real world perspectives.

The grammatically explained rules must be depicted diagrammatically. This fact depicts interrelated interaction of objects in a GIS system create communicable information. With this regard, the following propositions and rules steps were established for the GIS database logical consistency and information integrity.

2.2.2.1. Conceptual Representations and Constraints

Coastal Zone	Estuarine environmen **I**	Zone > An area or region where different Locations are encompassed
		ZoneCode > An identifier of the entity zone
		Location > sites of measurements and sampling belonging to different disciplines
		LocCode > An identifier of the entity Location
		CampaignDateData > An entity identified by data/time parameters
		FieldData > Descriptive observatins (data) performed around the measuremet locations
		Results > Measurement and analysis values pertaing to differenr disciplienes
	Coastal Geology **II**	There is a GeoLithology Entity, GeolEntity identified by LitID
		There is a Tectonic structur entity
		TectonicStructure Entity is identified by StrID

Zone vs. Location

Rule: 0.1 There is a Zone entity desribed by its zonal attributes
Rule: 0.1.1 A Zone entity is identified by a ZoneCode
Rule: 0.1.2 A ZoneCode belongs only to one Zone entity

Rule: 0.2 There is a Location entity desribed by its locational attributes
Rule: 0.2.1 A Location entity is identified by a LocID and a pair of concatenated geographic coordinates
Rule: 0.2.2 A LocId belongs only to one location entity

Rule: 0.1.1 + 0.2.1
A Zone entity is identified by a ZoneCode and contains Location entity identified by LocID and a pair of concatenated geographic coordinates

FieldData vs. Location and Zone

	Rule:0.3 There is a fieldData Entity described by field oriented attributes
	Rule:0.3 .1 FieldData Entty is identified by a fdCode
ER2	**Rule: 0.3.1+ Rule: 0.2.1 + Rule 0.1.1**
	FieldData Entty is identified by a fieldCode is contained within A Location entity identified by a LocationalID and a pair of concatenated geographic coordinates and in turn contained within A Zone entity identified by a its ZoneCode

Date Data vs. Measurement Results + FieldData vs. Location and Zone

	Rule: 0.4 There is a CampagainDateData entity
	Rule: 0.4.1 CampagainDateData entity is identified by DtCode
	Rule: 0.5 There is a MeasuredResult Entity
	Rule: 0.5.1 MeasuredResults Entity is identified by a MeasCode
ER3	**Rule: 0.5.1 + Rule: 0.4.1**
	MeasuredResults Entity identified by a MeasCode and collected in a campagiandate identified by dtcode.
ER4	**Rule: 0.5.1 + Rule: 0.4.1 + Rule: 0.3.1+ Rule: 0.2.1 + Rule 0.1.1** =
	MeasuredResults Entity identified by a MeasCode and collected in a campagiandate identified by dtcode and is processed from fieidData (fdcode) which in turn is contained within a Location entity identified by a LocID and a pair of concatenated geographic coordinates where this is contained within A Zone entity identified by a its ZoneCode.

Further decomposition of the rules illustrates the relationship's strength by LOT values pertaining to the entities under consideration, E.g., Rule: 0.2.1. A LocID and a pair of concatenated geographic coordinates identify a Location entity, where the LocID and geographic coordinates are mandatory attributes. This rule can be translated by incorporating the mandatory attribute values of that entity as follows.

Rule 0.2.1.1

8a (LocID' value) belongs to only one and only one Location concatenated with geographic coordinates 2^{O}:29.70' and 79^{O}:52.18'. This logical relationship reveals the functional dependency and relationship between entities and respective attribtes.

Rule 0.2.1.1: Defines the Functional Dependency among entities and attributes

Geolithology vs. Tectonic Structure

Coastal Entity Rule		Coastal Geology
	Entities	EstuaryMorphology
		GeoLithology
		GeoStructure Entities.
		0.6.0 There is a GeoLithology Entity
		0.6.1 GeoLithology Entity is identified by **LitID**
		0.7.0 There is a Tectonic Structur entity
		0.7.1 TectonicStructure Entity is identified by **StrID**
	CER1	**Rule 0.6.1 + 0.7.1**
		GeolLithology entity identified by LitID and is sheared by TectStr Entity identified by strID
		0.8.0 There is an estauarymorphology entity
		0.8.1 EstauryMorphilogy identified by **EstID**
	CER2	**Rule 0.6.1 + 0.7.1 + 0.8.1**
		GeolLithology entity identified by LitID is sheared by TectStr Entity identified by strID and in turn EstauryMorphology qualified by EstID characterised by distinct Geolithology.

Measurement Results and Geolithology

PR2+ER1	0.1.1 + 0.2.1 and Rule 0.6.1 + 0.7.1 +8.1
	It is possible to explore and identify an estuarine Zone entity identifieed by zonecode which is composed of Measurement location Entity identified by LocCode and hosted within Geolithologic entity Identified by a LitID which is sheared by tectonic structures.

2.3 Establishing Relationships among Entities

The above Entities/ Objects rules are fundamental to avoid common errors such as updating, deletion and addition of data. Furthermore, the propositions can be easily transformed into geometric relationship among.

Let us illustrate the relationship between the ***Measurement Results*** of a multidisciplinary scientific team working in *site-specific position* **(Location)** along the elongated estuarine environment sites, see figure 2-4.

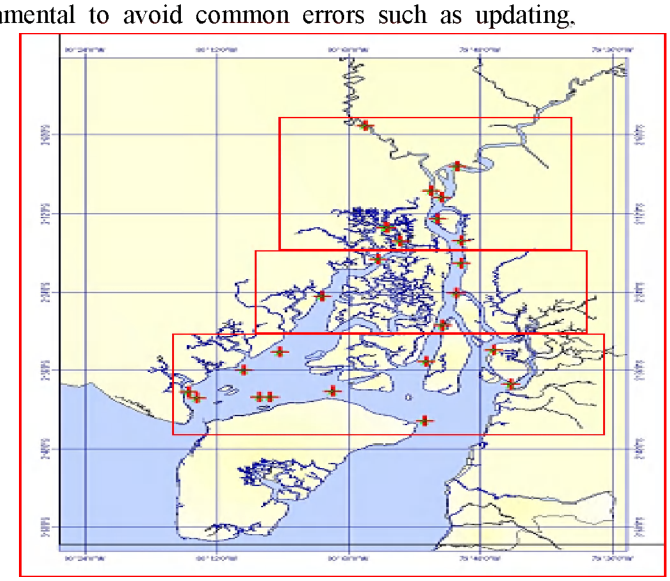


Figure 2-4 Measurement Locations

The estuary subdivided into zones marked by rectangles and crosses indicate the measurement locations.

2.3.1. Location vs. Multidiscipline Results Entities

LOCATION entity is described by the attributes that describe the spatial location reference co-ordinate of a specific geographic object. These are LonDegree and LatDegree, Perimeter, Area, and an identifier(s) attribute defined by a user choice and predefined attribute that descends from internal GIS model, (see figure 2-1).

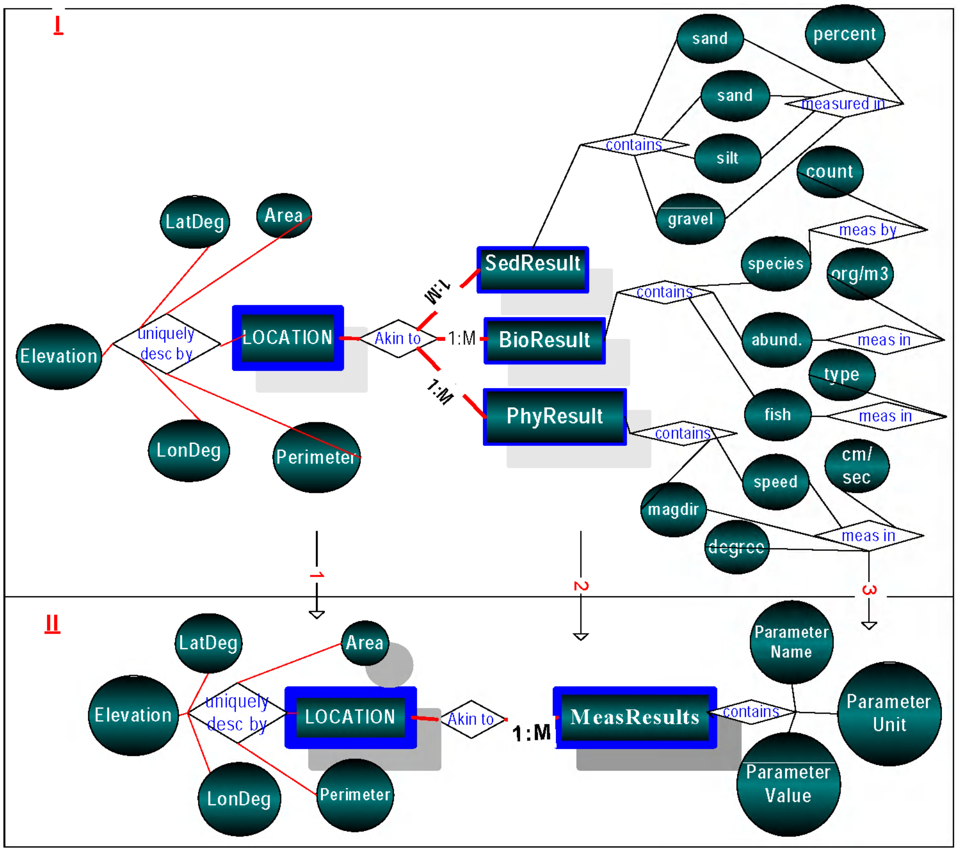


Figure 2-5 Measurement Results and Relation to the Location feature Entity

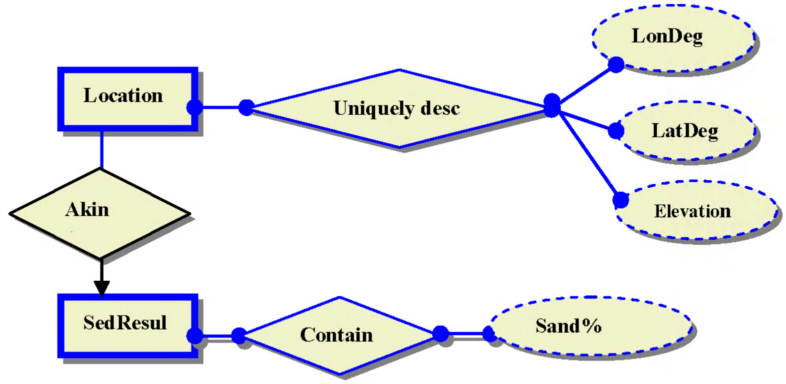
The unit and data type of these coordinate attributes depend on the type of GIS application and projection system respectively. Furthermore the Location (Measurement location) portrays a dual behavior, i.e., as an attribute data base entity in terms of bearing the spatial coordinates attribute values and its storage in the RDBMS and as a spatial object when it is associated with geographic elements and stored within a spatial engine as a feature class.

The full-fledged name of the attributes of every entity is fixed after every partially meaningful attribute is hooked to its unit of measurement, see figure 2-5. Thus, for instance sand is an ambiguous attribute; the correct nomenclature will be sand + unit, i.e. Sand percent meaning that the attribute value is measured in terms of percentage and it is related to the Location entity by Location Identifier migrating to SedResults entity (see figure 2-5).

2.3.1.1. Location vs. Sedimentology (sed) entity

The Sedimentology (sed) entity is described by measured parameters pertaining to the attributes names - sand, silt, clay, and gravel assigned to the measurement unit.

Figure 2-6 SedResults

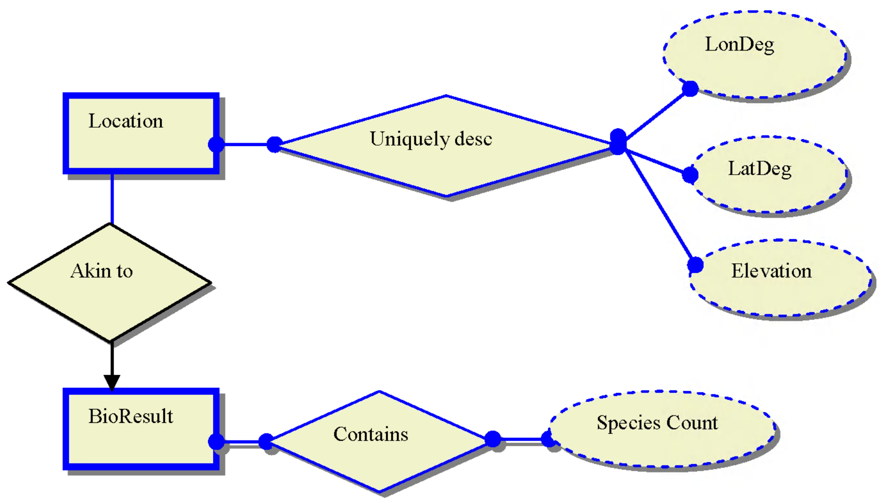


The nomenclature of the attributes depends on the Sedimentology analysis procedures used.

2.3.1.2. Biology (bio) Entity

The Biology (bio) entity is described by a measured parameters pertaining to the biology entity only.

Figure 2-7 BioResult Object

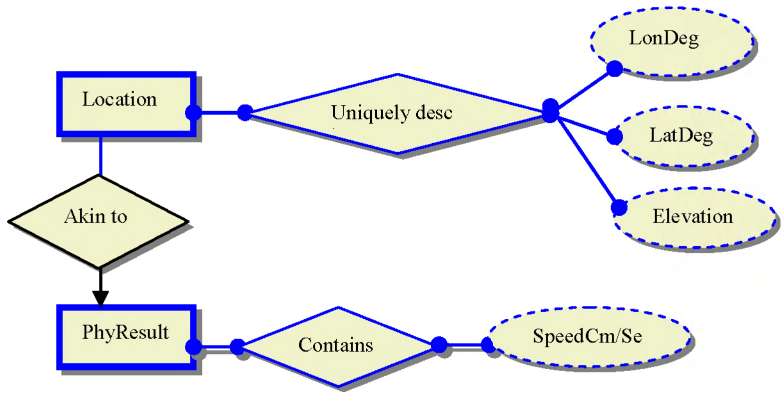


The attribute names that describe the bio entity can be species, fish, density, temperature... etc, + refer chapter 1. The nomenclature of the attributes depends on the biological counting machine set-up procedures and type of fish identified and the seasonal temperature, etc. In a similar reason, the attribute is hooked to its unit to create properly named attributes for the system design.

2.3.1.3. The Physical Entity

The Physical (Phy) Entity is described by the measured parameters pertaining to the physical entity only. The attribute names that reside within the physical entity can be current speed, current direction, tides strength, high tide and low tide and others.

Figure 2-8 PhyResults



The nomenclature of the attributes depends on the physical measurement set-up procedures. In a similar rationale, the partially meaningful attribute name is fixed after it is hooked to its unit of measurement. Hence, unambiguous nomenclature for current as current speed, and current direction are derived.

2.3.2. Cardinality Relationship

2.3.2.1. One to Many

In this case when we look for an attribute values belonging to **Sedimentology entity**, then we make an instantaneous enquiry about which measured attribute value belongs to which feature class. A Location ID (LocID) is a primary key field incorporated into an entity on level-2 (see figure 2-5) creates a pointer to map and trace the information on that specific station, The relationship between the Location entity and the other entities is termed as a one-to-many (1: M) see figure 2-5. Meaning that there can be many measured attributes that can be geo-referenced uniquely by the spatial feature pointer expressed relative to a position. The de-normalized form of the data model is depicted in figure 2-5 (II), showing the product of fusing entitles and related attributes.

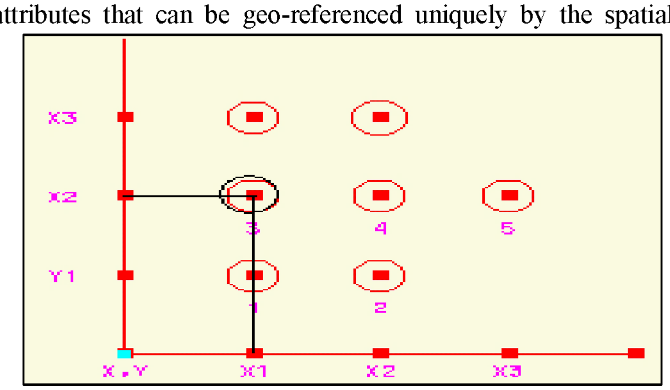


Figure 2-9 Example of 2D Map indicating a bore hole (BHs) Locations

2.3.2.2. One to One:

The relationship of one-to-one (1:1) can occur only when there is a correspondence between one Location (LocID) and a specific record pertaining to a specific discipline and that record at single borehole corresponds only to that location with LonDeg and LatDeg values.

For instance, the relationship of a Borehole entity and Location, see figure 2-9. This is true as long as the relationship between the entities is constrained to 1:1. However, in reality there is always database record represented by the Z value inclined at a specific angle, then comes the representation transfer of the information from x,y (two dimension feature) to a 3D (xyz) coordinate (see figure 2-10); which trespasses the uniqueness of the records referenced by a unique spatial element. In such condition, the spatial information retrieval would require an aggregating tool.

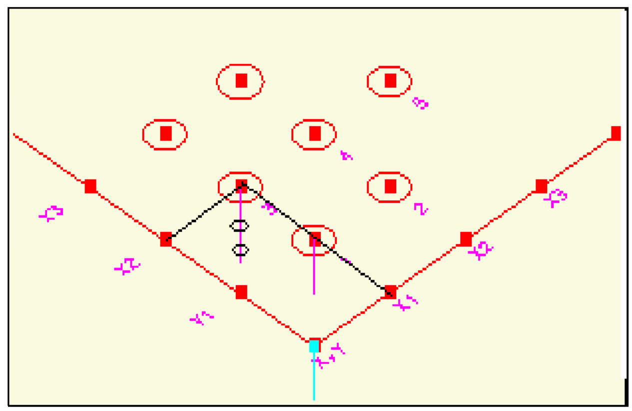


Figure 2-10 Schematic Illustration of a 3D Map

2.3.2.3. Many to Many

Many to Many: The many to many (M: M) relationships exist if there is a relationship in which many entity sets of one entity are related to many entities sets in other entity. For instance:

- A field can grow many types of crops,
- Many types of crops can also grow in one field,
- Many fault lines can shear the same Lithology (rock),
- A single fault line with specific direction can shear many Lithologies (see figure 2-11).

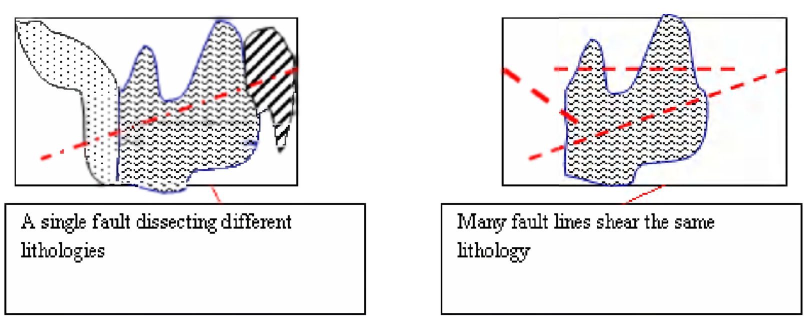


Figure 2-11 A many to many relationship illustration

Although the data modeling technique ERD (entity relationship diagram) permits the specification of a many to many relationships, these relationships are implemented in an object relational GIS database (see figure 2-12).

Because of such process, a many to many (M: M) relational model (see figure 2-12) uses a ***connector feature* table** that contains a migrating mandatory identifiers of the M: M related entities to form a series of 1: M related tables. This would enable us to pinpoint Lithology records are tectonically sheared by fault trends.

Similarly, the other entities (Field Data, Campaign Dates) and respective attributes describing any discipline involved in the GIS data collection and measurement are derived in a similar process as indicated in Figure 2-13.

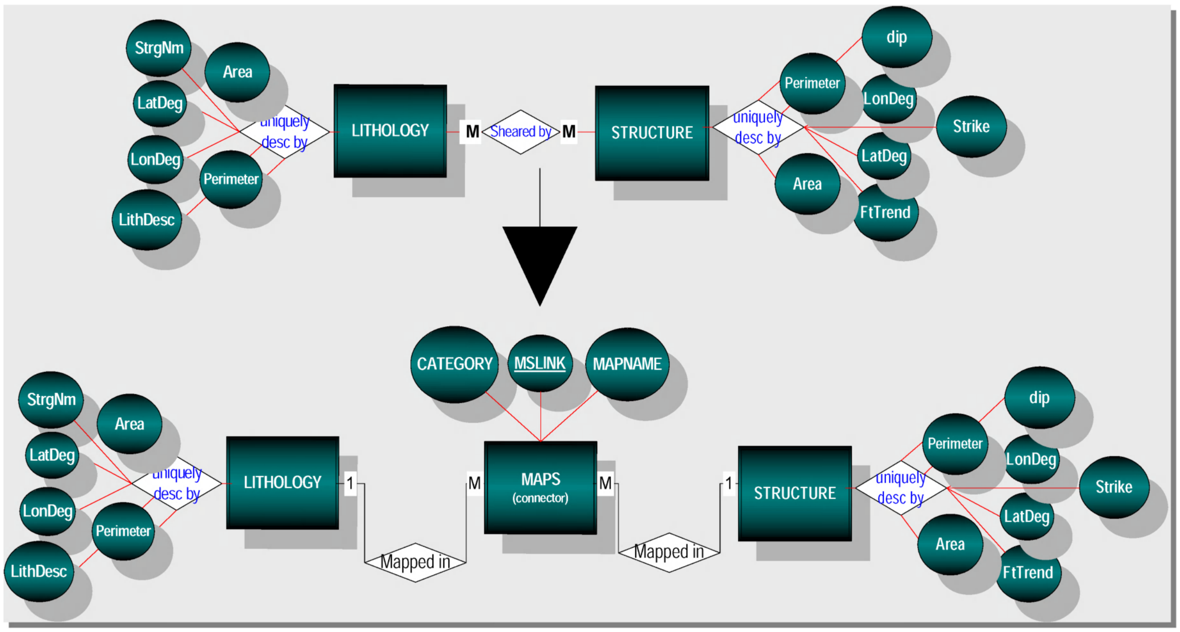
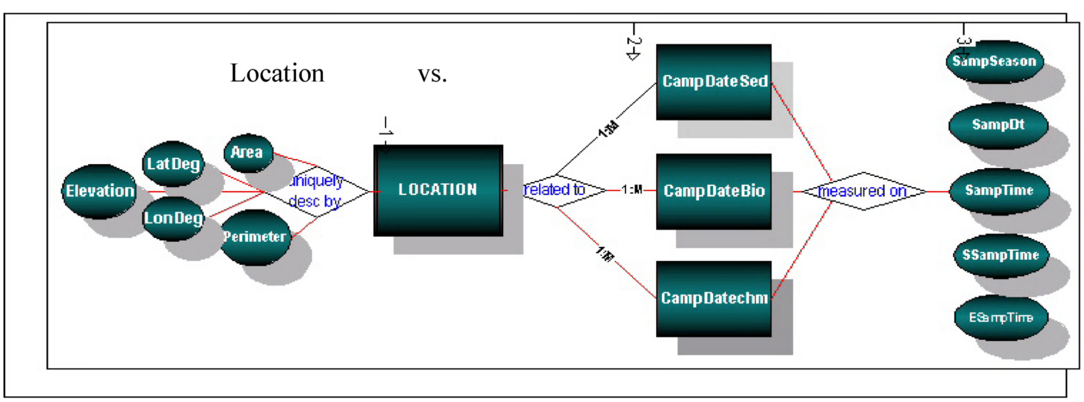


Figure 2-12 Conversion of Relations cardinality

The Campdate data entity is the result of the combined product of all the field data dates of measurement and sample collection during multidisciplinary GIS project activities.

Figure 2-13 Location vs. CampagindateData

This entity is populated by temporal attributes and related to a geo-referencing entity (see figure 2-13).



In a similar manner, the field data (see figure 2-14) entity is described mainly with attributes that bear field descriptions on the site.

For instance, a Sedimentology scientist may describe his initial observation a muddy data collected at the bottom of the water column as *silty-clay* type penetrated by roots and associated with benthic worms. Such description attributed to sample would help during interpretation of the environment spatially.

2.3.3. Maintaining Relational Integrity

Referential integrity enforcement enables consistency in interpretation of related information within the GIS database. For instance, the presence of unreferenced child records in the GIS database is flagged. Referential integrity prevents from deleting or updating record (s) on the "one" side if related records on the "many" side. The implication of referential integrity on data entry is obvious i.e. not possible to populate the "many" side until populating the "one" side. To avoid the anomalies (insertion, updating, and deletion) on related GIS tables (i.e. if values in the reference key are changed all values in the fk (foreign key) are changed); it is wise to disable the CASCADE UPDATES AND CASCADE DELETIONS options within the database.

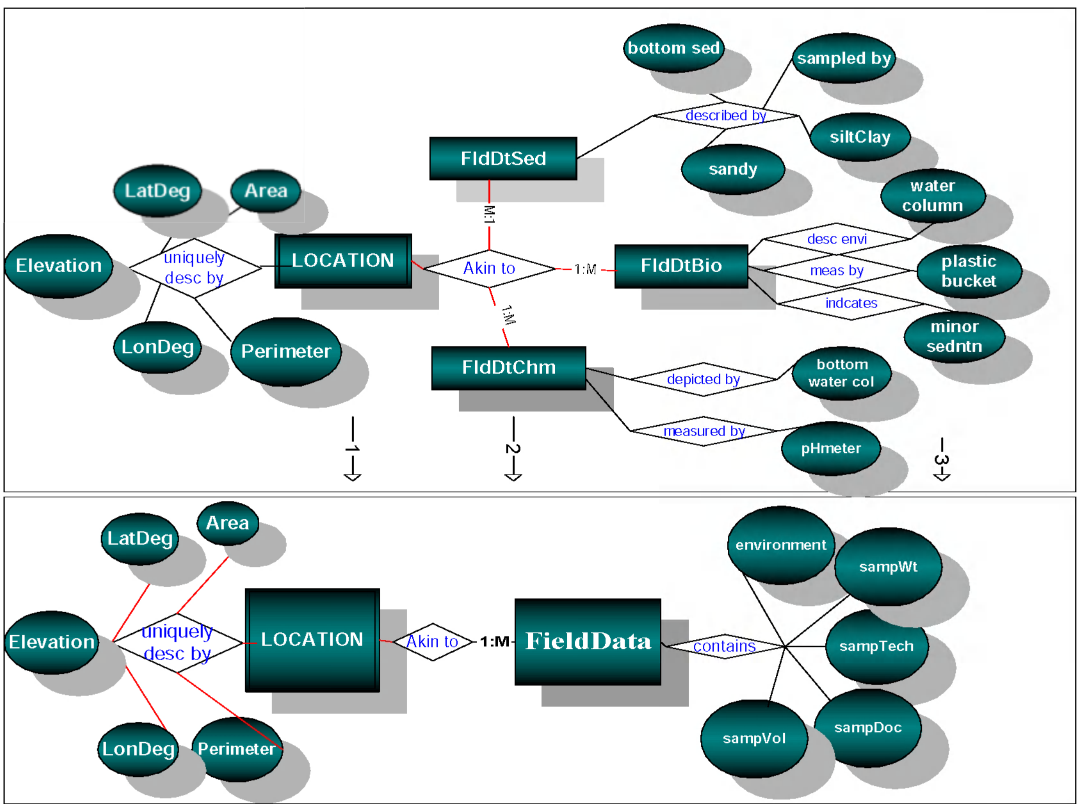


Figure 2-14 Location vs. field Data

2.4 Implementation (Transforming the Model)

The hatching of a GIS is incepted with the notion that every Object either dynamically or statically posses a position relative to space and time and can be geo-referenced to pin down its relative positional occurrence on the earth.

2.4.1. Spatial Entities

2.4.1.1. Object Composition

The attributes within the spatial feature table have been classified as - ***Informative attributes,*** **Identification attributes** and **Super Identification Attributes;** where the Informative attributes **are** fields that contain data items for informative purposes. **The Identification attributes** strictly utilized as a basis for uniquely identify records, searching, sorting and joining two or more objects.

Super Identification Attributes: - are specific fields, which migrate as physical pointers from the internal model to uniquely geo-reference associated GIS objects.

One can reference the Measurement Location object with one or more combined object identifiers. However, a single attribute entity, which uniquely identifies the database record akin to different fields but to the same entity, is required.

Close inspection of table 2-2 indicates that the station (LOCID) attribute is a key at the relational linkage level; however, this is true as long as it stays unique. An ObjID is an attribute defined to bridge the gap between the internal and external systems entities, spatially join, and retrieve referenced information.

2.4.1.2. Object Identifier

The presence of the elevation attribute within the LOCATION entity raises the problem of ambiguous records, which could stem out during sampling or measurement in a single location. At this point, the station (LOCID) attribute loses its constraining power and could not identify spatial information uniquely. However, it is possible to generate different object layers with respect to the Z values. Therefore, the ObjID and MAPID (Geographic and MGE, ObjID ArcView) identification attributes takes over the system integrity, functionality, i.e., by creating a pointer over a pointer as indicated below.

A Spatial Record: -

Location(ObjID)/ MapID	lat	lon	elevation	area	perimeter

2.4.1.3. Point Object: Measurement Location

The location entity is described by coordinate attributes and one or more internal mandatory pointer. Upon geodetic referencing the *LOCATION,* entity is used as the primary entity. In real world representation, the attributes of the location entity represent geographic point object. Depending on the data items and required visualization the real world object can be represented by a two-dimensional point, compose of latitude and longitude or a three-dimensional point, see table 2-2.

OBJID	MAPID	LOCID	Londec	Latdec	Lontxt	Lattxt	Eastkm	Northkm	Area	Perimeter	Elevation
		LOCID	Londec	Latdec	Lontxt	Lattxt	Eastkm	Northkm	Area	Perimeter	Elevation

Incorporation of Spatial Ids, at the feature-dbRecord association level

Representation of attributes at the datbase level.

Table 2-2 A double Pointer objects

The dual pointer data structure (table 2-2) depicts two important records. The first row with all possible spatial attributes, second row depict attributes before being associated to the spatial features. The different representation of latitude and longitude, (see table 2-2), (Londec and Lontxt) is to facilitate populating the geodatabase and generating objects in different GIS applications. The presence of elevation indicates the type of the seed file or template for a 3D GIS map.

A 2-dimensionl GIS contains mandatory coordinate attributes implies that the spatial relationship visualization is to be implemented on a 2-dimension map. On the other-hand a 3-dimension contains 3 mandatory coordinate attributes and implies that the GIS' object retrieval will include a third column of elevation to geo-reference, and visualization is implemented on a 3-dimension perspective. The fact that third dimension visualization in a GIS environment poses a problem can be resolved by a vertical scale modification.

2.4.1.4. Polygon objects: Estuary morphology and Zone

Spatially, the Estuary object contains measurement locations. The relationship between the Estuary object and location is 1: M. spatially the measurement locations are within the Estuary.

Zone: Polygon object

OBJID	MAPID	Zone	ZoneCode	Londec	Latdec	Lontxt	Lattxt	Eastkm	Northkm	area	perimeter
		Zone	ZoneCode	Londec	Latdec	Lontxt	Lattxt	Eastkm	Northkm	area	perimeter

2.4.1.5. GeoLithology and GeoTectonics: Polygon and Polyline Objects

OBJID	MAPID	Georef no	Londec	Latdec	Lontxt	Lattxt	Eastkm	Northkm	Area	Perimeter	stratgname	lithcomposition
		georefno	Londec	Latdec	Lontxt	Lattxt	Eastkm	Northkm	area	perimeter	stratgname	lithcomposition

GeoLithology: The Lithology object is described by informative attribute such as the lihological composition, rock types, lithologic contacts (boundary lines), stratigraphic name and geo-referencing coordinate attributes. The area and perimeter attributes depicts zone of influence of each rock composition distribution.

GeoTectonic Structure: GeoTectonic Structure entity is described with tectonic fault lineaments. This include the fault direction, dip and strike) along the shear zone. The Results Table was also structured in the same manner to describe and disclose the different relevant attributes.

OBJID	MAPID	georefno	Londec	Latdec	Lontxt	Lattxt	Eastkm	Northkm	trend	strike	strike
		georefno	Londec	Latdec	Lontxt	Lattxt	Eastkm	Northkm	trend	strike	strike

2.4.2. Relationally Structured Entities (RSE)

The Field Data, Campaign data, Disciplines and Results are the relationally structured entities controlled mainly by their own attribute database identifiers. However, they can be geo-referenced via migrating objecteID and related discipline name to generate any spatial object, See figure 2-15.

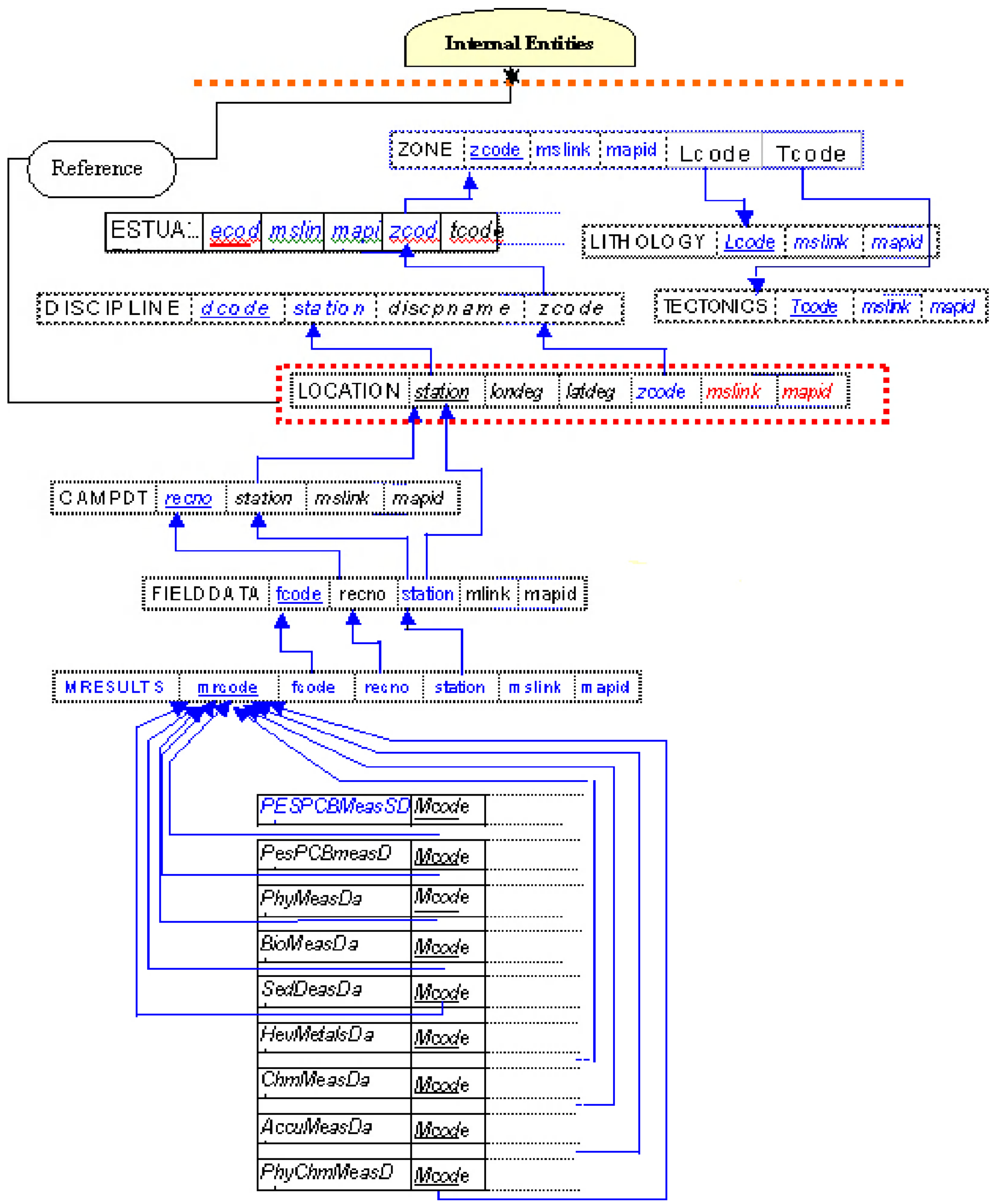


Figure 2-15 Relational structure of UDE

2.4.3. GeoDatabase Cardinality Relationship

	ROLE NAME (DB LEVEL)	ROLE NAME (GIS LEVEL)						
Entity- A	Entity- B	Relationship Name	Cardinality constraint	Mandatory	Geog+ MGE	Arc View	Arc GIS	Map Info
Location	Field Data	Belonging to	1:M	Station	MSLINK	FID	FID	MapInf_ID
Location	Campaign data	Measured on	1:M	Station	MSLINK	FID	FID	MapInfID
Location	Results	Pertaining to	1:M	Station	MSLINK	FID	FID	MapInfID
Location	Zone	Occurred in	M: 1	Station	MSLINK	FID	FID	MapInfID
FieldData	Campaign data	Collected on	M: 1	Fdcode	MSLINK	FID	FID	MapInfID
Fielddata	Results	Processed as	1:M	Fdcode	MSLINK	FID	FID	MapInfID
Fielddata	Zone	Contains	M: 1	Fdcode	MSLINK	FID	FID	MapInfID
Campaign data	Zone	In a	1:M	CampDtCode	MSLINK	FID	FID	MapInfID
Zone	Results	Of	1:M	Zone_code	MSLINK	FID	FID	MapInfID
MAPS	Location	Attached	1:M	MSLINK	MSLINK	FID	FID	MapInfID
MAPS	Estuary	Attached	1:M	MSLINK	MSLINK	FID	FID	MapInfID
MAPS	Lithology	Attached	1:M	MSLINK	MSLINK	FID	FID	MapInfID
MAPS	Structure	Attached	1:M	MSLINK	MSLINK	FID	FID	MapInfID
Lithology	Structure	Sheared by	M: M	MSLINK	MSLINK	FID	FID	MapInfID

Table 2-3 GIS Database Cardinality Relationship

2.4.4. Physical Structure

2.4.4.1. Schema Data Definition

The relatively higher-level representation of the database is defined as a schema or conceptual model. The database tool used to define the conceptual schema is a data definition language or DDL. At the physical level, the data items are defined in terms of parameters such as the number of bytes of storage they occupy and the address at which they are to be found in a physical memory. The physical creation of the entities and the attributes leads to the building of the GeoRelational GIS Database.

The physical definition encompasses –

(a) DDL or DAO for the aspatial, (b) Spatial interface functions for geographic elements and for the Meta data object. The considerations pertaining to (a) and (b) include -

- ➔ Field types
- ➔ Storage space
- ➔ Operations anticipated on the attribute
- ➔ Calculation (numbers OR currencies) not texts or OLE.
- ➔ OLE Object fields for metadata
- ➔ Decide if temporal query sorting (use date/time formats)

2.4.5. (DDL) The data definition language

In a dual architecture GIS, the definition of an ODBC enables database creation and facilitates the creation of a new GIS project connectivity and workspace. The workspace is populated by the system and user defined objects. Thus, establishing Open Data Base connectivity (ODBC) is mandatory to link the external and internal systems (details see chapter 3).

The definition of the attributes data types can be specified in the table design view, query parameter dialog, in visual basic, and in SQL view or within the spatial engine interface.

SQL (*structured query language*) is an access and manipulation language; it is acknowledged as the relational database language, [60]. SQL is a non-procedural, i.e., one need to tell the computer what data is interested to process and view. With SQL, system design specialist, application developers and end users can work together to perform smooth interaction of the application requirements.

```
Create table LOCATIONS (
MSLINK1 integer CONSTRAINT PKMSLINK  PRIMARY KEY,
MAPID INTEGER NOT NULL,
Station1 text (5) UNIQUE,
LonDegTxt text (10),
LatDegTxt text (10),
LonDegDec float,
LatDegDec float,
EastingKm float,
NorthingKm float,
Area float,
Perimeter float,
zone_code1 integer REFERENCES ZONE (zone_code)
);
```

Figure 2-16 Location GeoTable

Out of the many data types, only numeric, textual (char) and date/time data types are defined applying non-procedural SQL's DDL. Otherwise, data such as images, points, lines and shapes can be defined using special graphic programs. However, the procedural method is more secured from the database integrity and security perspective but it requires a database programming knowledge. Both methods were used during the physical design and implementation of the geodatabase, see figure 2-16.

The DDL components of SQL (specific to Access) include:

CREATE, ALTER, and DROP.

The CREATE command syntax.

CREATE TABLE name

(ColumnDefintion), [Multicolumn - Constraint]) [Single-constraint]

ColumnDefintion is column name, followed by a data type (with size if appropriate), and followed by a single column constraint.

Figure 2-16 illustrates the definition of the master table location using the DDL. The MSLINK is a Primary key. It is designed to be an object ID of the feature class table (object). The MAPID is specific to MicroStation Geographics. It is required for spatial connection between the map and database records. The LatDeg and LonDeg are coordinates in different formats. Area and perimeter are specific for polygons but are incorporated with alternatives formats and the Easting and Northing are coordinates in map units.

```
create table CAMPDATE
(
Dtcode integer CONSTRAINT pkDtcode PRIMARY KEY,
MSLINK integer,
mapid integer,
Station text (6) REFERENCES Location (station),
Samp_date date,
Samp_time_st date,
Samp_time_e date
);
```

Figure 2-16 CampDate GeoTable

In the Campdate table, the MSLINK (definition of CampDate) is a migrated key from the location feature class whereas the temporal data were collected. The MAPID and station have the same context as the description of table location. The samp_date, samp_time, samp_time_e, and samp_time_St are the temporal parameters (see figure 2-17).

```
create table RESULTS(
MSLINK integer REFERENCES MSLINK (LOCATION),
mapid integer,
zone_code integer REFERENCES ZONE (ZONE_CODE) ,
Station text (6) REFERENCES LOCATION (STATION),
Dtcode integer REFERENCES campdate (dtcode),
Field_code TEXT (6) REFERENCES FIELD (field_code),
Parameter text (15),
Meas_doc text (25),
Meas_doc text (25),
Pract_value float,
Pract_unit text (6),
Precision float,
Samp_depth_m float,
Echo_depth_m float,
Meas_code text (15) CONSTRAINT Pkmcod PRIMARY KEY
);
```

Figure 2-18: Results GeoTable

The temporal attributes pertaining to table CampDateData references the feature table LOCATION so that spatial information retrieval can also be interpreted with respect to temporal aspects.

The definition of Measurement Result table is described by multidisciplinary attributes. All the other tables are made to indicate the pointers towards this table. Thus, all the marine information stored in the other tables can also be reference.

2.4.5.1. Indexing Tables (non procedural)

CREATE INDEX command is described by the following syntax.

Create [unique] index Name

On TabName ([Colname) [asc/desc)

[With (primary) ~disallow null or ignore null)]

Where the ASC and DESC stands for ascending and descending

Illustrating the creation of GeoRelational indices:

Create Unique Index LocationIndex on Location (Mslink, Station, and Asc) With Primary;

Create Unique Index Fielddataidx on FieldData (Field_Code) With Primary;

Create Unique Index Resultsidx on Results Meas_No) With Primary;

Indexing can be executed on a single column or in concatenated columns. Indexing an elected field(s) in a table is quite important for speeding up access and queries on the indexed fields, sorting and grouping operations. See appendix A, for the full-fledged geodatabase structured data definitions.

2.4.5.2. Enforcing Index and Uniqueness

Enforcing Index and Uniqueness is applied to guarantee that a column or combination columns is unique for every row in the table. A UNIQUE key word is used to enforce the information integrity. Indexing a mandatory spatial pointer enhances the retrieval process in general but may slow the updating.

Searching spatially geo-referenced records, either for tabular display or thematical visualization based on the attribute values associated with the geographic objects is better done by creating an index on the ObjID with Primary key restriction. Furthermore, besides the SQL DDL indexing procedure, DAO (Data Access Object) was implemented to index the specific mandatory field of the GIS tables (figure 2-19).

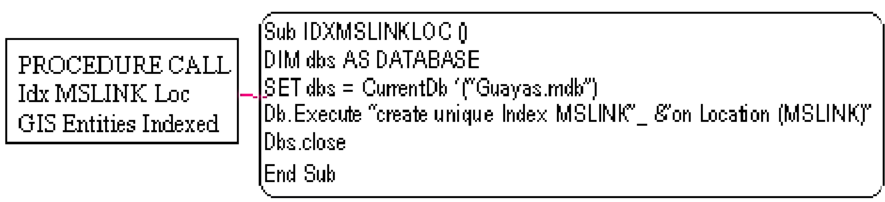


Figure 2-17 : Enforcing an Index

Example, the following procedure creates an index on the Location Object mandatory ObjID known in this cases study as MSLINK. The dimension database is defined and is set to the database which is being active and is opened by the set dbs = OpenDatabase ("guayas.mdb"). This is followed by the db.execute to create the index with primary, ignore null, or unique…. In order to perform the indexing on all the selected tables, the procedures are called from a single command button interfaced within the attributed database.

2.4.5.3. Enforcing Referential Integrity

The *Relation object* provides information to the underlying database engine about the relationship between fields in two entities [34]. *For* instance, the relation object implements the referential integrity between the LOCATION and MAPS objects as follows.

```
• Sub UGMAPLOC ()
• Dim dbs As Database
• Dim rel As Relation
• Dim fld As Field
• Set dbs = CurrentDb
• Set rel = dbs. CreateRelation ("UGMAPLOC", "UGMAP", "LOCATION")
• 'Set referential integrity with cascading updates
• Rel.Attributes = dbRelationUpdateCascade
• 'Set referential integrity with cascading delete
```

```
• Rel. Attributes = dbRelationDeleteCascade
• 'Specify the a key field in referenced table
• Set fld = rel. CreateField ("MAPID")
• "Specify the a foreign field in referenced table
• fld. ForeignName = "MAPID"
• 'Append field object to field collection of rel
• Rel.Fields.Append fld
• 'Append rel objects to rel collection
• Dbs.RELATIONS .Append rel
. End sub
```

Figure 2-18 : Enforcing Referential Integrity

Referential integrity is designed to implement a set of rules established to preserve relationships between tables whenever a change occurs on the GeoRelational database. Enforcing referential integrity disallow users from adding records to a connected table for which there is no principal key, changing values in a primary table that would result in orphaned records in a joined table.

2.4.6. The data Manipulation language (DML)

Data Definition and management manipulation usually go hand in hand. Once a GIS database is physically structured then, it is the turn on testing the system by creating tools of data manipulation language (DML) related to a hybrid object relational query methodology.

Typically, this will be accessible from an application program in the form of special purpose procedures, which allow an interactive dialog with the database management system. A command in the DML allows a user to retrieve specific data items that matches certain retrieving criteria. In the absence of matching field criteria, objects are used to establish relationship and create spatial information by intercalating spatial operators in the s object relational query.

The most common DML on the attribute database part include commands such as SELECT, UPDATE, UNION, DELETE, INSERT INTO, SELECT INTO, TRANSFORM and PARAMETER in the world of RDBMS, whereas this process is altered in the Georelational information extraction procedure. It includes the spatial operators such as the INTERSECT, UNION, CONTAIN, DISTANCE OF, etc., associable with the SQL proper during spatial operations.

However, before getting into manipulating the GIS database, the structured database must be populated appropriately. The following populating methodology are designed and implemented during the research work.

2.4.6.1. Populating Procedure

1. ***Automated loading (Macro)***
2. ***Importing textual data***
3. ***Selecting from a database pool.***
4. ***Data loaders (Oracle)***

1) Automated loading (Macro)

a. *An action macro defined to import textual data (Spreadsheet)*

b. *Action: Transfer Spreadsheet*

c. *Transfer type: >Import*

d. *Spreadsheet type:> format or application*

e. *Structured table name: Location*

f. *File name: drive:\x\x1*

g. Field names (y/n):> yes

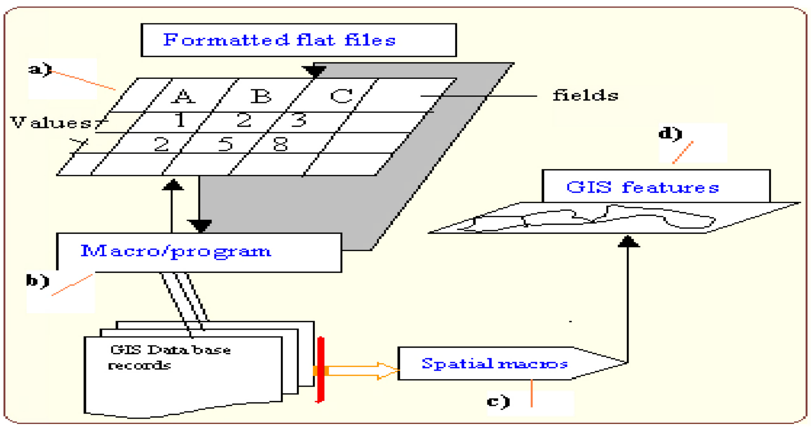


Figure 2-21Populating Process

The steps applied to achieve figure 2-16 are -

Formatting raw data or retrieving from a structured geodatabase

Establishing a populating program

Spatial function to manipulate the spatial objects

Accordingly, the data in a remote location (flat file or geodatabase) is populated into the target table at any time by clicking a loading command button attached to an interfaced macro.

2. Importing textual data

The importing of external data is rather specific to a database wizard application. The external data could be directly imported into the database or linked. However, linking will not allow the database to be modified.

3. Selecting from a database pool: Query Database data pool

<u>Syntax</u>

- *Insert into A (a1, a2, a3…) (a1…an are attributes of A)*
- *Select (b1, b2, b3.) from B (b1…bn attributes of B)*
- *Where A.Id (all possible operators);*

The above syntax indicates data extraction possibility from a source table (TbB) to an empty structure table (TbA). For instance, it is possible to create different structured tables from a single table that contain completely heterogeneous attributes information together.

2.4.6.2 Select Statement

The SELECT statement is the workhorse of the SQL commands.

It can return a table and perform the relational algebra SELECTION and PROJECTION.

SELECT: denotes the relational algebra operation of Projection and the WHERE performs the Selection. The predicate indicates the handling of the duplicate return rows.

ALL: (distinct, distinctrow) return the entire column description and the distinctrow return unique records not unique value. Therefore, if we have attribute name named as station with data item in 1, in ten records the distinctrow returns all the ten unique records with data item 1 record. To avoid the duplicate value the three characters of the Key word (*DISTINCTROW*) are removed and returns unique values.

FROM TblExpression: The FROM clause specifies the tables or queries from which the SELECT statement is to take its rows. The TblExpression can be a single or more tables separated by commas or joins.

WHERE Row Condition: any expression such as the attribute names, constants, arithmetic expression such as (>, =.... BETWEEN) and logical (AND, or, XOR, not as well as functions and relations) e.g., LIKE, min (attribute name)…etc.

GROUPBY CRITERIA: The group by criteria allows records to be grouped together for computing the value of an aggregate function, (Avg, count, min, max... etc), (see figure 2-23a).For instance, the group by function is very important, especially to relate the spatial table or associated table with RSE. It returns results corresponding to the spatial entity. The result retrieved can be spatial and thematically visualized in an associated feature table.

HAVING Group Criteria: - The having option is used in conjunction with group by option. It allows the query to specify criteria in terms of aggregate functions for deciding which data to display. It is shown that the

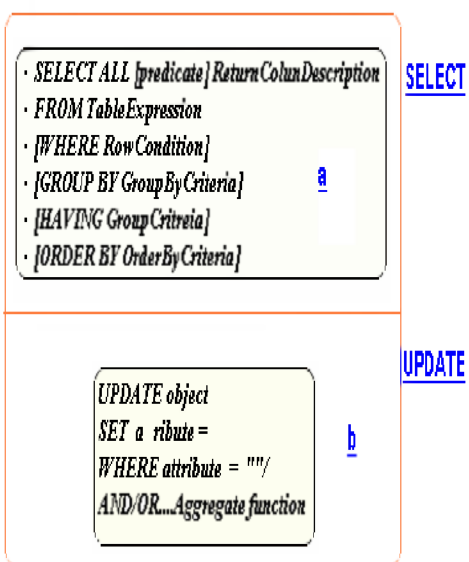


Figure 2-22 The SELECT and UPDATE

WHERE clause restricts the number of attributes or columns that participate in the grouping, and hence contribute to the value of the aggregate functions, whereas the HAVING clause affects only

the attribute values to be displayed. ORDER BY option sets the default sort order of the database records. Likewise, spatial operators are applied on spatial operations to retrieve and perform spatial analysis using the spatial operating tools.

2.4.6.3 Updating Database

An updateable Table enables us to change and edit the content of the GIS database and any change is reflected on the underlying GIS tables. Updating is important especially when the GIS databases develop through time and a change is required (see figure 2-23b.

The possibilities of updateable tables depend on the conceptual relationship of the entities and the possible definition of enable cascade update. If the query is mainly based on a single table or, in a one to one relationship then there is less difficulty compared to a one-to-many relationship. The Cascade Update Related Fields must be updated to execute the changes.

2.5 Results and Conclusions

Designing an endurable and flexible Geodatabase system requires conceptual structuring of the geodata model. This depends on the extent of understanding clearly a targeted problem and time allocated to perform a sequence of Design and Implementation tests; this process has been done during the conceptual and physical design of the geodatabase model.

The Construction and Integration of the coastal zone Multidisciplinary Geo-Relational data model have been founded on object relational and the conceptual entities were represented using information structure diagrams (ISD).

Data Definition Language was applied to the physical GIS database creation and implementation.

The objects-pointers have been hooked to the relationally structured entities (RSE) to achieve the assimilation of geographic objects with attribute database records.

Amalgamating process has been implemented to avoid redundant Measurement Result entities belonging to different disciplines. This has been achieved by de-normalizing the normalized entities. The principle facilitated the mechanism of interacting objects and performs spatial analysis at the phase of spatial information mining.

Chapter 3: Building the Spatial Database

3.1 Introduction

Design of a GIS project can be done with little hindrance if there is a fair understanding of what the specific GIS project is comprises of and how it should be structured. Grasping this notion serves as bases for creating a powerful spatial database development environment for management, analyses and visualization geographic information system.

3.2 GIS Data Flow

Globally, the construction of Geographic Information System is based on two types of data, coined as Non Spatial (Aspatial) and Spatial (see Figure 3-1, I and II). Aspatial data are the characteristics that describe the spatial elements. Spatial data are any information about the location and shape of, and relationships among geographic features [25]. The non-spatial data are attribute data source for the data model and are structured and created before being integrated with the spatial objects in a dual object relational system.

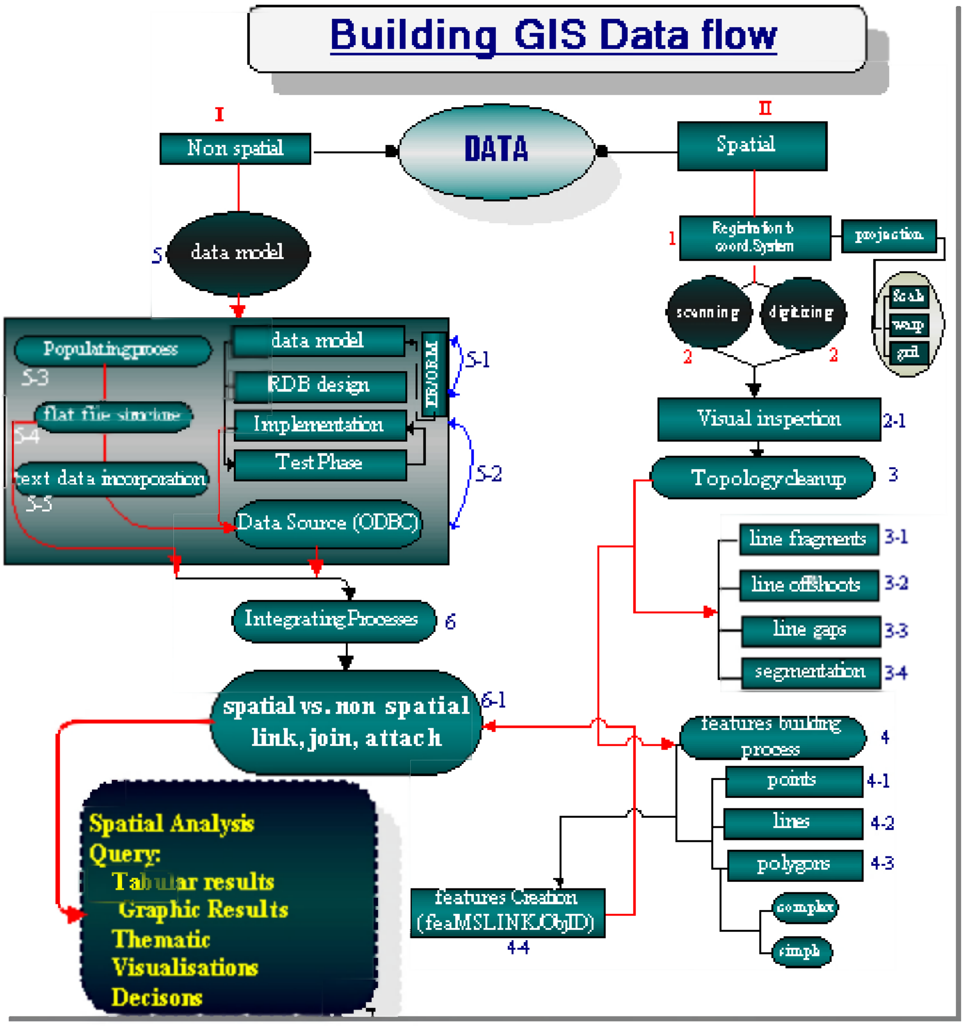


Figure 3- 1 Building GIS data flow diagram

Otherwise, the spatial data can be of raster (scanned paper or remote sensing image) or vector origin. One mandatory process required during the building of the spatial database is registration of the maps or assemblage of features with an appropriate projection system relevant to the specific area.

During scanning process, the data is stored as pixels form, which divides the imaged into regular grid structure of rows and columns. Each cell within this matrix contains an attribute value as well as location co-ordinates. Vector features are those geographic elements, which can be generated by tracing an image. Vector features are comprised of points, lines and polygons. All lines have a beginning and ending points (vertices). Space required by vector elements is less than that of raster. Once a feature is stored in the system, then anything outside is non-existing space.

Referring to figure 3-1,vectorised data require a visual inspection (step 2-1) to identify areas of interest and target features. The data generated in step 2 and visualized in step 2-1 are subjected into topology clean up processes (step 3), specially in the aftermath of digitizing, where so many undesired line fragments, line offshoots and gaps…etc., are produced, (see figure 3-1, steps3-1 to 3-4). Once laborious process of topology operation is accomplished, then the geometric elements are processed to produce associated geographic features, using appropriated spatial tools or spatial functions.

For instance the spatial function: - Place Point (X1, Y1) Values (_, _) creates a point by providing the coordinates. Likewise, the attaché spatial function would prompt geographic object to be attached with database record. Also a point feature table can be updated to create a line feature as follows- Update MYpointtable set Obj = createline (StartX, StartY, EndX, EndY)

The object building coordinates are stored within a feature table (see figure 3-1, step 4). Feature tables are distinguished from attribute tables in that the feature table represent object and object identifiers (see figure 3-1, step 4-1). Once step 4-1 is accomplished, the process of spatial and aspatial integration can be executed provided the geodatabase structuring process (data modeling) is completed. If not then step 5; process of data model (attribute data) is completed by executing (see figure 3-1, steps 5-1 and 5-2), which are based on constraints established using information structure diagrams and physical creation of the attributes within the database.

Note: A quick creation of GIS can be achieved by populating georeferencing-bearing data (see figure 3-1, step 5-4 and 5-5) utilizing the integration process (see figure 3-1, step 6, 6-1). However, a stable and well-organized GIS involves the populating of the data (see figure 3-1, step 5-3) to the data source or database (see figure 3-1, 5-2) then after, step up the integration (see figure 3-1, 6, (6-1) of linking and association of the database to spatial elements.

The procedures of integrating (step I) and (step II), using (see figure 3-1, step 6-1) encompass the application of a spatial interface and spatial analysis tools. Results of the integration are expressed thematically and visualized spatially. The eventual output is employed in a crucial decision-making about the issue being explored (see figure 3-1, step 7)

3.2.1 Feature set up building Components

Spreading the multiple features pertaining to a single Category, for instance as implemented in this PhD research work, defined as the Marine Map or Geology over many levels is quite important for the spatial data management pre to the feature set up, defining features, category specification, assigning symbology to geographic object type is a essential.

Figure 3-2 depicts a typical data flow diagram of the GIS feature setup.

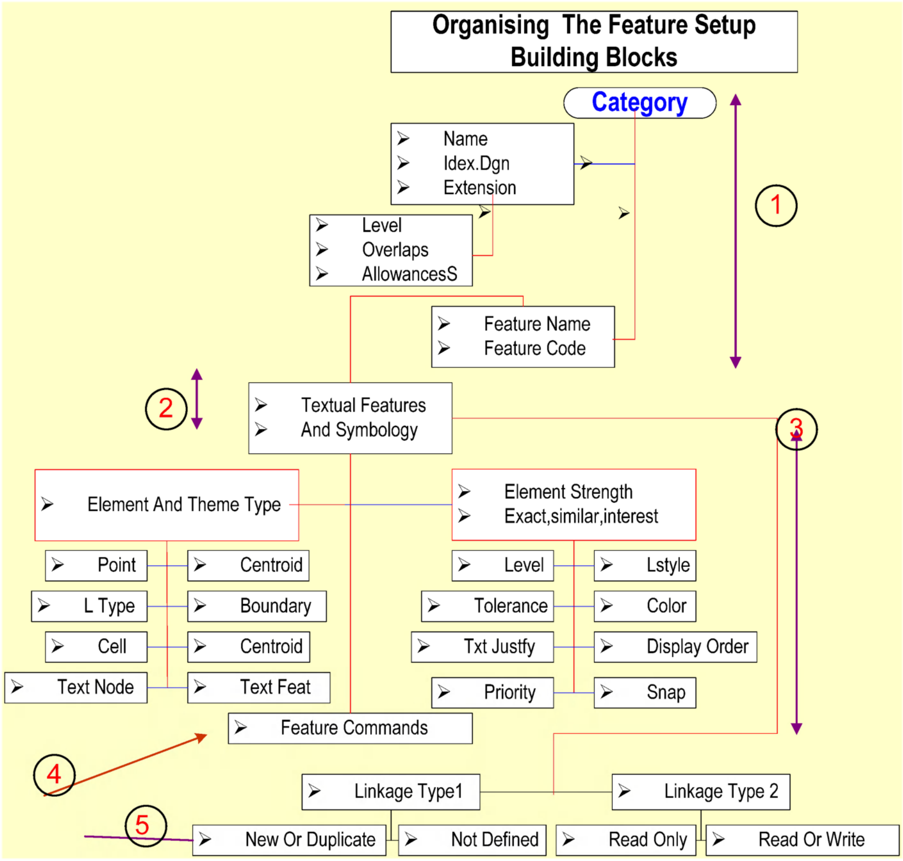


Figure 3- 2 Feature set up data flow

Referring to figure 3-2: -

→ (Figure 3-2, 1): - The Category is described by its own properties of the seed file type (map), its index, extension of the map to be generated. The different extensions related to the Category are used to distinctly differentiate maps in the GIS (as dgn, tab)…etc). The overlap is exploited for the possibility of importing other GIS projects to the existing GIS system and the level indicates the position of the category as distinct from the pertinent features.

→ (Figure 3-2, 2): - The assignment of the textual description and symbology is used to distinguish the feature types by their respective properties. The element and thematic type represent the objects to be attached spatially and the bounding elements.

→ (Figure 3-2, 3): - displays properties of the features, for instance, a point of centroid type can be associated to its boundary to generate a spatial extension of the associated database records.

→ (Figure 3-2, 4): - Different features can be distinguished by level, style, and color and feature command. Duplicate records are controlled by linkage type and the read/write type is specified with respect to the feature class table. The whole components defined in the hierarchical data flow diagram are properties of the special working system files, which are designed to be associated with spatial data source of the user and store the main tables that directly engaged with the spatial analysis and management of the spatial information.

3.3 GISs project structures

Different GIS applications have different structures. As an example1, the GIS project of MicroStation Geographics [11] is composed of Mscatalog, category, feature, *maps* and feature-command (SGEs) (see figure 3.2). Spatial and aspatial attributes creation and a linkage are committed within the project. As an example2, In an ArcView GIS (3.2a) [21], a project contains all the view, tables, charts, and layouts and scripts that used for a particular project work. A view defines the geographic data that will be used for spatial analysis. The step-by-step process of building GIS project is explained bellow.

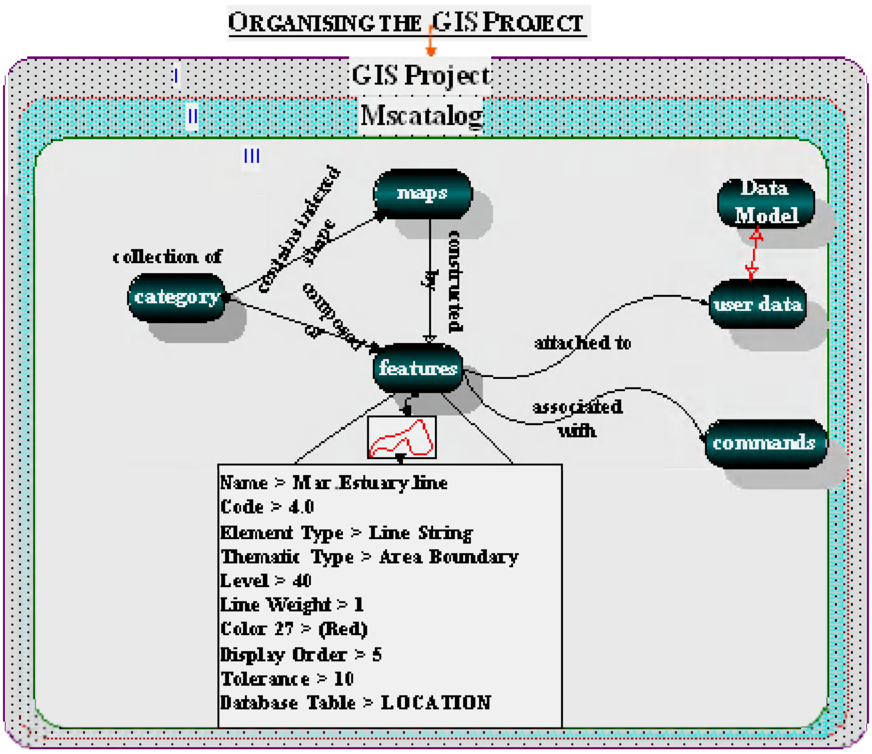


Figure 3- 3 Project specific to MicroStation Geographic and MGE GISs

3.3.1 The Spatial Components Work Space

3.3.1.1 Spatial components

Category: - is an assemblage of related features and is distinguished by specific extensions. For instance, the Marine maps category described by a map extension of the .MAR. The Mar.Estaury.centroid is feature description belonging to that category (see table 3-1).

1) Marine Maps (.MAR is an extension the marine maps)

2) Geology (.GEO is an extension of the geology maps)

Marine Map: composed of all the measurement Location features, all concerned with measured multidisciplinary data inside the estuary. Feature describing the measurement location belongs to the Marine Map category. Each category posses a specific level and is associated with an index shape (see figure 3-2, step 1) pertaining to a specific feature and that index corresponds to a map composed of a related features, whereas the Geology map is mainly composed of Geolithology and Geotectonic Features. Table 3-1 portrays the composition of the marine map.

Table 3- 1 Marine Map Category

CATEGORY MARINE MAP

SPATIAL ATTRIBUTES	NON SPATIAL ATTRIBUTES
mar Estuary.ObsPnt	Lat, lon, elevation
mar Estuary.label	GeoRefNo
mar Estuary.LocArea	area(zonal influence)
mar Estuary.LocBndy	Perimeter …

Features: - are graphic elements representing real world objects with a defined symbology and element types. A user defined feature Entity is defined with feature-name, code and category before it is associated to relevant database records. The features' textual descriptions (see table 3-2) are defined in the project spatial interface but stored in a RDBMS. On the other hand, the spatial objects (points, lines, polygons or shapes) are defined and stored within the GIS application [11].

Feature textual description	Possible sp elements
Multidiscipline measurement positions	Points and labels
Measured parameter distribution zones	Areas/polygons
Sheared zones	Areas / polygons
Lithology boundaries	Lines, areas/ polygo
Estuary boundaries	Areas/polygons
Tributary axis	Lines
Islands	Areas / polygons

Table 3-2 Feature Description and Related Geographic Elements

Feature commands: - Spatial functions, inbuilt specific to a feature type operation. A feature command of a line feature is different than a polygon command.

3.3.1.2 Work Space and Connectivity

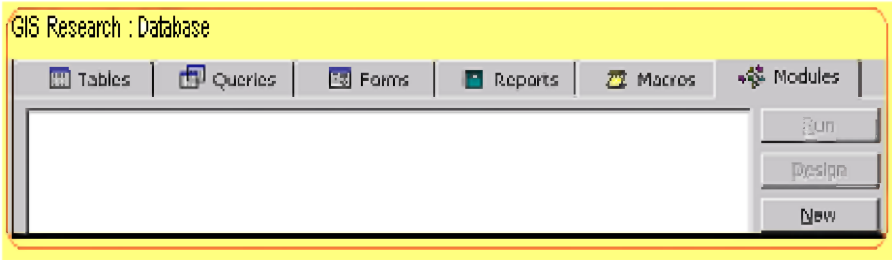
-Creating a new GIS project requires (dual GIS) connectivity between applications. Creation of Open Data Base connectivity (ODBC) is mandatory to link the RDBMS engine and the Spatial GIS engine.

Creating the workspace: ***Step 1***

Mandatory: (Version) > Define: Data source name > Set up: login/pw > Set up: path and dir> Execute

New empty geodatabase (personal geodatabase) workspace created (see figure 3-4).

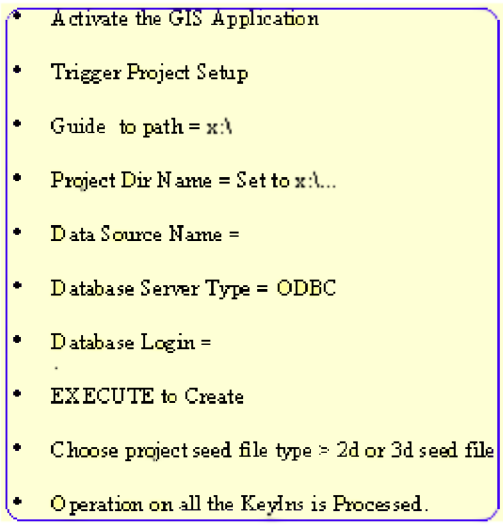
Figure 3-4 ODBC Specification



The workspace is populated by the system (GIS geographic, MGE and user defined tables. In the Case of the ArcView GIS, only the user-defined tables (UDEs) are stored in the database. SQL connect is used to link to the spatial engine (ArcView).

GIS Features Generation: ***Step 2***

Figure 3-5 Project Setup (MicroStation Geographics)



Eventually the system tables generated from within the GIS application are populated in the geodatabase workspace (see figure 3-6). From then on, they are available to be processed spatially in any GeoRelational GIS environment.

Figure 3-6 Populated Geodatabase work space

3.3.3 Features definition

Definition and implementation of the feature elements or geographic objects attributed to the user-defined feature entities is carried out in the feature set up interface. It is equipped with push button tools [Insert, Update, Delete Commit, and Rollback] and list box, which enable define categories, features and feature commands [1].

Insert - Key-in: FOCUS INSERT create a new category, feature, or command by adding a new row to the specified database table and populating the new row with data determined by user selections in the settings box.

A macro tool, MicroStation basic extension program is used to generate the category, type of file, map extension and level of the category (see figure 3-7). More over the FOCUS UPDATE, focus DELETE and COMMIT and ROLLBACK are applied to update, commit and undo feature operations respectively.

```
1.  Sub main
2.  Dim startPoint As MbePoint
3.  Dim point As MbePoint, point2 As MbePoint 'set variable ass
4.  MbeSetAppVariable "MAPADMIN","catInfo.name", "geology'
5.  MbeSetAppVariable "MAPADMIN","catInfo.idxfile", "dgn"
6.  MbeSetAppVariable "MAPADMIN","catInfo.ext", "geo"
7.  MbeSetAppVariable "MAPADMIN","catInfo.lv", 45&
8.  MbeSendCommand "FOCUS INSERT"
9.  MbeSetAppVariable "MAPADMIN","feaInfo.code", "01"
10. MbeSetAppVariable "MAPADMIN","feaInfo.name", ' Geology
11. MbeSendCommand "FOCUS INSERT"
12. MbeSetAppVariable "MAPADMIN","feaInfo.etype", 3&
13. MbeSetAppVariable "MAPADMIN","feaInfo.ftype", 4&
14. MbeSetAppVariable "MAPADMIN","feaInfo.lv", 15&
15. MbeSetAppVariable "MAPADMIN","feaInfo.dprio", 10&
16. MbeSetAppVariable "MAPADMIN","feaInfo.prio", 20&
17. MbeSetAppVariable "MAPADMIN","feaInfo.wt", 6&
18. MbeSetAppVariable "MAPADMIN","feaInfo.co", 3&
19. MbeSetAppVariable "MAPADMIN","feaInfo.tname"," Geology
20. MbeSetAppVariable "MAPADMIN","cmdInfo.name", "PLACE
21. MbeSetAppVariable "MAPADMIN","cmdInfo.keyin", "PLACE
22. MbeSendCommand "FOCUS INSERT"
```

Step 1: define main
Step 2 –3 declare Variables
Step 5-8 Commands for the Categories
- Step 9-22 Setting the commands for loading the feature name, its code, category, symbology and feature commands applicable during geographic elements processing
Step 23 end of the program

Figure 3-7 Generating the Marine Map Categories and related features

Referring to figure 3-8, the populating of the category and related features is described as follow: -

Name>> the name of the selected category.

Extension>> the category name's extension. (3 letters)

Index >> the name of the category's index file

Level>> The MicroStation level that contains the index shapes.

Level used by the active category) highlighted.

Allow Foreign>> If on, permits the selected category to contain features belonging to other categories.

Overlaps>> Indicates that the index polygons for maps in the category may overlap.

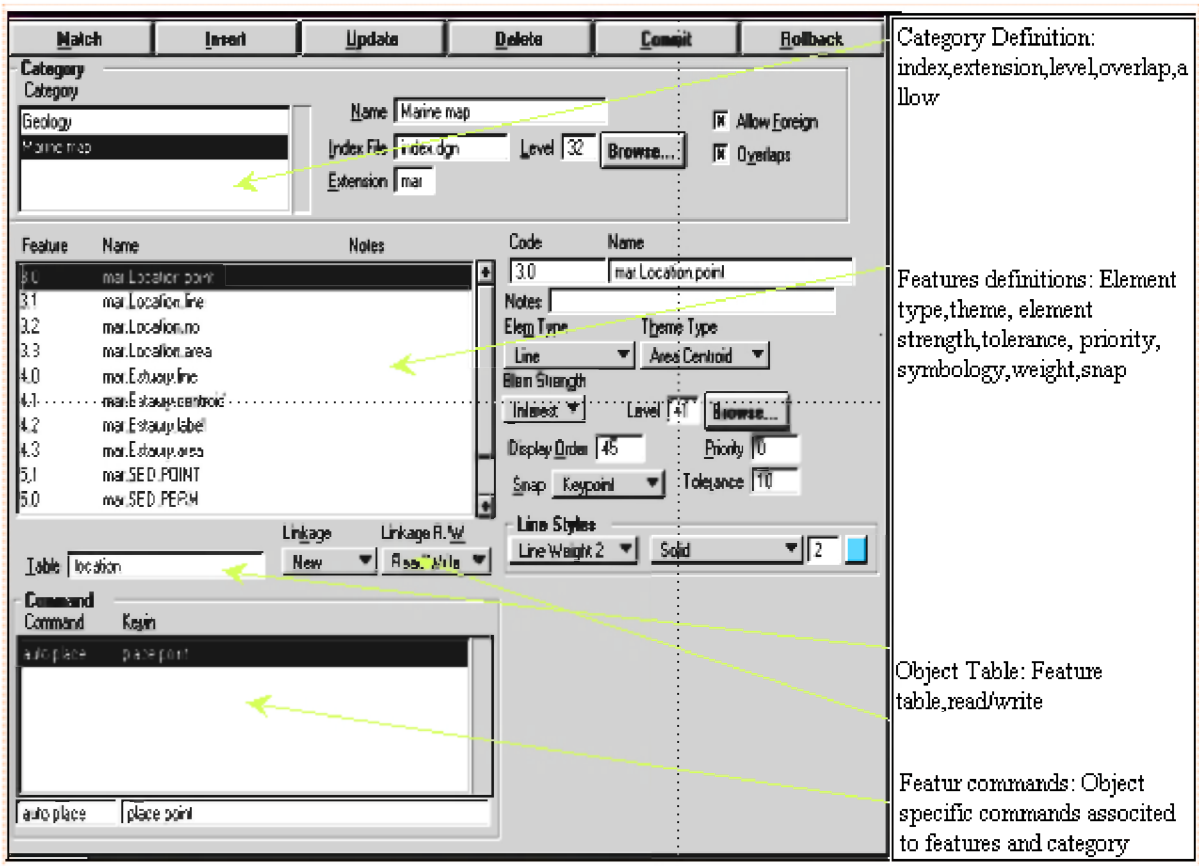


Figure 3-8 Categories and Features Definitions (Geographic GIS)

3.3.3.1 An Active Feature

The purpose of feature definition is critical since it is at this phase that the GIS features are decisively defined and implemented. Any structured database record of the project is to be associated with these spatial elements. A feature represents an object. It has its own descriptive symbology and usually contains descriptive information. Category Marine Map is triggered and its attributes are defined in space provided as features (see figure 3-9)

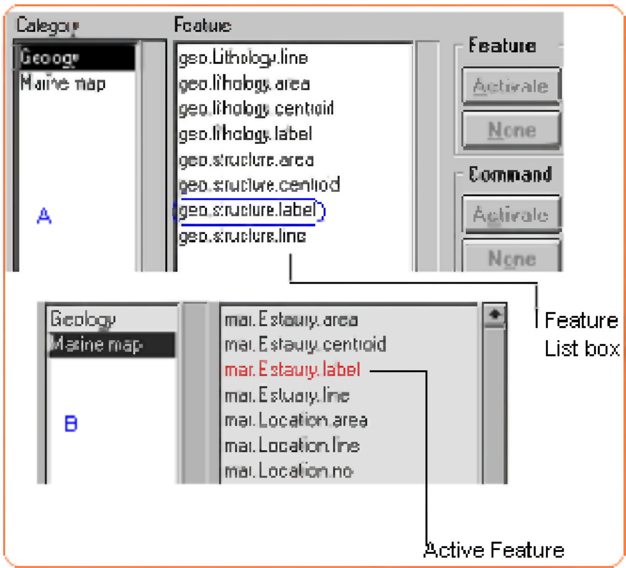


Figure 3-9 An active Category and Related Features

An active feature can be displayed for association process by triggering the category list. Selecting one of these will populate the Feature list box with the features pertaining to the category, see figure 3-9.

The textual features describe the Geographic objects, which would be linked to geometric objects. These Geographic objects references could be shapes, ellipsoid, point's lines and also texts.

CATEGORY GEOLOGY

SPATIAL FEATURES	NON SPATIAL ATTRIBUTES
geo.Lithology.centroid	Lat, lon
geo.Lithology.label	StationCode
geo.Lithology.area	area
geo.Lithology.boundar	Perimeter …

SPATIAL FEATURES	NON SPATIAL ATTRIBUTES
geo.Stru.point	Lat, lon
geo.Stru.label	GeoRefNo
geo.Stru.ShearedArea	area
geo.Struc.ShearedZone	Perimeter …

CATEGORY MARINE MAP

SPATIAL ATTRIBUTES	NON SPATIAL ATTRIBUTES
mar.Location.point	Lat, lon, elevation
mar.Location.label	StationCode
mar.Location.area	area (zonal influence)
mar.Location.line	Perimeter …

SPATIAL ATTRIBUTES	NON SPATIAL ATTRIBUTES
mar.Estuary.ObsPnt	Lat, lon, elevation
mar.Estuary.label	GeoRefNo
mar.Estuary.LocArea	area (zonal influence)
mar.Estuary.LocBndy	Perimeter …

Table 3-3 The Coastal Periphery and Main Estuary feature descriptions

3.3.3.2 The spatial Features' methods and properties

1) Element Type - the real world object feature e.g., LString, line, shape…etc.

2) Thematic Type- describes the spatial features visualization

3) Element strength- associability with related feature types

The steps (1-3) are crucial for later feature translations and interoperability among GIS applications (see chapter 6).

3.3.3.3 Element Type Validation

Setting to Interest - enables the designated Category-feature to be attached to any element

Setting to Similar- enables the designated feature to be attached to the option shown on Element Type

Setting to exact - enables the designated feature to be attached only to the element type option shown on **Element Type**. This is the same as defining an attribute as integer data type but trying to insert a non-integer value. That is what is termed as data validation rules. Defining clearly the feature type at this level facilitates the thematic resymbolisation.

- Theme Type- identifies a feature's topological type.
- Point Feature - identifies the feature as a point.
- Line Feature - identifies the feature as a linear element.
- *Text Feature* - identifies the feature as a text element. Used only when element type is set to a text.

Setting boundary: Boundary - identifies the feature as a linear element, implying that such features will obey topological rules

Setting Centroid - identifies the feature as a topological centroid. The associated element type can be a cell, point, or text type. The centroid feature is to be linked or joined to a unique database row whose attributes apply to the surrounding topological area.

Setting Label Features - text elements linked to a database row.

Display order: - Feature tags with low number display first than those with high number. Higher numbered features display on top of lower numbered. Hence, layers of maps can be visualized according to the defined order number. *Fence Sort Display* keyed in can display features in a sorted order during a thematic display operation.

Feature Table: - Feature table with database records identifiable by featureID Linked *to Centroid* where the centroid is associated to the area boundary feature. This object is also composed of all the possible categories and related feature descriptions describe every geometric object during any process of spatial analysis. The feature table is characterized by the each feature code that applied to distinctly identify any object and associate information. The feature codes are related spatially to the respective categories.

Referring table 3-4, the category (feature table location) is related to the feature codes – 3, 3.1, 3.2, 3.3, referring to the *Mar.Marine.Line, Mar.Amrine.Point, Mar.Marine.Area and Mar.Marine.No*. Furthermore, the feature type, feature level, feature color and feature weight are the symbology of every geographic element described by the respective feature table.

The feature length, feature weight and tolerance are defined to a specific feature type. The location feature table represents, multiple disciplinary measurement location and is point a feature type. On the other hand the Lithology and tectonics feature table with information related to the coastal or periphery of the main estuary.

The sed feature table is one of the measured result feature tables for sediments. On the left side of the table, 3-4 is an attribute named MSLINK. This is a unique feature identifier is generally generated by the spatial application during feature creation.

Mslink	Feat code	Feature name	Category	Table name	Feat type	feat level	Feat. weight	Feat color	Digcmd	Feat element	Feat angle	Feat height	Feat width	Snap tolerance
34	3	mar.Location.point	5	location	4	41	2	2		3	0	0	0	10
35	3.1	mar.Location.line	5		3	43	0	52		4	0	0	0	10
36	3.2	mar.Location.no	5		5	47	0	5		17	0	0.5	0.5	10
37	3.3	mar.Location.area	5		97	49	0	6		6	0	0	0	10
38	1	geo.Lithology.line	4		3	12	0	46		4	0	0	0	10
39	1.1	geo.lithology.centroi d	4	Lithology	4	14	2	12		3	0	0	0	10
40	1.2	geo.lithology.label	4		5	16	0	0		17	0	0.5	0.5	10
41	1.3	geo.lithology.area	4		97	20	0	0		6	0	0	0	10
42	2	geo.structure.line	4		3	24	0	32		4	0	0	0	10
43	2.1	geo.structure.centroi d	4	structure	4	26	2	15		3	0	0	0	10
44	2.2	geo.structure.label	4		5	28	0	15		17	0	0.5	0.5	10
45	2.3	geo.structure.area	4		97	30	0	0		6	0	0	0	10
46	4	mar.Estuary.line	5		3	40	0	246		4	0	0	0	10
47	4.1	mar.Estuary.centroi d	5	Estuary	4	42	2	4		3	0	0	0	10
48	4.2	mar.Estuary.label	5		5	44	0	15		17	0	0.5	0.5	10
49	4.3	mar.Estuary.area	5		97	46	0	246		6	0	0	0	10
50	5	mar.sed.perm	5		3	34	1	7		15	0	0	0	10
51	5,1	mar.sed.point	5	sed	4	33	1	7		3	0	0	0	10
52	5.2	mar.sed.station_no	5		96	35	0	7		17	0	1	1	10
53	5.3	mar.sed.area	5		97	36	0	0		15	0	0	0	10

Table 3-4 GIS building Categories and Textual Features description

Ugcommand_table: - each defined feature is associated to a specific feature command name and a command key in. For instance, the *AUTO COMMAND* for the features *mar.Location.Point and mar.Location.Label* is *PLACE POINT and* PLACE *TEXT* respectively, see Table 3-5A.

Feature	Cname	Keyincmd
34	Auto Place	Place Point
35	Aoto Place	Place Lstring
36	Auto Place	Place Text
38	Place	Place Lstring
39	Place	Place Point
40	Place	Place Text
42	Place	Place Lstring
43	Place	Place Point
44	Place	Place Text
46	Place	Place Lstring
47	Place	Place Point
48	Place	Place Text
50	Place	Place Circle
51	Place	Place Point

A) feature Command

The maps table is designed to store the different GIS maps belonging to specific categories(4 and 5). Every map is composed of one or more features and is identified by its feature id (table3-4) whic is referened by the category in a one to many. Every feature is respon ds to a particular feature commands keyin, e.g, place point places a point on the Location.loc in the maps table.

Mslink	Category	Mapname
1	4	Lithology.Lit
2	4	Structure.Str
3	5	Estuary.Est
4	5	Location.Loc
5	5	Sed.Sed

B) Maps table

Table 3-5 (A) Feature Command (B) Maps table

The feature value is related to the Mslink of the features table (see table 3-4). This process of allows us to assign every feature a geometric indexing key i.e. the MSLINK. MSCATALOG TABLE: The GIS application requires a data dictionary table that stores and references all GIS building block entities.

Tablename	Entitynum
Category	1
Feature	2
Maps	3
Location	4
Lithology	5
Structure	6
Estuary	7
Results	8
Campdt	9
Field	10
Geology	11
Sed	14

The mscatalog is designedto store spatial engine recognsable entities and entity numbers. Any entity not in mscatalog is not available for manipulation and viualisation. Every entity is also stored in the system ugtable_cat with its respective primary key defined and UST code as 1. The alias is used for SQL retrieval process.

Entity name	Alias	Primary Key	Comment	UST
Lithology	Lt	MSLINK	Rock Types	1
Location	Loc	MSLINK	Measured Locations	1
Campdt	Cam	MSLINK	Date Of Measurements	1
Results	Res	MSLINK	Measurement Results	1
Sed	Sed	MSLINK	Measured Sediments Rate	1
Structure	Str	MSLINK	Coastal Tectonic Structure	1
Associated with features	For Sql Select Construct	Pointer (pk-mslink)	Descriptive Information	Graphic Link Indicator

A) Mscatalog B) Ugtable_Cat

Table 3-6 Mscatalog table and Ugtable-cat

Mscatalog: - Is composed of two mandatory attributes (*Tablename* and *entitynum*) while it generates automatically during the project creation. It is mandatory system table used to store in system tables. Implicitly, any table that is not incorporated in the Mscatalog could not be recognized by MicroStation geographic specific. The Ug_Table_Cat: - It is use to store the names of the objects associated to the GIS project and the spatial pointers that implement the linkage of attribute and graphic elements.

3.3.4 Integrating the GIS Entities

3.3.4.1 Interoperability

*The definition of the f*eatures in feature setup interface, utilizing feature transactions tools generates an exportable file (.EXP). The .EXP contains all the information stored in the GIS Project geodatabase. This extension is utilized to perform two types of linkages.

Perform feature description vs. spatial element linkage and (B)-Perform spatial elements (accomplished in A) vs. structured database records association. The first process enables us to label and identify any geographic object.

The second linkage is used to assimilate certain structured tabular information with the geographic elements by means of spatial functions (for instance the attach or detach function).

From the on, the associated object information can be spatially retrieved by utilising the object identifier (MSLINK), which is associated to every feature type and specific feature code. At this phase of the constructed Georelational GIS project can be communicated with other GIS applications, as indicated in figure 3-10 based on the object relational structure unveiled in figure 3-11.

The objects (features) are related to the system tables by two fields, MSLINK and MAPID (Geog. GIS) feature ID (ArcView and ArcGIS) and MapInfo_ID (MapInfo GIS).

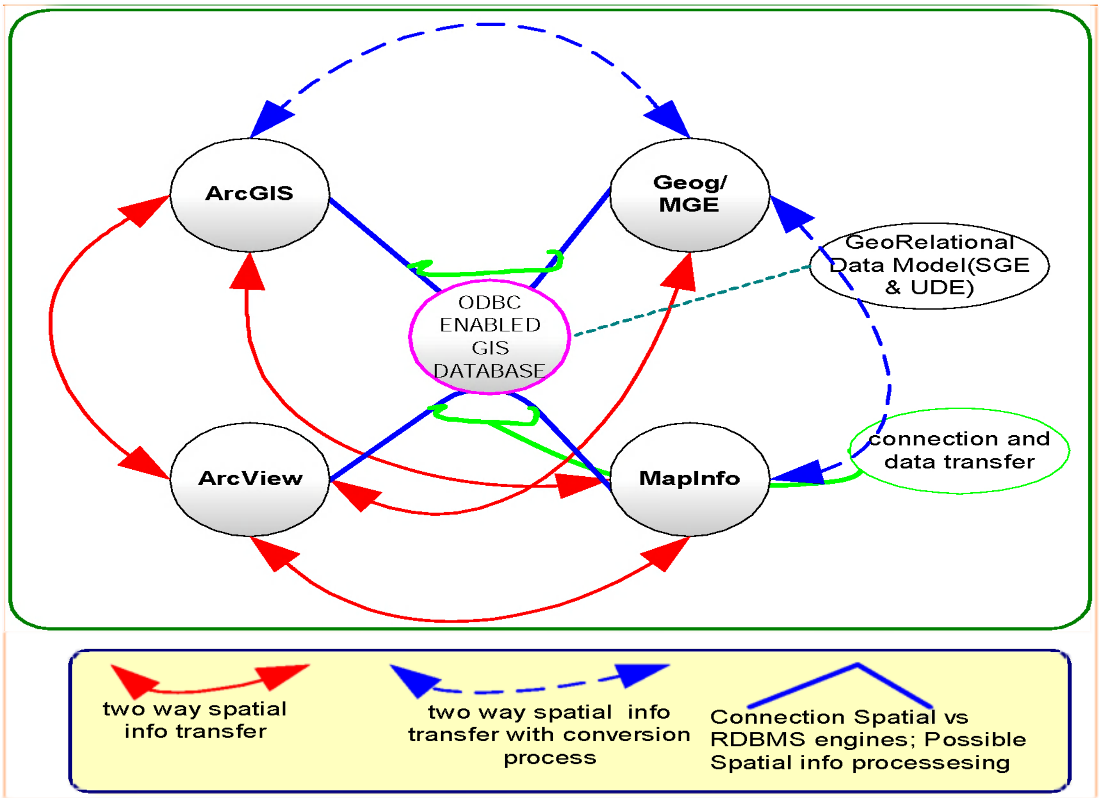


Figure 3-10 Possible communications among GIS applications projects

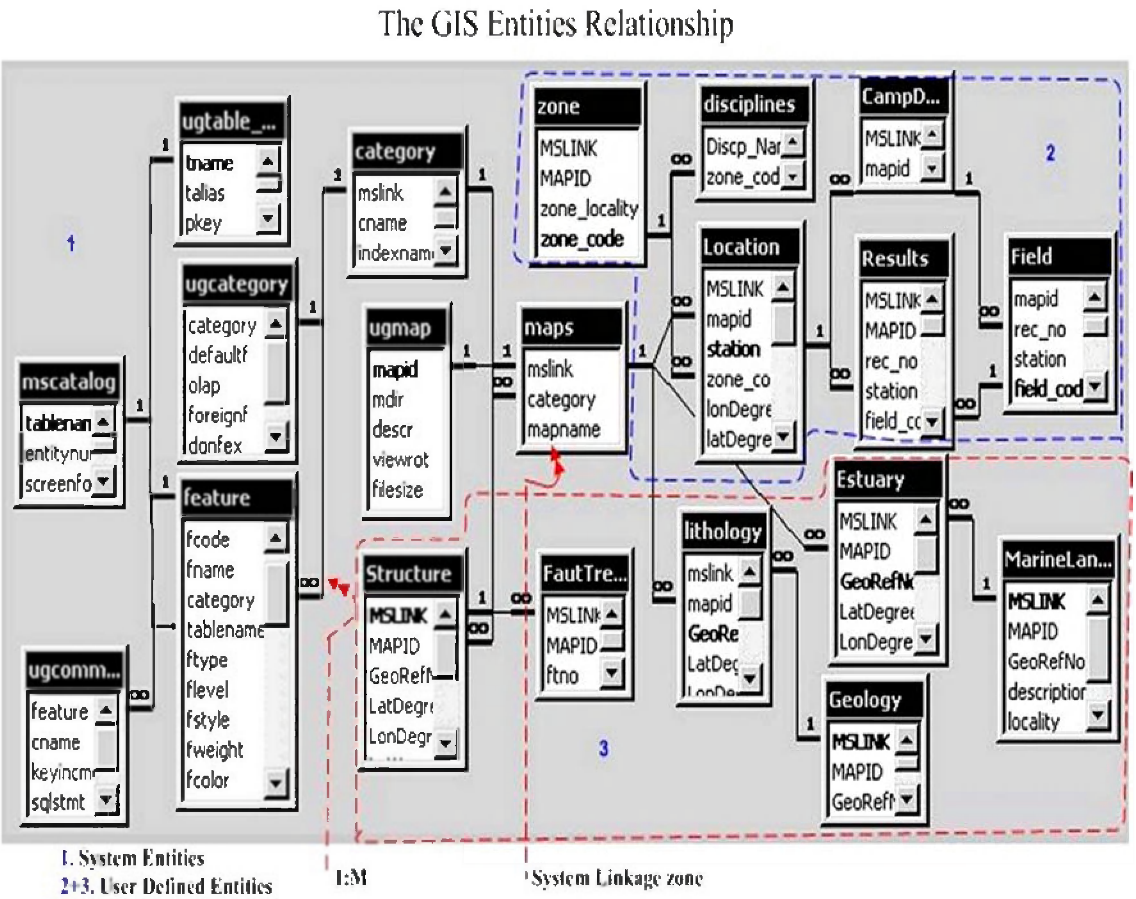
Three possibility of interoperability indicated (a) a two way spatial information transfer without loss of the spatial objects properties; for instance the preservation of shape and projection.

This process is executable among open GIS complaint applications and by means of feature translating applications. The connection between Georelational data model and spatial engines is achieved by means of application interfaces, which are composed of data transfer DLLs. This includes ODBC and ADO as experimented in this research work.

3.3.4.2 The Related GeoDatabase System

The Geodatabase model (see figure 3-11) is composed of (a) System generated entities - block 1, (b) Estuary environment entities, - block 2, (c) Coastal periphery Entities, - block 3 and relationally structured entities, which are hooked to the master, feature tables (objects). Both blocks (2 and 3) are connected to the system-generated entity via **maps entity** to complete the transfer of the information with the system. ***Maps entity*** is an entity that is described by attributes map-name, category and MSLINK. MSLINK is a migrating pointer from category entity in a 1: M relationships, likewise, the same information flow holds true for the category vs. feature tables (see figure 3-11).

Figure 3-11 Integrated GIS Database



The Location feature table is referenced to the maps system table by a common field; similarly, the Estuary,

Tectonic structure and the Geology Feature tables are hooked to the maps entity to create a path of spatial information flow. The feature table (object) and system-generated tables are stored within the Mscatalog Table (block 1) so that spatial process is executed successfully. The system linkage zone is performed between the user defined and associated feature table. For instance the location, lithology … etc., and the system maps table is related to the category and the category to the feature table. All are encompassed within the Mscatalog.

3.4 Results and Conclusions

- The process of spatial database building requires a series of conceptual, as well as practical experimentation. It requires piecing together of a data model, system entities and application tools, identifying features, connectivity among the spatial and aspatial data and fundamental know-how of the GIS objects during spatial operation phase of the GeoRelational GIS.
- The methodology of enacting varies from one spatial engine to the other; however, one common point that all GIS construction process requires construction of the GIS project where all the GIS building block entities are integrated by means of associating geometric objects to structured tabular information. These processes have been accomplished to achieve the full-fledged GIS project system.
- To implement its applicability, the Geodatabase model has been tested across different GIS applications. The connectivity of the attribute data model and the different spatial engines has been established by means of ODBC and ADO during the GIS project operational processes.
- To achieve a smooth interoperability, elected migrating spatial pointers and the relationship among the objects have been established, the seed file that generates different features type and dimensions have been defined appropriately.

Chapter 4: Spatial Database Structure

4.1 Introduction

An important subject matter of this chapter is spatial database structure construction. To begin with, first, an introduction will be given about the basic database models (Hierarchical, Network, and Relational) and will be ensued with more emphasis on the ***object-relational*** model, which is suitable for dealing with multidisciplinary spatial problems. Further, the importance of avoiding redundancy of spatial features and topological relationship (line, plotline and Polygon-Coordinate-Attributes) are discussed. Eventually, the processes of binding geographic objects are explained, using illustrative object relational methodology.

As a departure point, a single map composed of polygons, lines and points is provided. The common line boundary between polygons and vertices that connects the lines derive the relationship among the polygons. The practic1ality of this data structure is elaborated (see Figure 4 -1) and onward.

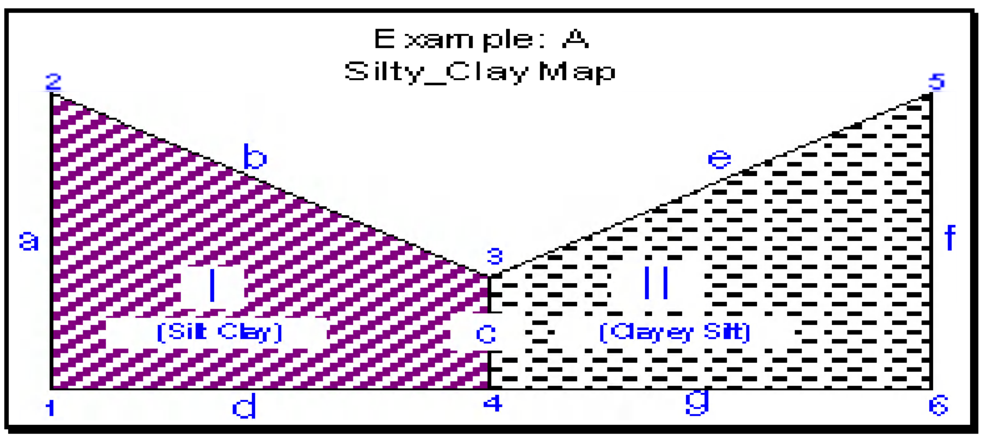


Figure 4- 1 An Illustrating Map

Object's Relationship:

1. ***Silt Clay*** *is a map*
2. ***Polygon I*** *is_part_of a Map.*
3. *Line **a** is_part_of Polygon I. (composed two points, at (1) x, y and at (2) x1, y1, (See figure 4-1)*

4.2 Basic Data Models

4.2.1 Hierarchical Data Model *(HDM)*

HDM is a type of database where data is modeled in a tree like structure. A single entity presents the source to which all the others are linked via parent-child relationships (hidden pointer). HDM used to be famous in the 1960-1970 on IBM's information management systems (IMS) [72]. This parent-child data segment structure implies that a database record can have repeating information, in most cases in the child data segments.

They are useful for data, which are characterized by one to many relationships; implying that the hierarchical mapping between entities is 1:M.Strict hierarchy along the relationship ensures unique keys applications.

A) For instance, location point and variety disciplines (Sedimentology, biology, hydrology…etc).

B) The relationship between staff name and staff's child forms a hierarchical relationship.

Advantage: They are useful for one to many relationships and allow quick retrieval of stored data suitable for such a structure.

Disadvantage: The parent-child relationship restricts a child segment to posses only one parent, causing it to be less flexible hence, not widely used within GIS environment [65]. Referencing is based on hidden pointers, includes large number of index files, complicated procedures required to alter its internal pointer system and existence of redundancy (e.g. line c, point 1, 2, 3, 4, 5, and 6).

Case In Point -1

Hierarchically, the map can be decomposed into 4 distinct levels as: - (1) A Map (2) Polygons (I&II), (3) Lines, (a, b, c, d, e, f, g) (4) Points (1,2,3,4,5,6), (see figure 4-2). At each level, elements are listed and linked (implicitly) to their parent elements and child elements and are identified uniquely at the respective levels depicting a hierarchical classification.

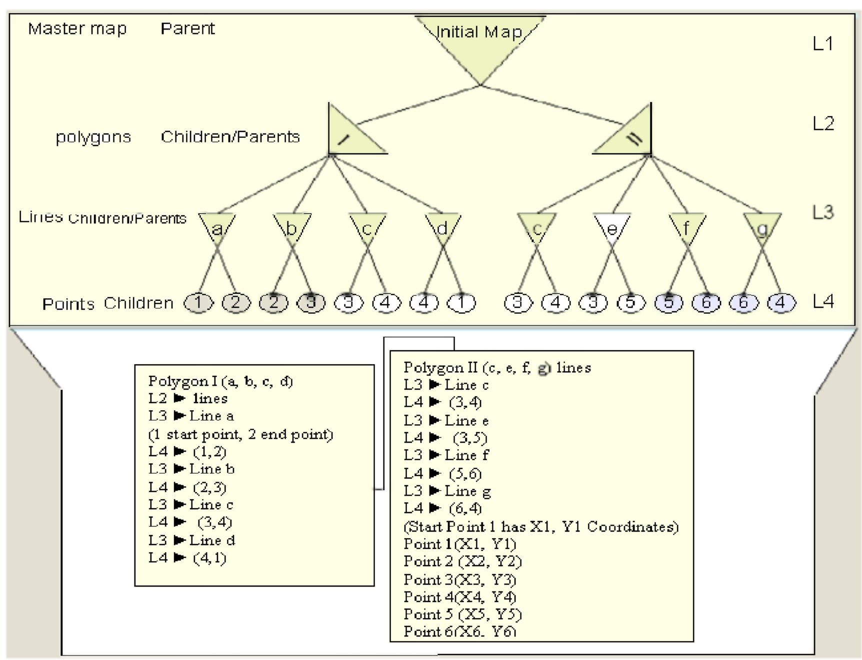


Figure 4-2 Hierarchical Representation

It is regarded as generalizations [25] as described by the objects at lower level which share the same characteristics of the higher level.

HDM constraint: = a child record is not supported to have a multiple parents.

4.2.2 Network data model (NDS)

It is a type of database structure where data is modeled in a many to many relationships between entities. A network data model is based upon the idea of explicit links between related entities. The most well known example of the network model is the CODASYL data model [73], which compensates the weakness of hierarchical database structure by permitting different parents to point to a single child or vice versa.

Advantage: Minimum redundancy, fast search via established network pointers. Disadvantage: inefficient in data editing and updating overhead caused by pointers.

Case In Point -2

The *Intersection* of polygon I and II (line c), (see figure 4-2), implies that two polygons sharing the same line and is a redundant element. This creates unnecessary presence of boundaries between two polygons. Network-wise the same map can be represented (see figure 4-3, a, b) without having a repetition of similar elements. The relations or links between the elements are built directly during the implementation phase.

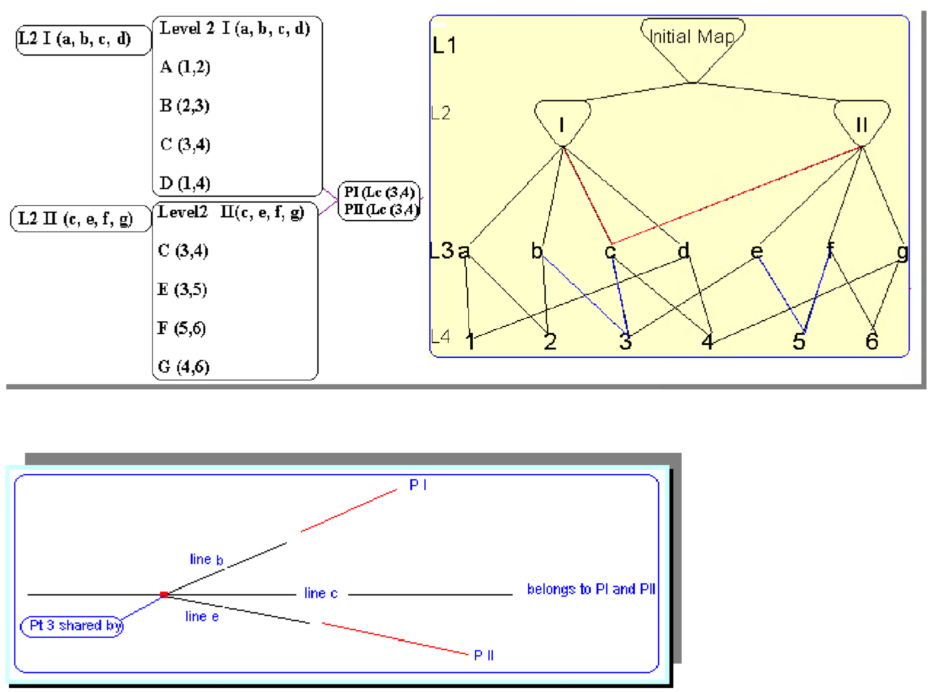


Figure 4- 3 Networking Relationship (top) and shared Geometric feature (bottom)

Advantage: The redundancy related to the map elements is reduced to the minimum and search via pointers is fast, however the associated shortcoming is inefficient data editing and updating overhead caused by multiple pointers.

4.2.3 Relational data structure (RDS)

<u>Case in point 3</u>: - Relational Database Management System is a type of database founded on a relational model developed by E.F.Codd, 1970 [74], [72]. A relational database is based on a relational algebra. It is composed of multiple tables, which are a collection of records and fields, with some sort of unambiguous links between them. It allows the definition of data structures, storage, retrieval operations and integrity constraints. Certain fields are designated as mandatory keys for the purpose of indexing to facilitate the speed of a search. Matching fields' values between two or more tables can be used to form a join tables and select related records from the database.

Operations based on structured tables are easily implemented based on common values that can be easily corrected and identified in case of system failures. A special language, called SQL's (Structured Query Language), DDL (data definition language) and DML (data manipulation language) are usually employed for data defining and retrieving operations.

Advantages: adding an attribute category is to add a column; adding a map element or object is to add a row (record), updating or editing is efficient and query is flexible and interactive.

Disadvantages: A key in a relational database should not be repeated and redundancy (e.g. line c and polygon Ids), (see figure 4-4).

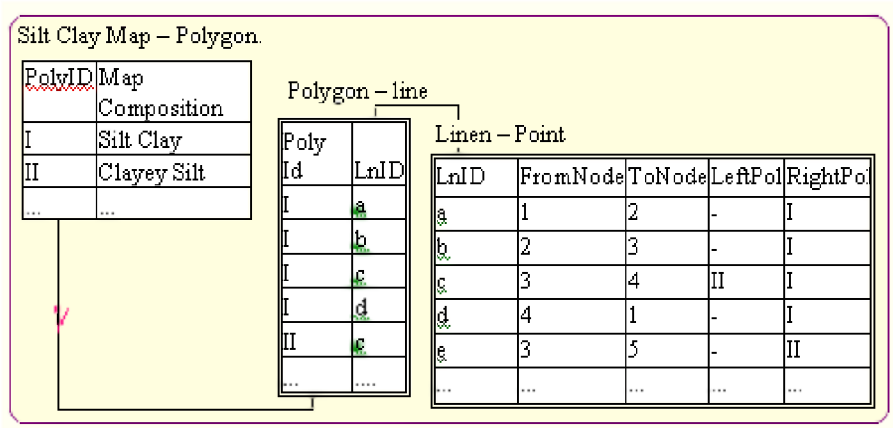


Figure 4- 4Objects Relational Representation

4.2.4 The open GIS notion

Interoperability: An international trade association that deals with the development of geoprocessing interoperable computing standards. It focuses on developing open and extensible software application programming interface for geographic information [79]. Open GIS addresses the fundamental constraint of geographic information management considering the propagation of different data types and diversity of geographic information systems and applications. Applications that adhere to the objectives of open GIS are more able to access various types of distributed and also utilize multiple geoprocessing tools. The open geographic information specification is an operational model that enable the translating of geodata from various sources into a single, comprehensive object based data model which can then be accessed directly from applications using a basic toolkit or operation tools.

Such optional application will reduce strict utilization of GIS applications to their internal models and enhance the exchange of spatial information.

4.2.5 Object –Relational Database **(OR)**

Object Relational database is a type of database that adds new object storage and data manipulation capabilities to the relational data structure and encompasses an object-relational (OR) implementation [75]. It enables to work with familiar tabular structures and data definition languages while assimilating new object management possibility of ***complex data***. Most of the operations and connections such: Querying, (SQL3), procedural languages, and API that provide cross –DBMS connectivity to wide range of SQL databases (ODBC, JDBC) in object relational database are all familiar extension of the relational database [76].

4.2.5.1 OR Features

- Object relational (OR) database organizes data same way to that of relational tabular structure
- OR database subsumes relational database model
- OR databases are incremental upgrade of the predecessor relational database.
- User defined type, (UDT), user defined functions (UDF), indexing and access methods are important components of OR database.

UDT are new logical data type, which can be associated with a particular UDF; can be implemented in any SQL expressions, to retrieve a string type or objects [77]. User can specify SQL styled constraints on defined columns by UDF.

ObjID	Latitude	Longitude	Data type	
			Attribute	Geometry
				•, ς, □

OBJECT	•			
	FIELD NAME	***DATA TYPES***		
	FEATURE ID	***OBJECT ID***		
	FEATURE/(SHAPE)	***GEOMETRY***	***PROPERTIES***	
	...	...	*GEOMTYPE*	*GeoRef*
	AREA	*DOUBLE*	*PRECISON*	*SCALE*

Table 4- 1 Object Relational Definition

An object-relational database, example ORACLE spatial is semantically equivalent to the SQL3 named row type [90]. An object type has one or more attributes and each attribute has a name and type. Objects have identity that is the foundation for true integration of object modeling. The structure of OR geodatabase is composed of ObjID, geometry data types, georeferencing data source and multiple attributes with the possibility of alias assignment. The geometry type could be of a set of feature class that includes the point, polyline and polygons. A required georefrence column is associated to define the projection of the feature class.

The Methods, Spatial operators and aggregates are defined with the objects. Each object could have a specific type method associated with it. Point Object has a specific method to generate it, for instance: -

- Point object: *Place Point* for generating a point based on an x and y coordinates
- Line object: *Place Line* based on the coordinates of x, y and x1 and y1).
- For a **Point object** inside a **polygon objects** the relationship is defined as
- Spatial Operator: **Point *CONTAINED WITHIN*** a **polygon**

4.2.5.2 Distinction between OR and Relational

Object-relational	**Relational**
SQL3, UDT, UDF *Complex data* *Complex schema / UDT* *Spatial data processing tools/spatial operators*	*SQL-89, SQL-92* *Simple tabular data* *Simple schema/ Standard DDL/DML* *Aspatial data or business data processing* *4G language, transaction, Security*

Example: Schema Creation

Simple schema	Complex Schema
Create table Species (*Stno Integer,* *Measuring date,* *SpeciesPictureSlide text,* *Depth float);*	*Create table site (* *SiteNo Integer,* *Location point (x, y);*

TABLE 4- 2 Object Relational Schema

A site number describes the right schema, and a geographic location coordinates. The position of every species picture slides can be captured using the coordinates (x, y) of the point. Georegistration is required. Queries utilized to retrieve the spatial information incorporate both standard SQL and spatial operators [78].

Illustration: - Find the distance between two or more sites two types of species slides pictures occur can be retrieved by incorporating tools related to SQL and geographic operators.

SELECT SpeciesPicture, Stno from SITE Within a distance of (10, unit);

4.2.6 Spatial objects Structure Implementation

The previous sections disclose the concepts of the fundamental database models and the object relational data models, which are currently becoming popular geospatial database systems.

Unlike the aspatial database structure, which is defined and constrained in the attribute database, the spatial objects can be defined and generated on the spatial engine by a relevant graphic program. The spatial objects generation involves spatial functions and spatial engine. The objects (Point, line and polygon) are created to be associated with database record and visualized thematically. Therefore, hereafter, the implementation and physical definition of geographic objects will be executed. The physical definitions of geographic elements is vital to illustrate and indicate the composition of the geodatabase and distinguish the difference between spatial and aspatial databases. The system developed has been developed within a client or personal database (.MDB).

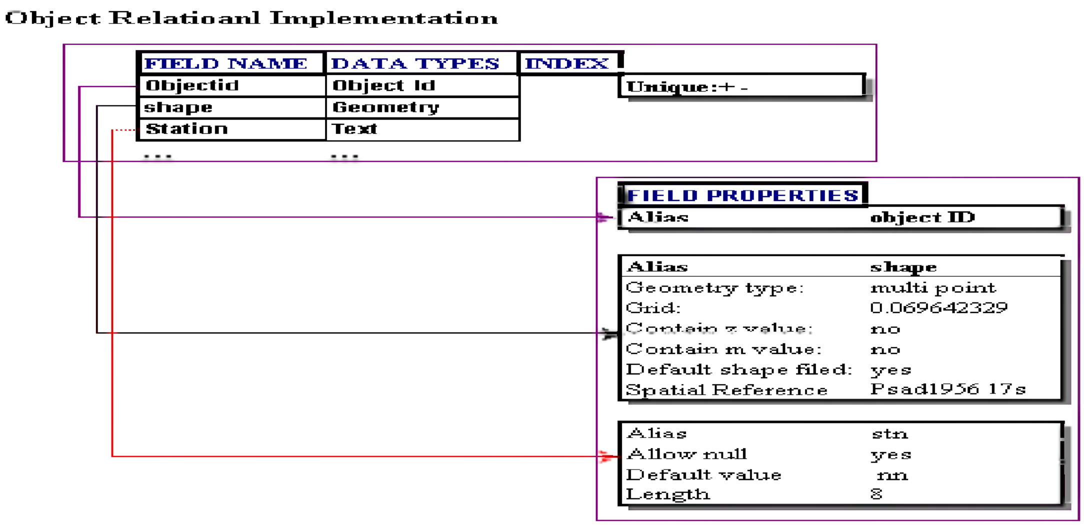


Figure 4-5 Objects Relational Representation

Object realtional founded on a certain fields, which includes field name and different data types. Object identifier and geometric types are the fundamental data types in addition to the standard relational database types. Every object ID could have its own alias and every geometry type is decomposed into point, line and or polygon and the possibility of including or containment of z and m attributes. One important characteristic of the object relational database is the possibility of performing spatial reference for every geometric type, which is intended to be associated with tabular structured records, (see figure 4-5). In order to facilitate and speed up the access, objects indexes are defined within the geodatabase for selected identified objects.

4.2.6.1 Point Object: (Location site)

Importing files that contain georeferencing coordinates to the spatial interface environment and triggering relevant functions to create point object can generate a point object. Graphic Customizing tools are also implemented. Procedures applied: -

Step 1: Importing of a spatial data source table containing numeric georeferencing fields

Step 2: Employ spatial interface as follows.

A) Get X coordinate from field
Get Y coordinate from field
Symbology: Font: Symbol: Color:
Multiply: Get X coordinate from field by
Multiply: Get Y coordinate from field by
Rotation: symbology in Degree
Projection: SAD1956

Figure 4- 6 Object creation from within a Spatial interface

A) Point Object is created with data structure and category (.TAB) in a seed file type of 2D.

(B) Object and Meta Data
1. MSLINK integer ;
2. mapid Integer ;
3. LonDegDec Float ;
4. LatDegDec Float ;
5. station Char (25) ;
6. zone_code Integer ;
7. Area Float ;
8. Perimeter Float ;
9. MYIMAGE Char (45) ;
10. EastingKm Float ;
11. NorthingKm Float ;
12. begin_metadata
13. "\ActiveObject" = ""
14. "\ActiveObject\Expr" = "MYIMAGE"
15. "\ActiveObject\Mode" = "HOTLINK_MODE_BOTH"
16. "\ActiveObject\Relative" = "TRUE"
17. "\IsReadOnly" = "FALSE"
18. end_metadata
The steps 1 to 11: structure of Georelational table structure.
Step 9: variable string type to store a keyname of a Meta data hotlink.
Step12-18: Meta data definition

Figure 4- 7 Object & Meta data structure generated

Data Structure

MSLINK	MAPID	LonDegDec	LatDegDec	Att	Att2 ...

4.2.6.2 Polyline Line Object: Geotectonic

Geotectonic: Line Object: By importing a database table that contains georeferencing fields (Longitude and latitude) into a spatial interface and then after employ a spatial functions to create the line Object.

The creation of the line is based on the vertices of the first pair and second pair of coordinates (LonDegDec, LatDegDec, LonDegDec2, and LatDegDec2).

4.2.6.3 Polygon object: Geolithology

a) By importing a database table that contains sorted georeferencing fields (Longitude and latitude) into a spatial interface and then after employ a spatial functions that create the polyline and later convert the polyline to polygon Objects.

b) Utilizing feature Creation Tools >> for instance Create polygon Tool (MBE)

ObjID	LonDegDec	LatDegDec	Area	Perimeter	Att	Att2 ...

4.2.6.4 Update Spatial Data Object (Point to Centroid)

Update Location Point

Set Obj = Create Circle (LonDegDec, LonDegDec, Unit)

The Point Object is converted into a circle with a specific filed radius in U (unit).

C) Update Circle Object

Set Obj= Create Point (Centroid (Obj)), (Centroid (Obj))

Output will be Point Object.

If seed file type is 3D type, then an elevation attribute is incorporated.

ObjID	LonDegDec	LatDegDec	**Elevation**	Att	Att2 ...

Test Results

MyLocations Browser

MSLINK	mapid	station	zone_code	LonDegDec	LatDegDec	Area	Perimeter	EastingKm	NorthingKm	AvgDepthm
1	4	1	1	-79.976	-1.976	7.24	10.78	613.93	9,781.45	4.11
2	4	10	3	-79.886	-2.73	19.09	17.48	623.99	9,698.23	6.46
3	4	11	3	-80.025	-2.653	19.09	17.48	608.49	9,706.72	4.75
4	4	12	3	-80.12	-2.668	6	9.8	598.07	9,704.59	7.84
23	4	12A	3	-80.136	-2.668	2.26	6.02	596.18	9,704.82	0
5	4	13	4	-80.231	-2.671	6.36	10.09	586.6	9,703.88	5.06
24	4	13A	4	-80.243	-2.655	9.91	12.58	583.61	9,703.88	0
6	4	14	4	-80.16	-2.6	19.09	17.48	592.98	9,712.22	6.41
7	4	15	4	-80.055	-2.553	19.09	17.48	604.49	9,721.38	3.4
8	4	16	4	-80.016	-2.411	19.09	17.48	608.62	9,733.22	3.52
9	4	17	4	-79.956	-2.318	19.09	17.40	616.26	9,743.77	12.79
10	4	18	4	-79.923	-2.271	7.87	11.27	619.03	9,749.01	11.61
11	4	19	4	-79.945	-2.235	6.01	9.81	621.74	9,747.03	5.59
12	4	2	1	-79.876	-2.143	7.24	10.78	625.35	9,763.4	3.2
13	4	20	4	-79.943	-2.236	19.09	17.48	617.49	9,753.06	11.51
14	4	3	1	-79.86	-2.16	7.24	10.78	626.59	9,761.01	2.23
15	4	4	1	-79.836	-2.09	7.24	10.78	628.34	9,770.45	1.6
16	4	5	2	-79.866	-2.213	7.24	10.78	624.58	9,756.54	5.68
17	4	6	2	-79.84	-2.27	19.09	17.48	626.99	9,750.85	4.51
25	4	6.5	2	-79.816	-2.328	19.09	17.48	630.01	9,742.31	0
18	4	7	2	-79.838	-2.403	19.09	17.48	628.16	9,733.23	4.96
19	4	8	2	-79.781	-2.548	19.09	17.48	635.72	9,720.2	1.6
20	4	8a	2	-79.858	-2.486	19.09	17.48	625.90	9,724.4	6.56

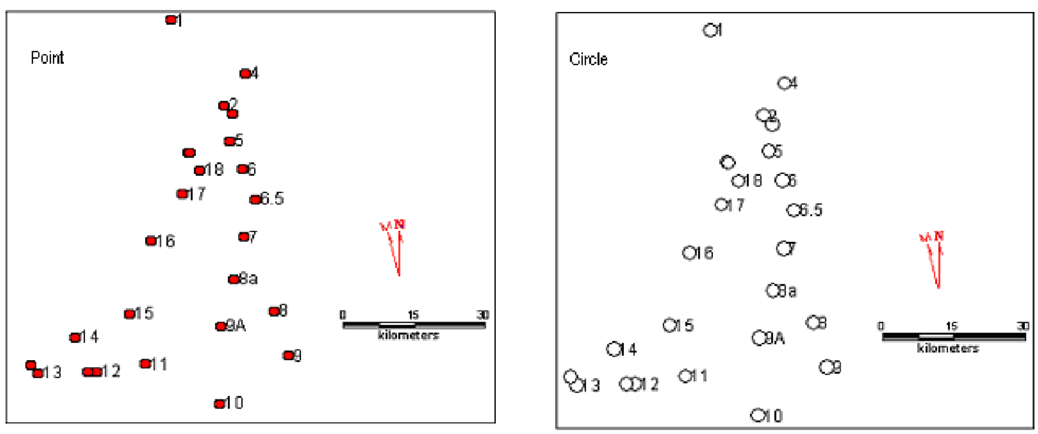


Figure 4- 8 Test Results Point Objects

4.2.6.5 Update Spatial Data Object (Line)

Set Obj = Create line (LonDegDec, LatDegDec, LonDegDec2, LatDegDec2)

Query2 Browser

LonDegDec	LatDegDec	LonDegDec1	LatDegDec1
-79.976	-1.976	-79.886	-2.73
-79.886	-2.73	-80.025	-2.653
-80.025	-2.653	-80.12	-2.668
-80.12	-2.668	-80.136	-2.668
-80.136	-2.668	-80.231	-2.671
-80.231	-2.671	-80.243	-2.655
-80.243	-2.655	-80.16	-2.6

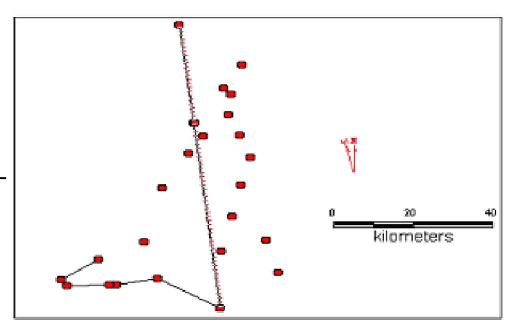


Figure 4-9 Test Results Point-Line

Data Structure

ObjID	LonDegDec	LatDegDec	LonDegDec2	LatDegDec2	Att	Att2 ...

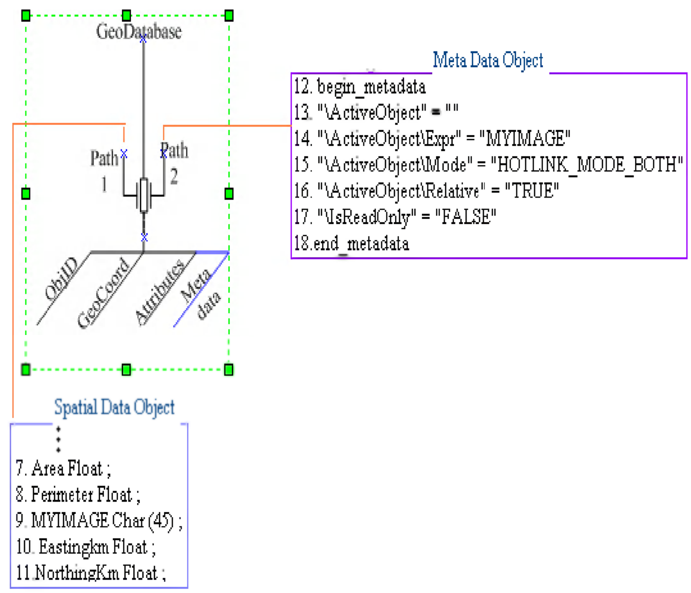
Test: Extract the distance on the map by typing the following code on the spatial interface

Distance SphericalDistance (LonDegDec, LatDegDec, LonDegDec1, LatDegDec2,"unit") > Numeric value

---

4.2.7 Meta data objects

Meta data are objects that elaborate more spatial information layer that have a common object pointer. Meta data are stored within an associated object. Creating metadata ensures that one can continue to use the data and make decisions based on the combined information. Meta data can be an image, audio or video or any other associated information.



We may have the chemical composition of analyzed rocks in a structured database table associated with geographic objects. A thin section or core image can be attaches as Meta data.

A volcanic pyroclastic material analysis results associated with geographic object can be supported by Meta data information (volcanic eruption video). Each Meta data has a key value which actually starts with a back slash “\” character. The key name never ends with a back slash. The key name is always a string.

4.2.7.1 Creation

Figure 4- 10 Meta Data Structure

Referring to the Location Point Object, the Meta data attribute definition is attached to the object definition, at the lower part of the table structure. The definition is carried out in the GIS project table's row as a text to store the path of the object that would be used to give further information about the spatial layer. The populated path of the Meta data points to the location of the hot link while it is bound to the same object identifier. Based on the generated structure the hotlink is stored as of Label, Object, or both [30] as indicated bellow.

Querying the table that stores the information can retrieve Meta data. The process includes setting the attribute to the keyname and triggering the event that opens the Meta data item, see chapter 6.

Data structure

OBJID	ATTRIBUTES	METADATA	

4.2.8 Spatial Database Operations

4.2.8.1 Object Decomposition and Mending

At a time where two or more polygons coexists representing different information, extra line creation adjacent to each polygon, as a means of demarcating polygons from each other is redundant since it creates buffer zone and it consumes extra space.

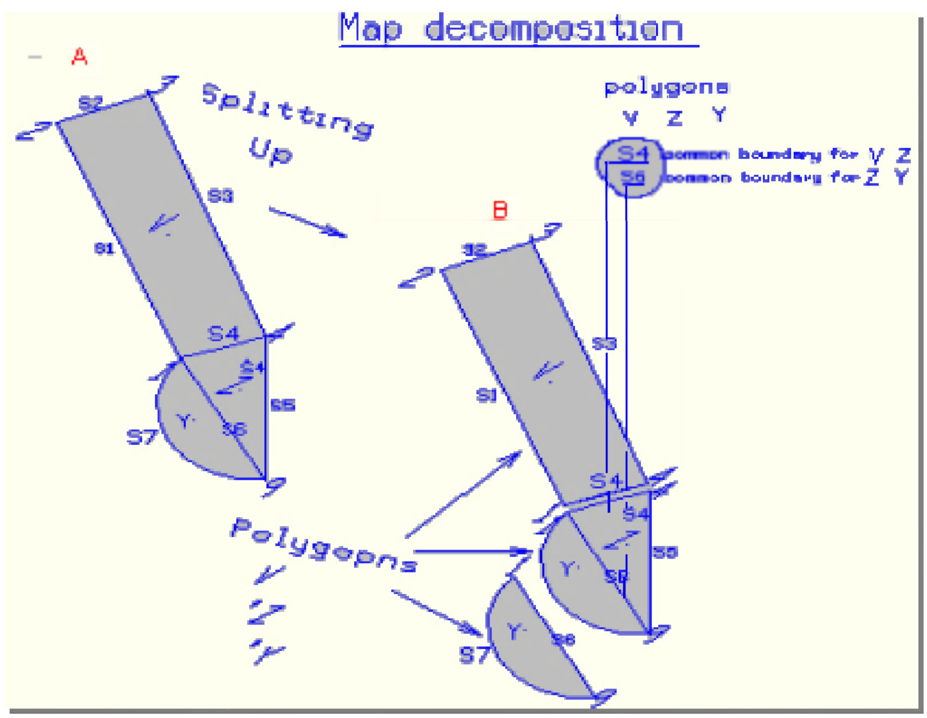


Figure 4- 11 Decomposition of polygon boundaries

Hence, these superfluous lines boundary must be mended to represent a single boundary in between the two and such mending of the topologic features is accomplished before the association of database records with the respective features. Referring to figure 4-14, the geometry is composed of three polygons (V, Z, and Y) with undefined polygonal boundary. They are neighbored by the adjacent line S4 as a boundary between Polygons V and Z and S6 between Z and Y respectively.

Splitting up the polygons results in identifying the adjacent lines and it requires bridging by means of a topological clean up processes.

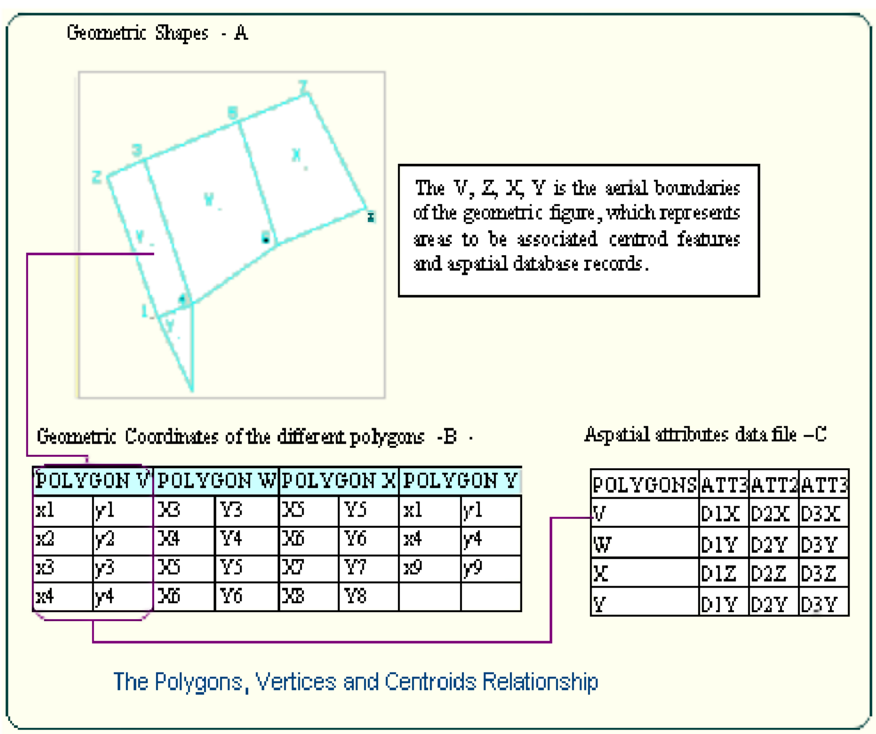
The splitting shows two polygons. Therefore instead of S4 is a boundary for polygon V and Z, result of the polygon creation with common boundary results in generating a single boundary for the polygons.

4.2.8.2 **Spatial vs. Aspatial data Linkage**

GIS differ from a CAD application by the power and resource tools it posses to geo-reference and link geometrical objects and tabular GIS database. The GIS database is a system in which most of the data are spatially indexed and spatial operations is possible. The Relationship between CAD and GIS is that GIS uses geographic coordinates systems and world map projections while CAD coordinates are relative to the object being modeled and are not usually relative to any particular place on earth [93]. In short, the difference between CAD and GIS is the difference between a drawing and a spatial database. GIS understands networks. For instance, the lines describing streets are related to one another. GIS understands enclosed areas (polygons) and their associativity with other objects and GIS understands connectivity and associativity, which enables spatial analysis. The geometric vs. non-geometric structural relationship is fundamental to the smooth communication among objects and is achieved by a process of joining matching attributes or performing spatial operations on the objects themselves.

Figure 4- 12 Polygon, Vertices and Centroids Relationship

A geometric object is composed of a series of nodes and vertices described by a unique coordinates to generate features such as a point, line and polygons/shapes. Choosing one of these objects and a structurally linked GIS database record



is fundamental to the hatching of geo-reference able information.

Referring to figure 4-12, every polygon is composed of a number of vertices in which the intersection of the line makes a point at X and Y coordinates.

The polygon V (see figure 4-9) contains 4 vertices represented by x1; y1 …x4, y4 and a close loop of the vertices produces a polygon. That polygon B (V) is described by its polygon ID and is attached to database record C (v).

If the feature is a point type feature, then each point object can also be associated to attribute records, which can be spatially georeferenced by a point rather than by a polygon.

For instance, in the case study GIS (Guayaquil project), measurement stations represented by latitude longitude coordinates, which are represented by points, associated to a linked Gua.mdb.

The connected lines at a given vertex pertaining to the given shape determine every polygon limit. Meanwhile its own spatial identifier identifies each polygon.

Thus, inter-connetiontion of the aspatial file with the geometric figures as depicted in figure 4-9 resulted in the founding of spatial-aspatial linkage (see figure 4-13).

Polygon-Coordinate-Attributes Relationship

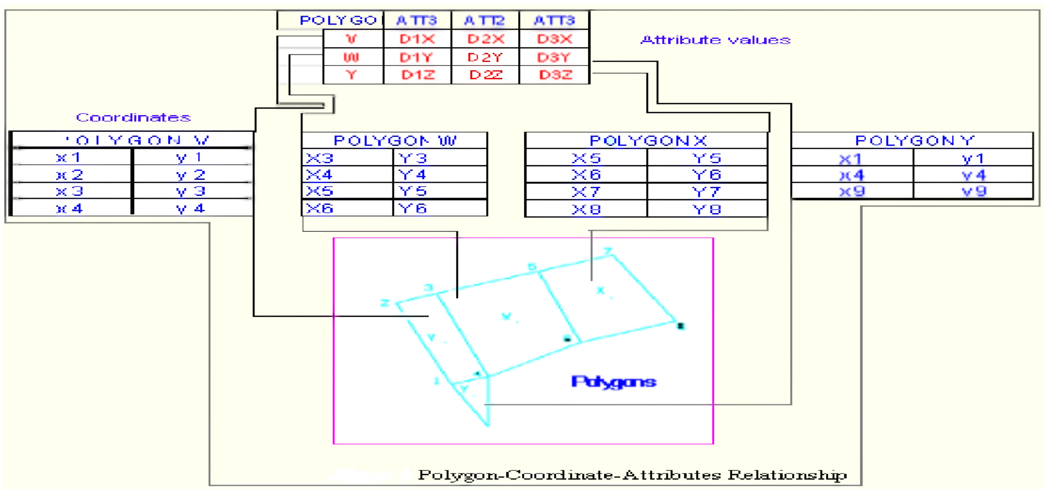


Figure 4- 13 Polygon-Coordinate-Attributes Relationship

4.2.8.3 Spatial Integration

GIS tools have the capability to dissolve a common boundary during a process of thematic buffering [20]. For example, it is possible to merge polygons together that have them same land use attribute. This would enable to see continuous areas where land use type could be of the same.

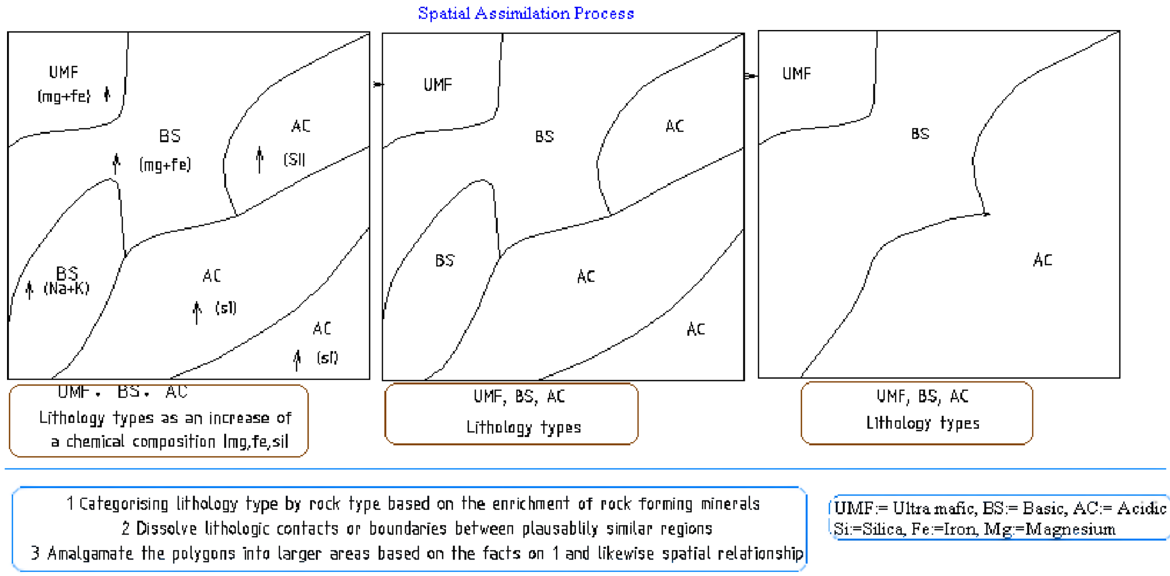


Figure 4-14 Spatial Assimilation

In the same analogy, the polygons (see figure 4-14) are demonstrating the application of thematic merging by means of gauging the variation in a rock forming composition. During thematic analysis on polygons, which are adjacent to each other and have similar characteristic, then, the theme attribute values can be visualized with uniform thematic symbols by dissolving the boundary between them.

4.2.8.4 Binding Geographic Objects

Case: MicroStation Geographics: - (The feature names reveal textual descriptions of (see chapter 3) geographic objects, such as shapes, lines, points or text nodes which are associated to the textual feature. The property of geographic objects can be displayed by attaching the textual feature description to the object by a means of feature building functions. There are two types of feature attachment.

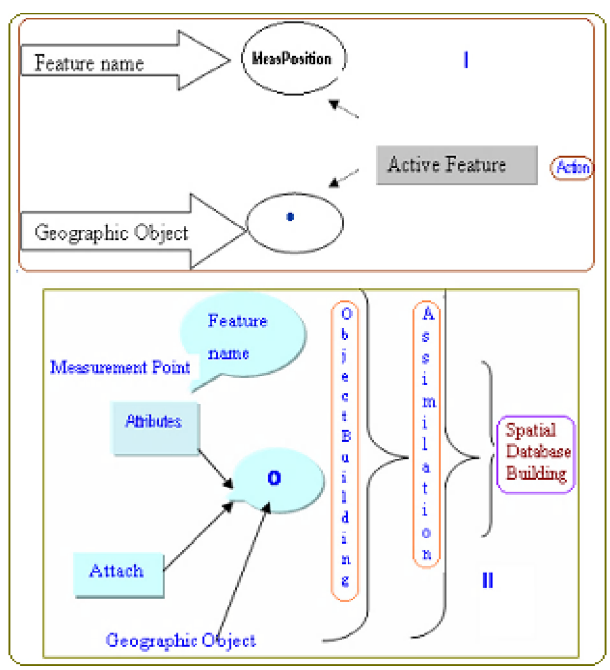


Figure 4-15 Binding:- Graphic feature description, (II)-Spatial Objects vs. DB records

I. Geographic Elements vs. Descriptive feature attachment: Defined in the project feature set-up and is related to a specific *category*. The feature description is stored within the system-generated feature table.

The spatial functions (attach and detach) are triggered from within the geographic interface. The textual description attached to the geographic object used to decipher the content of object upon clicking it, (see figure 4-15).

II- Database Record vs. Features Attachment: The structured database records are appended and assimilated to the geographic object after the ***attach operation.***

For instance, the database record stored in the feature (object) *Location* required to be attached to its *centroid* with specific OBJID is extracted

Extraction: = SELECT * FROM LOCATION WHERE OBJID = 1;

The query releases the result that corresponds to the geo-referencing coordinates.

ObjID	MapID	LonDeg	LonDeg	CurrentSpeed	MeasUnit
1	1	-2:30:45	-79:25:43	300 cm/sec	Cm/sec

Table 4- 3 Query Result

Activating object Measurement point (figure 4_15) and executing the ATTACH function will automatically result in assimilating the record within the Geographic object. This process is similar to the joining of an object and tabular information for spatial visualization. Furthermore, the attribute Talias in the Ugtable_Cat is used here to keep the consistency and integrity of the GIS information extraction by referencing the value of an attribute to its specific table.

Case ArcView GIS: In the case of ArcView, the feature Identifier can migrate as a Foreign Key and a join of the spatial object and aspatial database records is established. Linking or joining the database records depends on the cardinality relationship between the .dbf or .txt files and the ObjID for the respective feature type.

A relationship of type 1: M preferred type of association = LINKING

A relationship of type 1:1 preferred type of association = JOIN

Associating in a join of (1: M) results associated database records ONLY equal to the ObjID values. Linking enables to georefrence the database records associated to the feature but with no thematic displays. Event table with specific geodata source is directly loaded to generate point features if it adheres to the 1:1 mapping principle.

GIS Data Popula Possibilities	GIS Applications	Data files	Processing Tools	Outputs
	MGE	RDB Tables, ASCII Files	MGAL, macro, manual	Associated Point feature
	Geographic	RDB Tables, ASCII Files	Macro, MBE, manual	Associated Point feature

	ArcView	RDB Tables, ASCII Files	Importing, link	Associated Point feature
	MapInfo	RDB Tables, ASCII Files	Importing, link	Associated Point feature

Table 4- 4 Populating the GIS environments

4.2.9 Topology Cleanup processes

4.2.9.1 Topologically cleaned Maps

The aim of topology operation is to clean up maps in order to ensure the integrity of information, and perform successful spatial analysis. The topological relationship is determined with regard to the purpose of the GIS designed. Many unnecessary line elements may stem out during digitizing process, as consequence of converting of maps from one format to the other (e.g. .DGN to DXF). Eventually this may influence the topology relationships [25] because bounding elements between areas required to adhere to the process of GIS map construction, which includes performing topological clean up to remove the undesired line fragments and connectivity.

The following examples are related to the topologic clean up operations [11].

4.2.9.2 Snapping and Cleaning line fragments

Generally, GIS is equipped with topological clean up tools designed to find, modify and mend the unnecessary elements. They work on a line, Line strings, curves, and shapes. The tools in the case study, based on [11] were utilized to detect and update conditions outlined 1-6.

1. Duplicate line works
2. Similar line works,
3. Line fragments
4. Linear line segmentation
5. Finding gaps
6. Finding dangles

4.2.9.3 Duplicate line

A duplicate line (DL) is a linear element that shares the same coordinates as another linear element. A DL may differ by assigning a Level, View and element symbology, so that they can be turned on and off during the phase of attribute database record linkage and visualization. FIND DUPLICATE LINKWORK TOOL locates the DL and moves to a new level for appropriate operations indicated below.

Key-in: FENCE MOVE DUPLICATES [Level=n]

Key-in: FENCE DELETE DUPLICATES

Key-in: FENCE MERGE DUPLICATES

Fence: a fence on the target element

Move, delete and merge: are the underlying procedure calls.

N: number of a level (related 63 view levels).

4.2.9.4 Similar Line-work (SL)

A similar line work is a line that occupies a common area as the other line, almost identical or is partially over lapping. The similar line is detected by generating a zone specified tolerance value, (see figure 4-16).

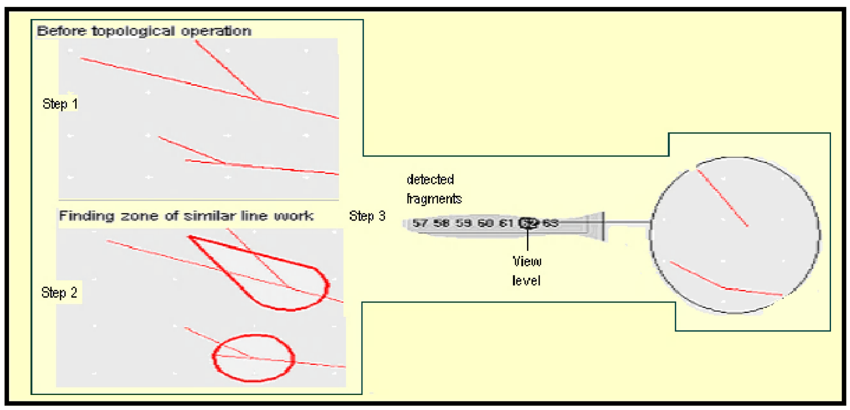
The output of the operation is singling out of the similar line fragments.

Key-in: FENCE MOVES SIMILAR [Toler=t] [Percent=p] [Level=l]

Key-in: FENCE DELETE SIMILAR [Toler=t] [Percent=p]

Key-in: FENCE FLAG SIMILAR [Toler=t] [Percent=p] [Color=c] [Weight=w] [Level=l]

Figure 4-16 Locating map's Similar Line-work



4.2.9.5 Line fragments (LF)

Line fragments are the riffraff elements that posses specific x, y coordinates that occur within a range of specific tolerance during unstable digitizing process.

Key-in: FENCE MOVE FRAGMENTS [Toler=t] [Level=l]

Key-in: FENCE DELETE FRAGMENTS [Toler=t]

Only the line fragment that meets the criteria of the specified tolerance value moved into specified level (L) (see figure 4-17, to find and clear the line fragments.

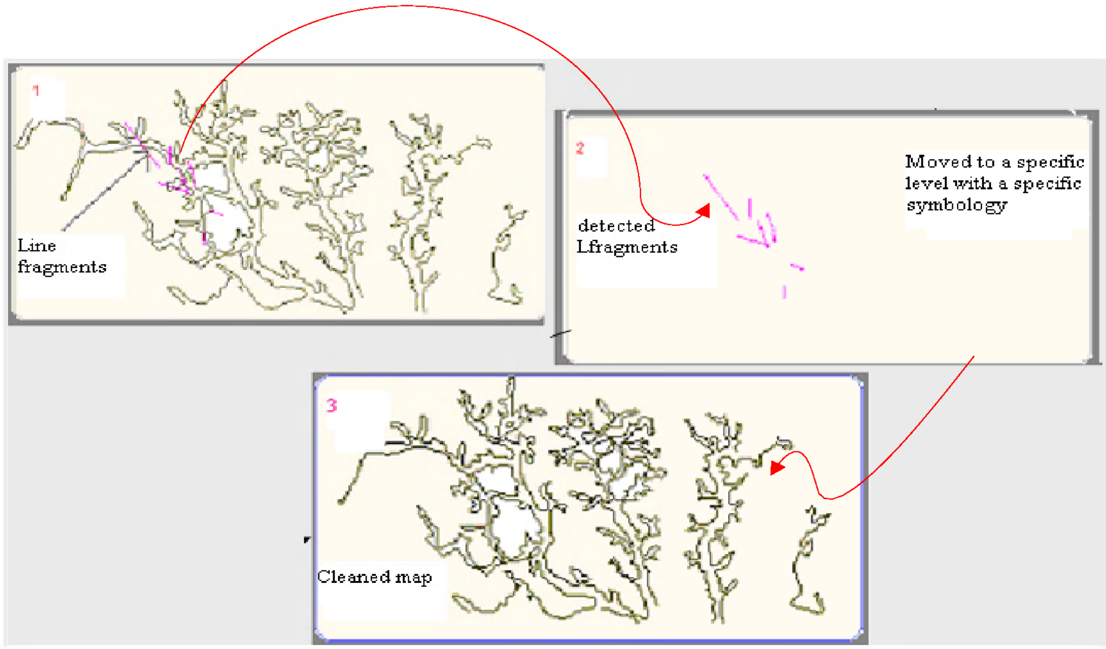


Figure 4-17 Avoiding LF : 1-raw map, 2-detected line fragments, 3-toplogically cleaned.

4.2.9.6 Linear Segmentation (LS)

A topological tool is used to create a network of distinct line segments between each pair of intersection or junction points. Operations related to this process include: -

- Self: breaks lines that are self-intersect element at the cross over points.
- Split: breaks overlapping linear elements at their intersection point to create linear elements.
- Elements: segments elements at point of intersection or near point of intersection if the gap meets the required tolerance.

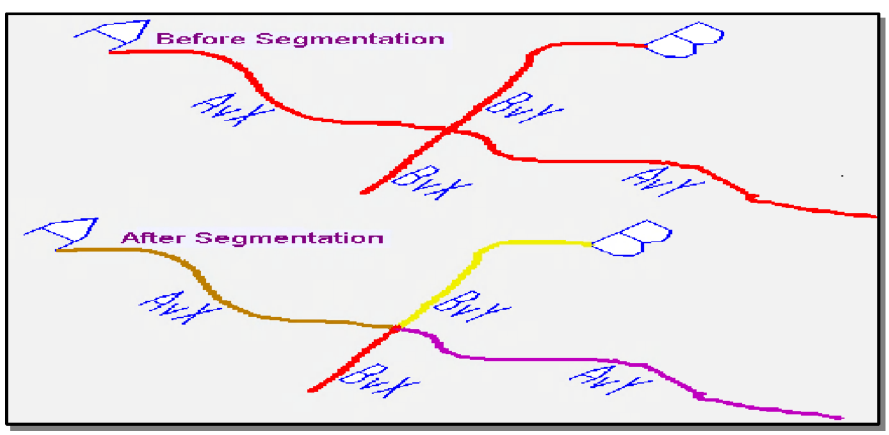


Figure 4- 18 Segmenting Geographic Elements

As a result of segmentation the input of two-line segment resulted to 4-segmented lines, (see figure 4-18), which are eventually to be tagged and associated with 4 unique object identifiers.

4.2.9.7 Gap among spatial elements (G)

Proximally located linear elements should share a common end point to close the gap among them. Thematic resymbolisation of areas or polygons is based on shapes.

Topologically, closed curves must be converted to shapes so that thematic visualization can be possible. The gap closing process requires the definition of tolerance to snap the two-end endpoint together. See illustration: Gap Tolerance setting-

Step 1 tolerance = user option

Test for 1, Gap value (A= 4) 2, Gap value (B= 7): - for a tolerance value of 4, gap A will be mended, whereas B will not. So, as a function of tolerance value, a gap size is detected and shape mended. See figure 4_19.

F (TolVal) > = (gVal) = gap repaired and F (tolVal) < = (gVal) gap not affected.

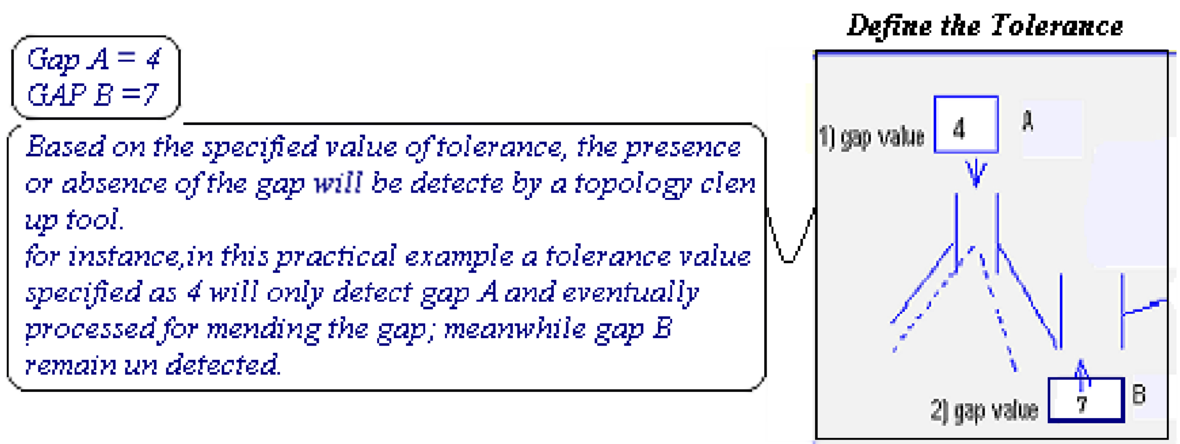


Figure 4- 19 Gap and Tolerance Size

Depending on the gaps among geographic elements, changing the value of the tolerance changes the flags of gaps detected, then gaps detected corresponding to the specified tolerance (See Figure 4-20 (A); in step 1, two gaps and two dangles lines are corrected and the shape is created. By increasing the tolerance value on step 2 (see figure.4-20B) to 1.000 the remaining gaps with higher values are flagged, eventually transferred to a correction chamber.

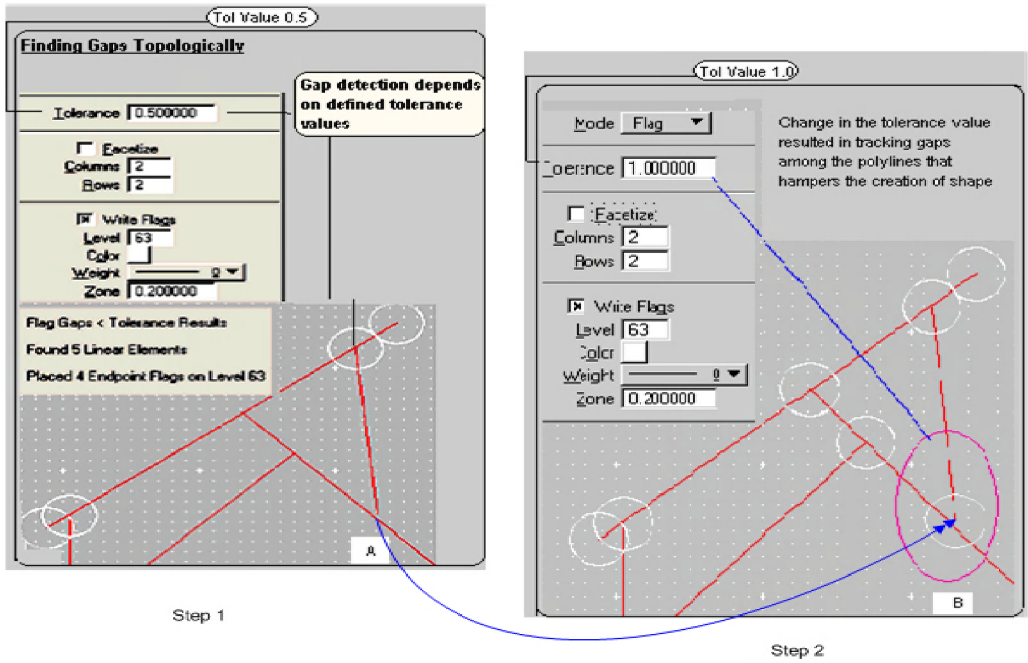


Figure 4- 20 Gaps and tolerance Variations

4.2.9.8 Overlapping Polygons

A polygon is defined by the lines that make up its boundary and a point inside its boundary for identification. Polygons have attributes that describe the geographic feature they represent. Polygons must form closed networks to enable the inference of areas. There should only be one linear element or common boundary between two areas, see figure 4 -21.

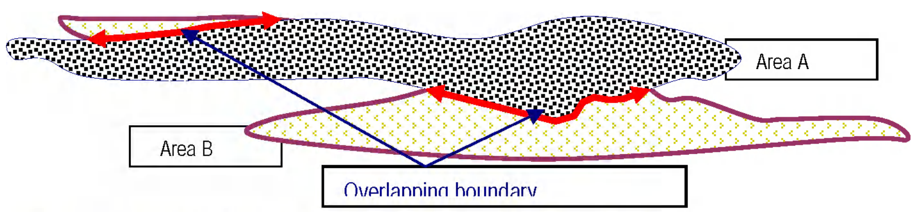


Figure 4- 21 Overlapping Boundaries (common boundary)

All areas within a single coverage must be exclusive and cannot overlap. Every point within a coverage theme falls unambiguously into at most one area. If two different areas represent the same aspatial information, then the two spatial identifiers of each polygon must be assimilated to the same aspatial records. So, Area B (see Figure 4-21) will be B/a, and B/b, indicate that they are spatially different but data content wise the same.

4.3 Results and Conclusions

➔ Structuring turns data into information, improves the way in which a large data are amassed persistently in the Geodatabase, and enhances retrieving efficiency and maintenance respectively.

➔ The Object Relational structure data model is flexible for the spatial data management because of its capability in storing objects, implementing SQL, SQL_3, and incorporating user defined functions (UDF) and spatial operators to extract, display and perform spatial analysis.

➔ The associativity of geometric objects and structured attribute tables requires a meticulous preparation. One mandatory process is checking for topological incompatibility (unnecessary gaps, overlapped polygons, presence of under or over shoots) of building block features, which has been implemented using topology clean up tools.

➔ Topology operation is indispensable to perform and achieve an appropriate object relational analysis and visualization of the information spatially.

➔ Overlapping of geographic objects could stem out of poorly represented boundary matches. Overlapped objects cause undesired ambiguity and misleading results during spatial interpretations. Creating clear topology relationships between objects before the action of spatial and aspatial data integrations have settled this problem.

Chapter 5: Constructing the GIS Maps

5.1 Introduction

Obviously, maps are the primary components of GIS. Their production requires knowledge of geo-mapping based on the principles of cartography, field surveying and spatial database managements. Typically, they could be of raster or vector electronic file types. The type and dimension of maps varies depending on the intended purpose. This chapter undertakes issues pertaining to appropriate GIS map generation within the scope and relevance to this research work.

Currently, different mapping software packages are being designed to draw and produce digital maps, example a CAD. However, such application is limited to graphical display, outputs non-relevant to spatial analytical capabilities when matched up to GIS, which is created to integrate multidisciplinary data and perform spatial analysis.

Creating full-fledged GIS maps involves storing data in a computer, *in a digital form. The process requires* a sequence of processes, such as, scanning, digitizing, geo-registering and amalgamating with structured databases.

Figure 5-1, is an illustration of GIS map of the northern part of Guayaquil Estuary (GIS case study), which depicts vectorised tributary flanks overlaying a satellite image and labeled measurement sites (★ 17). The different color indicates different information on the ground.

GIS maps which are composed of features are valuable for performing thematical display of integrated information layers [10]. Also a raster base map (composed of pixels) can be vectorised, and the output be applied to perform discrete spatial analysis of the associated database records for that specific area. Eventually, this fact enables us to evaluate visually discrete status of the target area. With this regard, it is natural to stress that the accuracy of GIS maps is vital not only for the intention of depicting geo-referenceable processed data but also for making important topologically related spatial decisions akin to public and private spatial assets.

Figure 5-1 Raster-Vector Overlap: Northern Guayaquil GIS Map

Examples: delineate zones susceptible to hazardous environment, demarcating fertile soil types and potential of economic resources, identify coastal zones with high demographic pressure, navigate and monitor remote research areas, urban and rural traffic managements …etc.

The means of generating discrete geo-reference able features in the form of vector elements by digitizing satellite images, scanned photos, numerical value derivative mapping, (2D and 3D) necessitates projection of research maps.

5.2 GIS Maps (Vector and Raster)

Vector map: It is composed of points, lines, and polygons, is an abstraction of the real world where positional data is represented in the form of x and y coordinates [21]. Point is represented by a Cartesian coordinates of x and y. Line is composed of series of ordered points. Polygon is represented as ordered list of points; with beginning and ending points are made to coincide in the same node and closed to create a defined polygon. Vector maps require complex data structure but occupy less storage space. However, maintaining topological relationship is easier especially when compared with raster based GIS, see figure 5-2.

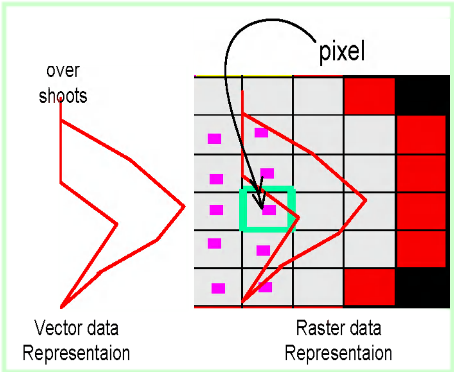


Figure 5 - 2 Maps representation

Raster Map: Raster based maps (systems) are composed of a matrix of pixels. Pixel refers to the smallest unit of information available in an image [25]. A unique reference coordinate represents each pixel and posses a discrete attribute assigned to it. Resolution depends on either the grid size or pixel and may vary from sub meters to kilometers [11], [21]. The resolution of the coastal satellite image in this research work is of 30 meters.

5.2.1 Scanning Pre-Existing Maps

Scanning is a process utilized to convert objects (e.g. paper maps) into image files. It is also equated to a means of sampling images with different color intensity. The paper map [see figure 5-3] is extracted from geo-scientific report related to stratigraphic, Sedimentology and Tectonics of Ecuador [16]. It has been scanned in an optical scanner of flat bed type and later digitized on a computer screen with proper registration [21], utilizing the area's projection Datum. Working on raster based maps is advantageous in the fields of Soil, forestry, rock types, marine and sub marine volcanology GIS to mention few; but there are some short comings which crops out as in the following (case 1-case 4).

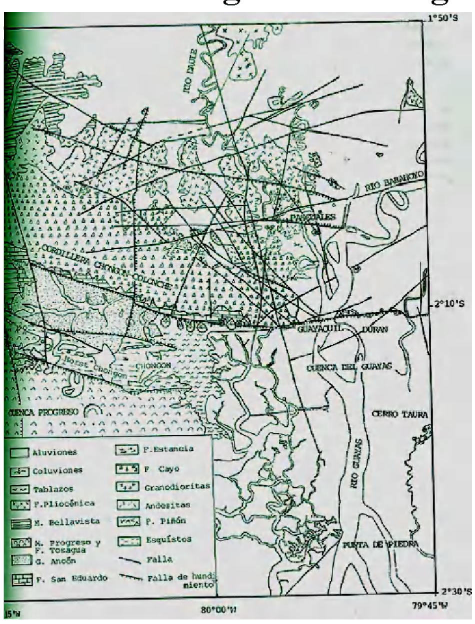


Figure5 - 3 Scanned Paper map

- Case 1 - The whole scanned image is converted to a single layer; hence, the apparently visible different colors within the image are dictated to be a single layer.
- Case 2 - Case 1 causes difficulties to distinct a river boundary and the measurement point features, which can be associated with database record (in a feature based GIS).
- Case 3 - In an image, a boundary can be visualized as a distinct set of specific pixel with specific color but it can't be relocated as a feature with a specific symbology.
- Case 4 - Raster files are large and can consume huge space in the system.

5.2.2 Vectorising

Converting images (see figure 5-3) into a distinct feature based map is a process of digitizing (see figure 5-4). This process has been executed on the scanned coastal map. Any scanned image with proper format can be viewed in a computer screen using an image viewer, manipulated (zoom, cut, paste…) and digitized appropriately. During digitizing the coordinates of every digitized element on the image are placed in a separate level with distinct symbology that identifies uniquely. This process can also be accomplished utilizing macros. Figure 5-4 is a display of the digitized and topologically cleaned and geo-referenced coastal map.

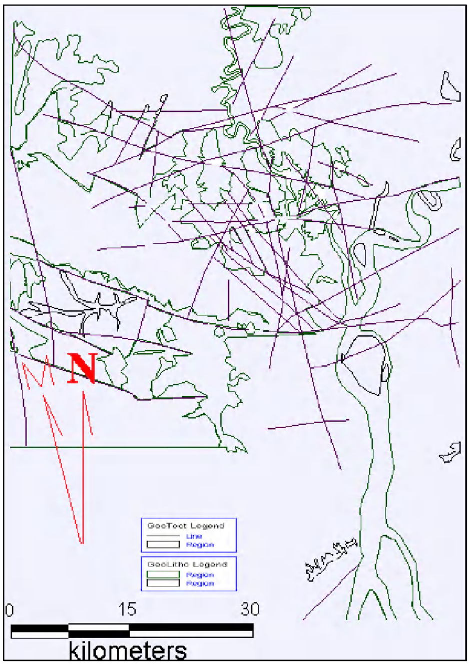


Figure 5-4 Vectorised and Topological clean up

5.2.2.1 Automated Scanning

Macro based digitized map is based on geo-coordinates corresponding to the underlying registered image file, (see figure 5-5). The vertices are joined to form lines (using mbe, see figure 5-5) that can be used as features during the GIS construction process.

```
1)  Sub main
2)  Dim start Point As MbePoint
3)  Dim point As MbePoint, point2 As MbePoint
4)  MbeSendKeyin "place lstring"
5)  MbeSendCommand "ACTIVE COLOR 5"
6)  MbeSendCommand "ACTIVE WEIGHT 1"
7)  MbeSendCommand "ACTIVE level 2"
8)  StartPoint.y = 5.350200#
9)  StartPoint.y = 5.260700#
10) StartPoint.y = 0.000000#
11) Point.x = startPoint.y
12) Point.x = startPoint.y
13) Point.x = startPoint.y
14) point2.x = point.x - 0.255600#
15) point2.y = point.y - 0.228300#
16) point2.z = point.z
17) MbeSendDragPoints point, point2, 1%
18) Point.x = startPoint.y - 0.432300#
19) Point.y = startPoint.y - 0.456600#
20) MbeSendReset
21) End Sub
```

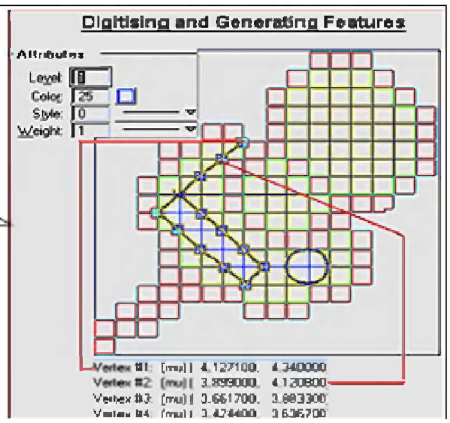


Figure5 -5 digitizing process

Also, the coordinates can be modified and re-sent to the GIS application to trace the image and produce vector maps provided the base map is registered and the coordinates are within range of the map's control points.

5.2.2.2 Auto to Semi-Automatic

Digitizing processes carried out through pattern recognition is of semi-automatic [31]. The automatic type is batch process, identifies objects and stores them in predefined layers. Objects within the image, with prominent intensity such as the roads, river boundary, measurement point ...etc are identified and used as active features to associate with database records.

Shortcomings:

- All features are digitized including the text unnecessarily
- Loss of closed shape features
- Digitizing causes noises that causes speckles (stains), gaps, line fragments and duplicates

This process requires the presence of a user, and hand on the mouse to respond to any message from the semi-auto digitizer. Since several objects are digitized at the same time, errors such overshoots, kickbacks (slices), dangling points and gaps occur [30]. The cleaning of this unnecessary feature is compulsory to establish an appropriate map suitable for the GIS analysis. A general view on the concept of their basic difference is indicated in table 5-1.

Requirements	Vector	Raster
Disk space requirement	Less	More
Topological relationship	Easy maintenance	Difficult
Maps output	Flexible, point-line-curve	Fixed images/intensity variation
Data structure	Complex	Simple data structure
Projection transformation	Manageable	More difficult
Hard and soft	Expensive	Depends on the size
Spatial analysis	Complex but flexible	Relatively Simple spatial analysis
Overlaying process	Time consuming and scale depend	Less Time consuming

Table 5-1 Vector and Raster files Dissimilarity

Creating features simultaneously during digitizing an image within a screen is more reliably positioned by zooming in the image to the extent of viewing the pixel size. This minimizes the possibility of having unnecessary geometric elements in the map.

With regard to georeferencing, raster files can be positioned in the right coordinates provided that certain known control points; relevant projection datum and ellipsoid are available. Otherwise, the vector map can be positioned - (A) by creating projected grid based on a control points and hook the tips of the grid to the target map (map to be projected). (B), by projecting individual features during the definition of the objects, which a major importance of the object relational data management.

In terms of the spatial geodatabase construction and related spatial analysis, the topologically cleaned features can be associated to individual geodatabase records based on the assigned ObjectID and geometry type. Furthermore, the features can be thematically represented by different symbols to represent the content of the associated, statistically classified geodatabase records.

Creating features from initially shrunken image will create discrepancy in the accuracy of the geo-referenced locations and thus creates ambiguity in the reality of the GIS analysis and interpretation process.

5.3 Case Study: Guayaquil Estuary

5.3.1 GIS Map's Features

In this case, study; the feature maps (see figure 5-6) are those that represent the real world objects associated to structured database records. They are described as types of line, polyline, polygon and text. Their symbology includes, the level situated, color, style, weight and the tolerance and priority of display. The vector map representation was chosen, for it is convenient to locate geographic objects that represent distinct area of interest (area or perimeter, point of measurement, boundary (contact zone), extension and direction of a tectonic shears) with specific element type description and symbology (see figure 5-6).

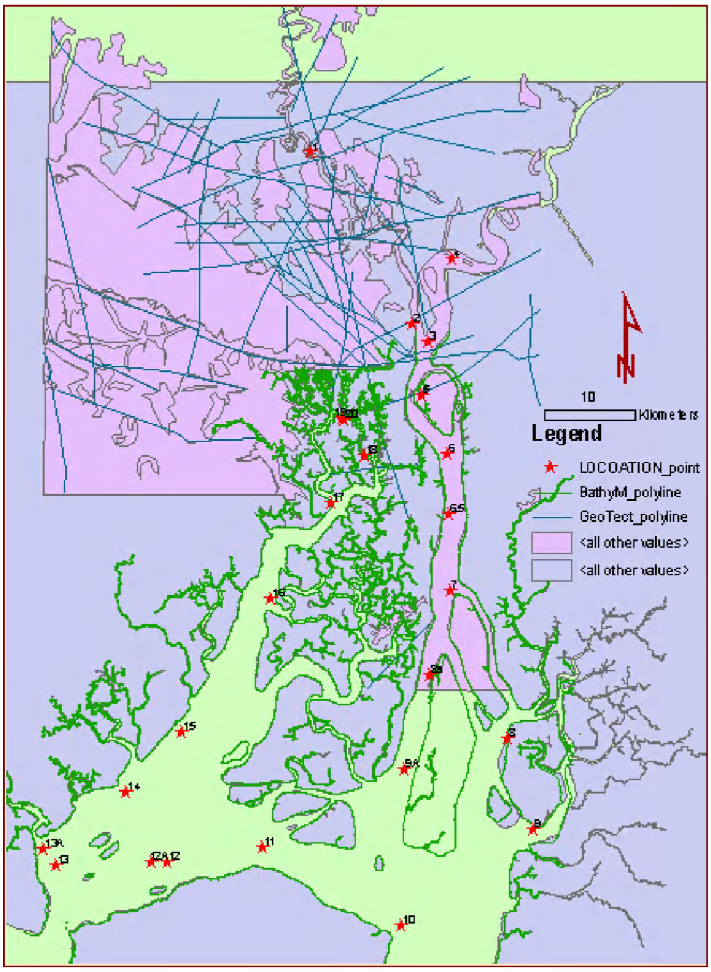


Figure5-6 Composite lithologic and Tectonic and Location Points

5.3.1.1 Coastal Geo-Lithology

According to the literature [16], the coastal geo set up of Guayaquil area is comprised of: -

- Oceanic crust composition (basaltic), and theoletic type; harzuburgite outcrops with pyrite and rarely copper dissemination; andesitic and dasitic basalt, dissected by dykes intrusive of granite.
- Unconsolidated sediments of sand, silts and clay, silt stone, lenticular layers of calizas algae

- Sedimentary environment composed of Cayo sandstone, Guayaquil siliceous limestone thickness ~= 100m.

The faults dissect the different features (lithology, estuary channels and measurement location that can be visualized by superimposing the features of the structural map onto the lihological map.

These descriptive lihological maps in the northern part of the estuary (see figure 5-6). The spatial relationship of the lihological and structural maps displays that the area had been subjected to geo-dynamic shearing forces of NE, NW, and E-W trends. Referring to same map, the NE trend tectonic structure dissects the NE part of the rivers and tributaries. However, it is also observed that NW structural trends seem to control the western part of the estuary.

5.3.1.2 Measurement sites Map (Location points)

A number of measurements Point-sites were established in a measurement GIS map, which can be used to identify the environment data set up of the estuary's different channels and to utilize GIS as spatial technology tool in understanding the integrated spatial distribution.

These sites are composed of heterogeneous multidisciplinary data and were collected from an estuary channels trending NE, N and EW. During the implementation, these point feature sites (see figure 5-7) were integrated with coastal maps under the same projection system (datum PSAD56 17S and International 124 Ellipsoid).

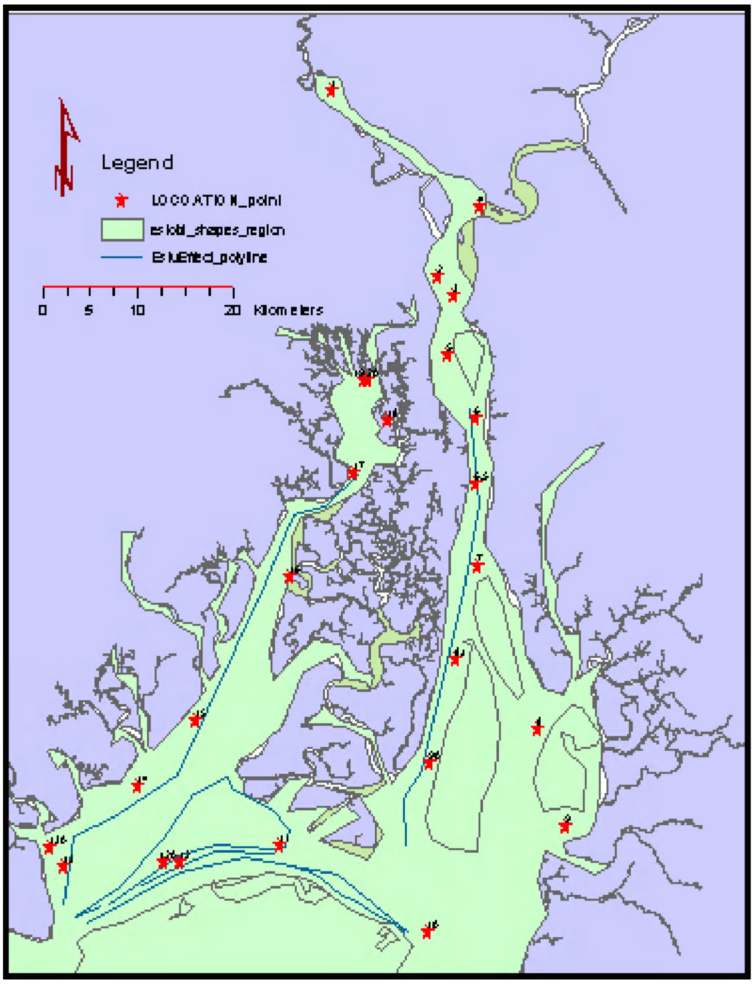


Figure5-7 Estuary and Measurement sites

5.3.1.3 Derived Spatial Features

The process is aimed to produce features, (including surface, ground and plan) and the generating of a 2d and 3d (spatial features) in the form of contours, triangulated maps, grids and cross sectional views of the

GIS features using the available resources applications [18], [19]. The attribute data source (x, y, and z) is extracted from the case study Guayaquil Salado project GIS geodatabase. Appropriate extraction of the coordinates from the geodatabase has been performed using SQL, associated spatial functions and related customizing languages (MBE, VB). The type of the attribute values depends on the global position of the area (see figure 5-8).

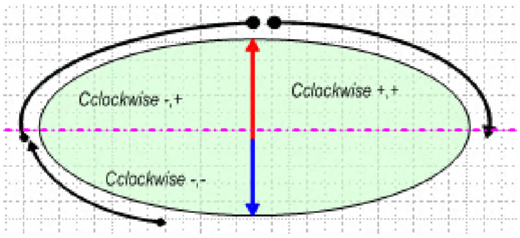


Figure5 - 8 Longitudes and Latitude Sign Representation

The accuracy of the longitude and latitude (LL) depends on the resolution of the GPS utilized to retrieve the Geocoordinator of the measurement points. On the other hand, the elevation (in this case study) is derived from the echo-sounding and projected bathymetric map. The ++ symbols lie in the first quadrant and the - - in the 3rd quadrants to indicate the coordinated hemisphere, (see figure 5-8).

The unit that corresponds to the Reference master (Lon, Lat) is degree, min, and sec. The difference of the values can be traced by tracking on any projected map. Master Reference geo-coordinates easting (x) and Northing (y)) are in a map unit (see figure 5-9), which could be either negative or positive depending on the locations quadrant as illustrated in Figure 5-8. The unit that corresponds to the Reference Master is longitude and latitude. East West and North-South tracking along a fixed latitudinal and longitudinal line measures the variation of the E-W or (longitude) and N-S (Latitude) values respectively.

Figure5 - 9 Easting (X) vs. Northing (Y)

Figure 5-9 discloses the equivalence of the two units on a Geocoordinator [22] projection application. Unlike the Reference Master, the master reference geo-referencing values (LL) are loadable as numeric values to an external 2d/3d geographic feature generating application

5.3.2 Retrieving Geodata Source

There are many possibilities of retrieving geodata sets; some of which implemented during this research works include: -

- *Retrieving the Master reference values directly from the appropriately projected map*
- *Convert the reference master to decimal LL values*
- *Retrieve the numerical values from geographic objects (convert features into a DXF file format)*
- *Derived from GIS database (using SQL and associated functions)*

During this research work, by arranging the attributes, a series of longitude, latitude and depth or elevation (L, L and D or X, Y and Z) were generated on both sides of an initial point (i) (see figure5-11). Therefore, the LL and D values at a point are represented by i and i + … n etc, values along different profiles across a bathymetric map.

Linearly: $= (i = (X \pm Xn)/2, (Y \pm Yn)/2, (Z \pm Zn)/2)$

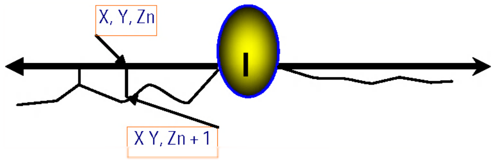


Figure5 - 10 Generating the 3D parameters

The attribute data that control the 3d surface generation has been created, taking into account the original values of OE, ON, OD *(see figure 5-10, and 5-11)* at a given point within a projected working map. For a fixed azimuthal direction (ON) there is a change on OE + - n and change of elevation on (OD).

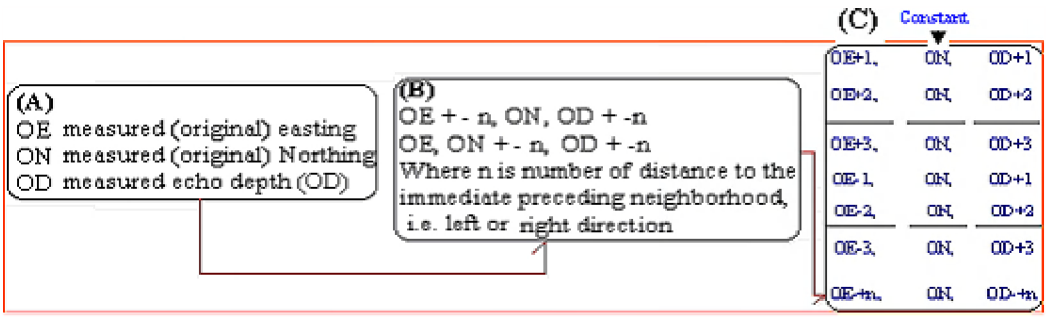


Figure5 -11 (A) Initial point of reference (B) extending (C) increment

5.3.2.1 Converting the Typed data

String type input (reference master values) of longitude and latitudes cannot be included into the calculations as they are. They ought to be converted into numeric values using extended SQL programs so that they can be included into the program calculation, see below the procedure applied. The conversion process includes following steps: -

```
A 1. Select station_loc.stno,
  2. Station_loc.lon, station_loc.lat,
  3. Val (left ([lon], 3)) as londeg,
  4. Val (right ([lon],8)) as lonmin,
  5. Right ([lon], 5) as lonsec,
  6. Val (left ([lat], 3)) as latdeg,
  7. Val (right ([lat],8)) as latmin, right ([lat], 5) as latsec
  8. From station_loc;
```

(<u>A</u>) Step1 - Step2 selects the attributes from the table,

Step3 - Step8 extracts the longitude, latitude numeric values and coins the name LonDeg, and LatDeg, LonMin and LatMin, and LonSec and LatSec for degree, minute and seconds respectively. The converted values are populated in the geodatabase with variables OE, ON, OD and further can be extracted in a sorted order to generate the geometric elements.

```
B 1.  SELECT OE, ON, OD       '> (point of departure)...
  2.  OE+1,   ON,   OD+1,     '> right of original feature
  3.  OE-1,   ON,   OD+1,     '> left of original feature...
  4.  OE+2,   ON,   OD+2,     '> right of original feature
  5.  OE-2,   ON,   OD+2,     '> left of original feature...
  6.  OE+3,   ON,   OD+3,     '> right of original feature
  7.  OE-3,   ON,   OD+3,     '> left of original feature...
  8.  STATION (location id)
  9.  FROM Location
  10. GROUP BY STATION
  11. ORDER DESC;
```

B) The program generates coordinates values converted and arranged in a series of ordered X (OE) and Y (ON) and respective Z (OD) coordinates with respect to original point of reference (Easting (X), Northing (Y) and elevation (Z), (see figure 5-12)

I		LET ON =Yo, OE=X, OE=Zo		
	0,3,0+	1,3,0+	2,3,0+	3,3
2	0,2,0+	1,2,0+	2,2,0+	3,2
	0,1,0+	1,1,0+	2,1,0+	3,1
	1	2	3	4
3	0,0,0	1,0,0+	2,0,0+	3,0,0+
	Xo,Yo,Zo	Xo+1.Yo.Zo+1	Xo+2.Yo.Zo+	Xo+3.Yo.Zo+
	(initial)			
4	0,-1,0+	-1,-1,0+	-2,-1,0+	-3,-1,0+
	0,-2,0+	-1,-2,0+	-2,-2,0+	-3,-2,0+
	0,-3,0+	-1,-3,0+	-2,-3,0+	-3,-3,0+
		coordinates at 3 = (coordinates at 2 + coordinates at 4)/		
	i	at 2 := (Xo+1,Xo+3)/2 = Xo+2,		
	ii	at 4:= (Yo+Yo)/2 = Yo		
5	ii	corresponding Z:= (Zo+1,Zo+3)/2= Zo+2		
	result	1+Xo+3)/2, (Yo+Yo)/2 ,(Zo+1+Zo+3)/2 = Xo+2,Yo, Zo+2		
6		Thus : at a point the value of referencing point including the Z will be Xo+n,Yo, Zo+n where Xo+n is the Easting(longitude),Yo is corresponding Northing. The Zo+n elevation concatenated with		

Figure5 - 12 Illustrating the process

The ON, OE and OZ are the initial or departure point references for recording the different elevation with respect to the change of the longitude and latitude coordinates. They ON+1, OE, OZ+1 indicate a move along the Northing, with no change of easting but change on elevation. The ON, OE+1, OZ+1 shows the shifting of the position eastwards with constant Northing as the initial point but with possible change on the elevation. In a similar manner, the leftward and rightward extension with respect to the possible changes of the elevation is indicated below, (see table 5-2).

5.3.2.2 Graphic data generation

Based on the procedure (section 5.3.2.1) the measured values of the co-ordinates and the corresponding elevation values are retrieved from the structured database. The values generated are loaded into a Macro to create a regular grid system for the geographic features that represent the GIS measurement points. Table 5-2 (a+b) shows the values corresponding to the variables defined in the database.

a

Station	Latkm	Lonkm	Echo_depth_m	12	398.07	9704.39	-12
1	612.93	9781.45	-11	12A	396.18	9704.32	-4
4	626.34	9770.45	-4	13	336.6	9703.38	-13
2	625.35	9763.4	-6	13_1	582.07	9605.93	-6
3	626.59	9761	-7	13A	583.61	9703.88	-4
5	624.58	9756.54	-11	14	592.98	9713.33	-14
6	626.59	9750.89	-8	15	604.49	9721.38	-7
6.6	630.01	9742.31	-10	16	605.62	9733.22	-11
7	628.16	9733.23	-12	17	616.26	9743.77	-19
8A	625.99	9724.4	-9	19	621.74	9747.03	-14
9A	622.48	9714.88	-7	18	519.03	9749.01	-17
11	608.49	9706.73	-7	20	617.49	9753.08	-19

b

Profile 1

St_No	E(X)	N(Y)	EC(D)
	628.928	9781.452	12
	625.928	9781.452	10
	622.928	9781.452	7
	619.928	9781.452	1
	616.928	9781.452	-5
1	613.928	9781.452	-11
	610.928	9781.452	7
	607.928	9781.452	9
	604.928	9781.452	3

Profile 2

St_No	E(X)	N(Y)	EC(D)
	616.946	9763.399	8.5
	619.346	9763.399	5
	622.946	9763.399	1.5
	625.346	9763.399	-2
2	628.346	9763.399	-6
	625.946	9763.299	3
	622.946	9763.399	6
	619.346	9763.399	8

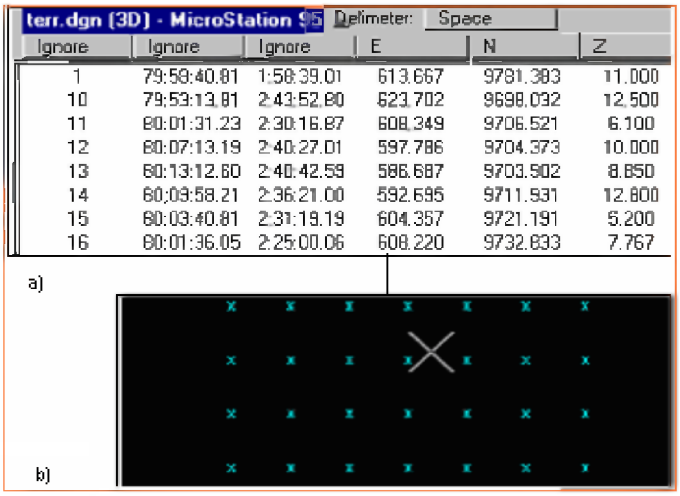
Profile 3

St_No	E(X)	N(Y)	EC(D)
	635.588	9761.006	6
	632.588	9761.006	3
	629.588	9761.006	-2
3	626.588	9761.006	-7
	623.588	9761.006	3
	620.588	9761.006	10

Table 5-2 (a) Geodata source (b) Extended 3D Measured Data source

It is illustrated that station 1 is taken as a departure point for profile 1, followed by station 2 /profile 2 and station 3/ profile3. The textual coordinate data are populated into a projected grid map to produce the appropriate position.

Figure5 - 13 A 3D data source (a) Grid map on E, N and Z (b)



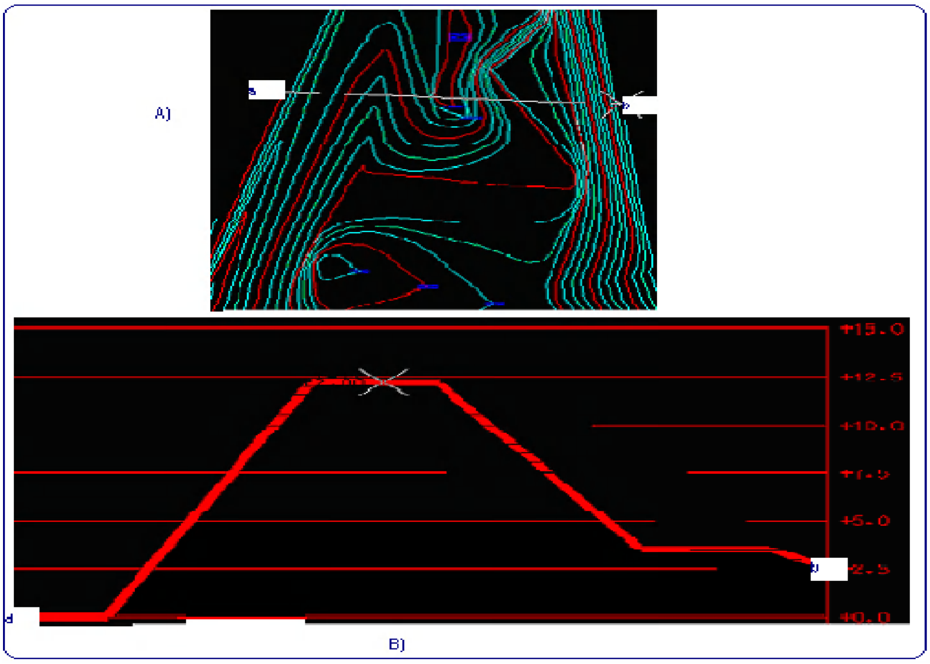
Ignore	Ignore	Ignore	E	N	Z
1	79:58:40.81	1:58:39.01	613.667	9781.383	11.000
10	79:53:13.81	2:43:52.80	623.702	9698.032	12.500
11	80:01:31.23	2:30:16.87	608.349	9706.521	6.100
12	80:07:13.19	2:40:27.01	597.786	9704.373	10.000
13	80:13:12.60	2:40:42.59	586.687	9703.902	8.850
14	80;09:58.21	2:36:21.00	592.695	9711.931	12.800
15	80:03:40.81	2:31:19.19	604.357	9721.191	5.200
16	80:01:36.05	2:25:00.06	608.220	9732.833	7.767

An operation is executed on the textual (XYZ / ENZ) data in a 3d applications generator [19] to achieve the visualization (see figure 5-13, a + b) of the points. The string data type of LL are set to ignore but previewed in the same corresponding row to the ENZ

5.3.3 Visualization: Cross Sectional View

Contours were created based on the specified range of Z values (see figure 5-13a) corresponding to the geo-referenced coordinates in a 3D seed file. A cross sectional view of the area of interest covered by contoured lines is generated based on the option of the user to visualize the vertical zone (see figure 5-13 and figure 5-14 (a + b). The filtered data, which applied for generating the visualisable theme, are stored in the structured GeoRelational database. Furthermore, in a similar methodology, appropriately formatted flat files can be used as textual data source for georeferencing coordinate attributes pertaining to the site of interest.

Figure5-14 (a) Contours (b) and Cross Section



A 3D map is essential for visualizing an area's morphology and certain activities in that area of interest. The above work shows the result overlay of encircled measurements sites over the constructed 3D map of the Guayaquil Estuary.

Scale vs. Visualization: The working map unit is expressed in km. In the case study, the OE and ON is also expressed in the maps working unit. If the Z value is assumed to be expressed in the same unit, then the depth (echo sounding or sampling depth) that is measured in meters will be unrealistically expressed.

Thus, the minus (-11 meters) value, which has an actual information value in meters, is considered as km.

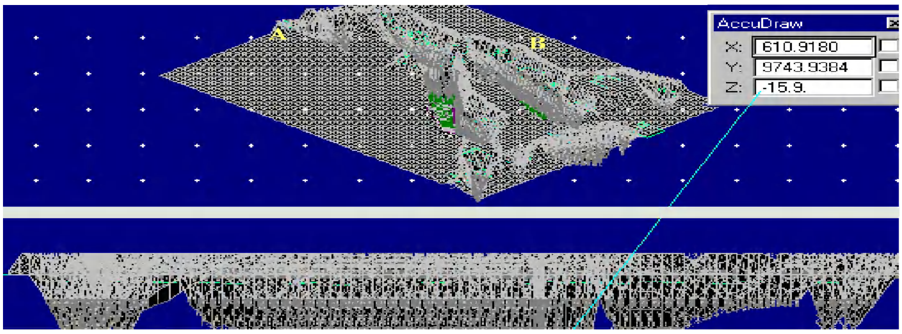


Figure5 - 15 Cross Sectional View

To avoid this, the visualization is executed at a scale (de-exaggerating coefficient) of 1:1/1000 i.e., the Z value is conceptually understood that it has been de-extended by the given coefficient to rectify with the actual depth and perspective view. In this case the Z= 15.9222 m (rounded to 15.9 m) in meters which is displayed according to the sub working scale (m) of the projected map.

Z= (Actual depth) (m) = $z * 10^{-3}$

5.3.3.1 3D Perspective View of Measurement object

Superimposing of associated measurement features and attributes values on a projected map are advantageous because there is always synchronized matching of the measured spatial database record and their respective position of that particularly information inside the 3D map. In such cases, the spatial analysis will take into account the vertical dimension, which indicates the elevation environment, (see figure 5-15).

Via closer visualization of the maps (see figure 5-16 a and b), one can see the layers of the real world features as: -

(1) a 3D map is at the base displaying the estuary geomorphology,

(2) Geo-referenced measurement points are placed at the right selected position, where all the possible multidisciplinary data were collected and an aerial extension of associated feature surrounds each centroid.

The bathymetric contour map layer blankets the area of study, showing variable contour width to reflect the submarine geomorphology. Even though the process of constructing and implementing is laborious and time consuming, but the output is very important for combined visualizations and spatial analysis, hence it is worth doing it.

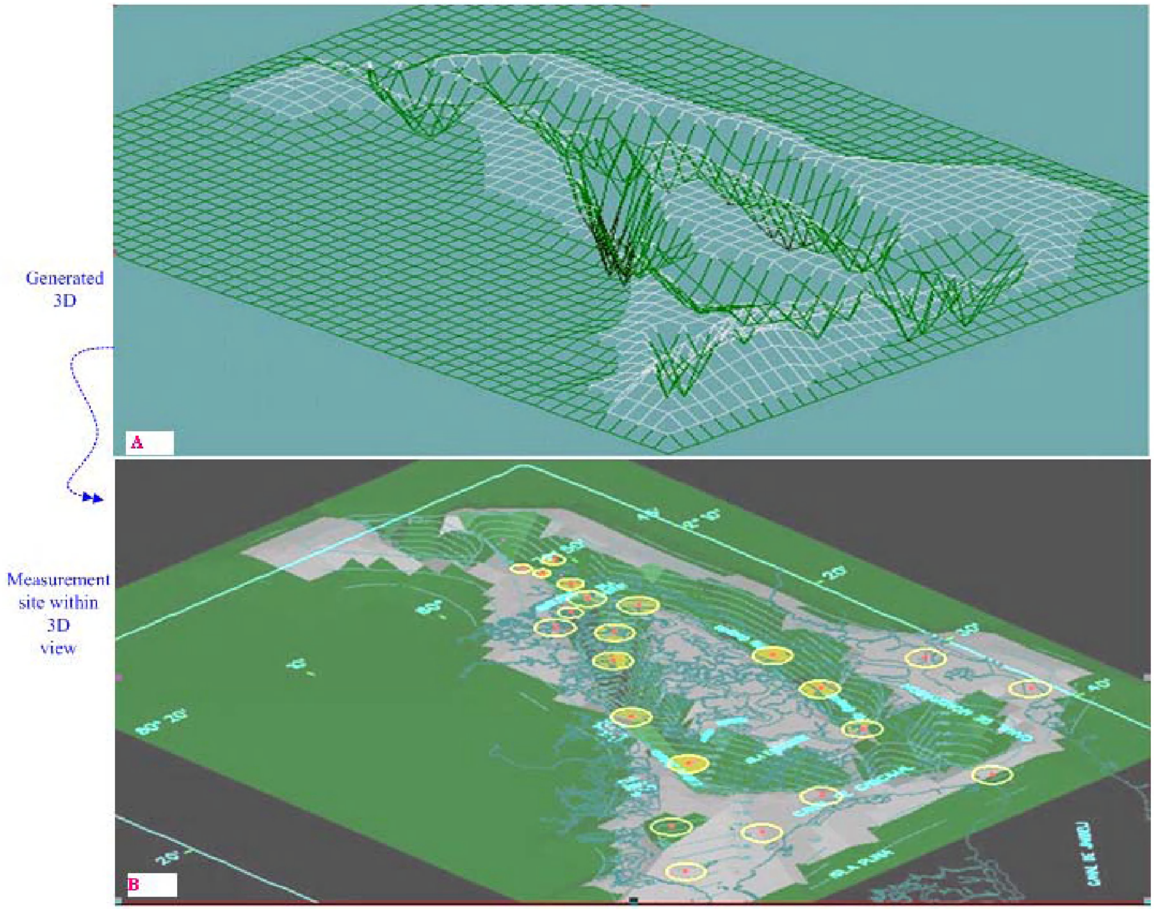


Figure5 - 16 (a) Submarine Morphology, (b) 3D, Bathymetric and measurement stations

5.3.3.2 Automated feature generation

Macros select tools and view controls, send key-ins, manipulate dialog boxes, and modify elements. The obvious advantage of writing a macro to perform a task that could otherwise be done manually is automating mechanical and repetitive tasks. The macro (refer appendix C) - (A) Loads the spatial data source with properties and symbology and (B) Generate measurement features. The steps followed are: -

Step 1: Design the macro (MBE) that loads the x, y and z values and creates and creates a synchronized position of geographic point features, Places the feature on the specified level;

Step2: Create the feature point and second feature zone of influence as an aerial extension with a radius defined, Changes the symbology, and ends the execution using the MbeSendReset.

Step 3: Adding Features Design that views the level of the surface water in the estuary channels, then setting Z value (echo-depth) to 0 as follows.

```
Sub main
MbeSendKeyin "place line"
MbeSendKeyin" xy=613.928, 9781.452, 0.00"  ' 1
MbeSendReset
End sub
```

Output:

- Geographic map with the specified properties and symbology
- Measurement along (23 stations) Estuary channels viewed with respective to depth (m).
- Elevation scales de-exaggeration is described textually or geometrically ($z * 10^{-3}$).
- Possible views of the map (top view, isometric, left and right views).

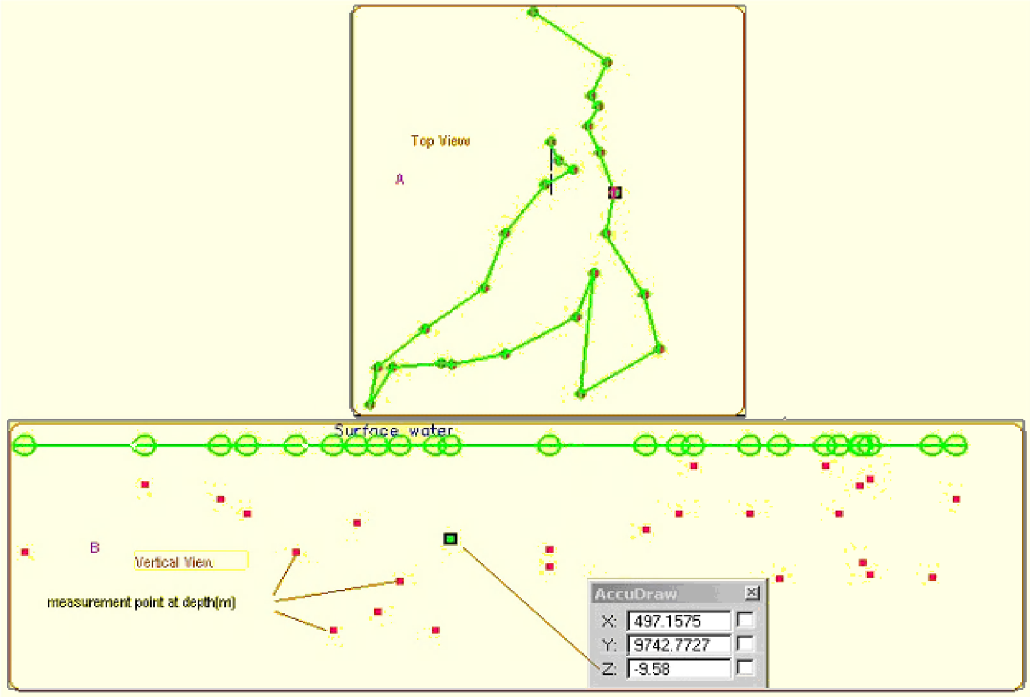


Figure5 –17 Geographic Features: a) top view b) left view (Z) meters View

5.4 Georeferencing

We know that the earth is not flat, yet, when we construct GIS maps, it becomes our effort to make them flat using projection system procedures. This process of altering a spheroid or curved earth's shapes to flat surface triggers a problem of distortion on the original setup up of maps. The earth is not sphere (not symmetric about its center), but it is of a spheroid-shape [70], which can be described by rotating an ellipse (see Figure 5-18), which is characterized by its major and minor axes about its axis. The spherical coordinates are the latitude and longitude ranging –90 to + 90 and –180 to + 180 respectively.

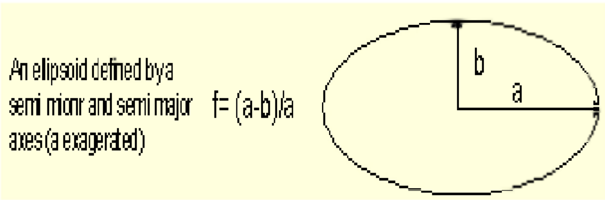


Figure5 - 18 (a), Semi-major axis (b) Semi-minor axis

Likewise, different measurements show different semi-major and semi-minor axes and this in turn creates different datums.

Thus, even if two shape files of the same scale unit (longitude and latitude) and area are treated on different datums they will not match perfectly. The following ellipsoid constants indicate the variation of the parameters [30]. Table 5-3 shows the international-1924 and WGS84 ellipsoids (of the local area of study) semi major and semi minor axes differences. According to [70], table 5-3 displays the parameters of the two ellipsoid and the flatness is the calculate coefficient value of the axes. Semi minor and semi major axes define the dimension of the earth ellipsoid shape [63]. This values can be combined to define the degree of flatness expressed as f = (a-b)/a. The value of f is given in the form of a fraction 1/n where n = a / (a-b), [63], (see table 5-3).

Axis	International_1924	Wgs84
Semi-Major	6378388.0000 (m)	6378137.0000(m)
Semi-Minor	6356912.0000 (m)	6356752.31425 (m)
Flattening (F)	0.003367004	0.003352811
	1/x = 297	1/x = 298

Table 5-1 Ellipsoids Parameters Variation

The flattening differences between the data (see table 5-3) are slightly visible, but when applied in local area scale the variations become more apparent. The International-1924 ellipsoid is related to the Geoid-datum PROJCS "PSAD_1956_UTM_Zone_17S", which is portrayed here as the GEOGCS "GCS_Provisional_S_American_1956", on the other hand the WGS84 ellipsoid is as a GEOGCS "GCS_WGS_1984", related to the PROJCS ["WGS_1984_UTM_Zone_17S",

Example

```
PROJCS ["PSAD_1956_UTM_Zone_17S",
GEOGCS ["GCS_Provisional_S_American_1956",
DATUM ["D_Provisional_S_American_1956",
SPHEROID ["International_1924", 6378388, 297]],
PRIMEM ["Greenwich", 0], UNIT ["Degree",
0.0174532925199433295]],
PROJECTION ["Transverse_Mercator"],
PARAMETER ["False_Easting", 500000],
PARAMETER ["False_Northing", 10000000],
PARAMETER ["Central_Meridian", 81],
PARAMETER ["Scale_Factor", 0.9996],
PARAMETER ["Latitude_Of_Origin", 0],
UNIT ["Meter", 1]]
```

```
PROJCS ["WGS_1984_UTM_Zone_17S",
GEOGCS ["GCS_WGS_1984",
DATUM ["D_WGS_1984",
SPHEROID ["WGS_1984", 6378137, 298.257223563]],
PRIMEM ["Greenwich", 0], UNIT ["Degree",
0.0174532925199433295]],
PROJECTION ["Transverse_Mercator"],
PARAMETER ["False_Easting", 500000],
PARAMETER ["False_Northing", 10000000],
PARAMETER ["Central_Meridian", 81],
PARAMETER ["Scale_Factor", 0.9996],
PARAMETER ["Latitude_Of_Origin", 0],
UNIT ["Meter", 1]]
```

5.4.1 Geodetic Considerations

One of the most important knowledge required during map projection process is the perception of the earth's shape and size. This issue is dealt geodetically (measures of the shape and size of the earth exact position of a particular point with respect to earth's curvature.

5.4.1.1 Position

The concept of position as defined by coordinate system is essential both to the process of map making and to the performances of spatial search and analyses of geographical information [32]. For instance, the key attribute of the coordinates is used to guide or make a spatial search, determine which feature occurs in, on or in the vicinity of the other feature. With this regard, to plot geographical features on a map, it is crucial to define the position of the point features with respect to a common references or coordinate system.

The coordinate system that constitutes the frame of references necessary for mapping and searching geographical information allows us to specify the position in terms of distance, direction (from a fixed point), lines or surfaces. The representation can be revealed either in a two-dimensional planar (rectangular) or three-dimensional polar coordinate.

5.4.1.2 Datum

A datum is a set of parameters defining a coordinate system and control points whose geometric relationships are known, either through measurement or calculation [21]. In the last fifteen years, satellites have provided geodesists with new measurements to define the best earth-fitting ellipsoid, which relates coordinates to the earth's center mass. The most recently widely used datum is the World Geodetic System of 1984 (WGS84) [32], where the measurements are collected using GPS (Global Positioning System).

A datum is characterized by vertical and horizontal characteristic. Horizontal datum is the set of constants specifying the coordinate system to which horizontal coordinates are referred to, whereas a vertical datum is a set of constants specifying the coordinate system to which elevations are referred.

Substantial irregularities in the surface created by global mean see level (MSL) [15] is observed. These irregularities form very gentle but massive "hills" and "valleys. This finding was made possible through the use of GPS, a technology designed by *national imagery and mapping agency* (NIMA) [82]. The GPS receivers compute and store coordinates in terms of WGS84, then transform to other datums when information is displayed.

5.4.1.3 Mean Sea Level

The shape of the earth can also be defined by the surface of the oceans, which covers two thirds of the Earth's surface. The level of the oceans changes as the gravitational pull of the sun and the moon produce the phenomena known as tides ellipsoid [80]. Compositionally, the earth is not uniform throughout. Regions of denser material exist intermingled with regions of less dense material. As a function of the earth, mass material the gravitational force varies unpredictably from one place to another. Result is complex undulating shape with many peaks and valleys distributed over the entire surface of the Earth. "However, geodesists have been able to establish an ellipsoid such that the height of the highest peaks and the depths of the deepest valleys are in the order of 100 meters from this best fitting ellipsoid" [80]. So, *Geoid, a term derived from the Greek word meaning earthlike [25], is used to refer to the rather odd shape of the imaginary earth shape] The* Geoid approximates the **mean sea level** (MSL) [81].

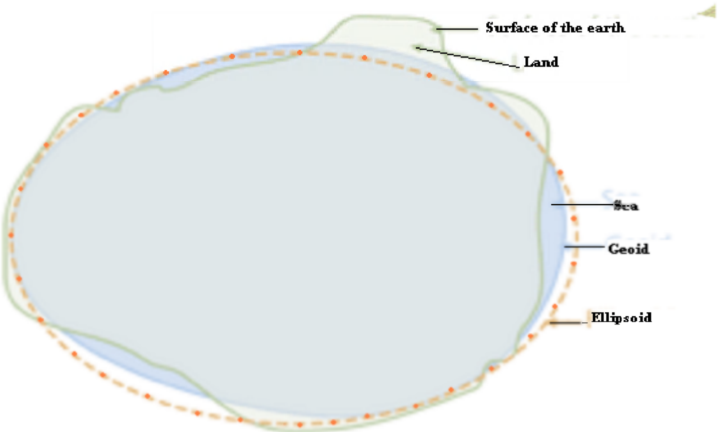


Figure5-19 The Geoid, (After Witold Fraczek)

The MSL is described as a tidal datum that is the arithmetic mean of hourly water elevations observed over a specific 19-year cycle [81]. This definition averages out tidal highs and lows caused by the changing effects of the gravitational forces from the moon and the sun. It is a local zero elevation and is called the vertical datum. With respect to map making the surface of the MSL conforms to the gravitational field. However, the MSL is in a state of gravitational equilibrium, regarded as extending under the continents and is close approximate to the Geoid. In most cases, at the coastlines, the MSL and Geoid are assumed to be essentially the same, at some spots the Geoid actually differ from MSL by several meters [81].

5.4.2 Map projections

Projection is a mathematical model that transforms the locations of features on the Earth's surface to locations on a two-dimensional surface [82]. The process enables us to obtain position of **features** on the earth's surface, on a map with slight distortion. Projection of curved surface causes certain distortions [25], [22] which could include area, distance or direction to some extent. The impact of this distortion depends on the scale of the map being processed.

On large-scale maps, such as local street maps, the distortion caused by the map projection being used may be negligible due to the nature of the map small area coverage on the earth surface.

On smaller scale maps, such as regional and world maps, (where a small distance on the map represents a considerable distance on the Earth), the distortion may have a bigger impact.

5.4.2.1 A Case study: GIS Map Georeferencing process

Certain predefined projections displayed as "standard" projections are associated with *specific spheroids*. For instance, during this research, the Datum PSAD1956 is associated with the *International 1924* ellipsoid.

The Datum PSAD1956 was established in 1956 with an origin at La Canoa, Venezuela (South America) [83]. The fundamental point pertaining this datum, at La Canoa is: - Φ: = Latitude 8 deg 34 min 17.170 sec N,Λ: = Longitude 63 deg 51 min 34.880 sec W. [83], See table 5-4, for detail parameters.

Country	Area of use	Coordinate System	Transformation method	Geoid. Datum	Ellipsoid	Zone	Unit
South America Chile; Ecuador; Peru	South America (Chile; Ecuador; Peru) 84degW to 78deg W.	PSAD56 zone 17S	Transverse Mercator	Provisional South American Datum 1956	International 1924	UTM zone 17S	Meter

Table 5-2 The projection Parameters

According to [84], the area encompasses 84-degree **w** to 78-degree **w** and this Geoid datum aligns to the international 1924 spheroid table (5-4). The coordinate system of PASD56 projection is based on the Universal transverse Mercator and is hooked to the **17S** zone in order to distinguish from other zones in of the same datum.

Projection requires a grid map generation based on control points, related to a known datum and a target map that needs georeferencing corresponding to the datum based control points, (see figure 5-20). The intersection of x and y at a specific angle makes the map locatable. Example of such map projection grid is the Universal Transversal Mercator (UTM) A projected coordinate system that divides the world (globe) into 60 north and south zones, six degrees of longitude wide. Each UTM zone has its own central meridian from which it spans 3 degrees west and 3 degrees east of that central meridian.

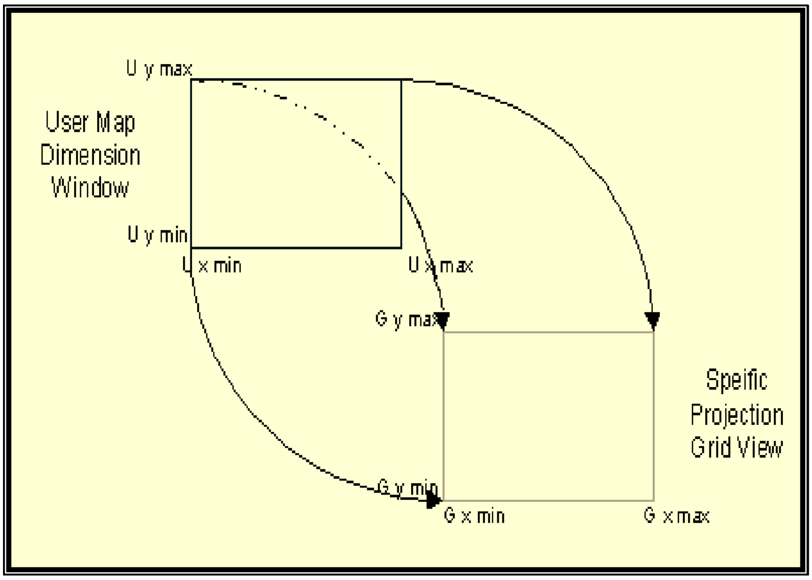


Figure5 -20 Map projections

The limits of each zone are 84° N, 80° S. The origin for each zone is the *Equator* and its *central meridian*. To eliminate negative coordinates, the projection alters the coordinate values at the origin. The value given to the central meridian is the false easting, and the value assigned to the Equator is the false Northing.

For locations in the Northern Hemisphere, the origin is assigned a false easting of 500,000, and a false Northing of 0. For locations in the Southern Hemisphere, the origin is assigned a false easting of 500,000 and a false Northing of 10,000,000.

The zone's Northing starts at the equator as 0,000,000 and is numbered northward in meters. The easting (longitude) coordinate is measured from an arbitrary number 500000 meters to the west of the central meridian indicating that each central meridian is measured 500000 meters apart [27], [10].

For the southern hemisphere an offset of 10, 0000 km is applied to obtain specific coordinates. Each central meridian is measured 50, 000 meters apart.

5.4.3 Implemented Projection Procedures

The process of the projection involved the definition of the grid and identification of the datum as given in the operational GIS project. The steps utilized are as follows: -

5.4.3.1 Step 1: - Targeting Coordinate choice

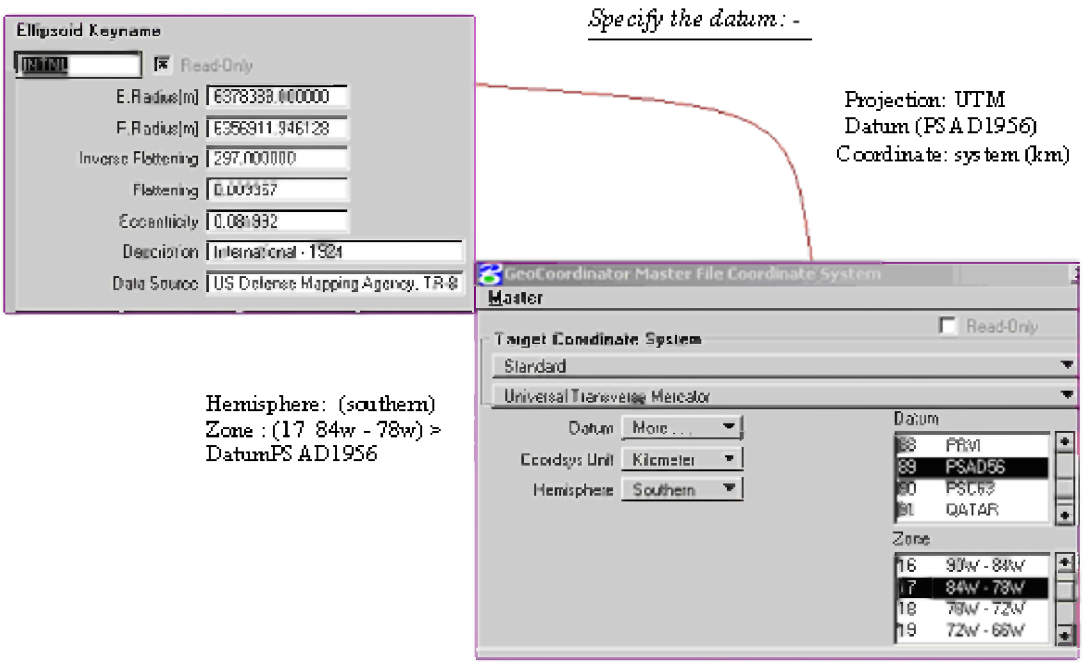


Figure5 - 21 Datum Specifications

The Master file coordinate system *GRID* was created with the Longitude and Latitudes (LL) at four corners within an empty design file. MDL (MicroStation development language) keying is used to activate the applications. So MDL LOAD > loads the MDL and MDL LOAD GCOORD loads the Geocoordinator application.

5.4.3.2 Step 2: - Define Control Pnts.

Grid Generation: - Grid line parameters include - Longitude (x) and latitude (y), density of the intervals and Min and Max values of the coordinates, level of the grid and related symbology utilized to distinguish it from geographic features.

5.4.3.3 Step 3: Wrapping and Merging

Transformation: - *Step3 involves the Merging of the projected grid with the target map user map, which has known coordinate from the data source of the image.*

Key in: - MDL LOAD MERGE (invokes merging application).

Path: - MERGE C: / ECUADOR\GUAYAS. DGN (dgn files)

Key in: - GCOORD PLACE CONTROL POINT:

1. *Identify: source point =➔target point;*
2. *Map to be hooked =➔map in projection;*
3. *4 control points selected are attached to the map*
4. *Warp ➔Set-Up ➔Fills ➔Fills (Ctl Point);*
5. *Warp➔all (as fence)➔open .ctl >> transfer coordinate to target map (see figure 5-22)*
6. *Nailing of the 4 coordinate points of the grid to the corresponding map.*

The map generated according to specified control point (4 ctl points) parameters, Datum parameters (PSAD56) related spheroid and selected projection System (UTM). The projected grid map and the target map (coastal periphery map) are fused. Eventually, the projected map, (see figure 5-22), is merged with the main estuary map as displayed in figure 5-23.

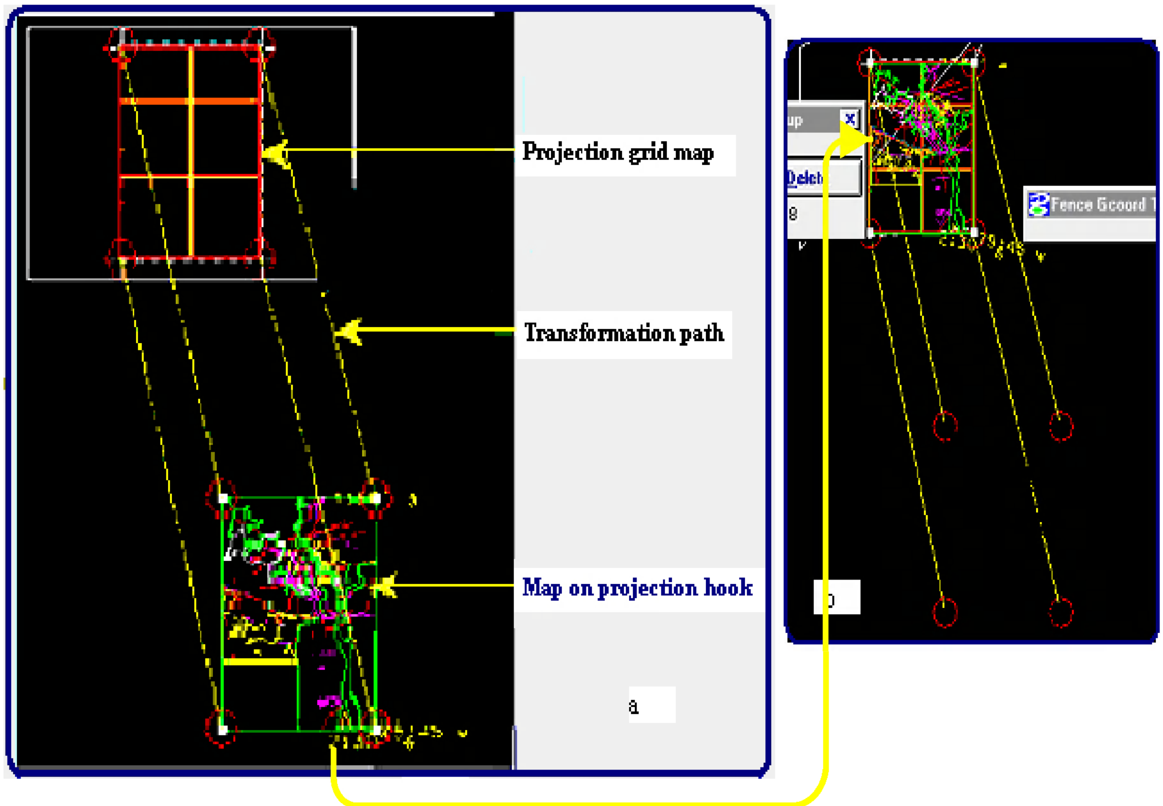


Figure5 – 22 Assimilation of a Grid and User Map

5.4.3.4 Step 4: Integrating the project maps

The area bounded by a rectangle is the newly projected map and is fitted to the main estuary map composed of point measurement and estuary coastline geographic elements (see figure 5-23).

The performance of a perfect merging process of all the projected working features resulted to the production of an integrated geo-referenceable map of the area of interest.

Eventually, this process facilitated the process of performing spatial analysis among the geographic features, mainly – the measurement sites map within the Estuary and the coastal periphery maps, where the later were derived from previous geological works, (see figure 5-23).

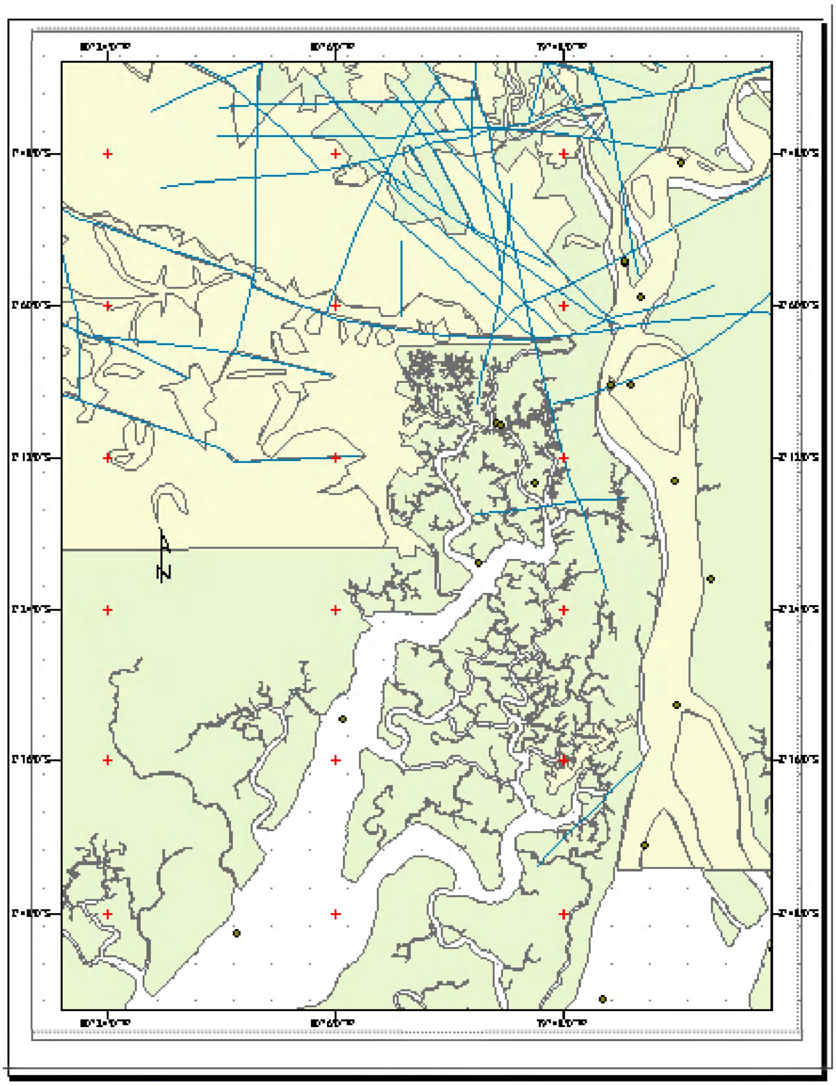


Figure5 - 23 Projected and Topologically cleaned GIS Maps

5.5 Results and Conclusions

- The Indispensability of GIS maps is not simply for depicting selected associated information but also for making important locational and visual spatial analysis and decisions on public and private assets, utilize in the application of sustainable environmental management, implement in the sector of mobility of transportations and also in the identification and evaluation of economically viable potential resources, …etc. With regard to this research work, to achieve the outlined goals, the processes of map making (digitizing, scanning, topology and georeferencing) have been implemented.
- Simultaneous digitizing and feature generating techniques have been applied to reduce the amount of time consumed to clean maps subjected to different format conversion process.
- Coastal paper maps have been scanned, vectorised, topologically cleaned and projected. Likewise, a satellite image of the area has been registered by pin pointing known control points, conformable to the provided PSAD56 datum.
- Macro programs have been developed to generate topologically cleaned feature maps; and create 3D GIS maps by increasing density points of observation on a 3D seed file and 3D.
- The application of the developed vector and raster GIS maps were crucial to facilitate the creation of distinct and associatable measurement features, generate thematically analyzed spatial information by relating the developed objects and objects' identifiers.

Chapter 6: Spatial Analysis

6.1. Introduction

Prior to this chapter, a focus was given to the making of a GIS maps. That issue raised, that spatial analysis (SA) performance required appropriately geo-referenced maps. Commonly, during spatial analysis the data in the Geodatabase are examined by executing spatial operations with the intent to create new data that fulfills some required condition(s). The process comprises spatial operations such as *polygon overlay*, *buffer generation*, *intersects*, *union*, *contains*, *completely within* and within *distance of,* and others which can be intercalated with spatial queries. For instance, (a) the *Union* process creates a new theme by overlaying two polygon themes; and (b) the *completely within* selects objects that fall completely within an object. Then what is a SA?

Spatial Analysis (SA) is a technique of analyzing and visualizing associated geographic objects. The association is mainly between geographic elements (graphic elements and tabular data). It is vital in interpreting the results based on the model being applied [64].

SA encompasses topological operation analysis procedures for determining the spatial coincidence of geographic features. Any collection of topology layers is assumed to share same coordinate system to avoid unpredictable results. Once these requirements are met, spatial analysis is implemented to obtain spatial results of selected specific problems.

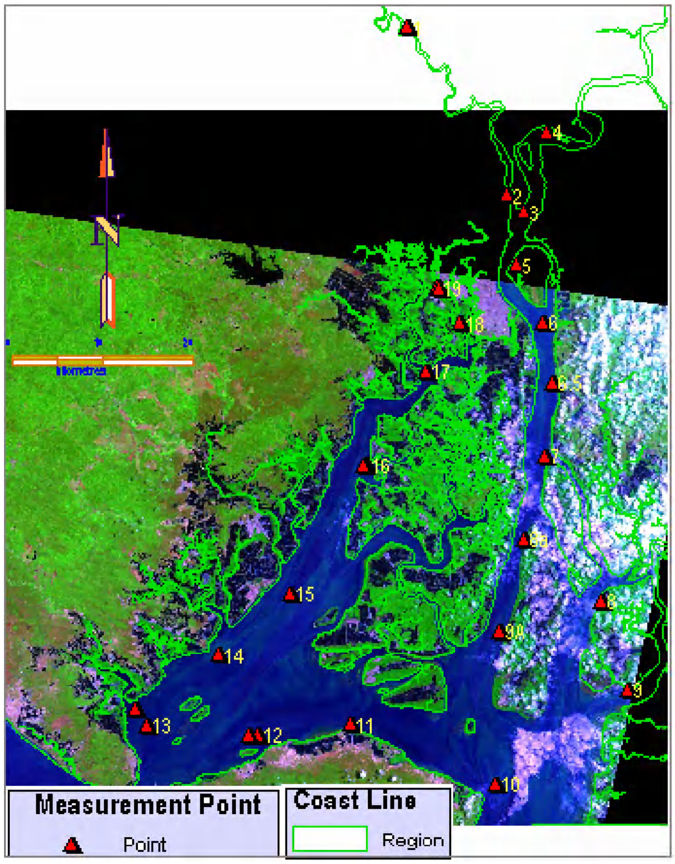
Henceforth, the main theme of this chapter is to demonstrate and perform spatial analysis on the constructed Geodatabase and illustrate the interacting objects in challenging certain *selected* environmental problems.

6.2. Spatial Data Processes

GIS provides mechanisms to integrate multidisciplinary data and allows the description, prediction and monitoring of alternative coastal management options. This is associated to its ability to organize large volume of heterogeneous spatial, aspatial and temporal data and its holistic visualizing power with respect to geo-referenced maps, which is indispensable for detecting impact [44], risk forecasting, and mitigations issues.

A base map is requisite in order to perform overlay analysis under a common geo-referencing coordinate system. To actualize the process, Geographic vector objects were created based on longitude and latitude values by application development automating tools, such as MicroStation Basic Extension (MBE) and Mapbasic.

Point objects were generated (see figure 6-1) to represent measurement point, such as the BioObject, Sedobj, Heavy Metals Object… etc., whereas the Polyline and polygons represent the coastal GeoLithology, GeoTectonic Coastline on the Guayaquil Estuary etc., and were made to share the same coordinate system by means of a given projection datum and ellipsoid. Moreover, the satellite image of the estuary and its surrounding has been fitted to the vector objects (see figure 6-1), for the purpose of understanding the relationship of the measurements sites and raster type maps of the coastal area.



Explanation

For the purpose of spatial interpretation the Guayaquil Estuary satellite-image map was utilized as a partial base map.

The overlaying vector maps include coastline, Estuary's major rivers, islands & measurement points (red triangles) along the estuary channels (see figure 6-1).

Figure 6-1. Measurement Points

6.3. Spatial Geodatabase Communications

Geodatabase contains geographic information and provide services for managing geographic data such as validation rules, relationships, and topological associations. Feature classes can be organized into a feature dataset; they can also exist independently in the geodatabase. Feature classes store geographic features represented as points, lines, or polygons, and their attributes. *All feature classes in a feature dataset share the same coordinate system* [70]; hence, the information retrieved is spatially synchronized and implemented across different GIS applications.

6.3.1 Interoperability operations Tests

Several tests of utilizing the geodatabase on different spatial engines have been performed in order to grasp the process of possible interoperability among the spatial engines and respective geographic objects, (see figure 6-2). At the center is the data model and the three GIS applications are connected to exchange the spatial information with the GIS applications. The result depicts loss of some spatial properties during the exchange of geographic features (especially on non Open GIS complaint). For instance, unlike the shape objects, the Data Exchange Format, a format for storing vector data in ASCII or binary files (.dxf) and text (.txt) objects depict a two-way communications.

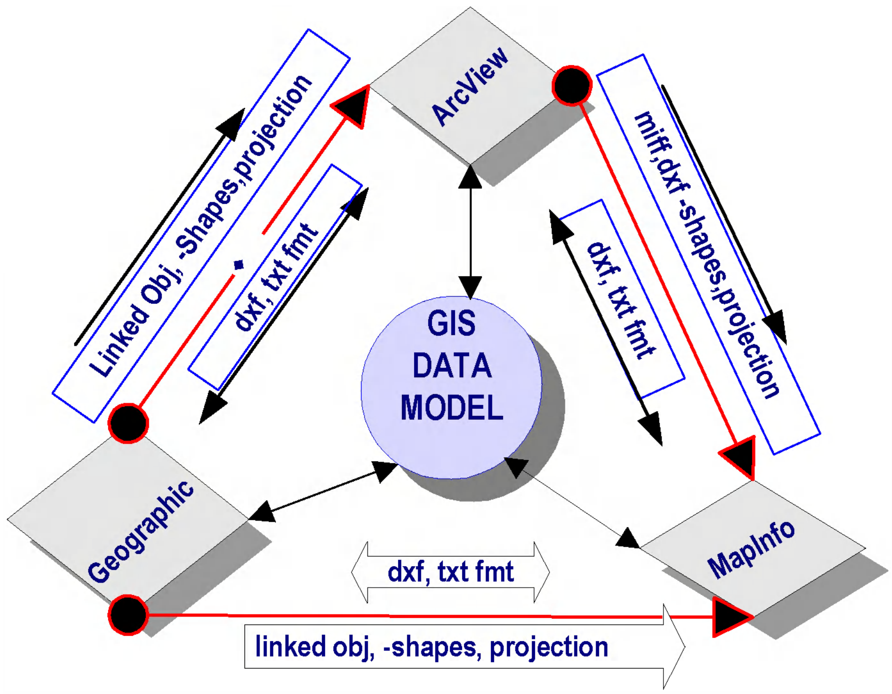


Figure 6-2 Interoperability

This test has been executed initially, using MicroStation Geographics GIS features (dgn seed file) and later applied in MapInfo, ArcView and ArcGIS GIS applications.

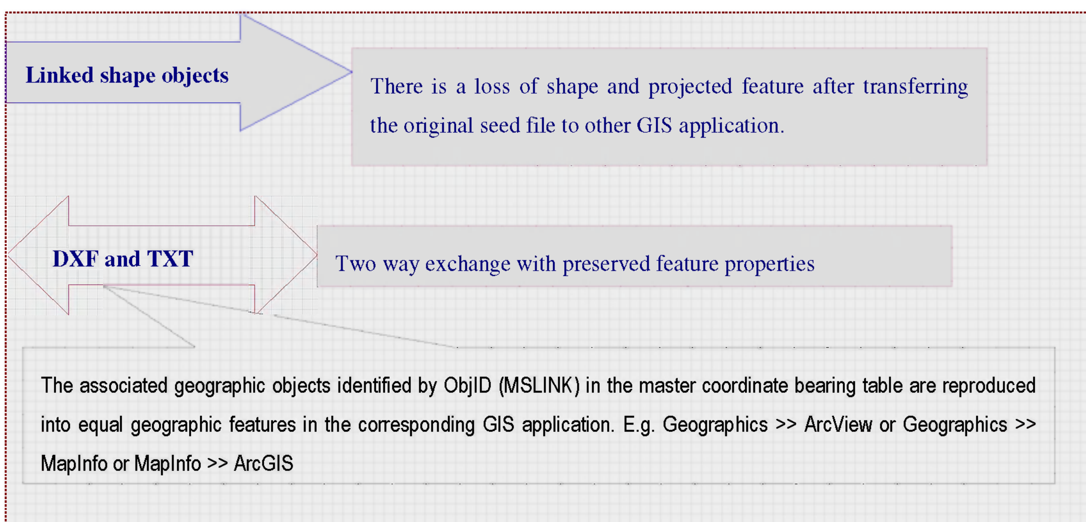


Figure 6-3 Compatibility of objects

6.3.2 Interoperability Outputs

The tests also show that, during an exchange of the ODBC – enabled Geodatabase, linkages are regenerated with prefixed occurrence number of the original GIS application when converted to the other applications. For instance the ObjID (MSLINK) of the Geographic GIS would be feature identifier with prefix for the ArcView GIS as FID =➔ Geo.FID$_n$, see table 6-1, A and B, indicating a generic characteristics of the ObjID. Table 6-2 displays the conversion of MicroStation Geographic GIS feature classes to a map info features. Likewise, table 6-3 discloses the extension of the transformation process of table 6-2; MapInfo GIS features to ArcView and ArcGIS. This illustration indicates .DGN seed file based feature is converted to a .TAB and the .TAB to a .SHP or a .LYR respectively. During the exchange process, certain properties of the features are preserved and lost. A summary for the process is displayed in table 6-4.

Table 6-1 Generic Characteristics of the Object Pointers

(A) Step 1

Process 1: dgn to shp	***Process 2:dgn to tab***
MicStationGeo.Obj = ArcView.Obj	*MicroStaionGeog.ObjID = MapInfo.ObjID*
MicStationGeo.MSLINK = ArcView.ODBC_MSLINK	*MicStationGeo.MSLINK = MapInfoMSLINK*
DGN.link =SHP.Link	*DGN.link = tab. Link*

(B) Step 2

Process 3: shp to tab	**Process 4: tab to dgn**
ArcView.ObjID = MapInfo.ObjID	MapInfo.ObjID = MicStationGeo.Obj
SHP.Link = tab. Link	TAB.link = DGN.link

Elucidation: -

A: DGN.link=SHP.Link, DGN.Mslink=SHP.Mslink_n / Geo vs. ArcView
B: DGN.link=TAB.link, DGN.Mslink=TAB.Mslink_n / Geo vs. MapInfo
C: SHP.Link=TAB.link, SHP.FID=TAB.MIF.ID / ArcView vs. MapInfo
D: SHP.Link=TAB.link, SHP.FID=TAB.MIF.ID / ArcGIS vs. MapInfo

Transformation of MicroStation Geographics to MapInfo GIS

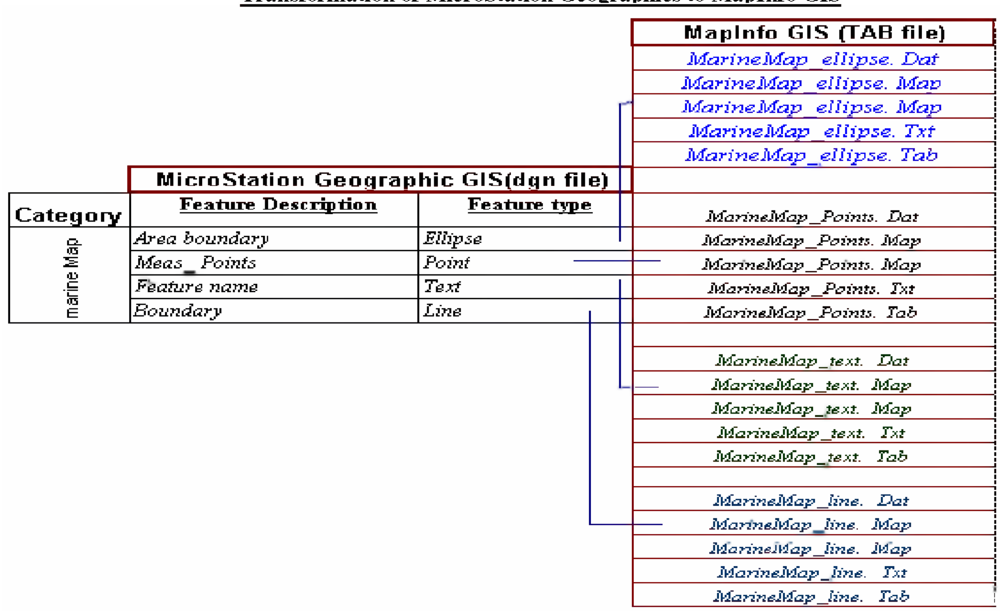


Table 6-2 Transformation Processes: MicroStation Geographics GIS >> MapInfo GIS

Transformation of MicroStation Geographics >> MapInfo GIS >>ArcView and ArcGIS

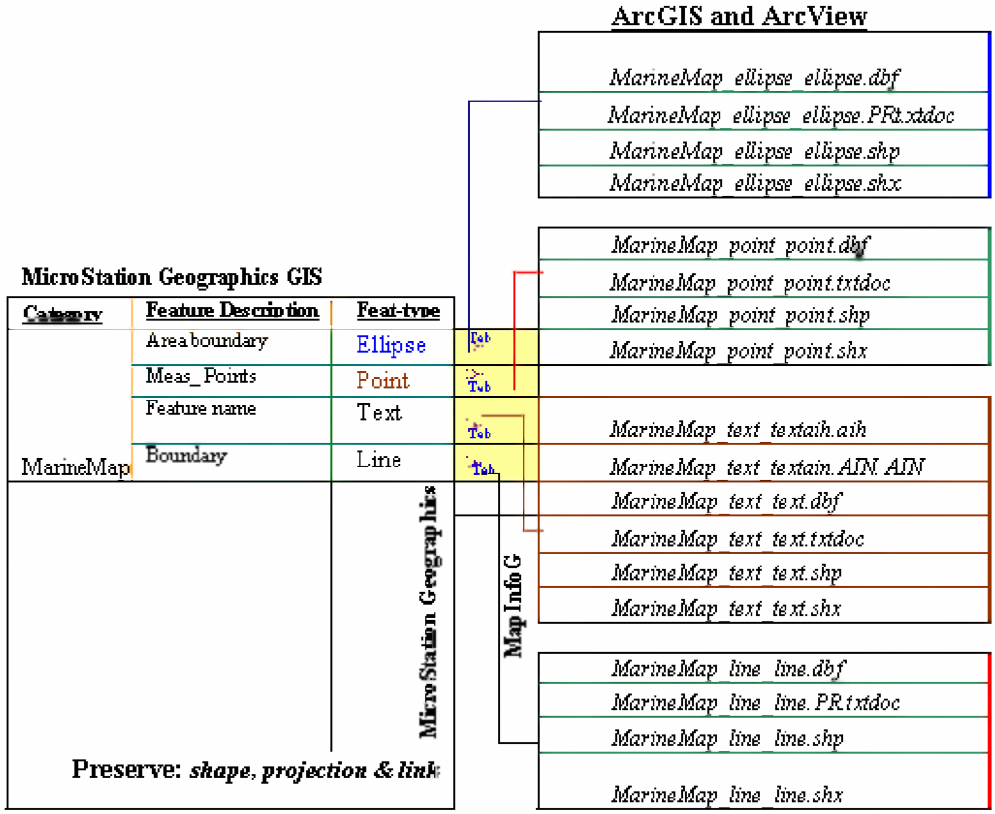


Table 6-3 Extended Transformation Processes: MicroStionGeog GIS >> MapInfo >> AAGIS

The Preserved and Lost of features properties

Transformation Proces		Preserved	Loss
Geographic	*MapInfo*	*Dxf, txt, linkage*	Shape, projection
Geographic	*ArcView*	*Dxf, txt, linkage*	Shape
ArcView	*MapInfo*	*DXF, txt, linkage, miff*	Shape, projection
MapInfo	ArcView	Dxf, txt, shape, projection, link	Projection
MapInfo	ArcGIS	Shape, projection and linkage	No loss

Table 6-4 Preservation and loss of Objects Properties

6.4. Spatial Information Process

Spatial-Query perception requires knowledge of the data, measurement methodology and analysis procedures that vary on time and locatable media being measured. It is imperative to understand that the limit of the data before the onset of the *Spatial Query Formulations* (SQF). Query formulation with unrealistic data can lead to error. A GIS is a data driven application, then its performance and usefulness is only as good as the data and the structure in which the data are made to interact each other. For instance, the Geodatabase GIS built during this research work accommodates variety spatial queries related to biologists, chemists, geologists …etc., because the data model is founded on multidiscipline perspectives. It has also been tested in different GIS applications to evaluate the possibility of reusing the same seed file among variety spatial engines (see table 6-3). Moreover, the efficiency of the spatial information depends on the specific GIS's user-friendliness of the interface. A user interface is a principal component of the GIS application. Some GIS applications provide interface tools that permit a full-blown object relational formulation of spatial quires and spatial interrogation to the system [37].

6.4.1 Interrogating Spatial Database Practice

Extracting spatial information is executed by posing different questions to the building block GIS objects. To mention few, with respect to implementation of the model in the case study: -

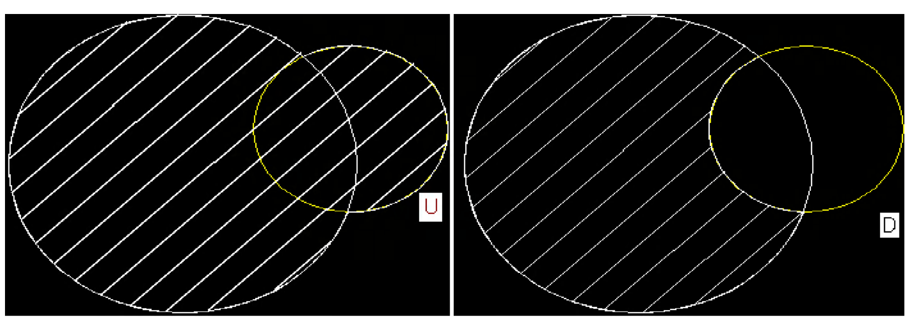
- Find abnormal heavy metal concentration (within estuary channels)? Query posed to Heavy_metal Object
- Which part of the estuary is strongly polluted by pesticides? – PestPCBs Object
- Find the relationship of sediments distribution and biotic species '? (SedResults a and BioResults objects)
- Where and when this effect happened – Spatio-temporal?
- Where and when was the diurnal variation (temperature) affecting the area? Spatio-Temporal.

Implementing these basic inquires and retrieving spatial and Spatio-temporal information requires know-how on a spatial analytical concept, the data model, GIS applications characteristics and the building block objects interactive relationships where spatial layers are derived. The first step in Spatial Analysis is to create spatial layer of information. This can be done either by matching two or more objects (rows) or by harnessing and combining spatial keyword ***object***. **Obj** [object] is a special key word [30]. Thus, if there exist two objects: - ObjA, and ObjB and respective attributes, (a1, a2, a3) and (b1, b2, b3); then topological operations are put into practical effect to retrieve spatial information belonging to the two.

6.4.2 Objects Expression approaches

On interacting objects

Union and Difference: ObjA $\cup$ ObjB: - extracts all objects.

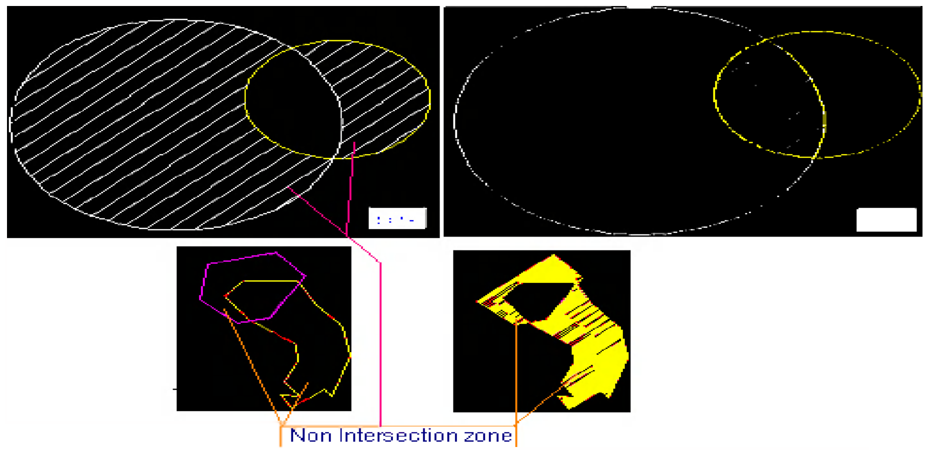


A union overlay is the result sum of all the polygons being involved in the operation. - (aUb)

DIFFERENCE (D): - A directional operation that subtracts the second polygon from the first- (a-b)

Figure 6-4. Union and Difference

Non-Intersecting and Intersecting: ObjA ∩ ObjB



XOR (Non-I): - Retrieves all polygons that belong to the respective objects but not in the	*AND: - Retrieves all polygons that INTERSECT (I) between two input polygon topology.*

Figure 6-5 Intersecting and Non Intersection

Contains Entirely or Entirely Within

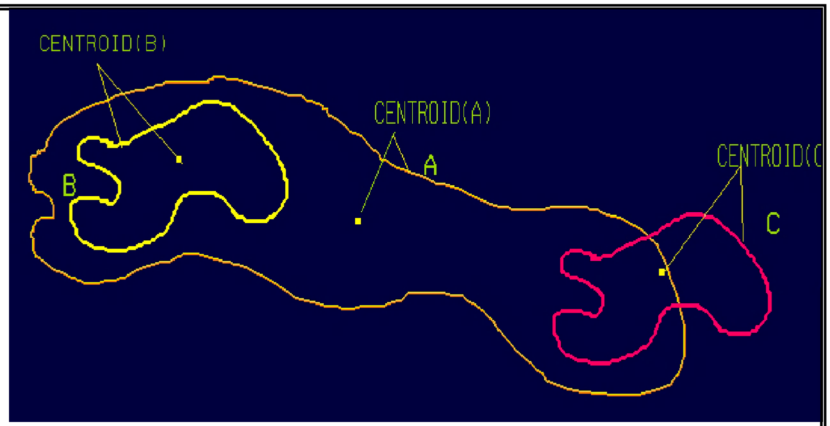
Obj A Contains Entirely O *Or* *Obj B Entirely Within Obj*	
OBJ A intersects OBJ B *Or Obj B intersects A*	
Obj A contains Obj C *Or Obj C within Obj A* *(BY CONSTRAINT CENTROID)*	*Centroid requires shape object o be created* *Centroid type: = Zero length line* *Options: = Text Node, Cell*

Figure 6-6 Containment and within

6.4.3 Consistency on Spatial Object Operations

- *C-1: ObjA INTERSECTS ObjB: A new object is derived based on criteria of bounding coincidence of the objects. Object retrieved includes those, which are in both objects.*
- *C-2: - ObjA – ObjB: extracts all object's contents, which are in ObjA but not in ObjB*
- *C-3: - ObjA WITHIN ObjB: Objects pertaining to ObjA that contained inside ObjB are extracted*
- *C-4: - ObjA CONTAINS ObjB: Object contained within ObjB is extracted and displayed*
- *C-5: ObjA CONTAINS ENTIRE ObjB: ObjA contains entire ObjB if B's centroid is contained in A's boundary*
- *C-6: ObjA CONTAINS ENTIRELY ObjB: Object B is entirely retrieved if B's boundary is exclusively contained in A's boundary.*

On Matching Objects: *Besides, topological operations are executed based on matching objects (object identifiers).*

If ObjA described as ObjA (a1, a2, a3) AND

ObjB described as ObjB (b1, b2, b3)

THEN ***ObjA.a1 = ObjB.b1***

The Object is created based on the criteria of matching of the objects (rows) between the objects.

The main difference between (contains and within) in one hand and CONTAIN ENTIRE and ENTIRELY WITHIN is mainly due to the position of a centroid object and the status of a bounded object, (i.e., one object encompassed within the other object) respectively. In the absence of matching column, geographic objects are used to relate between two or more objects. Both (object and matching field) techniques imply spatial analysis process in the form of attribute and feature based spatial analysis. For instance it is possible to JOIN and extract the measurement information related to MeasredHeavymetals object related to Geolithology Object composition as indicated in the following formulation: -

MeasHeavymetals.OBJ WITHIN Geolithology.OBJ or Geolithology.OBJ CONTAINS MeasHeavymet

This shows that in an object relational GIS model, the communication among the objects is not only based on matching numeric or textual attributes but also on objects that occur on both tables, either as one object containing or intersecting the other.

6.4.4 Case Study: Object Relational Processes

Structurally, the Guayaquil zone is composed of NNW, NNE and E-W trend channels. The estuary expands into the Gulf of Guayaquil, gets continental water supply from the perennial rivers (see section 1.4.1) that flow to this partially enclosed body of water [17], [14]. Environmentally, the area is composed of distinct aquatic environment interfaces, extending from the *estuary-water-surface to estuary-bottom zone. This classification and the associated objects are used* to interpret spatially the environment of the estuary by employing certain statistical tools.

6.4.5 Spatial Interpretation (SI)

The spatial analysis process includes objects of the multidisciplinary integrated coastal and main estuary objects. Object relational Querying, Statistically classified thematical displays; overlay and buffering based interpretations have been applied. However, before delving into detail, a brief description of the statistical ranging process is given below.

Aggregation: Suppose one wants to present a thematic distribution of sediments (gravel, sand, silt and clay) with respect to the measurement stations. The nature of the data is that a single station is related not only to the x and y coordinates but also to the sampling depth in the same station. In principle, one spatial object is supposed to be associated to one database record or tuple. Then, how can this performed if the data format occurs as follows (see table 6-5)

Station	Parameter	Pract_value	MeasUnt	SampType
1	Gravel	6.49	%	Bulk sed
3	Sand	43.95	%	Bulk sed
6	Clay	7.17	%	Bulk sed
7	Gravel	0.29	%	Bulk sed
7	Sand	74.76	%	Bulk sed
8	Sand	4.66	%	Bulk sed
8	Clay	22.9	%	Bulk sed
8A	Gravel	0.13	%	Bulk sed
8A	Sand	79.84	%	Bulk sed
1	Clay	3.5	%	Bulk sed
8A	Clay	16.91	%	Bulk sed
9	Gravel	0.12	%	Bulk sed
12	Sand	8.77	%	Bulk sed
20	Gravel	9.86	%	Bulk sed

Table 6-5 Analysis Results table

A single station contains different informative database records. ***A centroid is assumed to be associated to a database record, NOT records.*** A test on associating attribute records to spatial features indicate the possibility of appending 80 database records to a single centroid feature in (MicroStation Geographic) centroid, but to avoid unpredictable results the **one to one** relationship is recommended in [11], [21], likewise a one to one join for the thematic mapping is suggested *[30]*. Taking into account this natural occurrence of data, GIS applications are equipped with aggregating functions.

Solution: - The multi-record-per-station nature of data shows that there are 180 records for the 25 stations. Thus, the data ought to be aggregated so that spatial feature with a specific geo-referencing point fits to respective object (see table 6-6). For this purpose, a special SQL query is designed.

```
TRANSFORM Avg (Results.pract_value) AS MeasValue
SELECT Location.station, Location.LonDegDec, LOCATION.LatDegDec,
Results.pract_unit AS MeasUnit, Field.environment, Field.discipline_name
FROM Location, field, Results
Where LOCATION.station = Field.station and
Field.field_code = Results.field_code
And Field.discipline_name = "SEDIMENTOLOGY"
GROUP BY Location.station, Field.environment
PIVOT Results.parameter;
```

Output

STATION	ENVIRONMENT	LONDEGDEC	LATDEGDEC	CLAY	GRAVEL	SAND	SILT
1	Bottom sediments	-79.976	-1.976	2.1425	3.285	66.12	28.11
10	Bottom sediments	-79.886	-2.73	4.825	0.115	52.53	42.53
11	Bottom sediments	-80.025	-2.653	7.49	0.57	29.86	62.075
12	Bottom sediments	-80.12	-2.668	7.6	0.815	8.25	83.335
13	Bottom sediments	-80.231	-2.671	0.16	18.2	66.955	14.68
14	Bottom sediments	-80.16	-2.6	0	29.72	20.28	0
15	Bottom sediments	-80.055	-2.553	10.485	0	11.74	77.77
16	Bottom sediments	-80.016	-2.411	7.2	21.22	15.94	55.63
17	Bottom sediments	-79.956	-2.318	16.49	2.93	15.035	65.54
18	Bottom sediments	-79.923	-2.271	15.14	0.82	16.31	67.73
19	Bottom sediments	-79.945	-2.235	6.955	0.37	24.325	68.345
2	Bottom sediments	-79.876	-2.143	3.275	0.105	49.02	47.595
20	Bottom sediments	-79.943	-2.236	5.77	0.965	47.19	46.075
3	Bottom sediments	-79.86	-2.16	0	2.165	69.555	26.53
4	Bottom sediments	-79.836	-2.08	1.86	0	32.75	65.39
5	Bottom sediments	-79.866	-2.213	2.16	0.135	77.395	20.31
6	Bottom sediments	-79.82	-2.24	5.37	0.035	38.675	55.915
7	Bottom sediments	-79.838	-2.403	0.225	2.32	85.01	12.46
8	Bottom sediments	-79.781	-2.548	22.9	0	4.66	72.44
8A	Bottom sediments	-79.858	-2.486	11.55	0.043	30.7	57.69
9	Bottom sediments	-79.755	-2.636	15.69	0.12	19.35	64.84
9A	Bottom sediments	-79.883	-2.578	5.09	9.59	48.536	36.783

Table 6-6 Filtered Analysis Result table

Eventually, this output can be geo-referenced and appended. Appending of tabular data to objects can be accomplished only if there is a relational cardinality of ***1: 1 or ∞: 1.***

6.4.5.1 Statistical Data Representation

Generating thematically visible GIS maps requires summarizing the geodatabase attribute values. Main reason for this constraint is due to the 1: M cardinal relationships of a spatial object and the attribute values. Aggregating process enable us to assign each value its own symbol or group the values into classes applying different class for each symbol [89]. Therefore, classifying the bulk database records enhances the impetus of thematically visible values in the map.

Values are classified statistically according to the distribution and this enables us to visualize thematically the low, medium, high value pattern in the map. So if N = attribute database records for a specific measured field parameter (MP) then range (R) for MP is: -

$$Max\ (N) - min\ (N) = R\ of\ MP$$

A representative class value: = *(RCV or K = max* (MP) – min (MP) / K

Table 6-7 Classfication Ranges

Records	Class(k)=3	Mean/k
R1		
R2	R1-R3	R1-R3/k
R3		
R4		
R5	R4-R6	R4-R6/k
R6		
R7		
R8	R7-R9	R7-R9/k
R9		

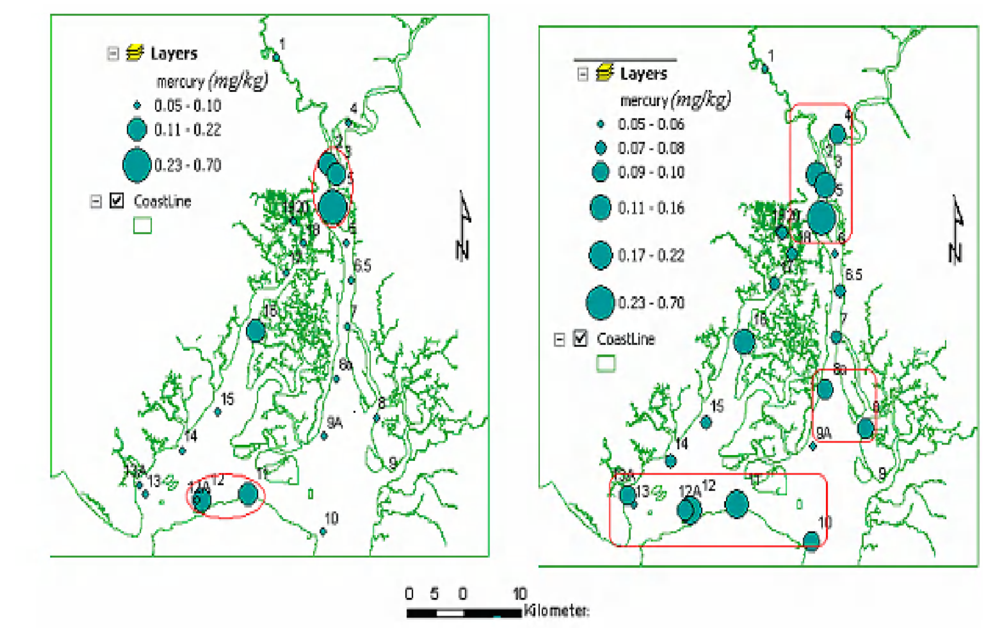


Figure 6-7 The Effect of Class Variation in Spatial Results display

Unique value mapping: Each unique value is symbolized with a different color. Drawing features based on unique attribute values shows how different feature types are located in relation to each other. This classification can also be used to sort the character typed attribute values.

Standard deviation: The classification scheme depicts the amount a feature's attribute value variation from the mean. A two or more color ramp could be used to mark out emphasis on values above and below the mean. **The mid range** breaks at the mean of the data values, and the ranges above and below the mid range is one standard deviation above or below the mean.

(a) Mean value, (b) classes above and below of (a) at Intervals of 1/4, 1/2, or 1 stdv

(c) Aggregates of any value beyond where the standard deviation is based on the formula:

$$\sqrt{\frac{n\sum x^2-(\sum x)^2}{n(n-1)}}$$

Natural Break classification: The identification of the break points in natural classification method is based on the identification of groupings and patterns inherent in the data (based on Jenk's optimization) This method is rather complex, but basically, the Jenk's method minimizes the sum of the variance within each of the classes. The features are divided into classes whose boundaries are set to relatively big jumps in the data values. It minimizes the variation within each class [21], because the range breaks are determined according to an algorithm such that the difference between the data values and the average of the data values is minimized on a per range basis [30]. A practical test on different number of classes from the same feature class (table) shows different results. For instance, from a given object, taken higher number class will produce an exaggerated distribution, view of graduated symbols; whereas a less number of classes will show a restricted area distribution, viewed in graduated symbols. Despite the discrepancy of the display that is due to the number of classes selected the spatial distribution lies within those measurement or areas.

6.4.6 The Objects within Estuary and Coastal Periphery

A number of objects incorporated in the spatial analysis process include (a) **MeasuredSed object**: Planned to comprehend sediments distribution and spatial affiliation to other discipline parameters. Correlate the output with relevant objects in space and time.

(b) **MeasuredBio object:** Intended to decipher the spatial distribution of species. Differentiate sites and zones biologically sensitive.

(c) **MeasuredPhy-Chm object**: planned to grasp the energetic water's current and direction variation and relate with phy-chm parameters (salinity, temperatures), spatial distributions considerations of human and natural impacts in that coastal region.

(d) **MeasuredChm object:** intended to explain the spatial dissemination of chemicals and their relationship with the sub marine environments.

(e) **MeasureHeavyMetals Object**: Aimed at understanding the magnitude heavy metals dissemination across the estuary data mediums.

(f) ***EstChannels Object:*** *Objects that display the different parts of the estuary channels.*

(g) **GeoLithology object:** Intended to explain the geo-setup, rock types and composition. Interpret the associated lithologic parameters results and tectonics in the coastal area.

(h) **GeoTectonics object:** Intended to assess the geo-tectonic trends of the estuary channels and shearing Lithology of the coastal zone.

6.4.7 Object Relational Spatial Analysis

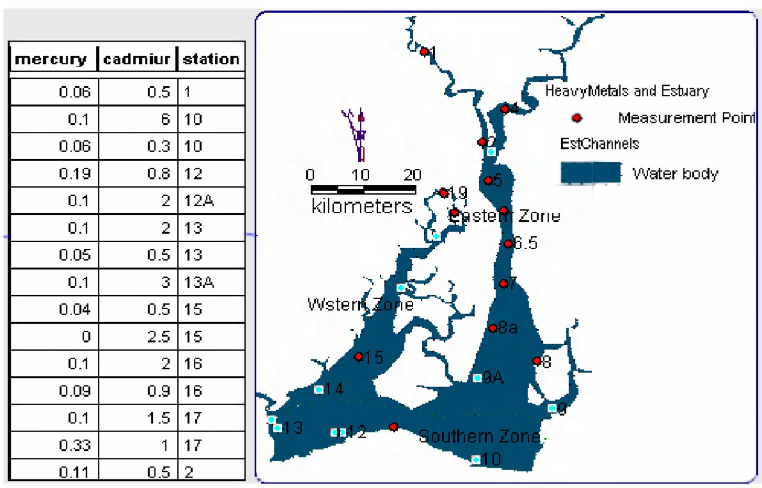
6.4.7.1 Problems and Solutions

Two objects (HeavyMetals and EstChannels) are involved. The HeavyMetals object is of Point type representing measurements sites whereas the EstChannels are the main parts of the estuary water body. The retrieving and visualization incorporates Object-Relational query, spatial and logical operators and aggregate functions.

6.4.7.2 Objects: HeavyMetals vs. EstChannels

? Find and display part of the estuary that shows higher measured values of cadmium than mercury (mg/kg).

```
SELECT *
FROM EstChannelaObject, HeavyMetalsObject.mercury
WHERE EstChannelsobject.obj
CONTAINS HeavyMetalsObject.obj
AND HeavyMetalsObj.cadmium  > HeavyMetalsObj.mercury
```



mercury	cadmiur	station
0.06	0.5	1
0.1	6	10
0.06	0.3	10
0.19	0.8	12
0.1	2	12A
0.1	2	13
0.05	0.5	13
0.1	3	13A
0.04	0.5	15
0	2.5	15
0.1	2	16
0.09	0.9	16
0.1	1.5	17
0.33	1	17
0.11	0.5	2

Figure 6-8 Output (Light blue) cadmium greater than mercury (mg/kg)

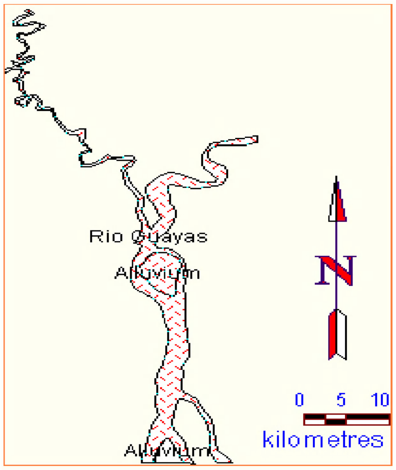
Output reveals that the southern channel is characterized by a low dissemination of Hg.

6.4.7.3 Objects: GeoLitho_region, Sediments Object

? Find and display the distribution of sediments confined within specific Lithology type.

- *SELECT * From GeoLitho_region, Sediments*
- *WHERE GeoLitho_region.obj Contains Entire SEDIMENTS.obj*
- *And Sediment.sandpercent > sediment.gravelPercent ;*

The output of the spatial query is:-



Query4 Bro...

LITHID	LITHODESC
50	Rio Guayas
50	Rio Guayas
50	Rio Guayas
50	Rio Guayas
50	Rio Guayas
50	Rio Guayas
50	Rio Guayas
50	Rio Guayas
50	Rio Guayas
50	Rio Guayas
50	Rio Guayas
50	Rio Guayas

Figure 6-9 Lithology containing MeasPoints and Sand>Gravel(%)

6.4.7.4 Objects: GeoLitho_region and GeoTect_polyline

Problem:

? What is the dominant Geolithologic composition (GeolithObject), which is strongly sheared by NW fault direction? - Identifying highly sheared, composition and trend. First step is to formulate the query as follows>

```
Select count (*)
From GeoLitho_region , GeoTect_polyline
GeoTect_polyline.obj Contains GeoLitho_region.obj
 And GeoTect_polyline.FTDESC = "NW"
Group by GeoTect_polyline.FTDESC, GeoLitho_region.LITHODESC
```

Formulation the spatial qury

LITHID	LITHODESC	LithoComposition
10	Pinon f	oceanic crust basalt
23	Cayo F	graywacks coarse grained sed
50	Rio Guayas	siliceuos linstone-cacareous sed

Retrieves lithology descriptions and related composition that are sheared by North West trending fault line. (In this case the objects type is of polygon)

```
SELECT * GeoTect_polyline, GeoLitho_region
FROM GeoTect_polyline.obj Intersects GeoLitho_region.obj And
ObjectLen(obj, "km") > 15 And GeoTect_polyline.FTDESC = "NW"
GROUPBY GeoTect_polyline.FTDESC,
GeoLitho_region.LITHODESC
```

Formulation the spatial qury

FTID	FTDESC	LITHIE	LITHODESC	LithoComposition
5	NW	23	Cayo F	graywacks coarse grained sed
5	NW	50	Rio Guayas	siliceuos limstone-calcareous sed
5	NW	21	Pinon f	sst and silt stone
31	NW	22	Granodiorite	Ocenic Crust and Pyrite dissemination
31	NW	15	Tablazos	siliceos limstone
1	NW	1	Bella visita M	harzuburgite pyrite-copper

Likewsie, the litho composition and litho description is retrieved with respect to the North west trending faults.(the object retrieved visualised is the of Polyline type)

The output comprises the intersected Geolithology by the Geotectonics faults lines trending NW and displayed symbolised by different colors. See figure 6-10

The output of the spatial query is:-

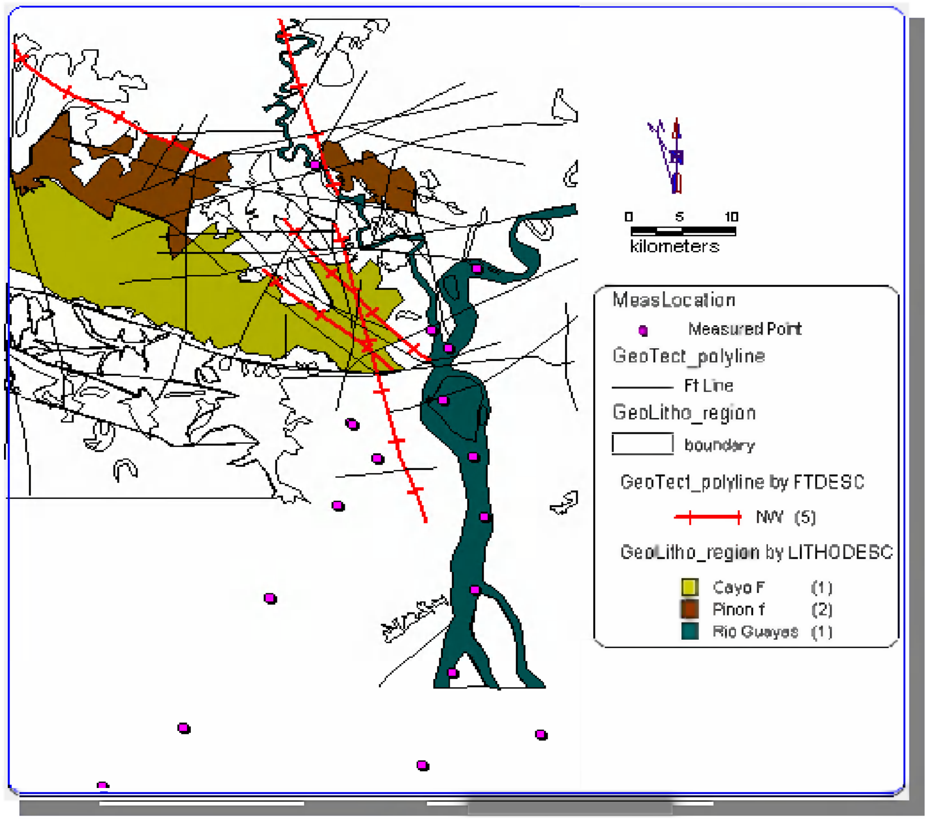


Figure 6-10 North Westerly Sheared Geolithology

The spatial process retrieves the Lithology extension, lithologic contact to the main estuary and sheared zone with trends mainly to the NW direction.

6.4.7.5 Objects: GeoLithology, GeoTectonics and MeaResults

The following spatial query extracts all the information in the three objects GeoLithology, GeoTectonics and MeaResults. The GeoLithology in the coastal area that is sheared by Geotectonic structures trending East-West direction and relates to the sites which contains maximum of silt% range between 60 and 80.

Problems and Solutions

Find and display the area dissected by E-W trending fault lines, maximum silt% ranging between 60 and 80 and the depth sampling between 1 and 10 m.

- *Select **
- *FROM GeoTect_polyline, GeoLitho_region, MeaResults*
- *WHERE GeoTect_polyline.obj INTERSECTS GeoLitho_region.obj*
- *AND GeoLitho_region. LithID = MeasResults.MSLINK*
- *AND GeoTect_polyline. FTDESC LIKE "%E-W" And*
- *MeasResults.MAX (SILTPERC)* ***BETWEEN*** *60 AND 80*
- *AND MeasResults.maxdepth* ***BETWEEN*** *1 AND 10 ;*

The output of the spatial query is:-

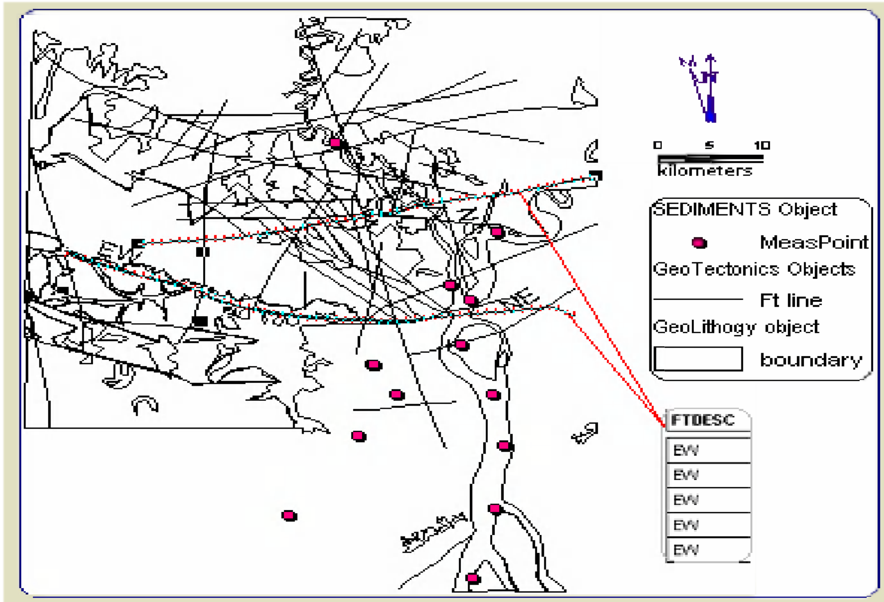


Figure 6-11 East – West dissecting faults

6.4.8 Coastal Area Spatial Analysis

Problem: finding the spatial information heavy metals distribution associated with tectonically sheared zone. Interacting objects are GeoLithology and GeoTectonics Objects and HeavyMetals. It does the followings.

- *Step 1: Find and retrieve the geolithology dissected by GeoTectonics trending E-W.*
- *Step 2 retrieve the geolithology description that sheared by this trend.*
- *Step 3 retrieves and display in a pie chart the concentration of heavy metals that meets the criteria stated in step1 and step 2; i.e., a lithology dissected by E-W faults and contains measurement sites related to the heavy metals dissemination.*

6.4.8.1 Geolithology and GeoTectonics

GeoLithology (Region or polygons)

Step 1.

```
SELECT *
    From GeoLitho_region, GeoTect_polyline
        Where GeoLitho_region.obj Contains  GeoTect_polyline.obj
            and GeoTect_polyline. FTDESC = "EW"
```

GeoTectonics (Polylines)

Step 2

```
SELECT *
    From GeoTect_polyline.obj, GeoLitho_region
        Where GeoTect_polyline.obj INTERSECTS GeoLitho_region.obj
            And GeoTect_polyline. FTDESC = "EW"
```

GeoLithology + GeoTectonic and HeavyMetals (measurement point info within region)

STEP 3

```
SELECT *
    HeavyMetals, GeoLitho_region, GeoTect_polyline
        WHERE HeavyMetal.obj Entirely Within GeoLitho_region.obj
            and GeoLitho_region.obj Contains GeoTect_polyline.obj
                and GeoTect_polyline. FTDESC = "EW"
```

The output of the spatial query is:-

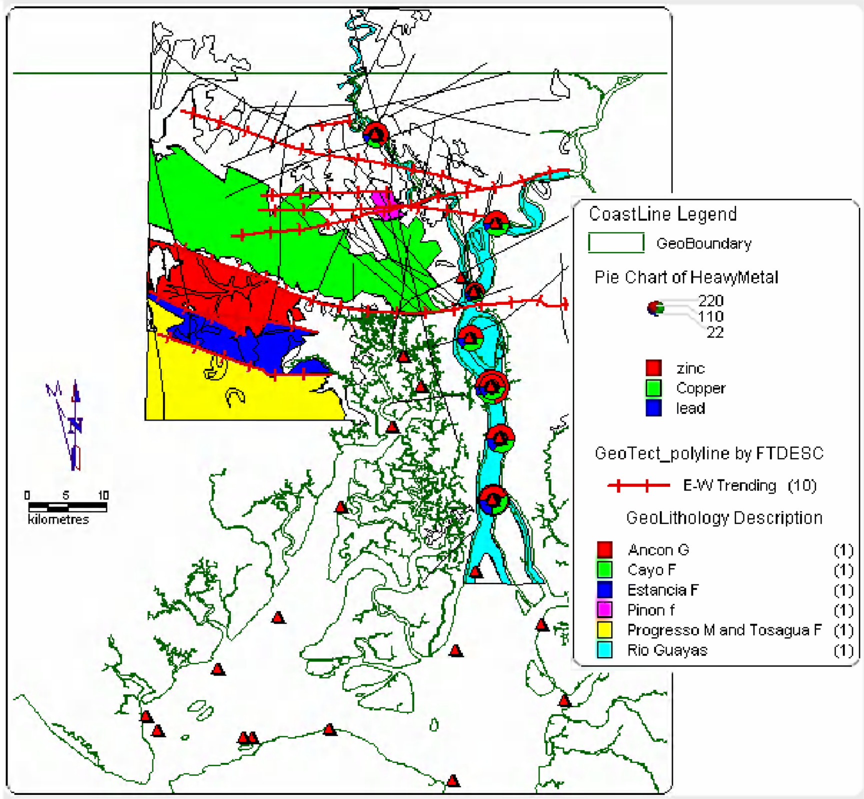


Figure 6-12 Distribution of Cu-Zn-Pb, associated thematical Geology and GeoTectonics

The thematical display performed by relating relevant objects of the measurement results, GeoLithology and GeoTectonics disclose that the major fault trending NS and NW dissect the different Lithologies in the coast (see figure 6-11). The sheared zone that extends southwards appears to have effect on the structure of the estuary.

Moreover, the HeavyMetals object thematic pie distribution shows higher zinc distribution (heavy metal) throughout the estuary than copper and lead (Pb).

The NW trending faults, close to the estuary flanks could have certain clue of mineralized solutions (sulfide) [16] that influence the concentration of the measured higher base metals, specially the zinc.

Furthermore, the description of the rocks indicates some pyrite and malachite rich outcrops, which support the possibility of mineralization along these fractures.

Despite the restricted data applied, this spatial analysis based hypothesis suggests a hint that in addition to the possible human impact, the origin to the measured higher concentration of Zinc could be attributed to the discharge of a sub-volcanic mineralized solution associated to shearing process close to the estuary.

6.4.9 Thematic Correlation

The thematic distribution pattern of the heavy metals shows variability.

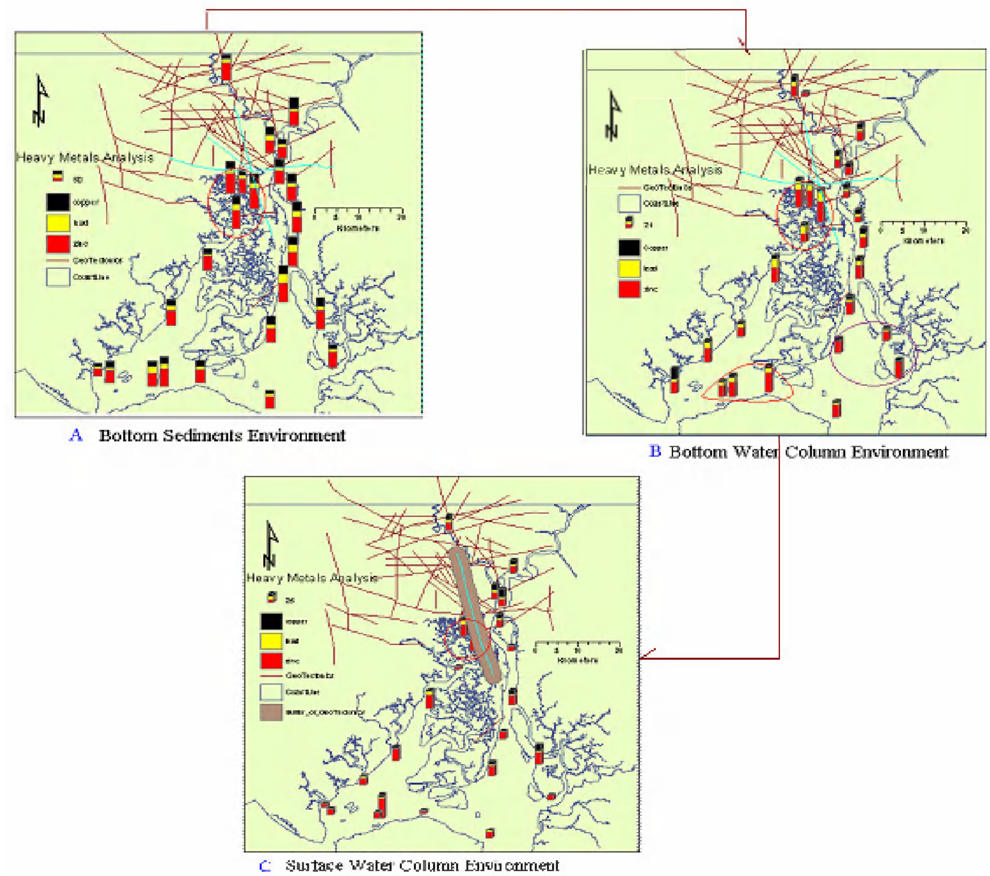
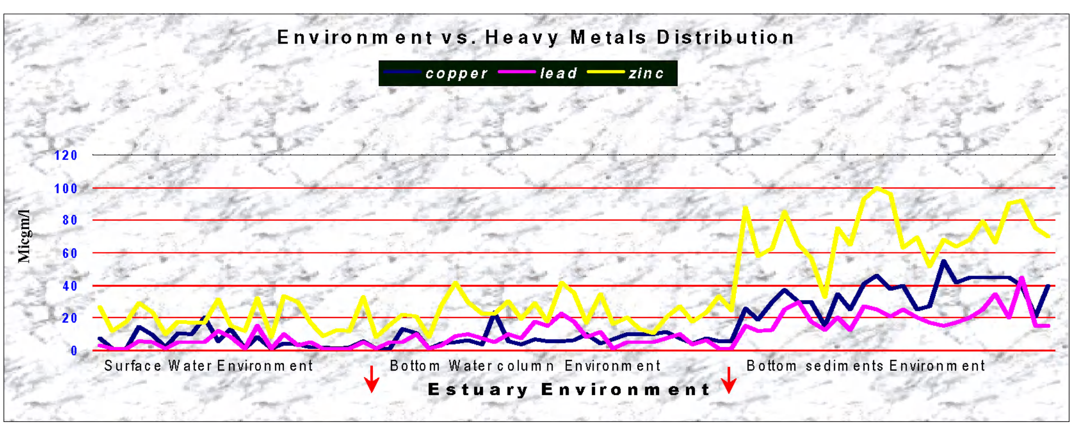


Figure 6-13 Correlated Pie thematic map of Zn,Pb and Pb

A comparison across different estuary measurement mediums (bottom sediment, bottom water and surface water), disclosed in figures 6-13 and 6-14, shows that Bottom sediments environment is characterized by relatively higher dissemination of Zn than Pb and Cu respectively.



FFigu

re 6-14 Correlative Environmental Distribution of Heavy Metals

6.4.10 Buffering - on Relevant Criteria

A buffer is created as concentric rings or measured specified distance from geographic features(s). The objects can be points, polylines or polygons.

Buffers are useful for the purpose of proximity or nearness analysis in area where geographic features are constructed for the performances of spatial analysis. (For example, finding measurement points within 500 meters of a proposed sheared zone).

For a point type object the point value can be either of Spherical or Cartesian x, y coordinates. The size of the buffer depends on the defined radius of the object in a specific unit. Using Latitude/Longitude data, the perfect buffer width, as defined in native Latitude/Longitude decimal degrees, may change on different portions of an object. This is because the width provided is in somehow flat measurement unit, (e.g. miles, meters), and the decimal degree to measurement transformation will vary depending on the location on the earth. For instance, a kilometer spans a larger number of latitude degrees as one move toward the poles of the earth and away from the equator. On small objects, the distance may be negligible. Buffering point type objects, in an area where they are scarcely populated, requires larger radius to generate an outline or rings around the objects. For instance, two point objects, 6 km apart can be buffered wholly by a radius a little greater than half distance (D), between them, see figure 6-15. Furthermore, the tabular information of the buffered polygon object is reported with the shape length, shape area and distance intervals, see table.

Attributes of Buffer_of_GeoLitho_region_region_4

ObjectID*	Shape*	Shape_Len	Shape_Area	FromBufDst	ToBufDist
1	Polygon	4.550294	0.020769	1	2.000000
2	Polygon	5.349529	0.024430	0	1.000000

Table 6-8 Buffer Class Ranges

During geographic element buffering, any object residing with a radius less than the distance between two points is included within the buffer zone. Specifying the desired distance from the polyline type object can also perform buffering.

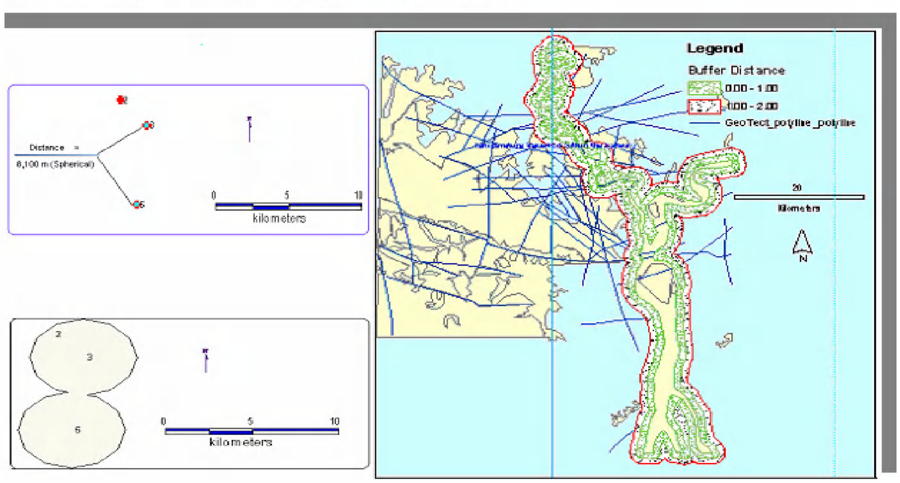


Figure 6-15 Buffered Points and Zone Generated

Like wise polygons can also be buffered inside or outside the object by setting the distance to a specific value, for instance the geolithology that extends to the main estuary see figure 6-15, is indicated buffered with a distance of 0 to 1 and 1 to 2 km outlines

Mercury: (Hq (µgm)/l)

A buffer zone is a polygon or an enclosing dimension according to a *specified distance (D)* from a spatial feature (point, line or polygon). It is created and extracted for the purposes of proximity analysis. The D (distance) between two linear points or features in a projected map is calculated by incorporating the spatial data source in the GIS Geodatabase and is extracted as: -

D = SQRT (abs (((x1-x2) ^2) + ((y1-y2) ^2))).

For example: - Finding a zone within a 2000m distance from measured object.

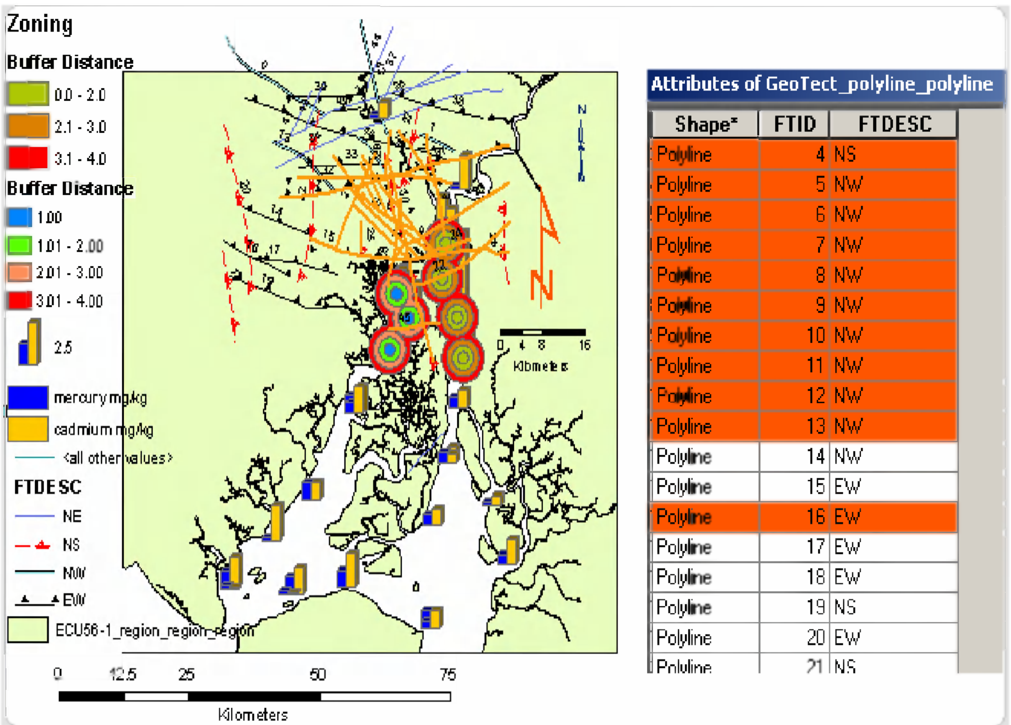


Figure 6-16 Buffered Zone of Cd and Hg and Proximity Tectonics

During buffering process, certain factors must be taken into account such as: -

- Mobility/dispersion rate of the measured elements (Chemical properties)
- Current's Speed and Direction *
- Sedimentation rate (%)
- Temporal factors (perennial/ seasons) *
- Elements Density *
- Foci or plum around an object
- Scale of the map *

* Considered

Figure 6-16, is an illustration of the buffer zone created to disclose the extension of the dissemination by certain distance from the point object observation outwardly. Three objects are involved during the spatial operation.

(A) The GeoTectonic (NW and NS fault alignments), (B) HeavyMetals object: (A bar thematic charted dissemination of Cd and Hg) and (C) The coastline features.

A spatial query on retrieving the geotectonic trending NW and EW are selected and thematically viewed. The NW structures alignment coincides with the northern part of the eastern channel. Furthermore, the NS and NW trending fault lines indicates the presence of catchments that flow towards the estuary with possible; mineralized solutions that dilute the estuary water body,

Concentration of Mercury and Cadmium displayed by means of bar chart type is characterized by elevated distribution of the elements in the northern part of the estuary.

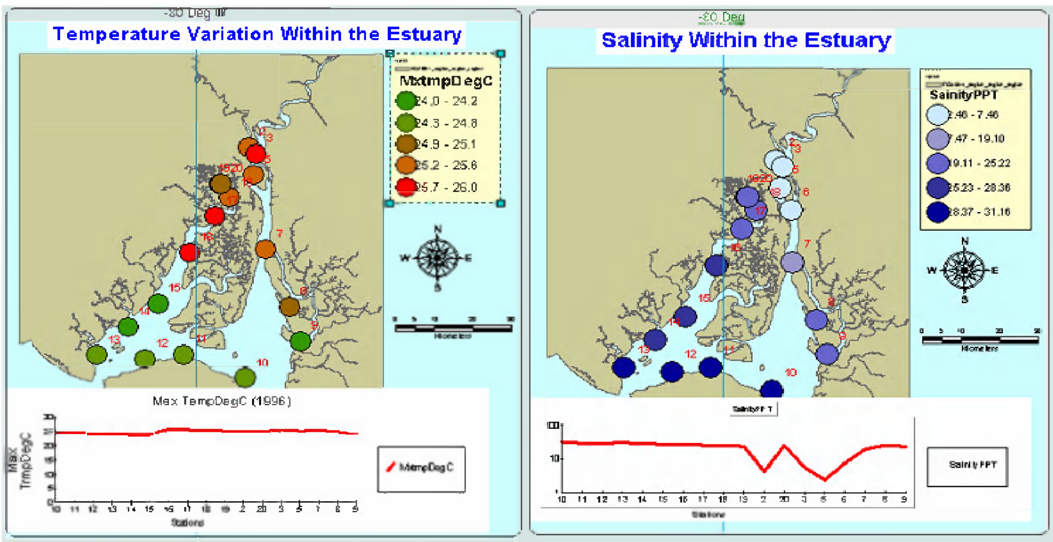


Figure 6-17 Estuary Water Temperature and Salinity

The buffering process (two regions), in the North West and North East, shows zones with maximum concentration distribution of mercury Hq (µgm) /l, (see figure 6-14). Applying a one km interval (bounded zone), the zone with the maximum concentration coincides along the southerly extending sheared zone or fault line (see figure 6-16), suggesting the effect of and influence geodynamic processes and the also possible effect of human activities.

6.4.10.1 Salinity and Temperature

Temperature and Salinity: The measured water temperature ranging 25.2 to 26 is higher, close to continental terrain, which is rather a normal phenomenon when contrasted to the seaward temperature. On the other hand, the southern zone is characterized by colder (symbolized by green color) temperature ranging 24 to 24.6 Celsius. This zone is close to the outlet of the estuary to the ocean.

The colder temperature is attributed to the cold-water current surge and swelling of colder current from the sea to wards the estuary, at the period of measurement. Otherwise, salinity is higher towards the ocean compared to the depleted salinity landwards (see figure 6_17).

6.4.10.2 Sediments and HeavyMetals

An attempt was also done to spatially analyze the relative relationship of the clay% standard distribution with the heavy metal Mercury (Hg, mg/kg) standard deviation distribution along the estuary's measurement stations. There is a positive relationship between the clay and mercury for values calculated close to the 1.5 stdv. The graduated symbolization shows that stations with higher mercury also display similarity in distribution of clay%. Furthermore, such relationship indicates that clay rich sediments are vulnerable to the effect of mercury contamination. The higher value of the clay corresponds to the higher values of mercury, suggesting that there is higher affinity of the mercury dissemination with distribution of clay. Such relationship indicates that clay rich sediments are vulnerable to effect of mercury contamination. To verify the area, buffer zones were created around the anomalous features, indicated as Z1 (Zone 1) and Z2 (zone 2), (see figure 6-18), polluted (stations 18, 19, 20) is close to activity zone with meandering and relatively narrow stream tributaries whereas, Z2 (station 11 and 12) is adjacent to environ prevailing a human activity zone. There are signs of elevated Hg, (kg/mg) in the north-eastern channels (station 5, 6), which were beneath coverage of a 1 km buffer zoning.

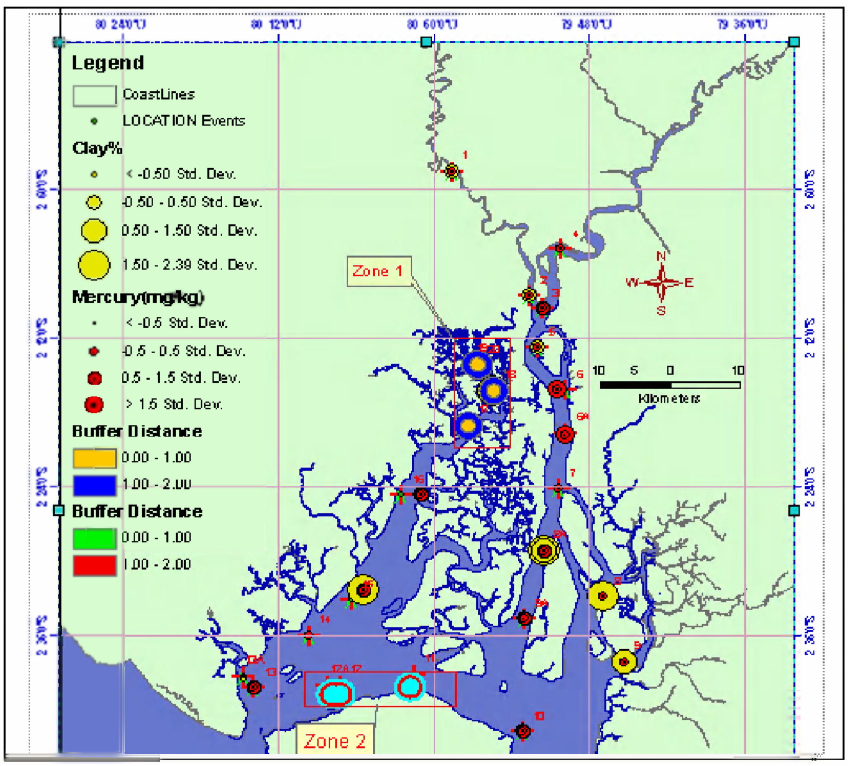


Figure 6-18 The standard deviation distribution of Clay and Mercury

6.4.10.3 Overlay Interpretations

Based on overlay spatial interpretation mechanisms, i.e., superimposing satellite image map and vector features, it was possible to disclose impacts of activities. These effects were thematically visualized close to the southern periphery of the estuary and regions under submarine erosion pressure, (see figure 6-19).

The process deciphered that the southern island's northern flank (resymbolised red color)) is deeply dissected and a canyon is being created. This may facilitate an early failure of the unconsolidated coastal sediments. Moreover, close up view of the spatial overlay, of thematic viewed maps suggest that southern part of the main estuary land is pinching out southwestward (see figure 6-19), most probably due to submarine erosion impact.

These evidences rounded up from the spatial overlay analysis imply that the dimension of the southwest estuary water body is expected to extend further northwards and the southern island might submerge as a repercussion of combined effects of human and nature dynamism.

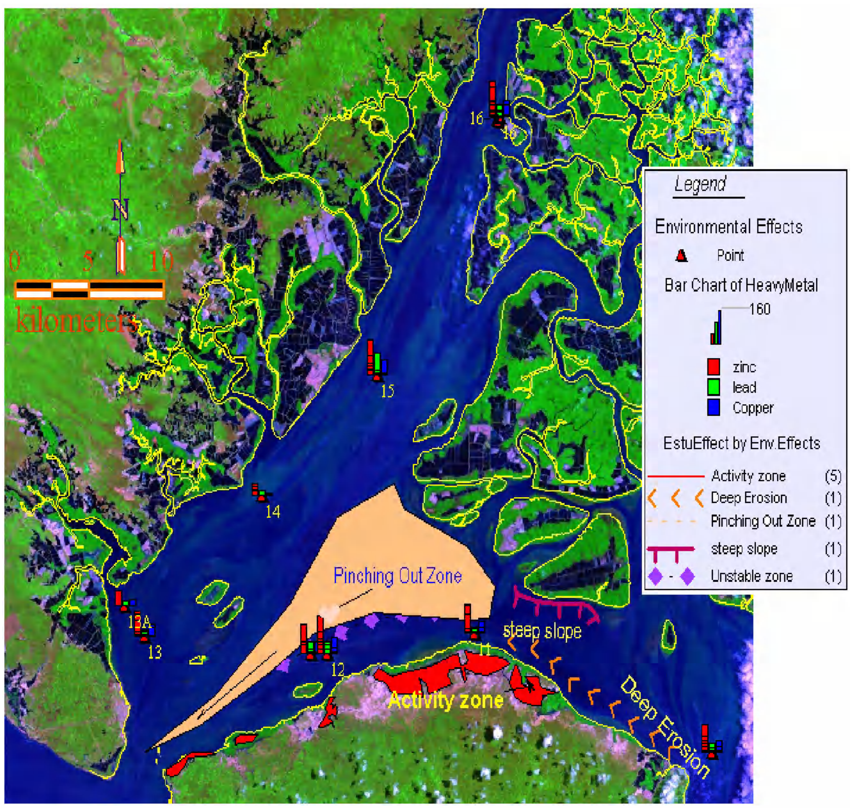


Figure 6-19 Submarine Processes and effects

6.4.11 Meta Data (MD)

6.4.11.1 Managing Meta Data

In the domain of GIS, Meta Data is advantageous in describing and understanding more an associated geographic object. Meta data are created as Hyperlinks or hot link types with a required full or relative path before being utilized. For instance D:\AMAPIFO2K44\CORE.BMP" is an image of .bmp type pointing to the root D. The Meta data variable (field) is of text type and the string path is the value stored and associated with the object. It inherits the object Identifier that describes it uniquely within Geodatabase system. The textual value of the Meta data attribute is retrieved by means of object querying methodology.

The examples below show the process of creating and managing core and video Meta data type associated to a respective object. The object is created within the Geodatabase; a separate field is established (for storage) for the Meta data path associatable with an object. The implementation is based on [37] and the attribute database is stored in .mdb.

Geodatabase Definition Table: = "equx.mdb"

Type ACCESS TABLE/ object "BioOrgAbundance"

```
a.  Step 1: Fields 20
b.  MSLINK Integer;
c.  Mapid Integer;
d.  Station Char (25);
e.  Area Float;
f.  Perimeter Float;
g.  Step 2:
h.  Video Path Char (100);
i.  CorePath char (100);
j.  Step 3:  Path Pointer
k.  Begin metadata
l.  "\ActiveObject" = ""
m.  "\ActiveObject\Expr" = "Video"
n.  "\ActiveObject\Mode" = "HOTLINK_MODE_BOTH"
o.  "\ActiveObject\Relative" = "TRUE"
p.  "\IsReadOnly" = "FALSE"
q.  End_metadata
r.  Begin_metadata
s.  "\ActiveObject" = ""
t.  "\ActiveObject\Expr" = "Core"
u.  "\ActiveObject\Mode" = "HOTLINK_MODE_BOTH"
v.  "\ActiveObject\Relative" = "TRUE"
w.  "\IsReadOnly" = "FALSE"
x.  End_metadata
```

Object relational spatial queries can retrieve Meta data (images, documents, videos and audio) integrated with specific spatial objects. .

6.4.11.2 Retrieving Approaches (Raster Type)

The ***MeasSediment Object*** is described by its geospatial set of data source and the measured attribute values pertaining to Sedimentology discipline. However, there exist additional data about the MeasSediment spatial feature. These are ***core samples*** showing the physical nature of the data, stored in a separate space but integrated to the specific object as a Meta data. Two objects (MeasSediment and the EstChannels) are involved in the process of retrieving and visualizing the Meta data.

See retrieval steps below: -

```
Step 1
    SELECT
        SEDIMENTS, EstChannels        ' two objects
            Where EstChannels.Obj Contains Sediments.Obj  ' first object contains second
                And SEDIMENTS.CORE1 = "D:\AMAPIFO2K44\CORE.BMP"  'pointer to core path
```

The region and the measurement points are retrieved.

Step 2

```
Select
    SEDIMENTS, EstChannels ' two objects
        Where SEDIMENTS.obj within EstChannels.Obj ' ' first object within second
            And SEDIMENTS.CORE1 = "D:\AMAPIFO2K44\CORE.BMP"' Pointer to core path
```

Output: an object of POINT type intercalated within the Estuary region object and associated attribute values (see figure 6-20). Eventually, combining the two objects generates a new object that discloses the Meta data and objects.

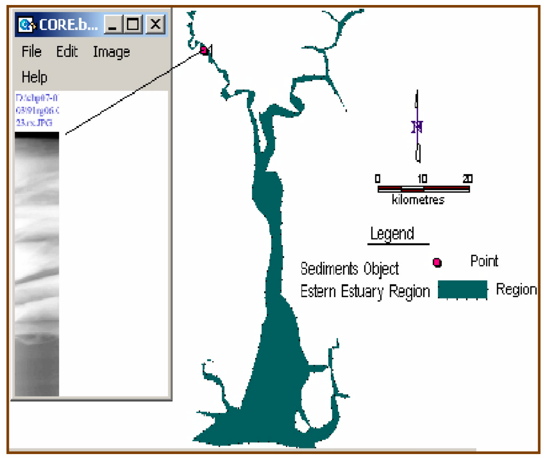


Figure 6-20 Geographic object and A Core Sample image Meta data

6.4.11.3 Retrieving Approaches (Video Type)

Illustrating: The retrieval of the video Meta data requires knowledge of the object with which it is associated. A BioOrganicAbundance object is applied for this case study.

Step 1: Retrieving a Video

➢ ***Select Video from BioOrgAbundance*** **Where Video Like "%. Upj"**

The retrieved query displays the location of the point in which the Video information is associated with. Eventually, a hyper link tool triggers the highlighted object and the video Meta data is played pointing to the location hooked in. (see figure6-21)

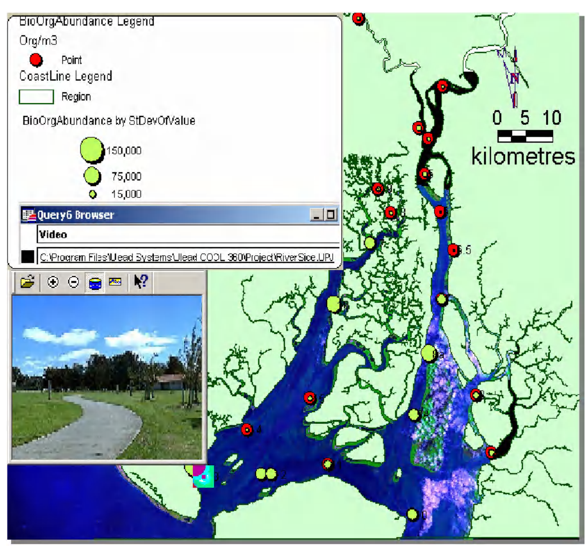


Figure 6-21 Geographic object and a Video Display Meta Data

The implementation of the GeoRelational data model and spatial operators reveal the advantage of applying integrated spatial information and the methodology of exploiting the system graphically. As a matter of facts, the eventual integrated results plays an important role in carrying out a decision on the issue being explored with a higher degree of prospect and possibility.

6.5. Results and Conclusions

- Overlay analysis interpretations of the interdisciplinary objects have been carried out by implementing object-relational analytical methodology
- Interoperability of features among different GIS applications and the Georelational model has been executed via SQL and ODBC connections. One of the interoperability processes includes - translating features type specific to a spatial engine. The output of the test disclosed preservation and loss of features properties on non OPEN GIS complaint applications.
- A Hybrid of Object Relational spatial operators and SQL statements were constructed to perform spatial search and display thematical information. The process has been accomplished by executing the required topological relationship, checking containment of the spatial features, georeferencing compatibility of the geographic objects and creating migrating spatial pointers among the objects.
- A methodology of integrating and retrieving Meta Data associated with geographic objects has been developed. The output revealed the possibility of utilizing objects and object relational operators to retrieve and display full-fledged Meta data spatial information of such as video, audio, image and documents that further elaborates the results of the spatial interpretation.
- Implementation of the Georelational GIS data model carried out in the *Guayaquil estuary* GIS case study reveals zones of contaminated sediments, anomalous affinity of heavy metals to sediments (clay); indicating that clay rich sediments are conducive medium to mercury deposition.
- Buffering process of the point type objects shows that the northeast and north west of the estuary are characterized by higher concentration of mercury and that zone coincides with the southerly extending shear zone, indicating geodynamic effects in addition to the human impacts.
- Comparison of surface water, bottom water and Bottom sediments environment revealed that the surface water is characterized by relatively higher dissemination of Cd than Hg.
- An interpretation of the satellite image and vectorised features (southern part of the estuary) discloses the presence of unstable submarine zones as a repercussion of human and submarine erosion process.

Chapter 7: Spatio -Temporal Analysis

7.1. Introduction

In the field of location based geosciences, GIS, is composed of space, time and attribute components. Connected with this, at the phase of a spatial analysis, a set of geometry-based spatial objects are applied to represent thematic reality using different symbols with respect to classified time intervals. In this work, the main spatio-temporal analysis focuses on the current velocity and direction in the Guayaquil estuary. Furthermore, an extended theoretical explanatory aspect on the causes of tide generating forces and possible influence on the nature of the current's velocity and direction is encompassed within the chapter. With this regard, the core theme concentrates on exploring the possible ways of processing and analyzing spatio-temporal data in a coastal marine environment GIS. Moreover, it emphasizes the analysis intended to extract and visualize environmental phenomenon in a spatio-temporal perspectives and the importance of tracking and processing of a real-world time elapsed ever since an event had been in the process in order to manage and predict about future changes. Henceforth, a brief description on temporal concepts in relation to spatial sciences is given, pursued by the theoretical aspects on the causes of tides and processes of spatio-temporal implementation of the Geodatabase GIS.

7.2: Spatio -Temporal Conception

In spatial science, the temporal information is associated with time-stamped individual layers, which can be explained as the temporal map set (TMS) [85], (see Figure 7-1 and snapshot models [86]. In the snapshot model, every layer is a collection of temporally homogeneous units of one theme. It shows the states of a geographic distribution at different times without explicit temporal relations among layers.

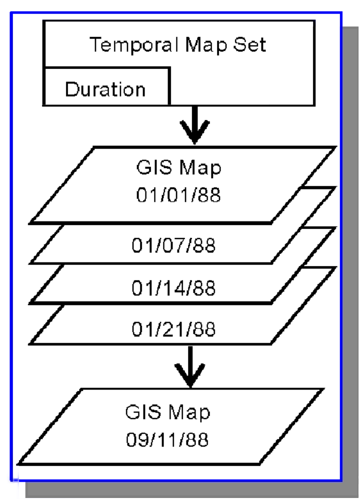


Figure 7- 1: TMS Model (after Beller et. 1991)

The fact that location based information is dependent on time, implies that, a location can't exist without a time (t) and remain always-interconnected issues. It implies that both spatial and temporal references are required to define a location. The design of TMS endeavors to model geographic events in a defined area. The major drawback is its data redundancy and the risk of data inconsistency [88].

On the other hand, the Space -Time Composites (STC) model represents the world as a set of spatially homogenous and temporally uniform objects [87] in 2D space (see Figure7-2). The space-time composites can be derived by temporal overlays of time-stamped layers (snapshots) and attribute changes are recorded at discrete times.

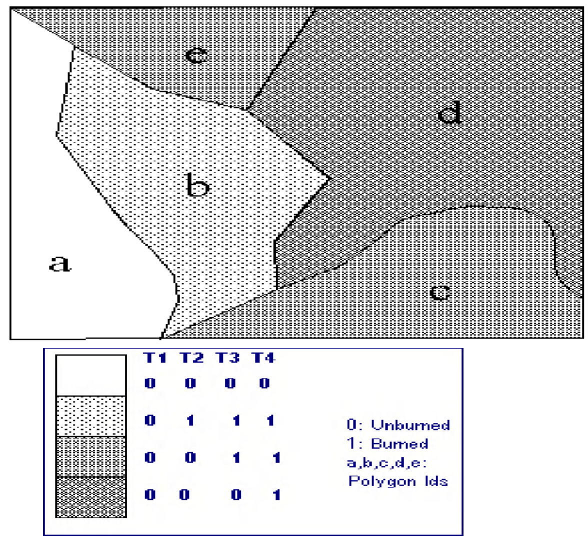


Figure 7- 2: An example of an STC layer for burns (Modified from Lnagran and Chrisman, 1988)

The STC model enables to record temporality within the largest common units of attribute, space, and time (i.e. change in situ), but according to [87] this model fails to capture temporality among attributes across space (i.e., in motion or movement).

7.2.1 Spatio-Temporal Processes

7.2.1.1 Spatio-Temporal Significance

Incorporating temporal analysis of data in GIS is vital for a number of logical reasons: -

Every event and process that occurs on the earth's data happens through a chain of time spans; and most data are subjected into different transforming processes either pre or post measurements.

Therefore, as a function of time (F (t), attributes compositional variations can be gauged. Example, a steady dynamic fluctuation of the coastal process through time results in reshaping the coastal morphology and changes the habitat of the ecosystem.

As an illustration of the process, in the coastal zone, the study of current mobility and direction allows us understanding and interpreting maps in the form of *category time_t_map, category time_t+1_ map, category time_t+2_ map* …etc.

7.2.1.2 Spatio-temporal Analysis Process (*STA*)

The purpose of such STA is to associate informative attributes values and temporal marker data with their respective geo-referenceable geographic features (see figure 7-3). The factors described as Dim 1, Dim2, Dim3 and Dim4 (see figure 7-4) represent a geographic element, time stamp, measured informative attribute values and aggregated values respectively. As spatio-temporal information is information indexed with time [40], then the issue of thematic display becomes complex; especially when multiple attribute records are not only referenced to two dimension features (point, line) but also to time-stamp component of the geodatabase.

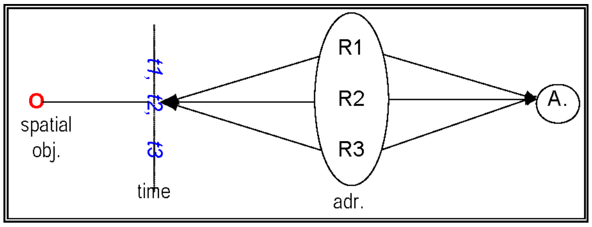


Figure 7- 3: Spatio-Temporal Retrieval Cycle

At this juncture, the need of aggregating process (see figure 7-3) crops out and is carried out to establish correspondence between associated database records (D3) and specific spatial object (D1) tagged to specific date and time (D2), (see figure 7-4).

Thus, temporal queries have been incorporated to enable smooth search of possible answers pertaining to what had happened, is happening and would happen along geo-reference able sites through time.

Thus, for instance, if a regularly measured temperature gradient is increasing gradually from time-1 to time-2 and the influencing factors are outlined; it might be possible to establish a possible model that help to predict and project the phenomenon in a geo-referenced time-$_n$. To enact it, additional availability of elapsed period's measurements is prerequisite. It is possible to incorporate influencing factors (seasonal, global climate changes and human activities impact) such as ELNINO [15], which influence the climate variation in the Gulf of Guayaquil (Guayaquil estuary).

7.2.1.3 Composing Spatio-temporally

Normally, a geographic object occurs uniquely in a specific geodatabase system. But, some times a single spatial object can be related to other attribute database records (adr.), linked to different Temporal attributes (see figure 7-3). This would rather create a relationship of *I: M* type where a geographic element is related to many attribute records and this contradicts the principle of 1:1 mapping. In such conditions the natural relationship between a spatial object and the attribute database records (adr.), in a 2D GIS, results in producing a number of information layers represented by different symbols to represent the evolution of a single parameter values through time. Referring to figure 7-4, the Dim 1 (dimension) represents the spatial object coordinate that is described by Dim 2 (temporal attributes) pertaining to alphanumeric attributes (Dim 3).

Any change in the magnitude of dim 3 as F(t) should be reflected in the change of spatial object (dim1). The point is that the spatial object should respond to changes that occur in Dim 3 via Dim 2 to indicate that spatial objects are also dynamic.

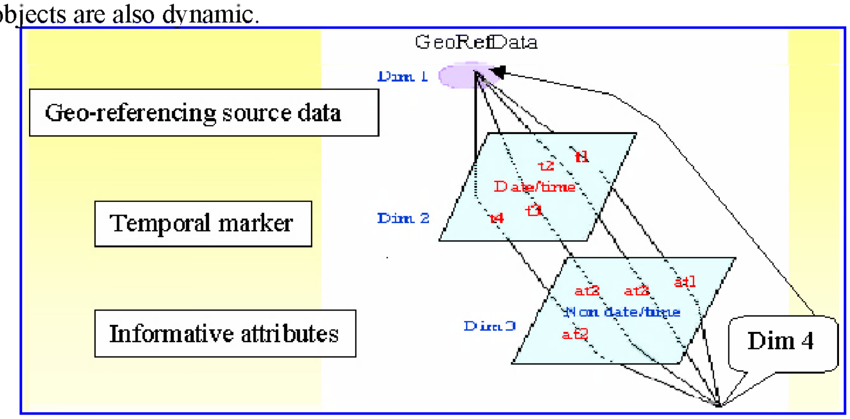


Figure 7-4: Spatio-Temporal data processing

Otherwise, Dim 3 data should be aggregated with specific time such that as F (t) and F (R1 to R1+n) then an aggregate (A) that corresponds to a spatial object is generated, (see figure 7-4). On the temporal dimension could not be aggregated because it represents a specific temporal event in the system that can't roll back. Hence, a roll back operation cannot be committed is ruled out.

In the case of a single spatial object S where (S1=S2= S3=S4 …) S=S1 to Sn, the spatio-temporal analysis can only be carried out by creating different Spatio-Temporal Layers (STLs) that correspond to Dim 3, or adr, (See figures 7-5), and this process of can be explained as follows.

For the L1 = layer 1, L2 = layer 2: R1, R2 records, at x, y, t

L1 = corresponds to S1 & R1 at time t1

L2 = corresponds to S2 & R2 at time 2: where S1 =S2

In a multiple dimensions, (Dim 1, Dim 2,) which are represented by (S=S1-Sn) and (T=T1-Tn) respectively, the possible spatio-temporal layers (STLs) can be retrieved by changing relationship between the spatial object and time to M: 1 respectively.

To retrieve and symbolize information related to the question what happen in different geographic locations at a particular time.

Thus: -For 2D geographic objects:

L1= X, Y related to R1 tagged to t1 = X, Y: R1T1

L2= X, Y related to R2 tagged to t2 = X, Y: R2T2

If the x, y of L1 = x, y for L2 the spatio-temporally tagged data is symbolized once at a time.

For 3D geographic objects:

L1= X, Y, Z related to R1 tagged to t1 = X, Y, and Z: R1T1

L2= X, Y, Z related to R2 tagged to t2 = X, Y, and Z: R2T2

Based on this spatio-temporal relationship, the objects thematical resymbolisation is performed discretely.

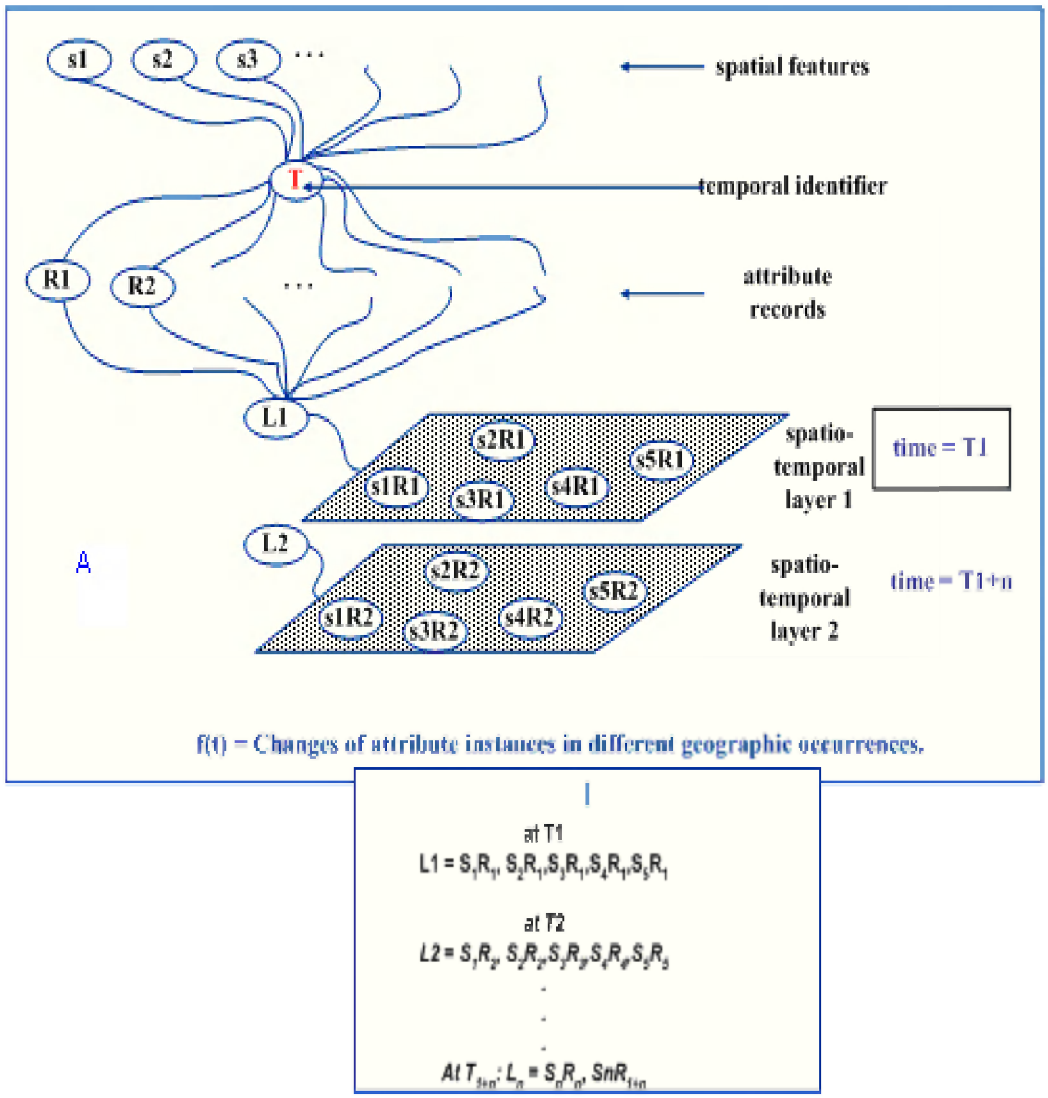
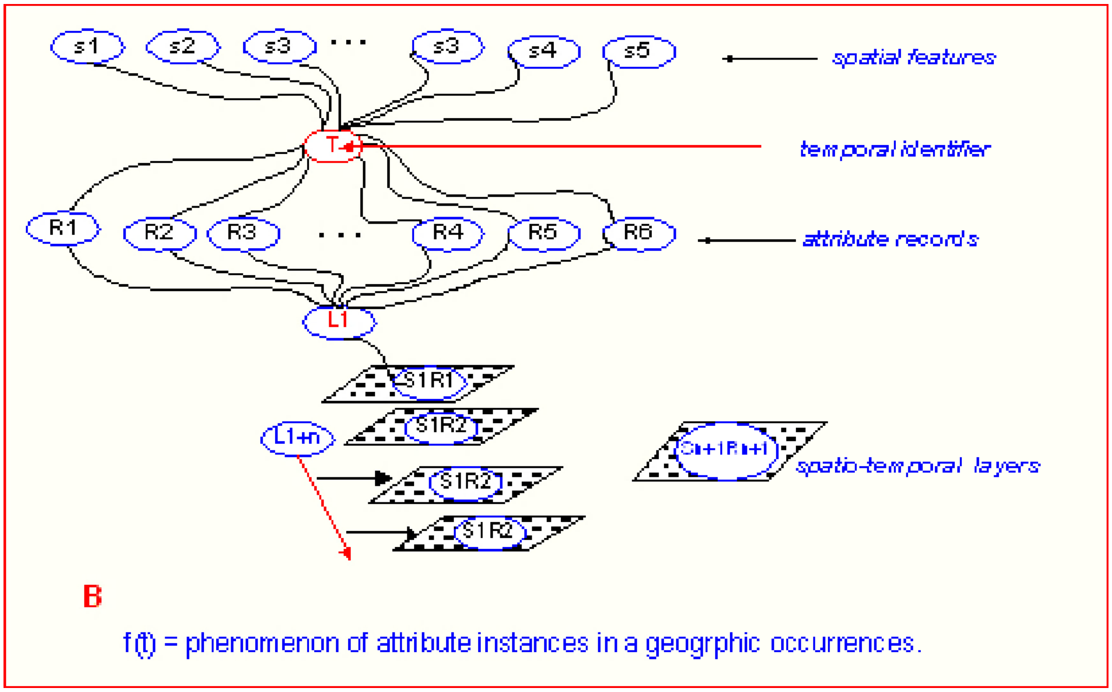


Figure 7- 5: (A) Multiple Spatial Objects at Time1 (t1) (B) Changes R to R1+1 in S1 as F (t])



The layer information (L1), (see figure 7-5 A) is the output of the combined spatio-temporal and associated informative database records, ranging from record1 (R1) to record6 (R6) constrained with specific time filter. Further, layers of information are derived in the same pattern for (T=T1 to Tn) and geographic features (S=S1 to Sn) for any event that occurs through time in different geo-referenceable observation points.

The possible changes on an associated attribute values, on a specific site and a sequence of time includes -

At Time (t1), L1 = is described by R1S1 (attributes assimilation to unique geographic element)

At Time (t2), L2 = is described by R2S1 = At Time (TN+1) Ln = is described by RnSn

The changes on the associated attribute values, as a function of time are distinguished using different symbols.

Such phenomenon can be illustrated by the changes of attribute composition recorded in a specific geo-referencing point at different times.

For instance at time T, concatenated to a specific LL coordinate, the attribute (for instance sediment composition) value transition of grain size can be described as silty at time 1 and can be gauged at T (i+1) as sandy, depending on events that took place during T (i+1).

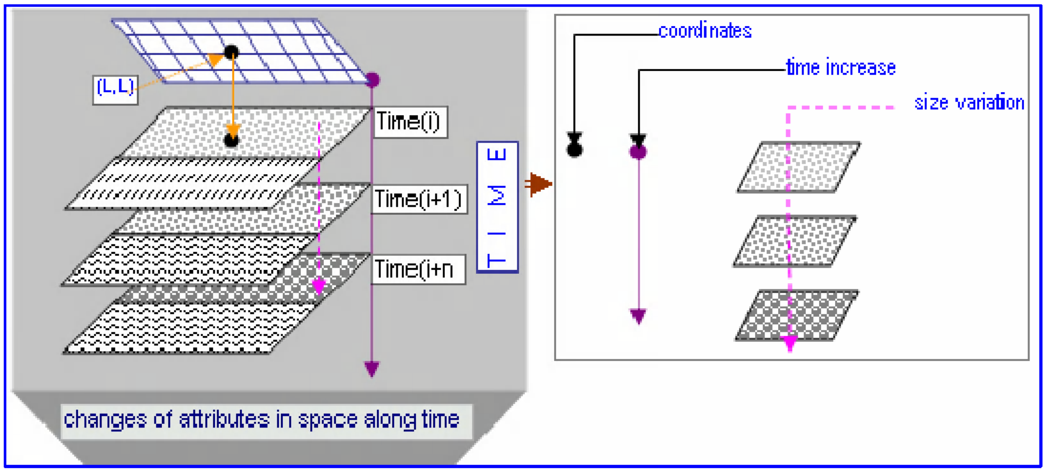


Figure 7- 6: Spatio-temporal effects on attribute components

Moreover, the situation may also be described as gravelly composition at T (i+2), depending on the grain size changes of the sediments, as schematically illustrated (see figure 7-6).

7.3: The Causes of Tides: A Theoretical Aspect

Daily, ocean water intrudes the shorelines to flood bays and estuaries. It inundates mud flats and marshes, raises the water levels, and surges landward with sufficient force. As the process continues, salt water mingles with fresh water, and within hours, the brackish brew slackens briefly to deposit valuable nutrients that feed countless organisms residing in coastal waters or in the complex estuarine system. Then, the process reverses, and receding waters flush the estuary, carrying organics and inorganic materials and even potentially harmful pollutants to the sea.

These predictable and periodic movements of ocean waters are known as tides and are caused by the attractive forces of the moon and the sun. Sir Isaac Newton's law of gravitation tells us that any two bodies in the universe are attracted to each other and that strength of this attraction depends on the bodies' mass and distance from each other [103].

The sun's mass is greater than that of the moon but also the distance is further from the earth in contrast to the moon. Therefore, although the sun affects the tides, the moon exerts greater gravitational attraction because of its proximity to our planet.

Besides, the great variety of the earth's topography, as well as other terrestrial influences causes the tides to differ in various ways and exhibit certain similarity. Along the coasts, tides can vary greatly, depending on the topography and other influences. In some parts of the world, the range of the tides is measured in inches; elsewhere, the disparity can be dramatic. At the Bay of Fund, in Nova Scotia, for example, the difference between high and low waters can be as much as 15m [103] whereas in the Guayaquil estuary the tidal ranges 3 to 5 meters [96].

7.3.1 Definition

The word "tides" is a generic term used to define the periodic rise and fall of the sea level with respect to the land, produced by the gravitational attraction of the moon and the sun [104]. In other words, it is astronomically induced vertical change in the height of the sea surface caused by slight variations in gravitational attraction between the *Earth,* the *moon* and the *sun* [105] and geometric relationship with locations on the Earth's surface [106].

The moon is the primary factor controlling the temporal rhythm and height of tides. The moon produces two tidal bulges somewhere on the Earth through the effects of gravitational attraction. The height of these tidal bulges is controlled by the moon's gravitational force and the Earth's gravity pulling of the water back toward itself.

The second factor controlling tides on the Earth's surface is the sun's gravity. The height of the average solar tide is about 50 % the average lunar tide [112]. At certain times during the moon's revolution around the Earth, the direction of its gravitational attraction is aligned with the sun's gravitational force. According to [106], at location on the Earth closest to the moon, seawater is drawn toward the moon because of the greater strength of gravitational attraction. On the opposite side of the Earth, another tidal bulge is produced away from the moon (due to the fact that at this point on the Earth the force of the moon's gravity is at its weakest). Considering this information, any given point on the Earth's surface should experience two tidal crests and two tidal troughs during each tidal period (figure 7-7).

Knowledge of the times, heights and event of inflow and outflow of tidal waters is of significant importance in a wide range of practical applications such as in: navigation through intracoastal waterways, within estuaries, bays and harbors, establishment of standard datum, and furnishing of data indispensable to fishing …etc and other considerable related issues.

7.3.2 Tidal Ranges Fluctuation

Currents reflect the horizontal movement of water, whereas tides reflect vertical movements. This movement is primarily caused by the gravitational pull of celestial bodies and other factors playing a significant role include - differences in water temperatures, differences in salinity caused by rain, evaporation and friction … etc. Thus, tides are vertical rise and fall of the surface of water caused primarily by the differences in gravitational attraction of the moon, and to a lesser extent the sun, when the positions of the moon and sun change with respect to the earth. The process results in generating different types of tides such as the spring and neap tides...

Spring tide occurs when the sun, earth and moon are aligned straight with a tide larger than average. On the other hand, the Neap tide occurs (smaller than average) average [100], when the moon is at right angles to the earth-sun line.

The effects of landmasses, constrained waterways, friction, may distort this basic pattern … etc. The incoming tide along the coast and into the bays and estuaries is the *flood tide* and the outgoing is the *ebb tide.* As the tide rises, water moves towards the shore (flood current) and as it recedes moves away from the shore (ebb current), (see figure 7-7).

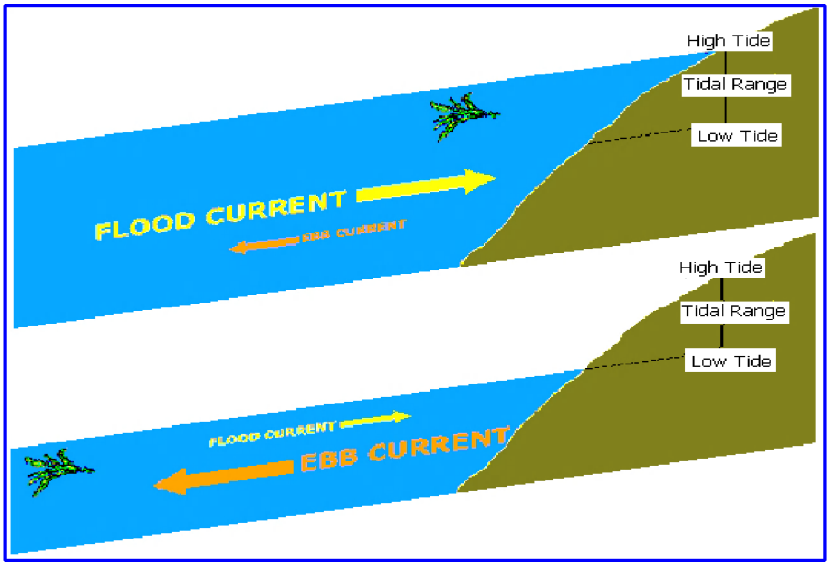


Figure 7- 7: The flood and Ebb Tidal Ranges

In the open ocean, tidal currents are relatively weak. Near estuary entrances, narrow straits and inlets, the speed of the currents can reach up to several kilometers per hour [111], but it can be slowed by friction against the bottom of the ocean.

These dynamic aspects of tides result in variation of the number of highs and lows per day at different locations.

Therefore, even though the forces that move the tide are well understood, the tides at any spot are essentially impossible to calculate theoretically, [113].

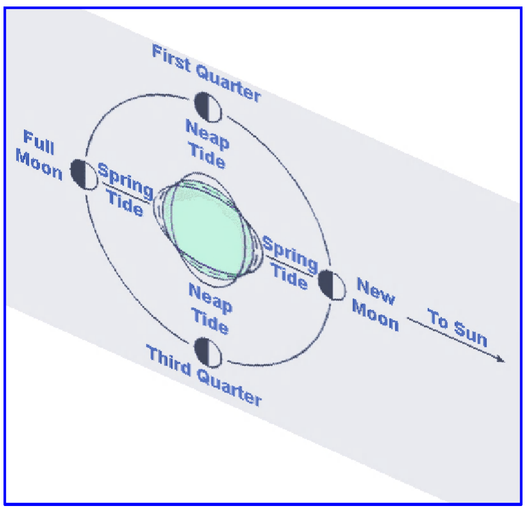
What we can do is to record the height of the tide at that spot over a certain period, and use these measurements to predict the tides in the future.

7.3.3 How are they created?

7.3.3.1 Positional Effects

Understanding how a tide forms require considering, that, the pull of the moon is slightly stronger on the side facing the earth. This causes the earth to elongate slightly towards the moon, and due to reason that water is more flexible than rocks, most of stretching occurs on oceans. This raises a small tidal bulge on the earth facing the moon and on the opposite sides of the earth, (sees figure 7-11). The timing of these tidal events is related to the Earth's rotation and the revolution of the moon around the earth. One revolution takes about 27 days and adds up about 50 minutes to the tidal cycle [107], [108].

As a result, the **tidal period** (Time it takes for one tidal cycle) is 24 hours and 50 minutes in length. The **tides** at a given place in the Earth's oceans occur about an hour later each day. These situations are explained with respect to the positional phases of the moon known as the *syzygy* and *quadrature,* [106] (see figure 7-8).



The gravitational attractions (and resultant tidal force envelopes) produced by the Moon and Sun reinforce each other at times of new and full moon to increase the range of the tides, and counteract each other at the first and third quarters to reduce the tidal range, (see figure 7-8). The variation of tides can be explained as follows.

Figure 7- 8: The Phase Inequality: Spring and Neap Tides

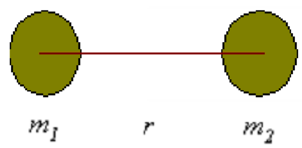
Quadrature: When the moon is at first and third-quarter phase (quadrature, perpendicular position to the sun), the gravitational attraction of the moon and the sun upon the water of the earth are exerted at right angles and relatively small tidal ranges, known as neap tides generated.

Syzygy: When the moon is at new and full phase (syzygy), the gravitational attraction of the moon and the sun align to act and reinforce each other. Thus, the resultant tidal force is also increased; the observed high tides are higher. Such greater-than-average tides resulting at the syzygy position of the moon are known as spring tides; a term indicating welling up of the water or short-period, astronomically induced vertical change in the height of the sea surface, [104], (and 7-12).

7.3.3.2 Parallel effects

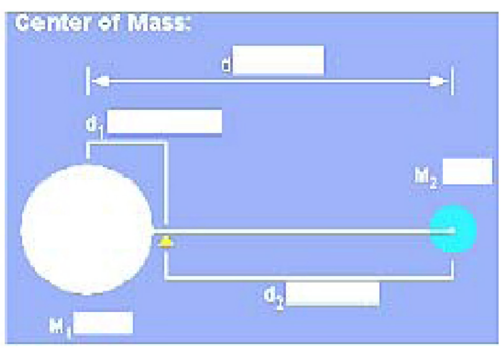
Since the moon follows an elliptical path, the distance between the moon and the earth will vary throughout the month. The Moon exerts a gravitational force on every object on and in the Earth. Some parts of the Earth are closer to the Moon than other parts, and since the gravitational force drops off as the inverse square distance [108], those parts closer experience a larger gravitational tug from the Moon than parts that are further away [109].

According to [108], Every object in the universe attracts every other object with a force directed along the line of centers for the two objects that is proportional to the product of the masses and inversely proportional to the square of the separation between the two objects (i.e., Law of universal gravitation) is defined by: -



$$Fg = G\frac{m_1 m_2}{r^2}$$

Where Fg is the gravitational force, G is universal gravitational constant, m_1 and m2 are the masses of the two objects and r is the separation between the two objects. Thus, the distance is a function of the mass attracting forces and any change of it will influence the force of gravity being exerted on the earth surface there by influencing the nature of the tides range. For instance changing the d2 towards left will shift the center of mass towards m1 to keep the center of mass in balance and vv, (see figure 7-9).



m1d1 = m2d2 and d1 + d2 = d (ly)

d1 = [m2/(m1 + m2)] d

d2 = [m1/(m1+m2)] d

Figure 7- 9: The Center of mass

With this regard, once a month when the earth orbit is closest to the moon's orbit (perigee), [104], the tide generating force will be higher than usual, thus producing more than-average-tide ranges. Conversely, about two weeks later when the moon is at the farthest (apogee) from the earth, the lunar tide raising force will be lower and the tide ranges will be below average. Similarly, in the earth-sun system, at the perihelion (sun's closest position to the earth,) and aphelion (sun's furthest position), the tidal range will be enhanced and reduced respectively, (see figure 7-10).

The fluctuating tidal heights and the changing of current direction as well as in speed are mainly the result of the fluctuating gravitational forces of sun and moon on the water masses of the earth [107].

Further, the speeds of the tidal currents are associated with ebbs and floods phase of the tides, the high speed is thus, related to the flood and the low speed with ebb [110].

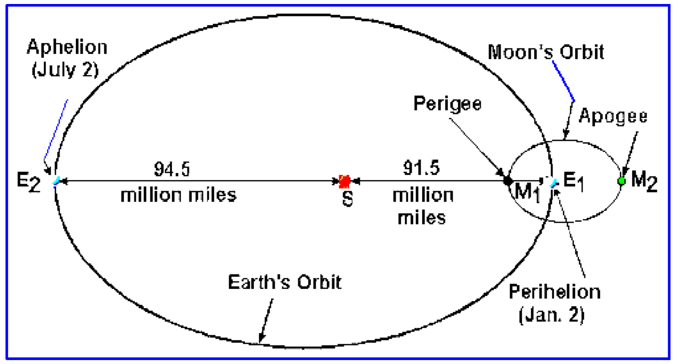


Figure 7- 10: The Lunar and Solar Parallax Inequalities

7.3.3.3 The Tractive Forces

Tidal Generating Components: At the center of the earth, the centripetal acceleration provided by the gravitational attraction between the moon and the earth exactly equals the centrifugal acceleration due to the rotation about the common center of mass, which lies inside the earth. In consequence, the moon revolves in a closed orbit around the earth, with out either escaping from, or falling into the earth and the earth likewise does not collide with the moon. However, at local points, the gravitational force of the moon varies over the surface of the earth [see figure 7-11].

Hence, above, or within the earth, the forces of centrifugal (outward) and centripetal (inward) are not in equilibrium, consequently- oceanic, atmospheric and earth tides are the resulted, known as tide-generating force (TGF). The horizontal component, of the TGF is called the Tractive force, (see figure 7-11).

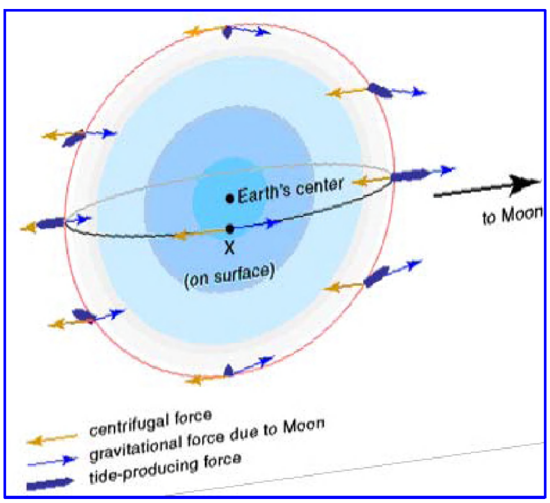


Figure 7- 11: Tide Generating Components

Gravitational force effects: While the effect of the centrifugal force is constant for all positions on the earth, the effects of external gravitational force produced by another astronomical body may be different at different positions on the earth because the magnitude of the gravitational force varies with distance of the attracting body [105]. The relative gravitational force exerted at various positions is indicated in figure 7-12.

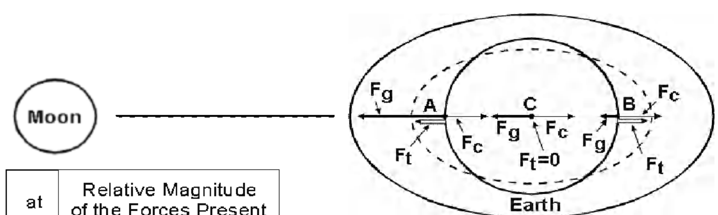
Net Tide-Raising Forces: Referring to figure 7-12, the center-of-mass of the earth and moon remain in equilibrium at constant distances from the barycentre. The centrifugal force acting upon the center of the earth (Point C) must be equal and opposite to the gravitational forces exerted by the moon on the center of the earth [104]. At point A (see figure 7-12), the force produced by the gravitational pull of the moon is considerably larger than the gravitational force at C due to the moon.

The net tide producing force at A obtained by taking the difference between the gravitational force and the centrifugal forces is in favor of the gravitational component outward towards the moon. The tide raising force at point A is indicated by double arrow (see figure 7-12), extending vertical from the surface of the earth towards the direction of the moon.

At point B: Since gravitational force is less at B than at C, it follows that, the centrifugal force exerted at B is greater than the gravitational force exerted by the moon at point B. The resultant tide producing force at this point is, therefore, directed away from the earth center and opposite to the position of the moon.

The tide produced in this location halfway around the earth from the sub lunar point, coincidentally with the direct tide, is known as the opposite tide.

Type of Force	Designation
F_c = centrifugal force due to Earth's revolution around the barycenter	thin arrow
F_g = gravitational force due to the Moon	heavy arrow
F_t = the resultant tide-raising force due to the Moon	double shafted arrow



at	Relative Magnitude of the Forces Present
A	Fg > Fc > Ft
	v = v
C	Fg = Fc > 0
	v = ^
B	Fg < Fc > Ft

A north-south cross-section through the Earth's center in the plane of the Moon's hour angle; the dashed ellipse represents a profile through the spheroid composing the tidal force envelope; the solid ellipse shows the resulting effect on the Earth's waters.

Figure 7- 12: The Combination of Force of Lunar Origin Producing Tides

The tide raising force of the moon is, entirely insufficient to" LIFT" the waters physically against the far greater pull of earth gravity. Instead, the tides are produced by the component of the tide- raising force of the moon, which acts to draw the waters of the earth horizontally over its surface towards the sub lunar and antipodal points [104].

Hence, at any point of the earth surface the tidal force produced by the moon's gravitational attraction may be resolved into two components: -
(a)Vertical or perpendicular to the earth surface and (b) horizontal or tangent to the earth surface, the second component known as Tractive (drawing) component of force is the actual mechanism for producing the tides.

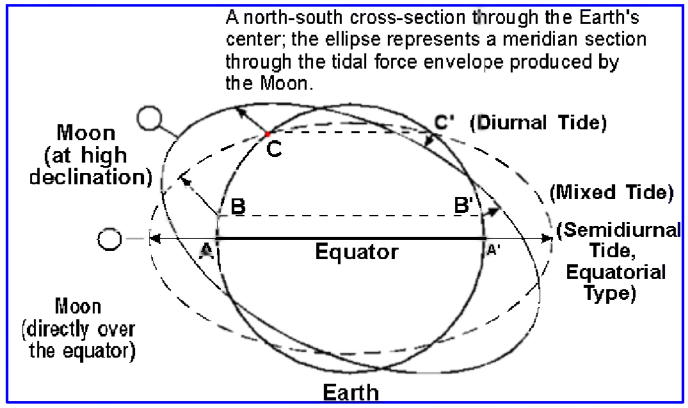


Figure 7-13: The Moon's Declination Effect on tides (Semidiurnal, Mixed, and Diurnal Tides)

These horizontal gravitational components, (TGF) cause the result of having two highs and two lows per lunar day. Thus, there exist an active tendency for water to be drawn from other points on the earth surface towards the sub lunar (point A) and antipodal (point B) (see figure 7-13) and to heaped in the two points in two tidal bulges, due to the effects and strength of gravitational and centrifugal forces.

7.3.4 The possible Types of Tides

A short description of the types of tides related to the explained theoretical processes is given below. The positional declination effects (see figure 7-13) of the moon with respect of the equator on the types of tides and the graphical visualization of the types of the tides that occur at different phases are also explained (see figure 7-14).

Diurnal tides: Tides vary from day to day and from place to place. The geometric relationship of the moon and sun to locations on earth surface and other influencing factors cause the creation of three different types of tides [106].

As they (earth and moon) orbit, their positions shift, causing slight variation in gravitational effects and initiates tides occurrence. In Figure 7-13, for example, the point C is seen to lie beneath a portion of the tidal force envelopes. One half day later, as this point rotates to point C' it is seen to lie above the tide force envelop. At this location, therefore, the tidal forces produce only one high water and one low water each day, [106]. These tides are called diurnal tides, (see figures 7-13 and 7-14 C).

Semidiurnal Tide: When the two highs and the two lows are about the same height, the pattern is called a semi-daily or semidiurnal tide. Consequently, successive highs and successive low are also nearly equally spaced in time and occur twice daily. (See figure 7-13 and figure 7-14, A). So, tidal data range related to the equatorial part of the earth falls to this category.

Mixed tide: However when the changing angular distance of the moon is above or below the equator, the tidal forces envelop produced by the moon is canted or changed, and the difference between the heights of two daily tides of the same phase began to occur. This situation gives rise to a twice-daily tide displaying unequal heights in successive highs or low tides with strong diurnal inequality (see figures 7-13 and 7-14, B).

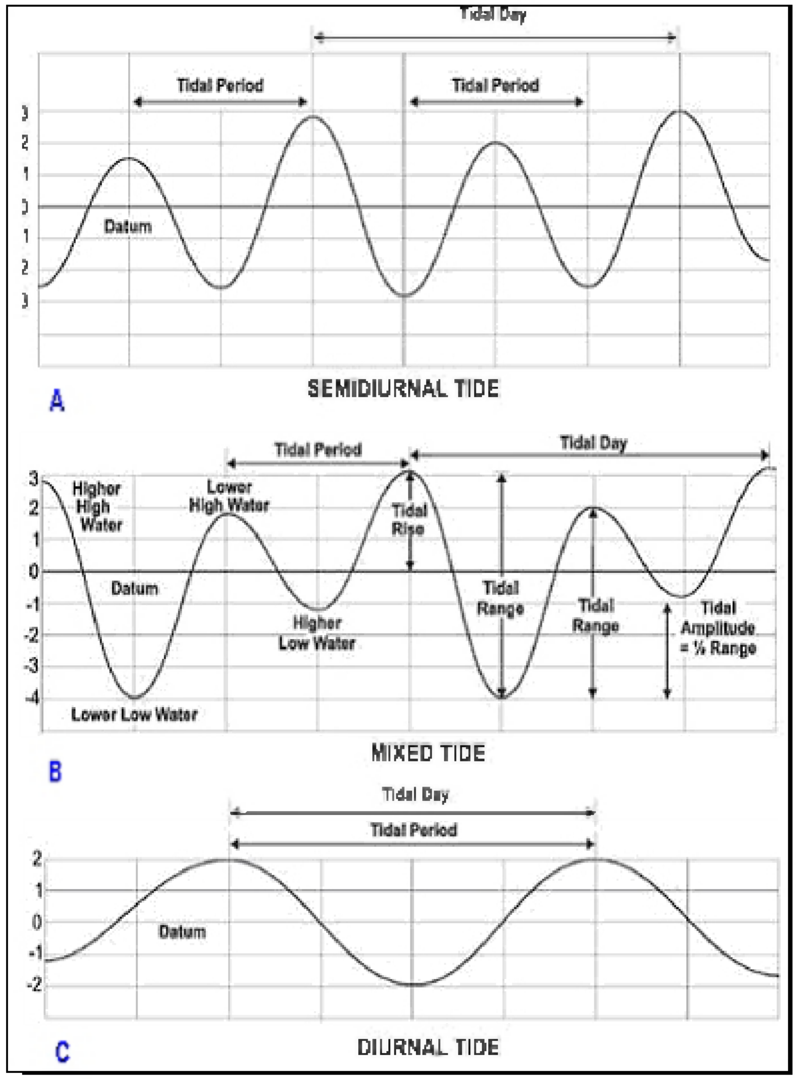


Figure 7- 14: Principal Types of Tides

Chapter 7: Spatio-Temporal Analysis Part II

7.4: Tidal Current's Velocity and Direction Analysis

7.4.1 Nature of the tidal data

Measurement data related to the coastal current (speed and direction), collected in five different locations, have been employed to interpret and understand the current situation in the Guayaquil estuary. These data are referenced by longitude, latitude, depth or elevation (LLE), and a specific time (hr) in a particular day.

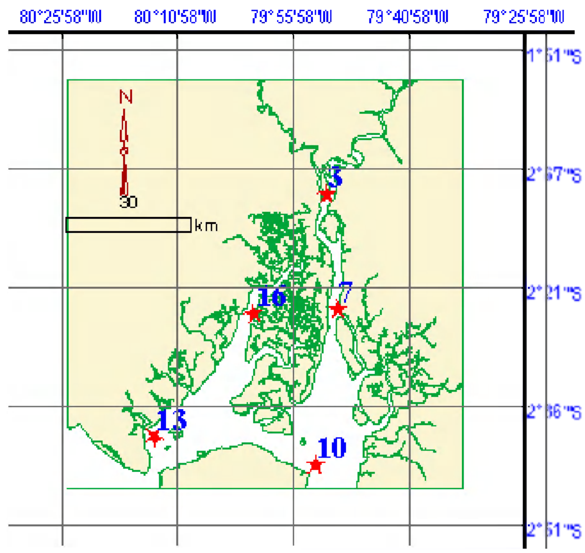


Figure 7- 15: Measurement Stations

Thus, the five stations' data reflect each day's (for 5 days) measurement (see table 7-1). No two or more stations were measured in the same date. Furthermore, one station (3) is characterized by tide type (ebb and flood) related to the quadrature positional phase of the moon (where moon and sun are perpendicular to each other and the gravitational forces are counteracted to produced a lower bulge of tide on the earth, known as neap tide).

On the other hand, the remaining stations are related to the positional phase of the moon (syzygy) where both the moon and sun are aligned, and the cumulative forces create higher bulge of tide on the earth known as the spring tide.

Table 7-1: Physical Data Summary

DATA SUMMARY	
Date Of Measurement	1996
? Many Measurement Records?	792
Parameters measured	Speed (396) Direction (396
? Many Stations	5(3,7,10,13and16)
Days Of Measurement =5 days	8,14,15,16,20 (8th Month 1996)
	Azimuth/Ebb & Azimuth/Flood
	Ebb/Quadrature &Flood/Quadrature
Nature Of Data	Ebb/Syzygy &Flood/Syzygy

With such kind of data, the water current's velocity and direction analysis is supposed to be restricted to date/time, elevation on a specific day uniquely. Example, a question such as what was the velocity of the current at 7:00 AM at a specific LLE and STATION can be retrieved and its spatio-temporal relationship visualized.

On the other-hand, the reverse of the question "what was the current velocity in all STATIONS at a particular LLE, and DATE/TIME cannot be retrieved due to the fact that no two or more stations were measured in the same day. Nevertheless, such limitations can be avoided by data acquired simultaneously at multiple stations.

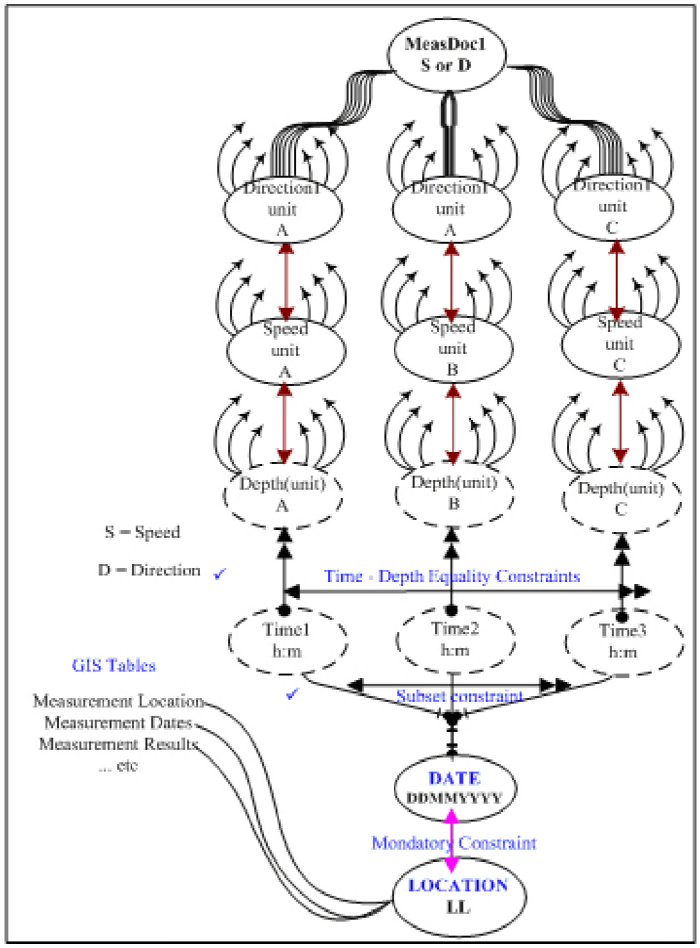


Figure 7- 16: Structural Relationship of the Physical and Spatio-Temporal Data

7.4.2 Analysis Processes and Results

Based on the conceptual relationship of the data models (see figure 7-16), the spatio-temporal situation of the current velocity and direction analysis has been realized.

Conditions that reveal the dynamicity of the current (current velocity cm/sec and current direction deg/mag) at different depths on particular time in a station have been executed applying the contrasted mean and measured value distribution of velocity (cm/sec) and current direction (deg/mag) per station at different depths. The tidal current is categorized as flood and Ebb type associated with the positional phases as syzygy and quadrants. Furthermore, the direction and velocity per specific measurement time has been calculated and measured value trend graphically visualized.

7.4.2.1 Flood Tidal Velocity: Measured and Mean

The process of the interpretation and results obtained are explained below for each measured flood tide, ebb tide associated to the tide velocity and direction with respect to time and depth in every measured station.

Station 3:

It is located close to land than the other stations and is of restricted dimension. The 9:00 velocity measurement in station 3, collected on 08/08/1996, across the different depth intervals oscillates between 100 and 150 cm/sec (see figure 7-17A). This is followed by the 10:00 hrs measurement time lower velocity, which fluctuates approximately between 50 and 110 cm/sec.

These two measurements hrs show a downward gradient of the velocity for the depth ranges 20 to 500 cm. However, the velocity starts to increase at the shallow depth (20 cm) on 11:00 and 12. All measurement along the depth on this time is found to be higher than the 10 and 11 hrs. Such trend indicates, the positive change of the tidal current after the 11:00 hrs measurement for the depth ranges 20-500 cm.

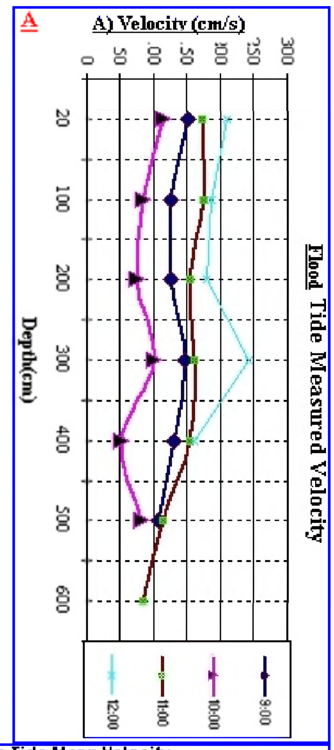


Figure7-17: Flood tide Velocity Measured and Mean Values Station 3: (Quadrature)

Then, after the velocity of the current is commenced to subside with depth; such changes could be attributed to changes in friction due to winds at variable times on this station besides the possible tract force (tide generating force) of the moon on the surface of the earth. The measured value and mean distribution of the current velocity (cm/sec) for the flood/ (quadrature) type of tide is indicated in figure below. The main flood tide velocity (quadrant) is vividly shown from the calculated mean values trend graph (see

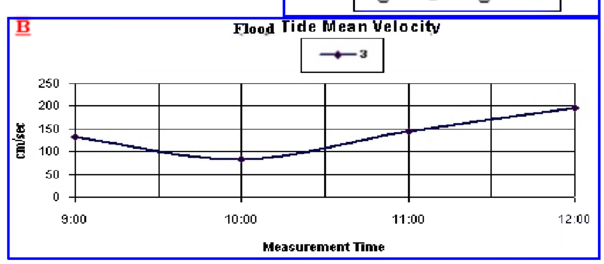


figure 7-17B). It is revealed that flood tide velocity between 9:00 and 10:00 displays a higher to lower 145 cm/sec and 10:00 12:00 an ascending trend of 85 cm/sec respectively.

Station 10:

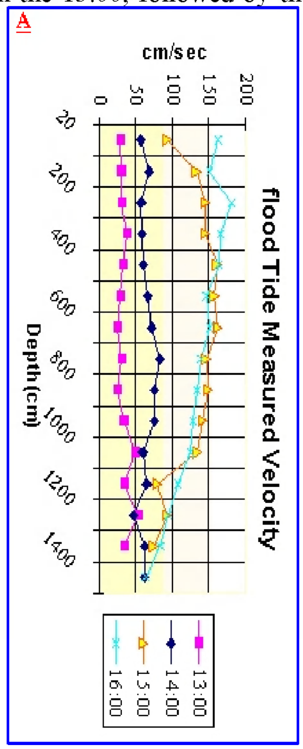
The station is situated close to the southern edge of the estuary (see figure 7-18) is relatively wider channel compared to stations 3 and 7.

With regard to the measured velocity, the lowest tidal velocity (associated to syzygy), collected on 08/ 14/ 1996) occurs close to the surface water across all the depths in the 13:00, followed by the 14:00 measurements time.

Therefore, no significant difference exists between shallow and relatively deeper water medium between the 13:00 and 14:00 measurement hours.

The min and max range for both measurement times is found to be 25-50 cm/sec and 55-85 cm/sec respectively.

However, during the 15:00, there relatively occurs a sharp increase of water current velocity from 20 to 400 cm and subsequently it remains high speed along the depth range 400 to 1000 cm; but the trend of the velocity descends with depth until 1400 cm.



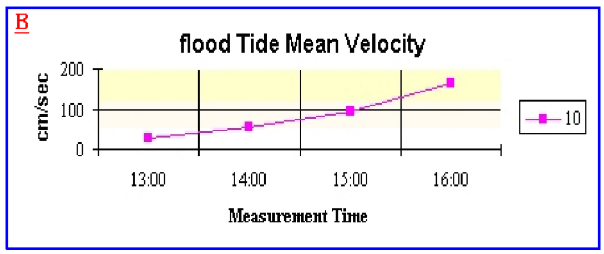


Figure 7-18: Flood tide (syzygy): Measured and Mean Values Station 10

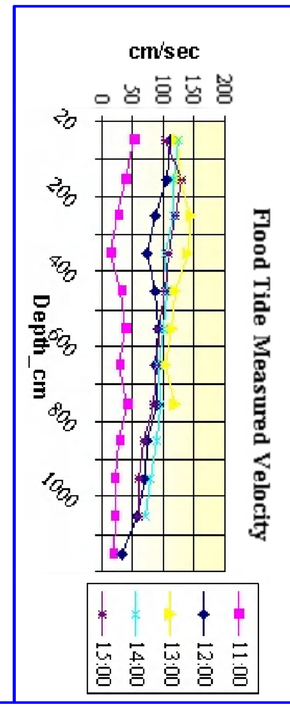
This feature is established both by the measured flood tide of time vs. depth and mean value distribution (see figure 7-18). Three conditions are established: -

Low tidal current water between 13:00 and 14: 00 along all the measurement points in this station, which suggest a calm environment; Between 15 and 16hrs the situation changes and higher tidal current is prevailed, mainly between 150 and 1050 cm; The general mean velocity discerns an increasing trend of the tidal to be between 13 and 16 hrs.

Station 7:

Topographically, station 7 is described to be of a narrow morphology (see figure 7-19). The measured data, near surface, on 20/08/1996, (associated with syzygy) water current shows a lower velocity fluctuation between 75, 25 cm/sec, 100, and 75 cm/sec at 11:00 and 12:00 respectively. However, the velocity descends around the 1050 cm to a rate of 50 to 25 cm/sec. The change of the velocity rate at (A) surface is related to frictional force, (B) at relatively higher depth to low friction water column and (C) at very low of velocity corresponding to higher depth due to changes of the morphology.

The mean velocity associated with the flood tide discloses increase of the velocity 11:00-13:00 and descends gradually towards 15:00. The interpretation result suggests that the dimension of the channel might be wider at depth than at the surface and current spread across the channel at a lower magnitude as observed with the depth range of 900- 1200 cm.



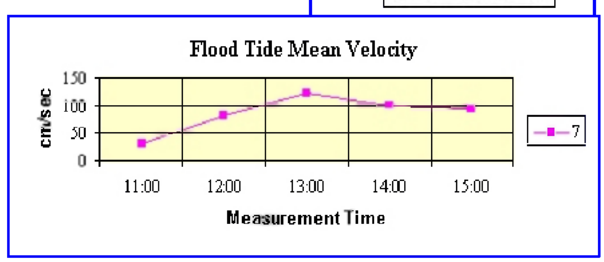


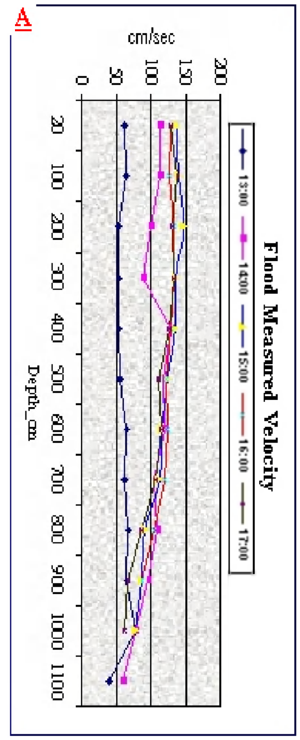
Figure 7-19: Flood tide (syzygy): Measured and Mean Values Station 7

Station 13:

This station is located in the western part of the estuary channel and is also close to the open ocean.

Referring to figure 7-20a, measurement data of 08/15/1996, (associated to syzygy) of the 13:00 measurement shows low velocity values near surface water (unlike to the 14:00, 15:00, 16:00 and 17:00 hrs, across all the depths (see figure7-20A) which are characterized by higher velocity).

This phenomenon with respect to time of measurements is well established by the mean value graphic display (see figure7-20B), related to the flood measured velocity in station 13.



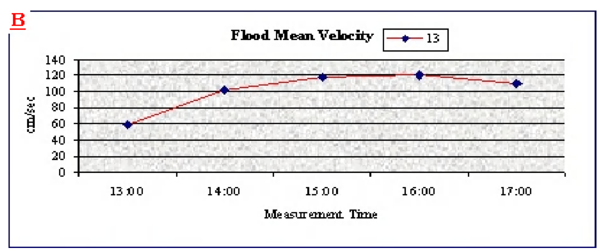


Figure 7-20: Flood tide (syzygy): Measured and Mean Values Station 13

Station 16:

Generally, the measurement in station 16 (on 08/16/1996) that is characterized by subsurface water column current velocity at the first measurement point of each hour and specific depth of (20 cm) are followed by low relatively higher velocity at 100 cm depth for each measurement time, (see figure 7-21).

As the depth ascends (within the depth range of 100 to 900 cm), the magnitude of the current velocity descends gradually. The gradual decrement of the velocity is occurs between a depth of 600 and 900 cm.

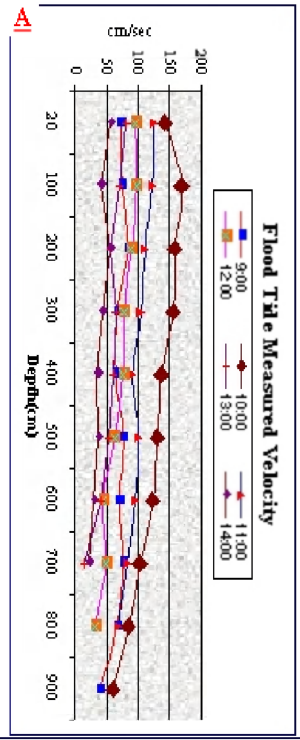
Possible influencing factors could be attributed to -

(1) To the subsurface dimension of the channel, around which the data has been collected i.e., wider bottom surface with depth and frictional force at shallow depth.

(2) As the dimension of the channel widens then the velocity might decrease too.

(3) Tide generating forces (related to syzygy) might have been fluctuating during the measurement hrs, which eventually resulted in weakening of the tidal pattern, (See figure 7-21).

A



B

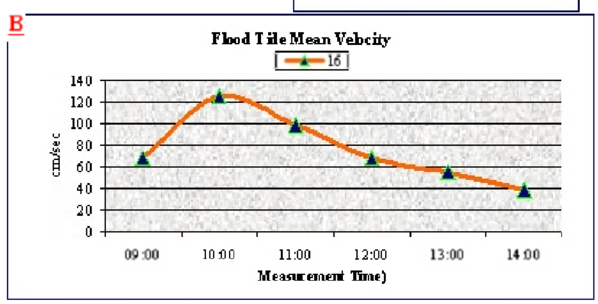


Figure 7-21: Flood tide (syzygy): Measured and Mean Values Station 16

7.4.2.2 Ebb Tidal Velocity: Measured and Mean on Depth vs. Time

Station 3:

(Measured on 08/08/1996, Quadrature): **a sub surface water depth (20cm) depicting high ebb tide velocity (250 cm/sec) characterizes This Station** at 7:00 measurement (see table 7-2). However, the measured trend of the 08:00 and 09:00 measurement times show weakening of the velocity with respect to the corresponding depth. The mean value of these measurements is indicated in the Mean Ebb Tide graph (see figure 7-22). The mean value of the velocity at each time varies with number of measurement occurrence (n) and measured value (mv) at each time. Example: mean (M) at 07:00 is defined by $M = \sum mv / n$, = 186.63 where n = four, i.e., based on the $\sum mv$, (see table 7-2). Therefore, as n varies with corresponding depth, the calculated mean values changes to reflect effect of the n, which is related to the specific depth.

A

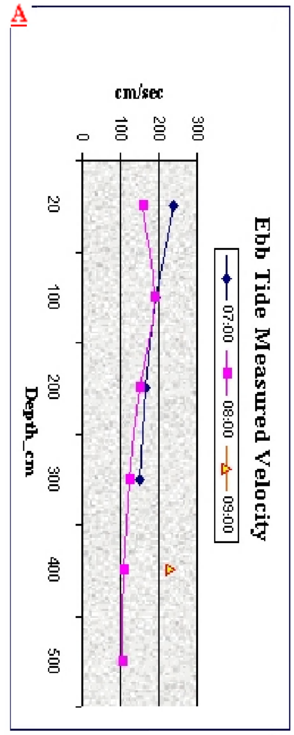
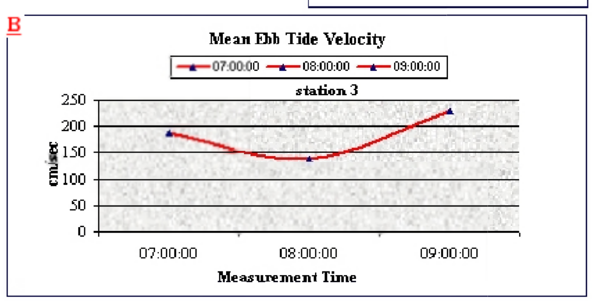


Figure 7-22: Ebb tide (Qua): Measured and Mean Values Station 3

Hence, at 08:00 $M = \sum mv / n$ = 138.88 cm / sec. where n = 6, i.e., based on the $\sum mv$. On the other hand, the 9:00 is single value (see table 7-2) due to the scarcity of data and it is equated to represent the mean value, even though higher values could have influence the velocity at that station with respect to the elevation location of measurement.

B

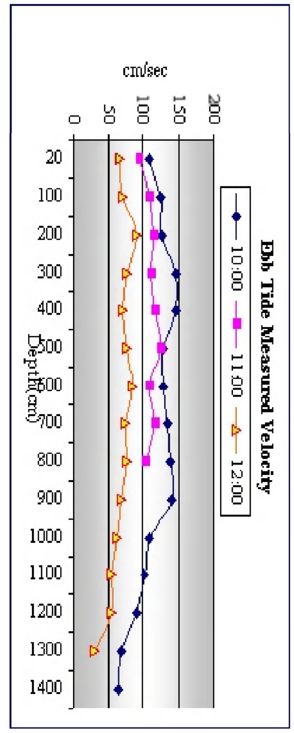


Station	LonDegDec	LatDegDec	Depth_cm	7:00:00	8:00:00	9:00
3	-79.86	-2.16	20	238.1	157.3	
3	-79.86	-2.16	100	193.6	190.1	
3	-79.86	-2.16	200	163.7	149.5	
3	-79.86	-2.16	300	151.1	123.9	
3	-79.86	-2.16	400		107.7	229.8
3	-79.86	-2.16	500		104.8	

Table 7-2: Calculated mean Ebb tide Velocity

Station 10:

The ebb tidal velocity on station 10, collected on 08/14/96, associated to sygyzy shows highest velocity at 10:00, followed by low value of the measurement times of 11:00 and 12:00 (see figure 7-23).



The number of measurement occurrence (n) for station 10, depth range 20 to 1400 cm are defined as follows; time (t) 10:00 = 15, time (t) 11:00 = 9, time (t) 12:00 = 12 respectively.

Thus, the mean value of the velocity varies with the n, which is established by $M = \sum mv/n$.

The general trend conforms to a reciprocal relationship of velocity vs. depth as shown by the fluctuating and diminution of the current velocity (see figure 7-23).

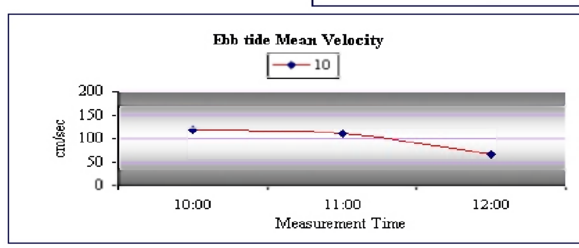


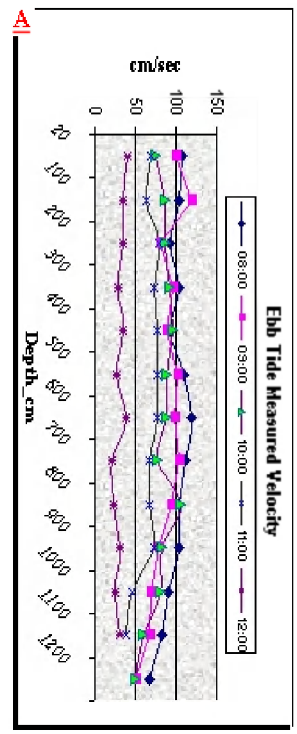
Figure 7-23: Ebb tide (syzygy): Measured and Mean Values Station 10

Station 13:

This station is characterized by higher velocity for measurements performed on 08/15/1996 between 8:00 and 9:00 for the corresponding depths between 20 and 30 cm.

This is followed by an abrupt lowering of the velocity between 200 and 500 cm. However, it reversed to be higher current speed between the 500, 700 cm, for the time ranges 8:00, and 11:00, (see figure 7-24).

However, the mean velocity is discovered to descending with time (8:00-12:00), across the water column or measurement intervals, which are displayed in below, (see figure 7-24).



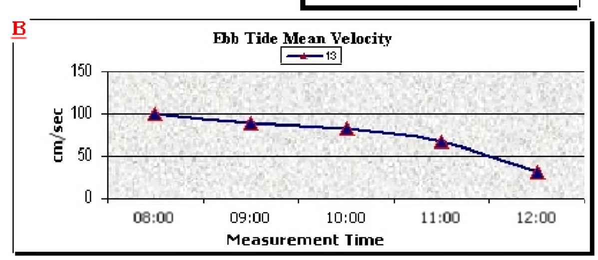


Figure 7-24: Ebb tide (syzygy): Measured and Mean Values Station 1

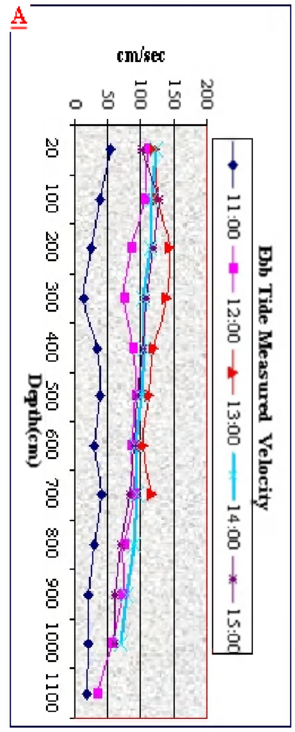
SAMP_TIME	DEPTH(cm)												
	20	100	200	300	400	500	600	700	800	900	1000	1100	1200
8:00	108.1	104.1	92.7	103.7	92.5	110.5	119.6	110.9	103.6	103.4	90.4	82.9	68
9:00	99.5	119.6	80.9	96.9	89	102.1	98.7	104.5	93.8	78.7	69.6	67.4	50
10:00	75.3	87.3	87.5	91.7	96.2	88.1	87.6	77.4	106.7	82.3	80.1	60.3	49.5
11:00	68.6	63.3	79.2	72.4	76.7	77.1	76.7	66.4	66.5	72.7	46.7	38.6	
12:00	41	35.2	35.3	28.6	34.1	26.5	38.3	21.4	22.2	30.9	25.8	31.6	

Table 7-3: Calculated Ebb tide Velocity with depth vs. time

Station 7:

Measurements performed on 20/08/96, in this station discerns certain oscillating pattern. For instance, the tide velocity on the depth of 20 cm at 11:00 is a little greater than 50 cm per second; at same depth but different measurement time (11:00 and 13:00), the velocity range is augmented dramatically to 80 and 120 cm/sec respectively.

A



This indicates velocity increase between 11:00 and 12:00 at and around the depth of 20 cm, for the 11:00 measurements.

Furthermore, as the depth increases from 20 to 300 cm, (see figure 7-25A), the corresponding velocity decreases.

The measurement documentation associated to this particular data indicates to the ebb tide type related to the syzygy positional phase of the moon.

The mean value of the measured velocity based on the occurrences of the depths shows an increase of the ebb velocity from the morning towards the after noon with peak value being between 12:00 and 13:00 hrs (see figure 7-25B).

B

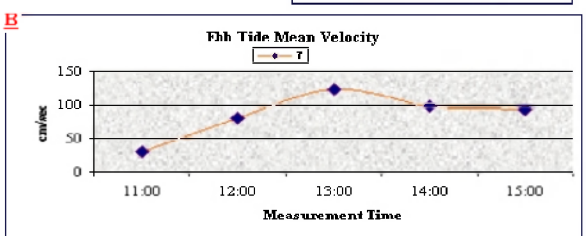


Figure 7-25: Ebb tide (syzygy): Measured and Mean Values Station 7

Station16:

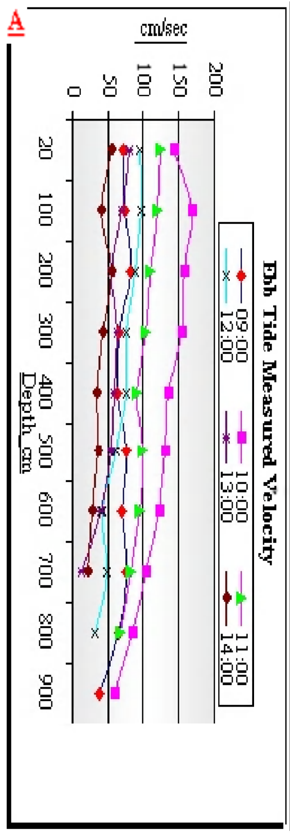
Geographically, station 16 is closer to the coastal land than to the main gulf of the estuary.

All the measurements times, in this station, related to the date of 08/16/96, show relatively lower current velocity at the 20 cm depths, (see figure 7-26).

This magnitude descends gently as the depth is elevated from 100 to 900 cm, for all measurements periods except 10:00, which shows specific peak at 100 cm.

This phase from low to high tends to subside gradually to indicate the changes in the ebb tide generating forces at different levels of the water column. Despite of the certain irregularity of the tidal current velocity the trend significantly discerns the lowering of the velocity with depth. Also, the over all mean velocity discerns a highest phase to coincide around the 100 cm and the trend the mean velocity cm/sec, found to gradually fall down with the increment of the depth and measurement time from 11:00 towards 14:00 hrs(see figure 7-26 A+B)

A



B

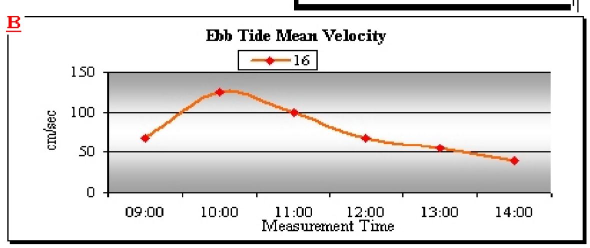


Figure 7-26: Ebb tide (syzygy): Measured and Mean Values Station 16

7.4.2.3 Ebb Tidal Velocity Direction: Measured and Mean with Depth vs. Time

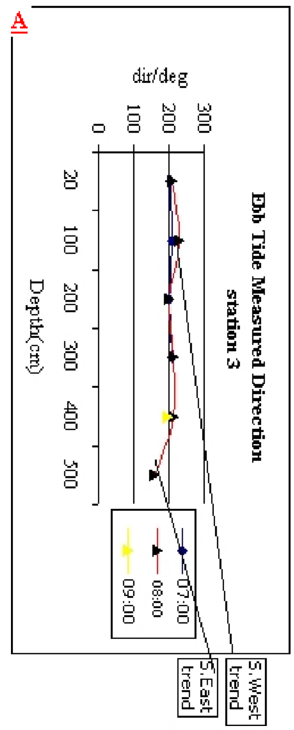
Station 3:

Measurement related to the Ebb Tidal Velocity Direction is charactrized by the depth level and the corresponding deviation of the velocity direction in magnetic degree. According to the measurement data, the graphical visualization of the ebb tide velocity direction shows high, low, high and low directional values.

This means that the direction fluctuates with increase of depth from S.West to S.East. For instance, the 200-measured degree (at 7:00) indicates the S.West direction and the 150 at a depth of 500 cm is S.East; see figure 7-27B and 7-27A respectively.

The interpretation is based on the geographical reading of the measured degree with respect to the Georeferenced map which contains the all the measurement sites.

This can be explained using the style of geography reading (0 degree = N, 90 degree =E, 180 degree = S and 270degree = W).



The mean value directional changes, as indicated by the measurement time (7:00 to 9:00) where the current velocity shifts its direction relatively from southwest towards southeast.

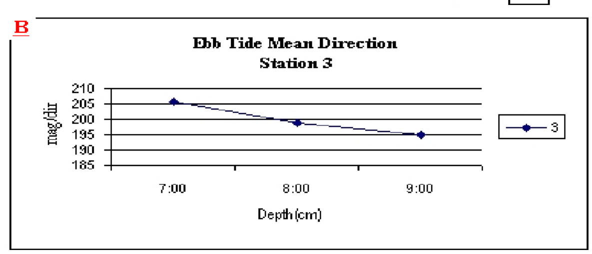


Figure 7-27: Ebb tide Direction (Quadrature): Measured and Mean Values Station 3

Probably, this could be attributed to the effects of the variation of changes in sub water topography or change on the intensity of the current velocity due to TGF.

Station 7:

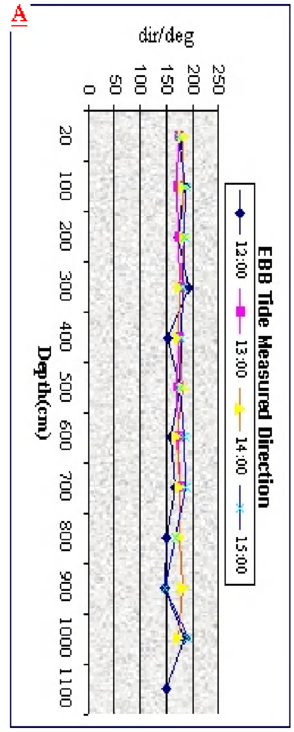
The station is located within a narrow channel of the statuary and is closer to coastal land than the stations 10, 13.

Since the dimension of the channel where this station is located is of restricted dimension, the possibility of the deviation of the current velocity is subjected to channel dimension controlled.

The measurements of the current direction between 12:00 and 15:00 (20/08/1996) show a pattern of little variation at all measured depths (see figure 7-28A).

The trend from southwest to southeast is associated with the slight perturbation of the direction observed on the 12:00 measurement time and along with depth increment. In other wards, the trend fluctuation is restricted within the 150 to 200 degree.

A



The calculated mean tidal direction (see figure 7-28B).ranges shows between170 and 180 degree between the measurement times of 12:00 and 15:00.

B

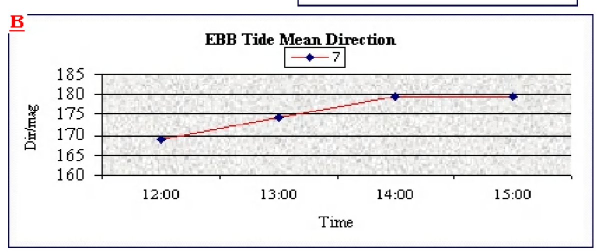


Figure 7-28: Ebb tide Direction (Quadrature): Measured & Mean Value Station 7

The results suggest a deviation of the current from South East to South, which corresponds to the mean degree direction of 170 to 180. It is unveiled that this current velocity direction continues to persist between measurement times of 14:00 and 15:00. Further more the trend seems to extend beyond the 14:00 with a north-south direction.

Station 10:

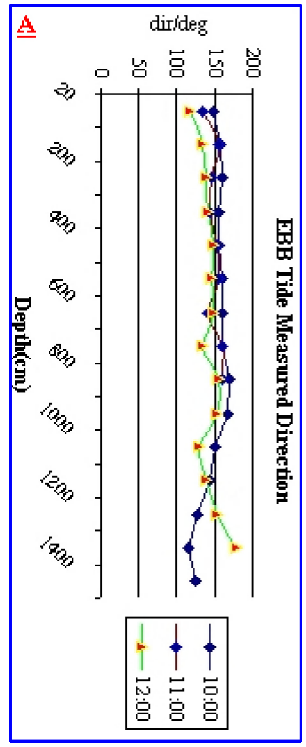
This station is close to the mouth of the sea and is relatively a wider channel, for instance, compared to station 3 and station 7.

The tidal current velocity directional measurement depth between 20 and 1000 cm ranges 105 to 153 degrees and it falls from East to S.East flowing direction category. However, there is rather a phase of the direction where all the different depths to indicate current velocity direction to follow a southeast direction, especially between the depth intervals 200 and 600 cm, (see figure 7-29A).

On the other hand, around 1200 cm, the measurements of the 11:00 shows a current velocity direction towards the east whereas at the same (x, y, z) but different t, 12:00 the velocity direction tends to deviate towards the south.

This result is interpreted to be due the change of tide generating forces in the same x, y, and z but at different times, i.e., 11:00 and 12:00.

This pattern is well visualized by the mean values along the measurement times (see figure 7-29B). The mean value Ebb tide current velocity direction also shows a persistence of the direction between the measurement times between 10:00 and 11:00 along the 150 degree (South East).



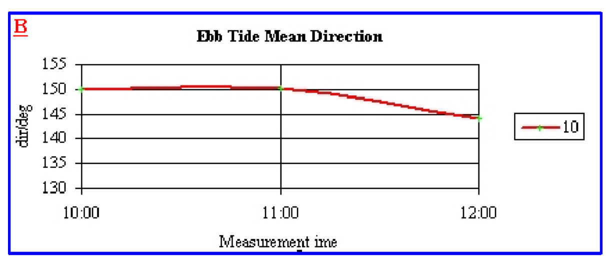


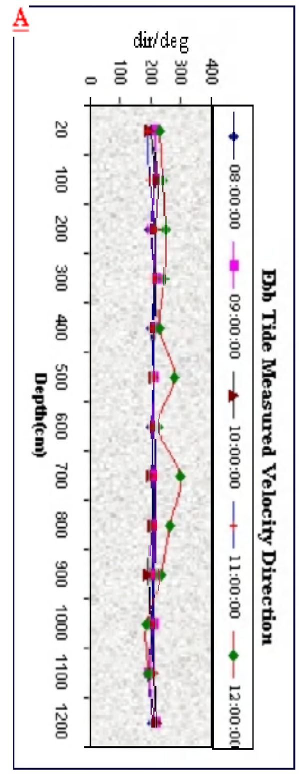
Figure 7-29: Ebb tide Direction (Quadrature): Measured and Mean Values Station 10

Station 13:

This station is characterized by a certain regularity of velocity direction around the 200-250 degree (S.West) along all the measured depths; with the exception of 12:00 (see figure 7-30A), which indicates certain perturbation on the depth ranging 400-900. The relatively similar direction is observed along all the depths measured on the 8:00, 9:00 and 10:00 measurement time.

However, the 12:00 hrs measurements mean value shows a shift of a westward direction, and this high value is indicated in the measured velocity direction to occur around the depth of 800 cm (see figure 7-30).

The later results indicate initiation of change in the tide generating force phase, which is completely different from the previous measurements. Base on the results of the current direction, it seems possible to indicate anticipation of tidal changes.



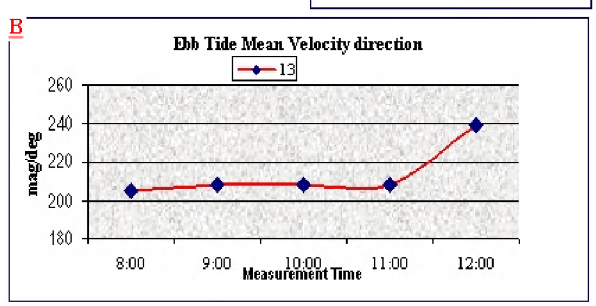


Figure 7-30: Ebb tide Direction (syzygy): Measured & Mean Values Station 13

Station 16:

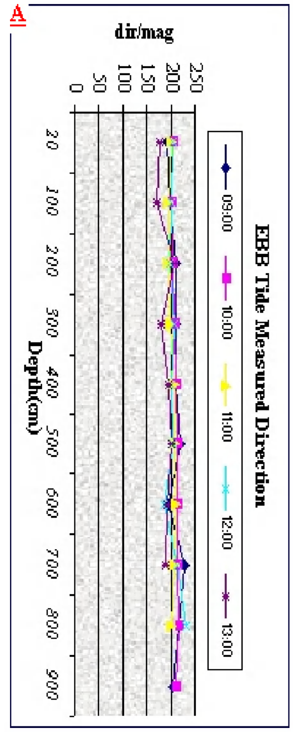
Measurements on this site do not show significant variation in velocity direction. The range of direction recorded is shown to be within 170 and 200 degree.

The first 150 cm depth along all the measurements points (x, y, z on different times) described by SE-SW trend; However, at a depth of 250 cm, deviation of the velocity direction coincides to be South Westerly (200 degree) on all the measurements times (9:00 to 13:00).

With the exception of measurement time 13:00, which shows slight directional fluctuations (see figure 7-32 A+B), the others display a regular SW velocity direction along all the measurement depths on all the different times.

As the depth decreases (900 cm), the velocity direction changes towards the South, which is discerned by the converging lines (see figure 7-31A) and the falling trend line, i.e. mean velocity direction distribution, (see figure 7-31B).

A



B

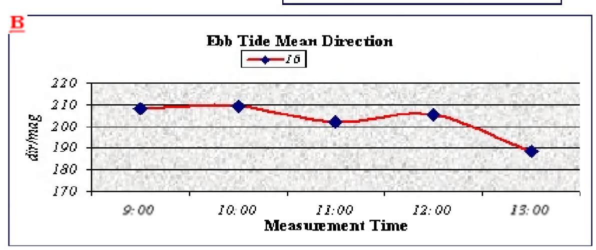
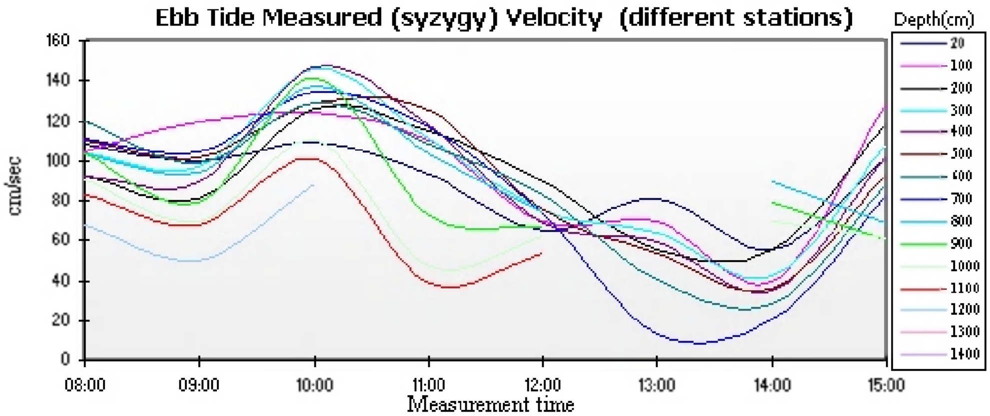
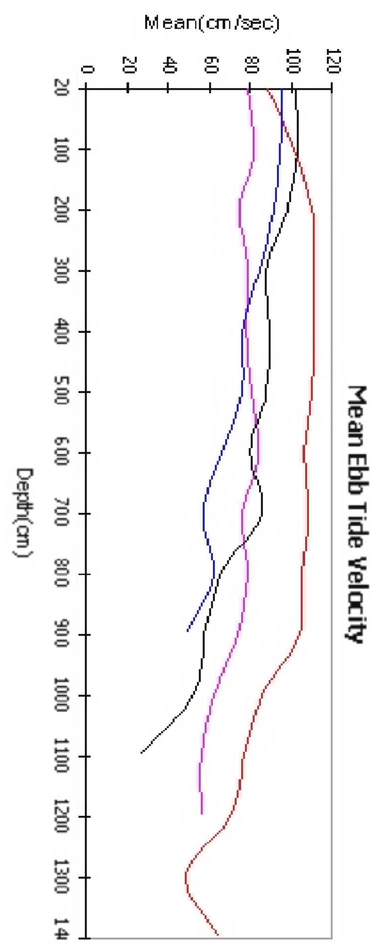


Figure 7-31: Ebb tide Direction (Quadrature): Measured & Mean Values Station 16



7.4.2.4 Current's Velocity and Direction (Ebb tide) in all stations



I. Velocity

Velocity: Velocity with respect to time and depth

0 to 9:00 - 8:00 Lower phase of the current velocity

Around 10:00 – Highest phase of the current velocity

11:00 to 14:00 – Descending phase of the current velocity

The velocity in station 10 is shown to be with highest mean, mainly with the depth range 150-900 (cm) and descends to lowest phase around the depth of 1300 -+ 50 cm.

The same trend has been unveiled on the other stations (7, 16, and 13) but with less mean value than station, 10(see figure 7-32)

Figure 7-32: Ebb tide Velocity: Measured and Mean Values in Stations (7, 10, 13, and 16)

II. Direction

Referring to figure 7-33A, the water column elevation in all the stations, along which the general velocity trends to SW-SE (deg/mag), corresponds to a depth range of 20-700 cm that is regardless the slight deflection of velocity direction in most of the measured depths.

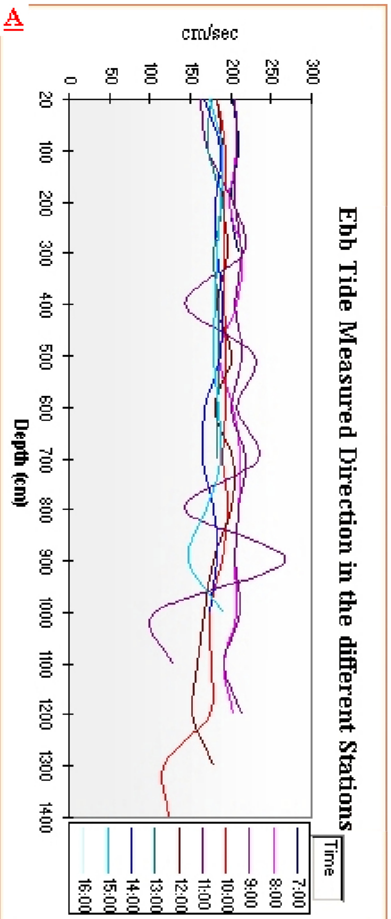
The variation of directional changes increases with depth strongly, for instance, as indicated, starting at the depth of 900, the change of the velocity direction increases more towards the east.

Here it is possible to assume that there is a sub water morphological change where the force of current velocity deflects from South West to South East.

The mean value velocity directional deviation in all the measured stations ranges between 150 and 250 degrees (see figure 7-33B). Station 16 is characterized with a minimum mean directional variation.

Nevertheless, mean graphical shows certain discontinuity with respect to time to indicate that all stations were not simultaneously measured at a specific time.

A



B

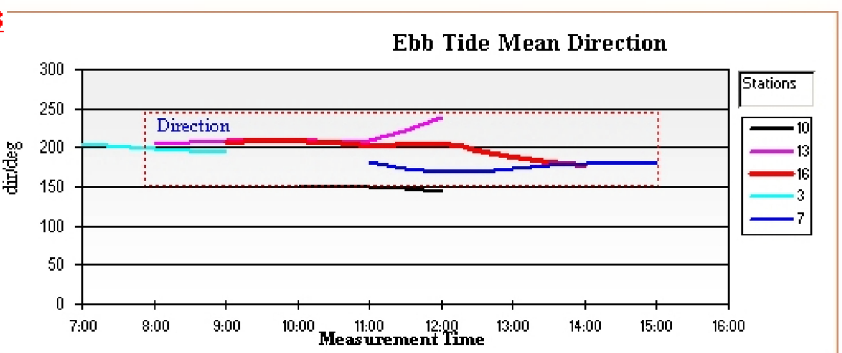


Figure 7-33: Ebb tide Velocity direction (cm/sec) in all stations

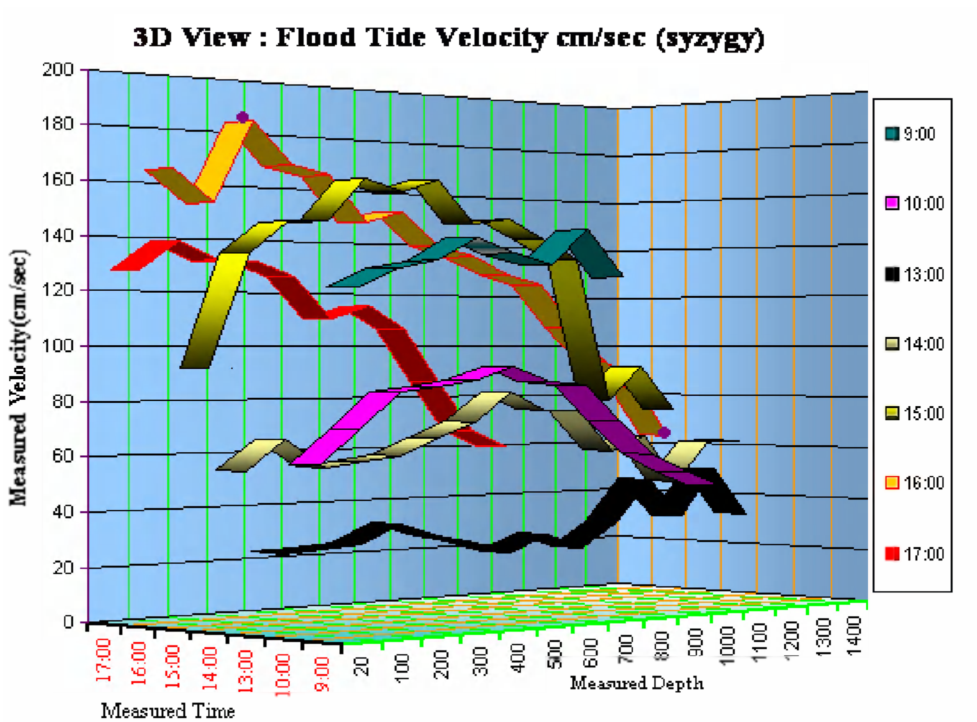
7.4.3. Flood Tide Velocity

A 3D line graph has been used to visualize the flood tide velocity with respect to time and depth data (see table 7-4) in the different measurement stations, which is described as follows. As depth increases, the flood tide velocity (measured velocity cm/sec) decreases to the lowest magnitude between depths ranges of 800-1400 cm and respective corresponding measurement times (see figure 7-35).

Measured Depth (cm)

Measurement Time		20	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400
1	09:00:00	120	127	130	138	133	129	142	125							
2	10:00:00	59.4	71.1	84.1	85.4	87.8	92.4	86.8	85.5	72.2	59.3	52.2	46.4			
3	13:00:00	28.3	28.8	30.3	36.7	31.4	28.2	24	29.9	23.9	32.9	48.6	34	52	34	
4	14:00:00	56.3	67	56.7	58.3	60	66.2	71.7	82.5	75.8	75.2	59.3	64.7	46	62	62
5	15:00:00	92.2	133	145	146	162	158	163	147	149	142	134	78.5	92	74	
6	16:00:00	163	152	182	167	164	147	151	139	135	128	124	107	94	83	63
7	17:00:00	128	138	132	132	126	110	115	107	85.9	66.4	60.1				

Table 7-4: Calculated Flood tide Velocity with time vs. depth



Chapter 7: Spatio-temporal Analysis

Figure 7-34: Flood tide Velocity direction (cm/sec) in all stations

For instance, the 13:00 measurement results show the lowest occurrence of the velocity in the specified time of the day along all the measured depths (20-1400 cm).

On the other hand, the 16:00 results reflect the tidal velocity ranges 63.2-182 cm/sec with respect to depth 1400 and 200 cm (see table 7-4). Some possible causes to the depletion or wedging out of the current velocity with depth can be attributed to a dimensional change of the channel with depth, which disperses the speed on the extended space and fluctuation of the tide generating tract forces.

7.4.4. Geo-referenced Spatio-temporal Interpretation

Velocity Direction at Specific Time (ebb): One of the important applications of GIS is its capability to process and perform spatial analysis on the data with respect to geo-referenced sites. Also as the application is extended to incorporate data associated with temporal parameters and visualize the information with view to the time associated during the genesis of the data in the environment where it was acquired for example at 10h, 11h and 12h, that is in different stations (see figure 7-35). The indicated

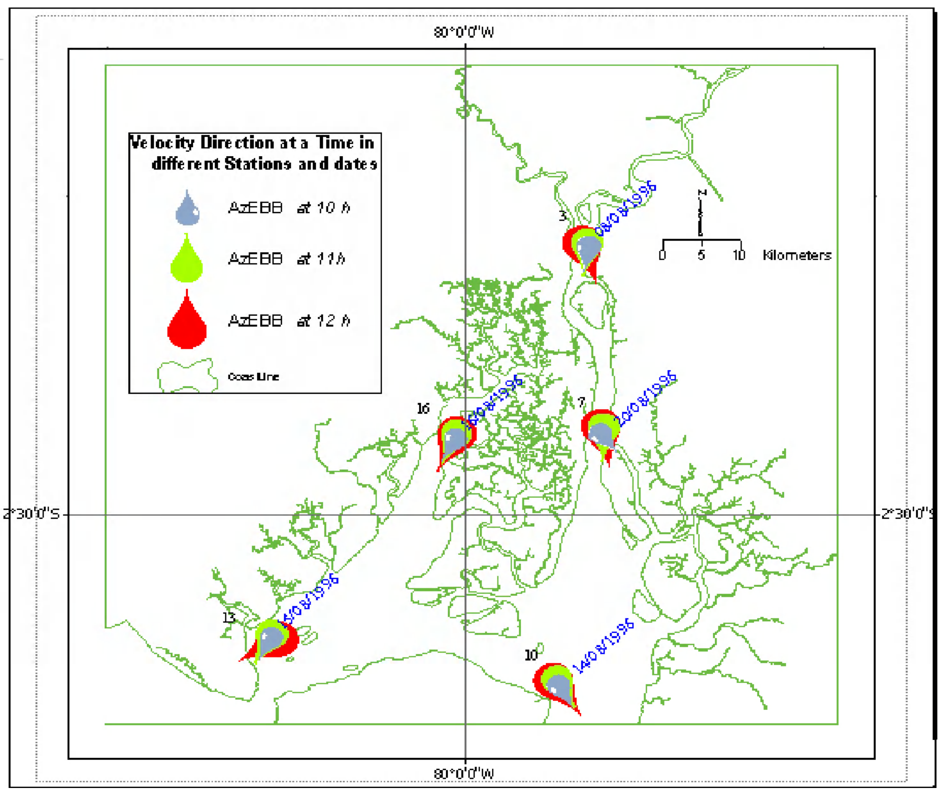


Figure 7-35: Georeferenced Spatio-Temporal Visualization of Velocity Directions (ebb tide)

Measurement times were selected because they contain data that can be represented and relevantly interpreted in the respective stations (see figure 7-35 and 7-36) without discontinuity

With this, regard the deviation of the current velocity direction, based on the geodatabase attribute values have been sptaio-temporally processed and revealed the following results (see figure 7-36)

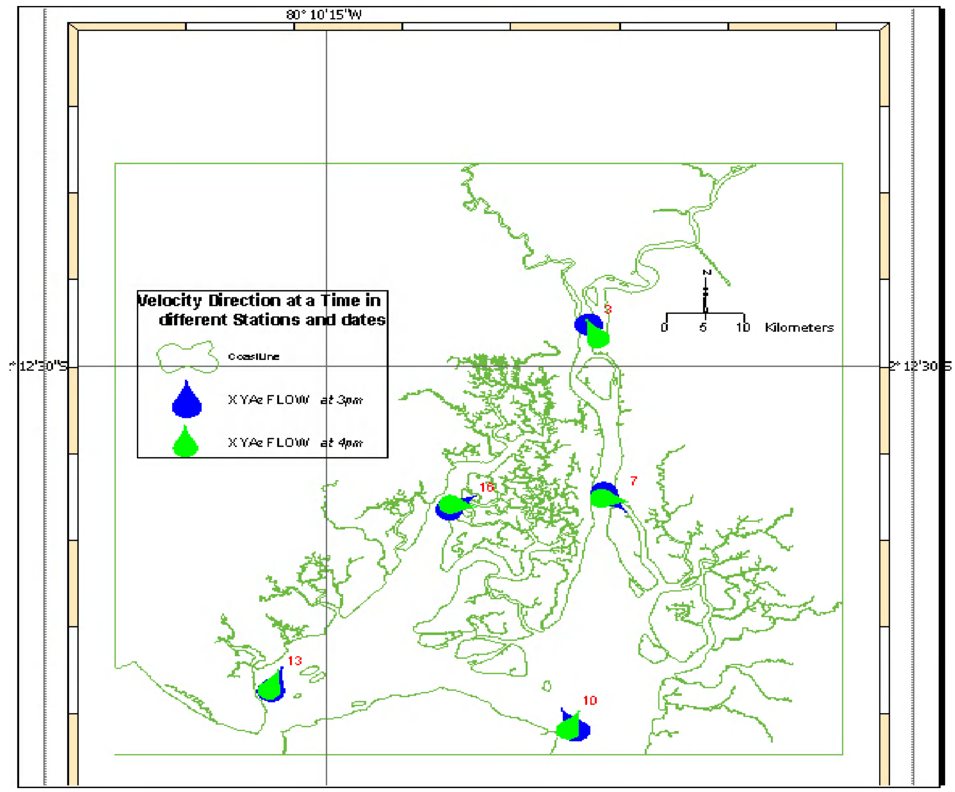


Figure 7-36: Georeferenced Spatio-Temporal Visualization of Velocity Directions (Flood tide)

Tidal Velocity at Specific Time flood: Combining the thematical views of velocity direction (mag/deg) and velocity (cm/sec) information enables us to asses the nature of the dynamicity and fluctuations of the current in different sites of measurements.

The resymbolised dimension indicates the magnitude of the current velocity in that particular station with respect to the time of measurement. According to the results of the analysis indicated (see figure 7-37), the highest range of the velocity associated to the situation of the syzygy occurs in station 7 and lowest in station 10.

Such occurrence is attributed to the strength of the tidal force components, which is stronger due to the alignment of the celestial bodies (syzygy), would eventually enhances the gravitational force on a specific site on earth surface. Under such systems interaction, the tidal currents are prone to influences which could be detected during relevant measurements and the processed data can be visualized spatio-temporally as illustrated in figure 7-37, for the flood tide related current velocity (cm/sec) at a specific time

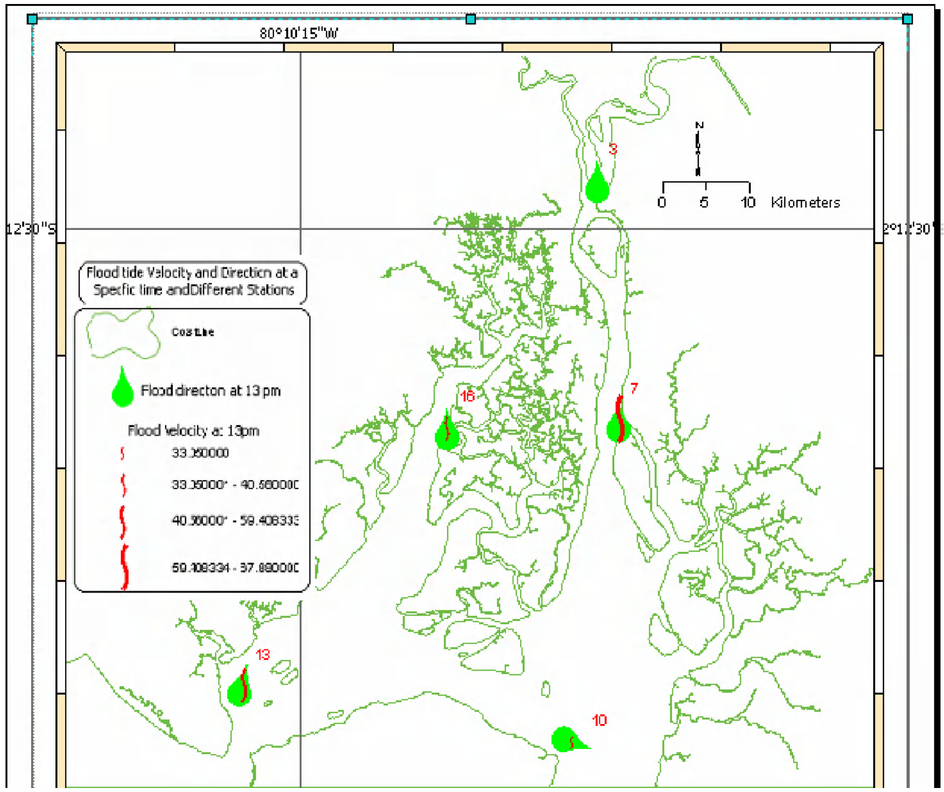


Figure 7-37: Spatio-Temporal Visualization of Mean Velocity and Direction at a specific time

Otherwise, station 10 is uncovered to have not the characteristics of station 7. This is attributed due to morphological difference (relatively wider) and proximity of the geographical proximity towards the open sea. The velocity of the current might diminish with increment of the width and the tract forces could have been at their lowest phase during the measurement. Nevertheless, one can see that whenever a high-density measurement data are available, GIS is a tool that can be applied to analyze the problem spatio-temporally and visualize the results thematically.

7.5. Results and Conclusions

a) The process of spatio-temporal analysis associated geographic features and tagged temporal parameters are complex. This fact is supported by the practical dependence of location-based information on time when many attribute data are collected in a single geo-referenced point at different times. The problem related to such spatial information layers representation i.e., as function of time has been resolved by formulating the layers of the associated features and temporal parameters as follows.

Layer (n) = F (Tn) on X, Y, (+ - (Z), m:

Where n in Layer (n) is number of layers, n in (Tn) is number of occurrence time, X, Y and Z are the coordinates and the m is possible measured value. The variation of m as a function of Tn has been retrieved based on - Ln+1 = f (Tn+1) on X, Y, (+ - (Z), m)

b) Spatio-temporal information is indexed with time. It becomes easier said than done to represent it thematically especially when multiple measured attributes (m) are associated and referenced to 2D features. Such difficulties have been sorted out by aggregating methodology, which encompass converting (of objects) mapping relationship of 1: M to 1:1. The following principle illustrates the process: Analyzing features (•r_o changes to •r1 and •r1 to •r2) function of time, f (t), at x, y, (+ - (z);

1) • S1 > •t_o > •r_o > •A

2) Layer1 (S_1) = f (t_1): r1 ↓

3) Layer1 (S_1) = f (t_2): r2 ↓

… Layer (S_n) = f (t_{n+1}): r_{n+1}

Thus, the layer corresponding to A (aggregate) is processed as: -

3) Layer (S_n) = f (t_n): f (r_{n+1})

c) A certain relationship between the current velocity and the depth environment along all the measurement stations shows a situation of a higher depth corresponds to diminishing of the current velocity. Likewise, the velocity of the current associated with the flood tide wedges out with depth. These results suggest the possible morphological change of the estuary channel at depth or weakening of the current due to friction at top water surface and possible fluctuation of the tide generating force (TF) at the sites of measurements.

d) The result at measurement time of 10:00, along all the measured depth related ebb tidal current velocity shows higher tidal activity phase contrary to the phase of the velocity in the time interval between 13:00 and 14:00 (see figure 7-33).
Furthermore, the 12:00 measurement time, related to azimuth/ebb tide velocity directional fluctuation, on the eastern and western channels shows an opposing trend. The S to SW and S to SE describe this direction and it rather tends to follow the trend of the major channels (see figure 7-37).

e) Referring to the figure 7-34, the ebb tide velocity associated to the positional phase of the moon (syzygy) shows a Time vs. Depth related fluctuations. With this regard, the measurement time ranging of 8:00 –8:30 indicates the descending of higher velocity to lower velocity and the 8:30 to 10:30 discloses the peak velocity which coincides to the 10:00+-00:20; and 10:20 to 15:00 displays the diminution of the velocity from lower to lowest phase. The situation could be attributed to the opposing frictional force at the surface, a calm environment of water column above the highest depth and morphological change of t channel at depth.

e) The temporal analysis results are derived from very few and widely dispersed measurement stations and limited respective depths. The methodology of interpretation can be implemented to unveil the relationship of tidal current speed and direction within an estuary in a better way by increasing the measurement density and incorporating more data types into the developed object relational geodatabase. Nevertheless, results obtained from such process can be exploited in grasping natural dynamic process and gauge human induced effects through time in the area of interest.

Chapter 8 : Aspatial Analysis

8.1 Introduction

The two preceding chapters have been focused on the spatial and spatio-temporal analysis processes. Space and/or time were incorporated as main components in spatial and spatio-temporal query. The theme of this chapter deals with aspatial analysis perception.

Aspatial is a term that used to describe non-spatial data associated to geographic objects [40]. Compositionally, aspatial data are heterogeneous in nature and are more complex when a multidisciplinary teams function together in an integrated Coastal/Marine environment GIS projects. They are valuable information assets and the potentiality of the value is appreciated when processed meticulously not only taking into consideration the spatial context (Georeferenced) but also analyze with respect to aspatial perspectives.

8.2 Aspatial Analysis Query (AAQ)

SQL Query Design: Query design is one of the most important components in the exploitation of the geodatabase. SQL is an interactive and powerful non-procedural program language, close to the human language if frequently used. The style of the aspatial query resembles that of spatial, but it does not need any spatial operator but its efficient retrieval depends on the interlocking migrating pointers.

8.2.1 Retrieval Efficiency

When a table is stored on disk, it is referred as a file with rows and column. During information extraction, the disk access is typically slow. Constructing an index file that provides a direct access to the data in the database file minimizes slowness of accessing and retrieving the needed information [61]. Indexing reduce the time to find and process information within the geodatabase. Figure 8-1A and figure 8-1B illustrates the possibility of data processing and analysis using Linked tables information flow (figure 8-1A) (*Location, Measurement Results, and Field*) and the corresponding SQL retrieving code is displayed (see figure 8-1B).

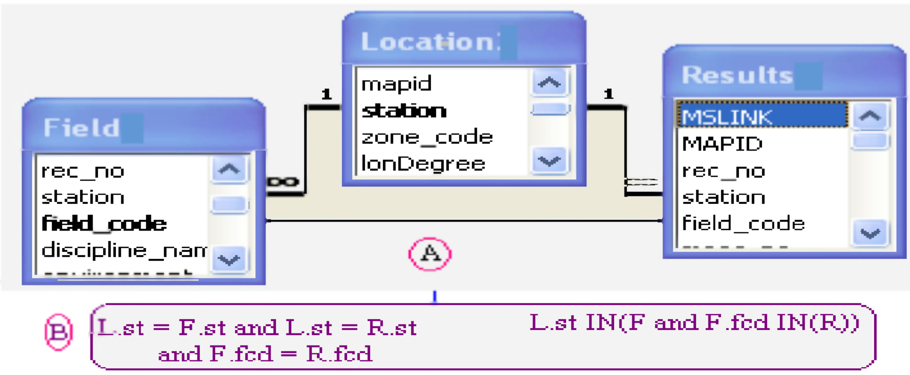


Figure 8-1 Tir-Table Information Extraction on a defined Relationship

In the case study, the Measurement-Location table's index is Station but also the MSLINK and MAPID are also indexed; the later were mainly employed as spatial indexing mandatory attributes.

8.2.2 Retrieval Illustrations

Example a query that displays Measurement Station with the following attributes:

- Estuarine environment type: > bottom estuarine,
- Name: > of the measured parameter,
- Concentration: > measured parameter > average,
- Elevation :> Depth range of measured records.

8.2.2.1 Test1: Retrieving embedded Stations

SELECT station FROM location WHERE station

IN (select station from FIELD where Field_Code IN

(Select Field_Code from RESULTS where parameter = "clay"

and pract_value > (Select (Avg (pract_value)) from RESULTS

Where parameter = "clay" and samp_depth_m 5)));

Results: Displayed station numbers.

Station	10 11	12	15 16	18 19 6	8a 9	12a	17

8.2.2.2 Test2: Retrieving Sites on Date and Aggregated output

In a similar query pattern it is possible to locate and find the date where the speed of measured current is greater than average of a specific date.

SELECT station FROM location WHERE station IN

(SELECT station FROM position WHERE samp_date like "*97*" AND station IN

(SELECT station FROM field WHERE discipline_name = "physics" AND Field_Code IN

(SELECT Field_Code FROM results WHERE parameter = "speed" AND pract_value >

(SELECT (AVG (pract_value)) FROM results WHERE parameter = "speed"))));

Result: 1

Stations	10	13	16	3	7

8.2.2.3 Aspatial Query Test3: Retrieving Information on Calculated time

SELECT DISTINCTROW position.samp_time_e, position.samp_time,

DateDiff ("h", [samp_time], [samp_time_e]) AS TimeElapsedHrs,

Results.parameter, results.pract_value, results.pract_unit, position.station

FROM [position], results

WHERE (((position.rec_no) = [Results]. [Rec_No]))

GROUP BY position.samp_time_e, position.samp_time, results.parameter,

Results.pract_value, results.pract_unit, position.station HAVING

(((Position.samp_time_e) Is Not Null) AND ((results.parameter)="mercury"));

Result: 2

samp_time	samp_time_e	neElapsedI	parameter	pract_value	pract_unit	station
6:57:00 AM	11:16:00 AM	5	mercury	0.2	ug/l	13
9:54:00 AM	11:55:00 AM	2	mercury	0.2	ug/l	10
6:00:00 AM	12:00:00 PM	6	mercury	0.2	ug/l	3
7:50:00 AM	12:00:00 PM	5	Mercury		ug/l	16
8:59:00 AM	12:04:00 PM	4	Mercury	0.2	ug/l	7
7:30:00 AM	12:10:00 PM	5	mercury	0.2	ug/l	16

Table 8- 1 Retrieved Results

8.3 Interfacing the GIS database

SQL query is powerful and flexible as far as it is applied to the purpose designed for. However, a novice user may encounter problem in typing SQL codes and retrieve properly the information. This is commonly encountered during practical works. A solution to this is to develop a user-friendly interface to perform operations on the underlying GIS database by clicking interfacial controls associated program codes. As a result of, many related actions on the underlain database are executed; some of which are:

- Process and retrieve information and design re-executable complex analytical query
- Communicate the underlying database tables graphically
- Display thematical results in a object-control based interface
- Locate the processed GIS database information on map-like form interface, indicate the coordinates pertaining to the list values

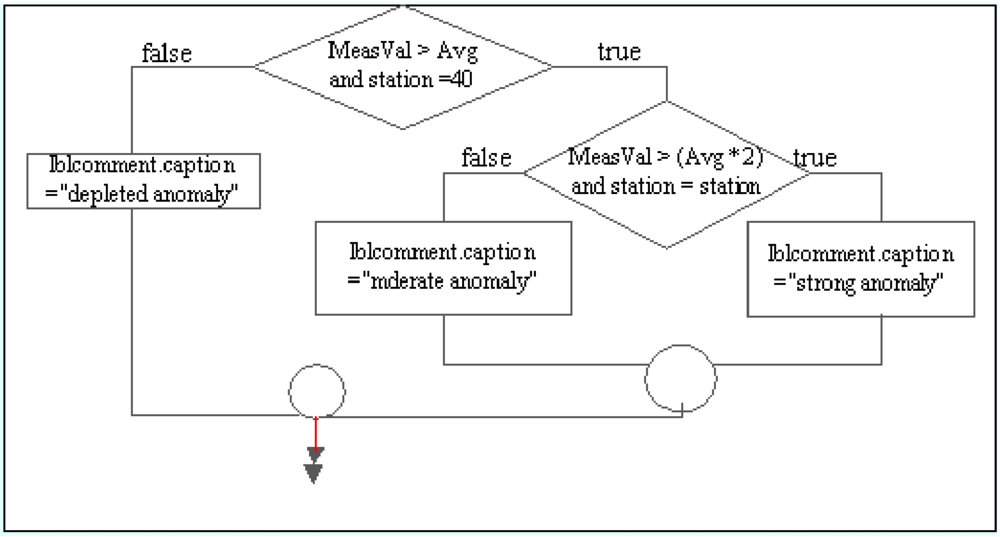


Figure 8-2 Information flow Diagram

8.3.1 Constructing the Interface

The construction of the interface includes combining the control structures (conditional statements) and embedding the SQL query within the visual basic event procedures. Thus, the flow of ideas between an SQL and defined variables is established, (see figure 8-2).

The branches from the symbol indicate which path to take when the condition evaluates TRUE or FALSE. The test of an IF-then-else-IF-else statement is based on a condition and logical operators (see table 8-2).

Symbol	Relation tested	Example
<	Less than	Val (txtMeasVal. TEXT)<n
>	Greater than	Val (txtMeasVal. TEXT)>n
=	Equal	Val (txtMeasVal. TEXT) =n
<>	Not equal	Val (txtMeasVal. TEXT)<>n
>=	Greater than or equal	Val (txtMeasVal) TEXT)>=n
<=	less than or equal	Val (txtMeasVal) TEXT) <=n

Table 8- 2 Conditional table

To compensate what is not available in structured query language (SQL), objects such as controls (command buttons, combo and list boxes, text and label) were bound to underlying GIS database by means of controls and defined event driven program in an object oriented environment.

8.3.1.1 A Retrieving user friendly process

Combo boxes usage: The combo box control gives the user the opportunity to select or enter new values in a click-able control interface.

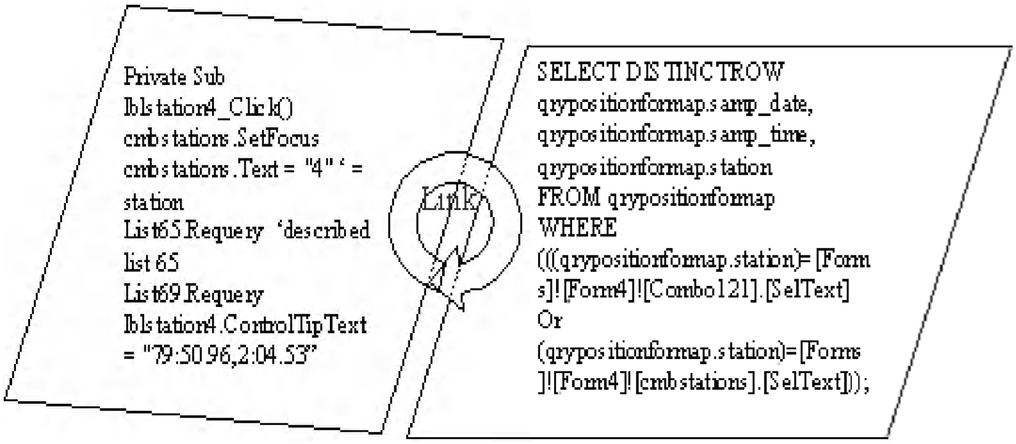


Figure 8-3 Automating the SQL

The values of the combo are associated with event procedures (see figure 8-3), linked to the database records to retrieve and display by selecting the attribute value from within the combo. It is possible to extract information (coordinates) stored on station 11 by clicking and selecting that station (see figure 8-4).

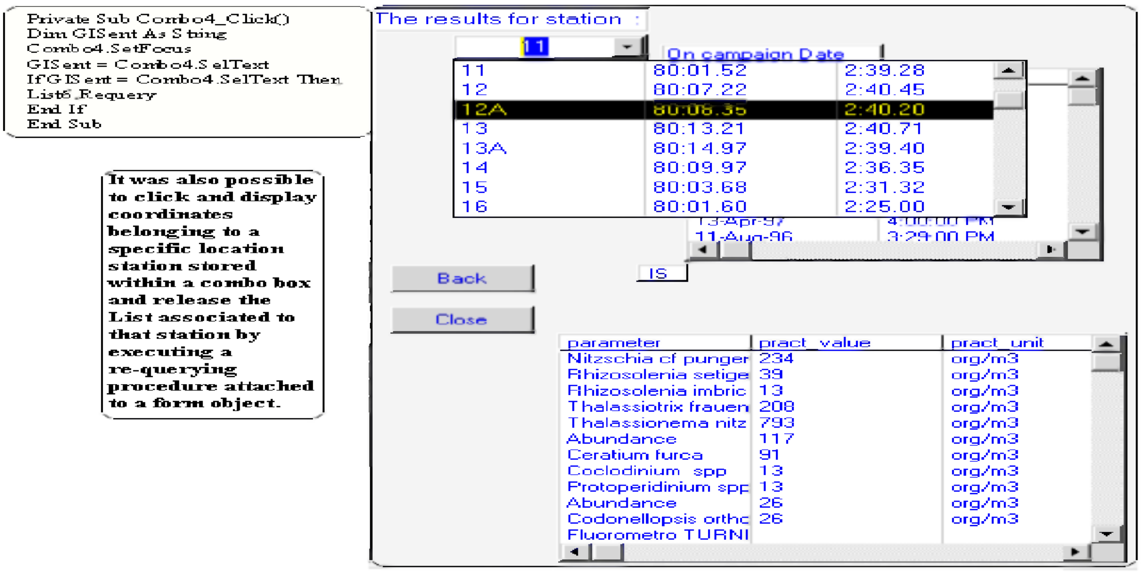


Figure 8-4 Exploring the GIS database Using User friendly Interface

8.3.1.2 Triggering

The above interface pops up by clicking control button. It allows exploring the underlying data bearing structured dual GIS database. Triggering the first button (figure 8-5a) displays the next object form (figure 8-5b) that depicts two major incoming issues; (a) GIS database Connections (b) GIS Database Modeling and structuring.

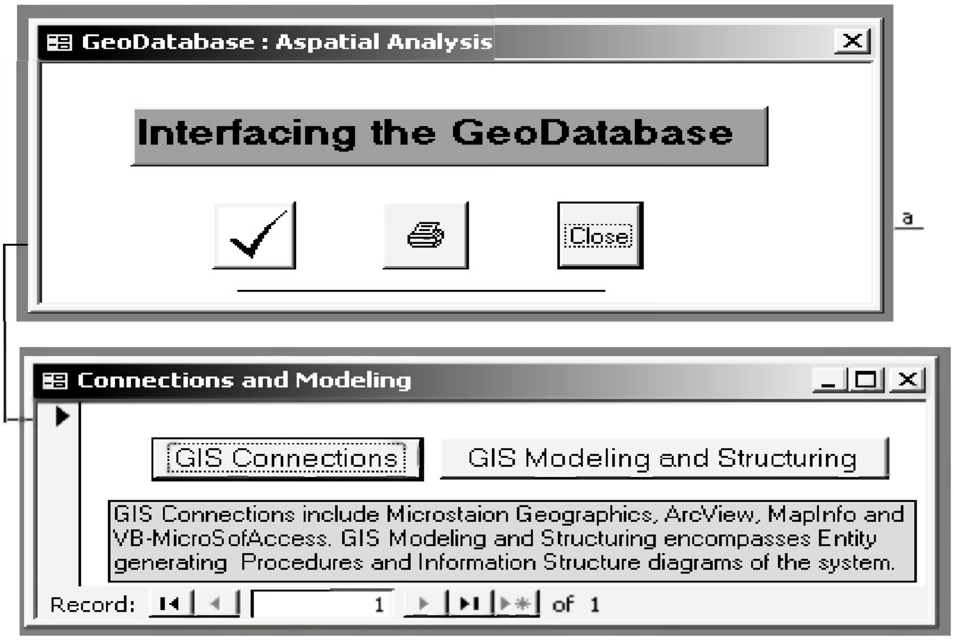


Figure 8-5 Connection to spatial engines

Upon triggering the ***GIS Connections***, the possible spatial engines become available (see figure 8-6) and the user can access the possible spatial engines. Example MicroStation Geographics is being accessed and this will lead to explore the GIS projects, which are connected, to the central database.

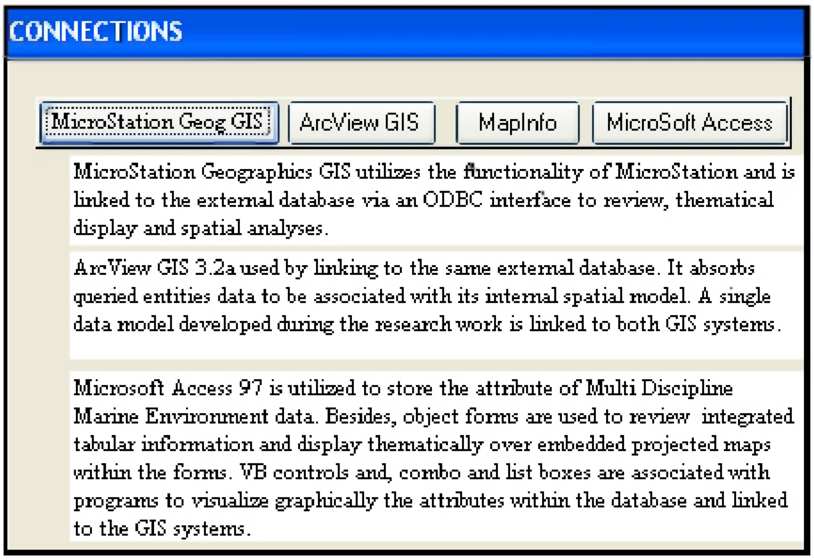


Figure 8-6 Available interfaces

The aspatial analysis focuses on how the attribute database part has been interfaced and exploited aspatial ly. The GIS applications unveiled under the GIS database connections interface form-based-control buttons were explained during the spatial analysis. They are indicated here only to show that, they can be accessed via the aspatial interface.

```
[Event Procedure]
Private Sub cmdaccess_Click ()
Cmdaccess.ControlTipText = "Aspatial
Analysis"
On Error GoTo Err_cmdaccess_Click
Dim stDocName As String
Dim stLinkCriteria As String
StDocName = "THEME AND REVIEW"
DoCmd.OpenForm stDocName, stLinkCriteria
End sub

Exit_cmdaccess_Click:
Exit Sub
Err_cmdaccess_Click:
MsgBox Err.Description
Resume Exit_cmdaccess_Click
End Sub
```

8.3.1.3 Connections

- Based On Macro: MicroStation Geographics GIS
- On Click: GoToGIS
- Action RunApp
- C:\WIN32APP\ustation\USTATION.EXE -wugeograph –wdodbc
    - ArcView GIS
    - On Click: AVGIS
    - Action RunApp
        - C:\esri\\av_gis30\arcview\bin32\arcview.exe
            - MapInfo
            - On Click: MapInfo
            - Action RunApp
            - "C:\ProgramFiles\MapInfo\Professional6.5\Mapinfow.Exe

A program associated with a control, used to open ensuing objects is described below.

Three important issues are disclosed as a result of triggering the VB-Microsoft Access control (see figure 8-6). Whenever the *Theme Display* tool is triggered (see figure 8-7), then figure 8-8 is disclosed with all the data processing interface buttons.

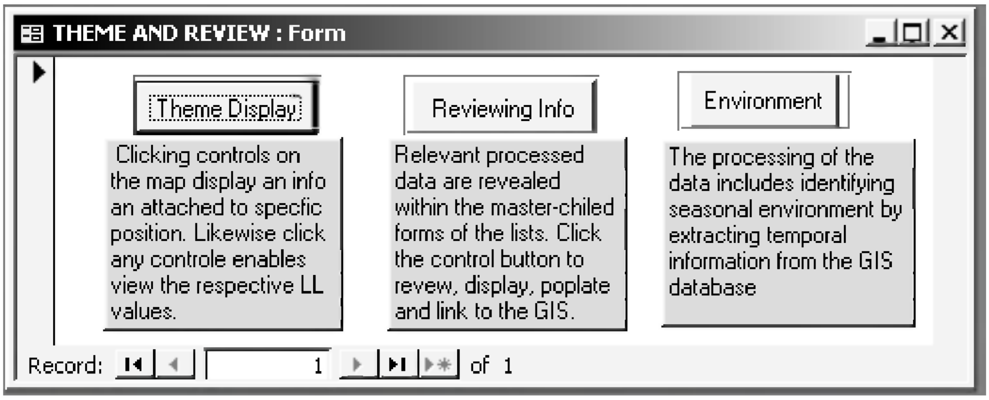


Figure 8-7 A) Thematic displays B) Review Info (C) Environment

8.3.2 Theme Display:

The theme display is based on a combination of the VB6 binding controls code program and embedded SQL beneath the interface. As a result of triggering the Theme Display tool, an aspatial information-analyzing interface is disclosed with a number of possible tools, see figure 8-8.

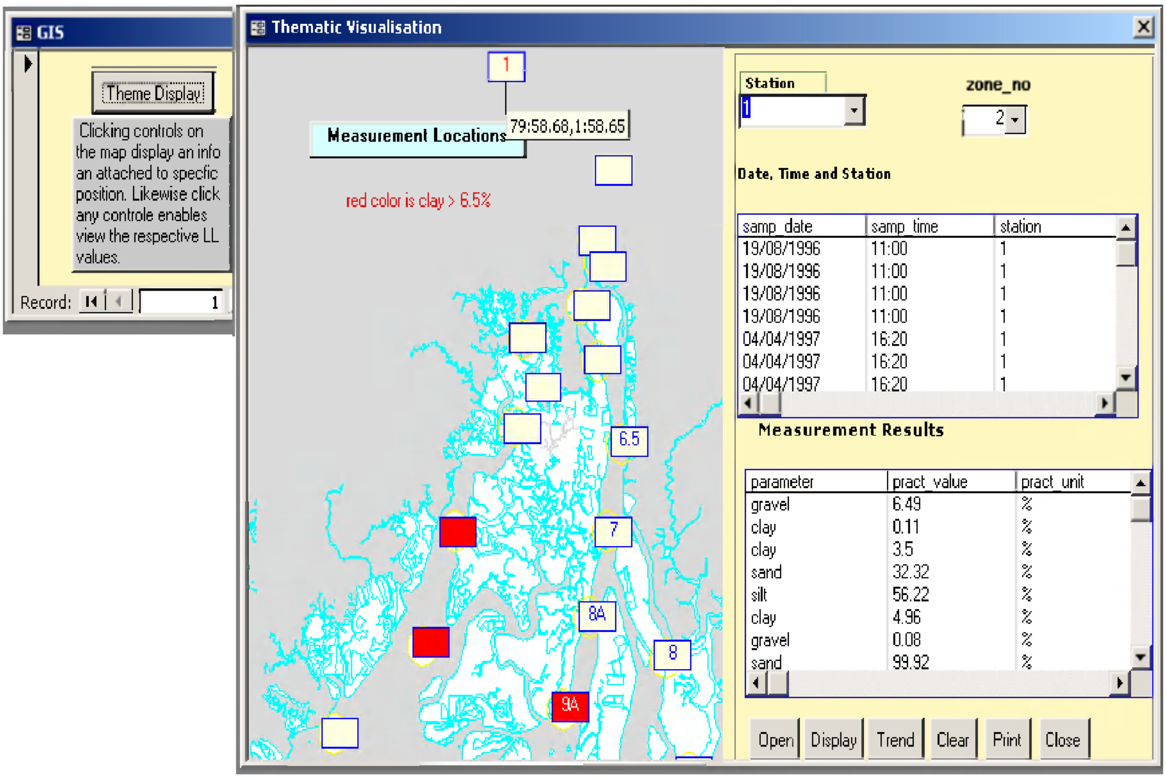


Figure 8-8 Theme and Associated Information

The above interface enables to extract instantaneously multi discipline information both graphically and in a tabular environment. Clicking an area represented by a box on the site where measurement has taken place will first display the georeferencing parameters stored within the structured database. Thus, one can understand the location coordinates that extracted from the underlying geodatabase abruptly without connecting the spatial engine. Eventually, the event procedure drives and display the station number corresponding to the georeferencing parameters within the given text box. After few seconds, the embedded SQL query is processed behind the scene and releases the temporal parameters of that station, and is filled in the first list with filed names ***date and sampling time***:

Furthermore, process of calculation takes place within the geodatabase reservoir by selecting analyzed data and compares with certain constants and display graphically, distinguished by different colors. On the given instance, the red color shows values of the clay greater *than 6.5 percent (figure 8-8).*

8.3.3 Retrieving Options

8.3.3.1 By Event: Optional slot STATION

NAME: **cmb**stations

Row Source:

```
Select Distinctrow Station_Loc.Station, Station_Loc.Lon, Station_Loc.Lat
From Station_Loc;
Private Sub Cmbstations_Click ()          'cmbstations is name of the event,
Dim MyString As String                    'MyString is a variable of string data
Cmbstations. SetFocus                     ' set focus inserts the cursor on box
MyString = cmbstations. SelText           'Assignment of value clicked in the combo box
If MyString = "1" Then                ' Test for decision
Lblstation1. Caption = MyString           'action replaces caption = 1, in the map
Lblstation1. ForeColor = vbRed            'if success value color (1) is red
List65.Requery                        ' requires the database based on the
List69.Requery
End If                            ' execution ends
```

The embedded SQL example, for List65.Requery and List69;

8.3.3.2 By Event: Optional slot ZONE

Unlike the retrieving by station, the "by zone" extraction is different. It Extracts the different sampling stations enclosed within a zone and displays them on the map. Furthermore, any measurement information that meets the matching criteria of the migrating zone pointer (within combo box) populates the corresponding two list boxes (List 65 and List 69). The following program explains the process of performing retrieval by zone task.

NAME: Cmbo121

1) Row source: SELECT DISTINCTROW [zone]. [Zone_code] FROM [zone];

- Private Sub Combo121_Click () ' Zone no contain stations
- Dim mytest As String ‘ variable defined
- Combo121.SetFocus ' cursor set to the combo box
- Mytest = Combo121.SelText ' variable equated to is variable Zone no
- If mytest = "1" Then
- Lblstation1. Caption = "1" 'station 1 is part of Zone no = 1 and reference the SQL
- Lblstation2. Caption = "2" 'is within zone no
- Lblstation3. Caption = "3" 'is within zone no
- Lblstation4. Caption = "4" 'is within zone no
- Lblstation5. Caption = "5" 'is within zone no
- Me! [Lblstation1]. ForeColor = vbRed
- List65.Requery
- List69.Requery
- End If
- End Sub

8.3.3.3 By graph

By graph: This method was developed to facilitate the retrieving of information by triggering graphic object (line or any shape) such as the location number and those coordinates corresponding to that point. Clickabel object.

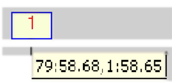


Figure 8-9 User Friendly Coordinate Display

The deriving force for the graphic retrieval process is based in the control bounded code described below. The following is an instance for a shape trigger and release station 1 and the corresponding coordinates in tabular information.

- Private Sub lblstation1_Click ()
- Const strlonlat1 As String = "79:58.68,1:58.65"
- Dim mysql As String
- Cmbstations. SetFocus
- Cmbstations. Text = "1"
- List65.Requery
- List69.Requery
- End Sub

8.3.3.4 By Labeled Site:

The value selected in the label box (station value = 17) references subtype query (*MEASUREMENT RESULTS)* that populates the list box 65 as a results of filtering the geodatabase information, see figure 8-10.

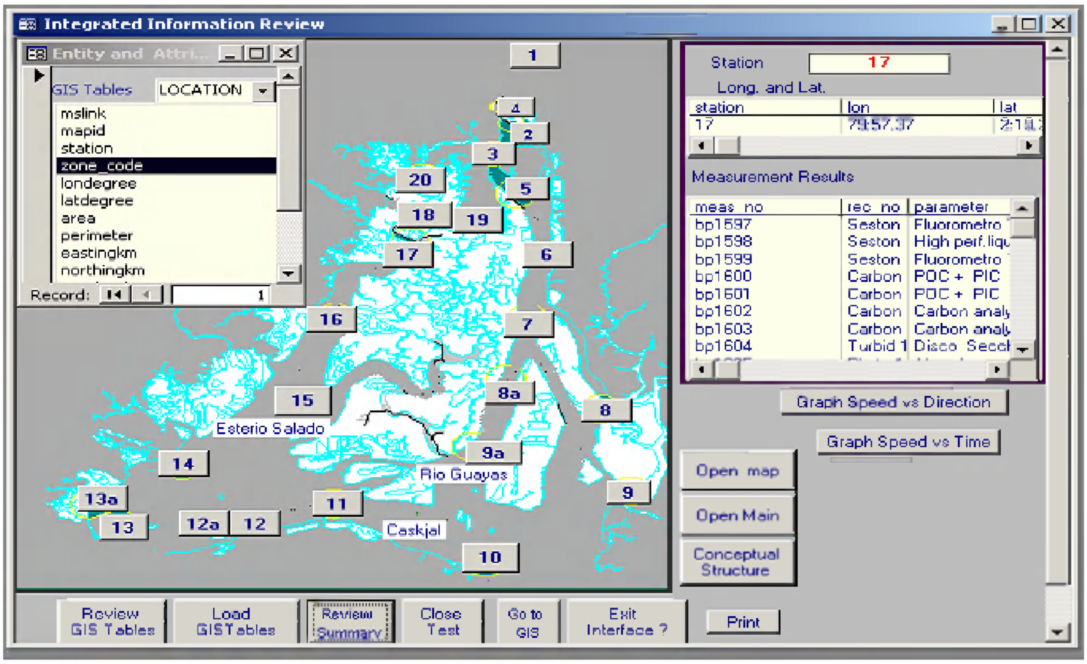


Figure 8-10 Multiple tools interface

Triggering a labeled station number (command button) discloses the station number in the

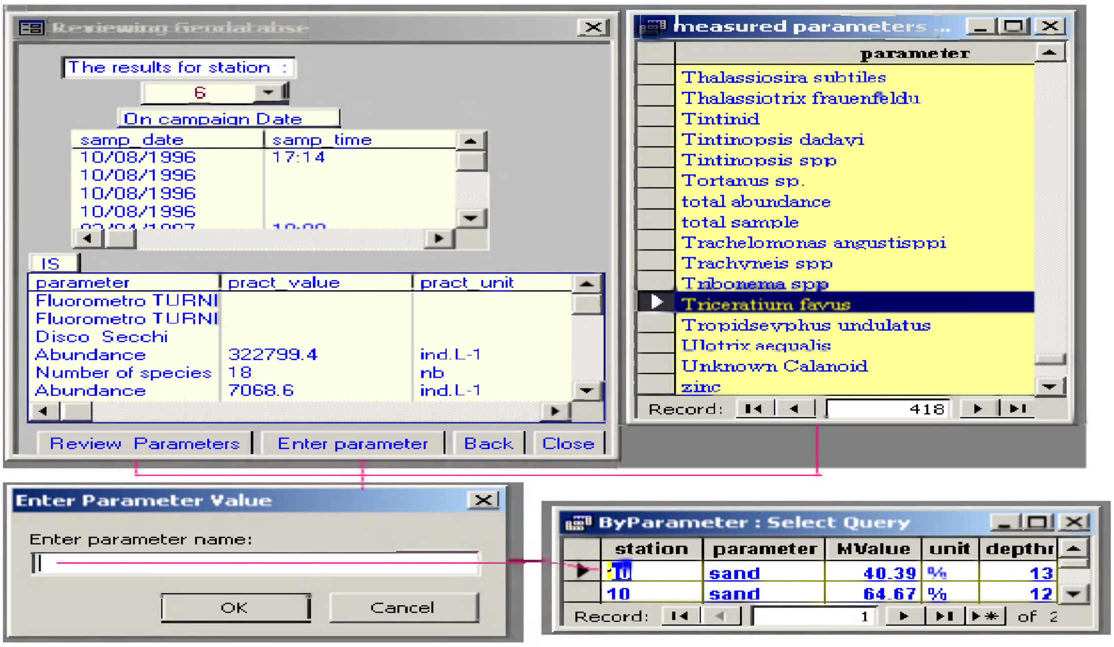


Figure 8-11 Interactive Querying and Outputs

defined combo box, (example station value 17), in a red color is displayed. Below, it is row that represents the station and corresponding coordinates. Besides the interactive information, other supportive tools are associated for reviewing, (Review GIS Tables), remote data loading (Load GIS Tables), review summary…etc., (see figure 8-10).

8.3.3.5 By Interactive Query (Parameter Requery)

Parameter query, interactively requests the user for a number of criteria. Based on that provided criteria a station number and the corresponding information is retrieved (see figure 8-11).

The provided information could be the site number, analyzed attribute, sampling environment, discipline type, date collected and analyzed and by whom it was collected, etc., in the area of interest.

The output of the results are displayed both in a tabular as well graphical. The advantage of this retrieving technique is that the user does not need to write programs but should know the stored attributes within the geodatabase. Further, more attribute values can be reviewed by clicking the attached controls, which are associated to event procedures and embedded queries.

8.3.3.6 By Environmental Indicator

The date/time parameters stored within the structured database indicate mainly the time of data collection and insitu measurements. Interpretation of time related aspatial data could be useful to identify associated annual or seasonal variations. An attempt has been done to develop an application that automates the extracting seasons out of the GeoRelational database and associate the information with images or video.

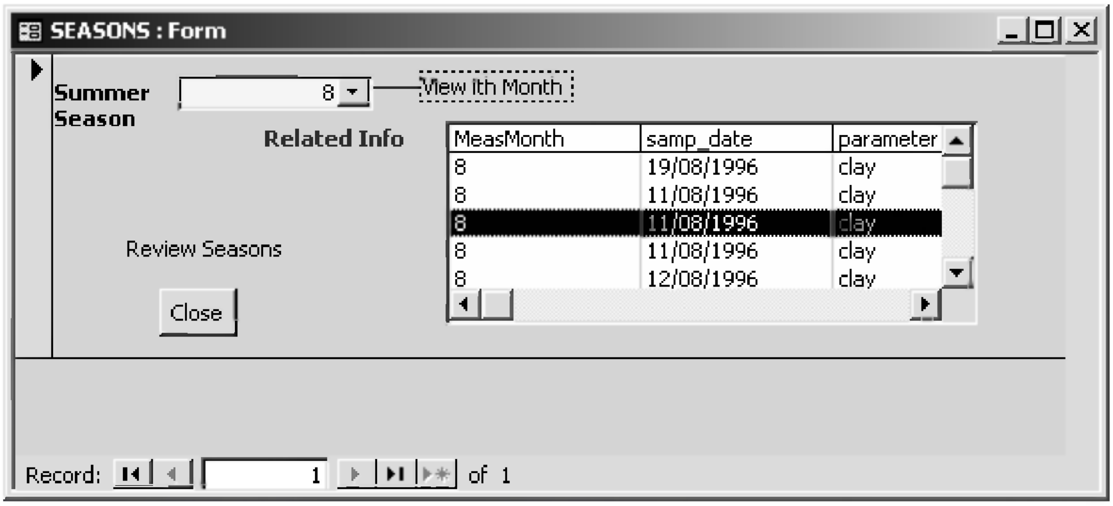


Figure 8-12 Extracting time dependent aspatial information

The possible type of seasons was considered as winter, summer, autumn and spring and is stored in the GeoRelational database. By electing and executing, a month number out of the slot or combo box, (see figure 8-12 top left, a message in a text form is instantaneously retrieved (winter season). Sampling dates and analysis results from an underlying query pertaining to the months are populated within the list box and corresponding core sample results are retrieved (see figure 8-12, left).

8.3.4 Correlative Interpretation by Trend Graph type

A cross tap type query result is used to generate the trend graph in association with aggregate function and a VB specific function linked with relevant Timer *event procedure*. A Line graph shows the rising and falling trends among several data values as indicated below.

Macro: HEVMETAL	
1. Action: OpenForm 2. Status: Design view 3. Name: Graph10	4. Class: MSGraph.Chart.5 5. Link child field: = station 6. Link Master field: = station

Row Source

1. *TRANSFORM Max (SUBQUERY1.pract_value) AS maxOfpract_value*
2. *SELECT SUBQUERY1.parameter*
3. *FROM SUBQUERY1*
4. *WHERE (((SUBQUERY1.discipline_name)="heavy_metal"*
5. *GROUP BY SUBQUERY1.parameter*
6. *PIVOT SUBQUERY1.station;*

< (Avg) (gm/kg), value is checked if less than average if true displayed message safe
2*(Avg) (gm/kg), measured value is checked, if True, displayed message is unsafe
3*(Avg) (gm/kg), measured value is checked, if True a displayed message is dangerous

For instance invoking a trend button displays graphically the heavy metals trend information. The application also display the magnitude of the concentration of the heavy metals as ***SAFE*** and **UNSAFE**, by calculating and comparing internally the values of the measured elements to a constant attribute values, see figure 8-13.

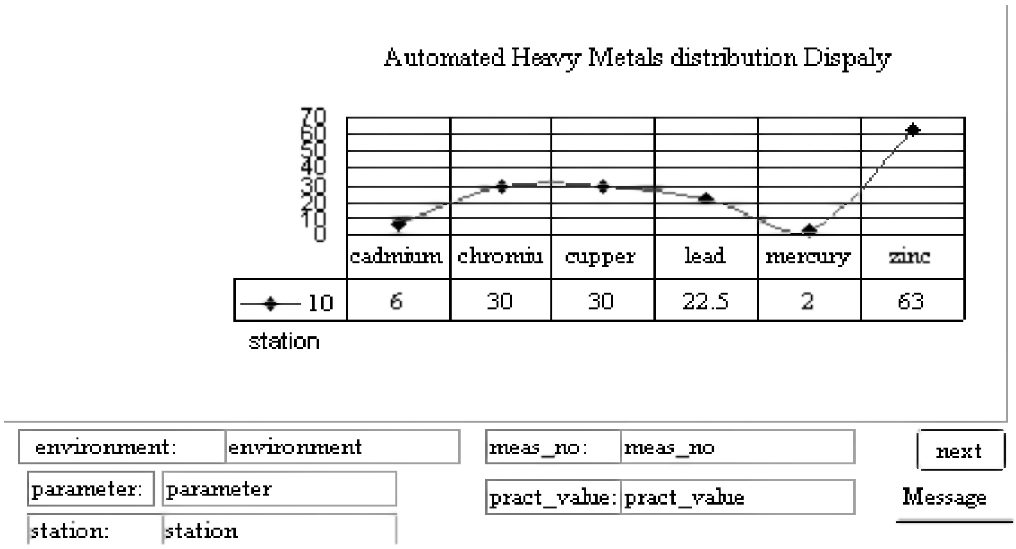
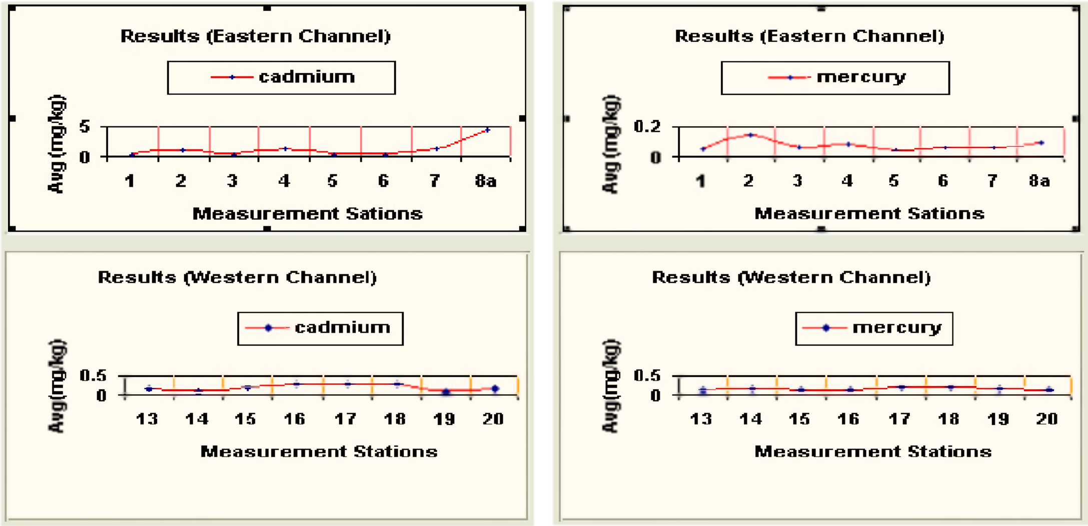


Figure 8-13 An automated trend analysis and message display

8.3.4.1 Zonal type

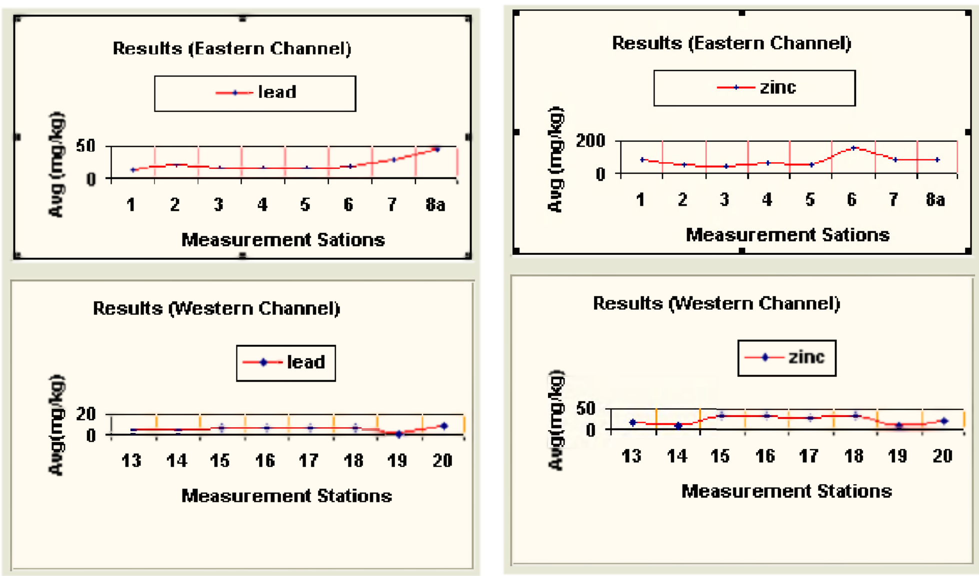
This correlative interpretation is based on measurement stations situated in eastern and to western channels (Esterio Salado as well as the Rio Guayas) respectively. Heavy metals (Cu, Cr, Zn, Hg, and Pb) were selected and incorporated into a sub-cross tap query type.



Automated Correlation of Heavy Metals in the Guayaquil Esstuary

Figure 8-14 Lead and Zinc distribution

Eventually the statistical values (Avg, stdv. and max, min) of the elements were derived. The embedded query was automated via linking it to a graph by means of controls (see figure 8-14). Anomalies traced are related to the estuaries natural set up and impacts of human activity.



Automated Correlation of Heavy Metals in the Guayaquil Esstuary

Figure 8-15 lead and zinc distribution

Eastern Channel: Cadmium and Mercury: Station 8a and station 2 are relatively depicted by higher value. On the other hand, the **AVG** concentration of the Cadmium and Mercury, in the western channel is relatively higher in station 15, 16, 17, and 18; whereas mercury's AVG value is displayed by less than 0.25 mg/kg in the western channel. Hooking a cross tab query to an event procedure Timer, and changing zone parameter from western to eastern or vice versa graphically display heavy metals concentration results displayed automatically (see figures15.) The automated correlation results displays that, in both channels the concentration of zinc is anomalously detected and is associated to the contaminated emission from the surrounding galvanic industry.

8.4 Results and Conclusions

Retrieving and filtering important informative issues from the underlying geodatabase requires know-how of *SQL (Structured Query Language)*, which is an important component in the exploitation of the constructed GIS. Different executable queries types such as -Parameter query sub-query and cross tab queries were designed, associated to underlying programs.

By embedding database specific query types such as the TSQ (Transform query) with Visual Basic (VB) program procedures that link user-friendly interface controls to the underlying Geodatabase, an interface has been developed.

As a result of the aspatial interface, it was possible to execute many related actions on the underlain database. Some of which are (a) user friendly process of retrieving information from database tables, (b), communicate the underlying geodatabase tabular information graphically and link to spatial engines) (c), display thematical results in an object-control based interface (d) Locate the processed database information on map-like form interface (e) System-Time linked automated graphic correlation of measurement results and related message displays.

Furthermore, it was possible to carry out an automated distribution graphic correlation of the selected heavy metals in the different estuary channels; for instance visualizing the average dissemination of Zn (zinc) on the eastern as well as western channels of the estuary on the different measurement stations (see figure 8-15).

The developed tool enables to retrieve process and evaluate the information from different disciplines incorporated in the geodatabase instantly, and distinguish the possible changes on updated information.

Chapter 9: Recapitulations and Suggestions

9.1. Recapitulations

- GIS's potency is based on in its capability to integrate and analyze the organized *multidisciplinary environmental data spatially*. With this regard, the need of designing and modeling of a geodatabase are considered appropriately. Moreover, approaches of GIS application and methodology of organizing diverse coastal raw data for constructing a functional geodatabase are described and graphically illustrated.
- Main emphasis is given to the Construction of Multidisciplinary *Object-Relational Data Model* conceptual entities communication rules, on the bases of a feature class representation as a Non Lexical Object Types (NOLOT) and Lexical object types (LOT).
- To avoid redundancy, enhance spatial and non spatial integrity and reduce multiple spatial joins, a method of amalgamating multidisciplinary entities belonging to different disciplines is developed. This has been achieved by objects layering process through adherence of the common property, method, type and dimensions of the objects.
- Furthermore, a master *Entity Measurement-Location* composed of a set of geospatial coordinates and migrating spatial pointer is constructed to reference any entity encapsulated within an amalgamated objects. Physical Implementations of the GeoRelational database entities; including that of enforcing referential integrity and indexing have been achieved by applying DDL and DAO.
- Likewise, feature data sets (points, lines and polygons) were defined and generated using graphic programs with the spatial engines. On this research work, Geographic Objects and relevant Meta data were created based on *georeferencing-coordinates-bearing data-files* (event tables) and operating macro digitizing.
- Well-designed *GIS project is vital* since it is a chamber for integrating and piecing together of system application tools; user defined tabular entities, geometric objects, topological operations and association of geographic objects. Seed files of 2D or 3D types and related geographic objects with respect to the properties and symbology of feature are created in a hierarchical pattern within a GIS project. Such practical implementation is illustrated as *Category => Marine Map (MP) > MP features > MP features name > MP features name display order*. Furthermore, features are indexed so that spatial association validation is executed based on the fact that a centroid is associated only once to its own attachable attribute values. Implementing the process strengthened the objects topological

relationship and integrity of spatial information. Moreover, this process has been vital in clearing any impediment of smooth interoperability between or among GIS applications.

- The Object Relational (OR) GIS data model constructed is suitable and flexible for treating complex data and it extends (RDBMS) possibility of defining and storing objects, implements both standard SQL and SQL.x, integrate user defined functions, implement spatial operators to display and perform spatial analysis by interacting and matching geographic objects.
- The structure of Object relational is composed of ObjID, Georeferencing data source and multiple attributes. Each object could have a specific method and property associated with it. For instance Point Object method: *PLACE POINT* is a method for generating a point based on x and y coordinates. Likewise, *PLACE LINE* generates geometric object line based on the coordinates of x, y and x_1 and y_1. Furthermore, the relationship among objects has been implemented based objects relationship example, for a Point object inside a polygon; the relationship is *Point object CONTAINED WITHIN a polygon* or object polygon contains point object…etc.
- GIS map is unique in its application due to the fact that every cited and processed data is geo-reference-able and topologically related. Research maps georeferencing was carried out applying a provided ellipsoid and datum of the area INTL–1924 and PSAD56 respectively.
- 3d Visualization has been executed by increasing the density of observation points (x, y, and z) along a profile on bathymetric map (estuary) and the tabular data has been processed to generate 3d view of the area.
- Interoperability experiments among different spatial engines reveal loss of some spatial properties (E.g. shape altered to polyline and projected features to non-projected) during the exchange of geographic features between non Open GIS complaint and open GIS complaints applications.
- The extracting of spatial information has been executed by introducing object-relational and statistical queries on the developed GIS Geodatabase. Spatial query requires knowledge of (a) feature data set and topological relationship, (b) sharing matching coordinate system and (c) topological cleanness.
- Furthermore, two important aspects are considered to perform the spatial operations, (i) Compatibility of Matching Rows and (ii) Interactivity of the Object themselves, as indicated in the example below.

(a) ObjA.FID = ObjB.FID: - extracts all matching objects' contents

(b) ObjA $\cup$ ObjB: - extracts all objects topologically related' contents

(c) ObjA $\cap$ ObjB: - Extracts objects common,

(d) ObjA contains ObjB or ObjB within ObjA …etc.

Base on this object relational spatial analysis, it was possible to achieve results related to: -

a) Identify channels, which disclose abnormality of heavy metals,

b) Retrieve Lithology extension sheared by tectonics,

c) Disclose the GeoTectonic trending dissecting different coastal Lithologies.

d) Reveal thematical variation of temperature within the estuary

e) Understanding Tidal pattern on the different channels velocity and direction

- According to the overlay spatial analysis results of the coastal area image map and vectorised features, the possible anthropological impacts and processes of submarine erosion pressure are thematically visualized close to the southern periphery of the estuary. This overlay analysis implies that the dimension of the southwest estuary water body may extend further northward and the southern island might submerge as a repercussion of submarine and human dynamism.
- Spatio-temporal analysis related to the tidal current velocity and direction, performed on the highly scattered measurement stations unveiled a certain relationship between the current velocity and the depth of measurement environment. In this case, the highest and lowest measurement depth points are associated with lower flood and ebb tide current velocity.
- The plausible reason suggested to such phenomenon is likely to be of morphological changes of the estuary channel at depth, weakening of the current velocity due to friction at top water surface and due oscillation of the tide generating force (TF) at the sites of measurements during the rise and fall of the tidal levels..

9.2. Suggestions

- System Applications: - The constructed and implemented Geodatabase model has been designed to deal with the management of multidisciplinary coastal / marine environmental problems. However, it is also open to be utilized in challenging spatial problems related to continental surface and subsurface areas.

- Data sites: - The lateral distribution of the measurement stations, incorporated in the designed geodatabase are few and sporadically dispersed. This fact has created a sense of constraint in generating continuous zone of thematic interpretation. Increasing the measurement density and integrating with historical data might lead to a better spatially visible result.

- Interface: During this research, the geodatabase has been implemented with different GIS applications. Nonetheless, an aspatial interface has been developed to exploit the underlying geodatabase pool in a user-friendly manner.

- Raster GIS development: The implemented geodatabase objects are mainly of vector GIS type. Relevant raster files (satellite images /scanned paper maps) were vectorised, topologically cleaned, and spatio-temporally integrated. This was an essential step to sort out spatio-temporal problems and suggest solutions related to coastal environment. However, developing a full-fledged raster and remote sensing coupled with feature based GIS can be a major theme and task in challenging issues concerning: -

  - Identifying areas of higher priorities and Diagnose environmental impacts
  - Perform remote aerial exploration and prospecting
  - Detect, Identify and Delineate source of economically viable deposits intended to the advantage and development of societal wellbeing.

Appendixes and References

Appendix 1: *GeoDatabase Application Structure*

User Defiend Entities

Create table ZONE (

MSLINK integer UNIQUE,
MAPID integer NOT NULL,
Zone_code integer CONSTRAINT pkMSLINK PRIMARY KEY,
Zone_locality TEXT (30));

Create table LOCATION (

MSLINK integer UNIQUE,
MAPID INTEGER NOT NULL,
Station text (5) CONSTRAINT pkST PRIMARY KEY,
LonDegTxt text (10),
LatDegTxt text (10),
LonDegDec float,
LatDegDec float,
EastingKm float,
NorthingKm float,
Area float,
Perimeter float,
zone_code integer REFERENCES ZONE (zone_code));

create table CAMPDATE(

Dtcode integer CONSTRAINT pkDtcode PRIMARY KEY,
MSLINK integer,
mapid integer,
Station text (6) REFERENCES Location (station),
Samp_date date,
Samp_time_st date,
Samp_time_e date);

create table FIELD(

MSLINK integer,
mapid integer,
Dtcode integer REFERENCES campdate (dtcode),
Field_code text (6) CONSTRAINT pkFcode PRIMARY KEY,
discipline_name TEXT(25),
Environment TEXT (25),
Samp_technique TEXT (25),
Samp_doc TEXT (25),
Samp_weight_kg FLOAT,
Samp_volume_m3 FLOAT,
Samp_volume_l FLOAT);

create table RESULTS(

MSLINK integer,
mapid integer,
zone_code integer REFERENCES ZONE (ZONE_CODE) ,
Station text (6) REFERENCES LOCATION (STATION),
Dtcode integer REFERENCES campdate (dtcode),
Field_code TEXT (6) REFERENCES FIELD (field_code),
Parameter text (15),
Meas_doc text (25),
Meas_doc text (25),
Pract_value float,
Pract_unit text (6),
SI_value float,
SI_unit text (6),
Precision float,
Samp_depth_m float,
Echo_depth_m float,
Abs_depth_m float,
Meas_code text (15) CONSTRAINT Pkmcod PRIMARY KEY);

Create table ESTUARY(

MSLINK integer,
MAPID integer,
Estation text (6) Constraint PKEst PRIMARY KEY,
zone_code integer REFERENCES ZONE(zone_code) ,
LonDegTxt text (10),
LonDegTxt text (10),
LonDegDec float,
LatDegDec float,
EastingKm float,
NorthingKm float,
Area float,
Perimeter float);

Create table LITHOLOGY(

MSLINK integer,
MAPID integer,
Georef integer CONSTRAINT Pkgeoref PRIMARY KEY,
zone_code integer References zone (zone_code),
LonDegTxt text (10),
LonDegTxt text (10),
LonDegDec float,
LatDegDec float,
EastingKm float,
NorthingKm float,
Area float,
Perimeter float,
StratgraphicName text (20),
Lithocomposition text (50)

Create table TECTONICSTRUCTURE(

MSLINK integer,
MAPID integer,
Georef integer CONSTRAINT Pkgeoref PRIMARY KEY,
zone_code integer References zone (zone_code),
LatDegTxt text (10),
LonDegTxt text (10),
LonDegDec float,
LatDegDec float,
EastingKm float,
NorthingKm float,
Area float,
Perimeter float,
Trend text (10));

Create table DISCIPLINES(

Discp_code text (6) CONSTRAINT pkdscpcd PRIMARY KEY,
Station text (6) REFERENCES Location (station),
Discp_zone_code text (20),
Discp_Name text (30),
Zone_code integer REFERENCES ZONE (zone_code));

Create Unique Index Locmslink On Location (Mslink Asc);
Create Unique Index Tecgeoref On Tectonicstructure (Tgeorefno Asc);
Create Unique Index Lgeoref On Lithology (Lgeorefno Asc);
Create Unique Index Estation On Estuary (Estation Asc);
Create Unique Index Discpcode On Disciplines (Discp_Code Asc);
Create Unique Index Fldcd On Field (Field_Code Asc);
Create Unique Index Cmpdt On Campdate (Dtcode Asc);
Create Unique Index Zncd On Zone (Zone_Code Asc);
Create Unique Index Meas-No On Results (Meas_Code Asc);

System Generated Entities

Create table FEATURE(

```
MSLINK Integer,
Fcode Char(12),
Fname Char (32),
Category Integer,
Tablename Char (18),
Ftype Smallint,
Flevel Smallint,
Fstyle Smallint,
Fweight Smallint,
Fcolor Smallint,
Digcmd Char (240),
Felement Smallint,
Fangle Char (16),
Fheight Float,
Fwidth Float,
Flinespace Float,
Linelength Smallint,
Ffont Smallint,
Fsymbol Char (1),
Fjustification Char (3),
Celllibrary Char (14),
Fcellname Char (6),
Cellscale Float,
Streamdelta Float,
Streamtolerance Float,
Streamunit Char (15),
Snaptype Smallint,
Snaptolerance Smallint,
Newdup Smallint);
```

Create table MSCATALOG(

```
Tablename char (32),
Entity integer);
Create table category (
MSLINK integer,
Cname char (32),
Indexname char (14),
Indexlevel Smallint);
```

Create tableUGCATEGORY (

```
Category integer,
Defaultf integer,
Olap Smallint,
Foreign Smallint,
Dgnfex char (3));
```

create table MAPS (

```
MSLINK integer,
Category integer,
Mapname char (14));
```

Create table UGMAP(

```
MAPID integer,
Mdir char (128),
Descr char (132),
Viewrot float,
Filesize integer);
```

Create table UGJOIN_CAT(

```
Jtype Smallint,
Table0 char (36),
Index0 char (36),
Table1 char (36),
Index1 char (36),
Value1 char (36),
Descr char (80));
```

Create table UGTABLE_CAT(

```
Tname char (128),
Talias char (32),
Pkey char (32),
Descr char (80),
Ustn Smallint);
```

Create table UGFEATURE(

```
Feature integer,
Elock Smallint,
Fclass Smallint
Fpriority Smallint,
Infomode Smallint,
Das Smallint,
Dprio integer,
Fodder char (16),
Descr char (132),
LsScale float,
DashScale float,
GapScale float,
StartWidth float,
EndWidth float,
Phase float,
Phasetype Smallint,
Slant float,
Cs float,
Underline Smallint,
Vertical Smallint,
Fraction Smallint,
LsName char (64));
```

Create tableUGCOMMAND(

```
Feature integer,
Cname char (32),
Keyincmd char (240),
Sqlstmt char (240),
Class Smallint );
Create Unique Index Mscatalog tname on Mscatalog (tablename);
Create Unique Index mscatalog_enum on Mscatalog (entitynum);
Create Unique Index category_msl on category (MSLINK);
Create Unique Index ugcategory_msl on ugcategory (category);
Create Unique Index ugfeature_msl on ugfeature (feature);
Create Unique Index ugcommand_feanam on ugcommand (feature, name);
Create Unique Index feature_msl on Feature (MSLINK);
Create Unique Index ugcategory_msl on ugcategory (category);
Create Unique Index ugfeature_msl on ugfeature (feature);
```

Appendix 2: Executable Spatio-temporal Query

Query type and statements	Performance Explanation
SELECT Sqr ((((lat.stnlat1)-(lat.stnlat2))^2) + (((Lon.stnlon1)-(lon.stnlon2))^2)) / DateDiff ("h", starttime1], [endtime]) AS the velocity FROM lon, lat, distime;	*Calculates the distance between two stations and divides the by the time taken from start to end to cover the distance. Saves it as a velocity of the moving object. The data is stored tables -lon, lon and distime.*
SELECT DISTINCT station, DateDiff ("yyyy", [samp_date], Now ()) AS YrsSincedayofsampling FROM [Position];	*Calculates the time elapsed since the date of the sampling of the measurement stations until present day. Saves as Yrs since day of sampling, it queries the attributes of the position table.*
SELECT DISTINCTROW Station, position.samp_time_e, position. Samp_time, DateDiff ("s", [samp_time], [samp_time_e]) AS Time Elapsed FROM [position] GROUP BY position.samp_time, position.samp_time_e;	*Calculates the time elapsed since the date of the sampling of the measurement stations until present day. Saves as Time Elapsed in seconds, it queries the attributes of the position table.*
*SELECT Position.samp_date, DateAdd ("yyyy", -10,Position.samp_DATE) AS Tbefore FROM [Position] WHERE SAMP_DATE LIKE "*96*";*	*It calculates retrieves the sampling date and deduct 10 years to show the corresponding results before 10 years. The query is saved as Tbefore*
SELECT DISTINCTROW STATION_LOC. MAPID, STATION_LOC. MSLINK, Results.parameter, Avg (RESULTS.pract_value) AS AVG_PRCT, position.samp_date, position.samp_time_e, position.samp_time, DateDiff ("h", [samp_time], [samp_time_e]) AS Time	*It utilizes the feature id, MAPID of the feature table LOCATION and attributes of the table Results to calculate the average value of the measured parameter, start and end time of measurement and time used to perform the measurement of the mercury bearing data for the stations measured between stated between 4-8-1996 and 4-6-1997.*

Elapsed, STATION_LOC.station FROM [position], STATION_LOC, RESULTS WHERE (((STATION_LOC.station)=[POSITION].[STATION]) AND ((POSITION.rec_no)=[RESULTS].[REC_NO]) AND ((Results.parameter)="MERCURY") AND ((position.samp_date) Between #4/8/96# And #4/6/97#)) GROUP BY STATION_LOC. MAPID, STATION_LOC. MSLINK, Results.parameter, position.samp_date, position.samp_time_e, position.samp_time, STATION_LOC.station;	
SELECT DISTINCT Position.samp_date, Count (Position.samp_time) AS CountOfsamp_time FROM [Position] GROUP BY Position.samp_date;	*Counts the number of measurement dates for collecting the GIS project data from a single table.*
TRANSFORM Avg (SUBQUERY1.pract_value) AS AvgOfpract_value SELECT SUBQUERY1.parameter GROUP BY SUBQUERY1.parameter PIVOT SUBQUERY1.station;	*Creates a spreadsheet like table for the average values of the attribute values of the attribute named parameter.*
SELECT STATION_LOC.station, station_loc.lat, meas_doc, station_loc.lon, POSITION.samp_time, POSITION.samp_depth_m, POSITION.rec_no, RESULTS.rec_no, RESULTS.parameter, RESULTS.pract_value FROM station_loc, POSITION, RESULTS WHERE station_loc.station =	*JOIN and UNION Query type* *The query process and retrieves information based on the defined SQL statements.* *The three attribute names processed are meas_doc values, station number, sampling time, sampling depth in meters, rec-number and the name of the parameter, value of the parameter retrieved from station_loc and Position*

```
POSITION.station
and  POSITION.rec_no = RESULTS.rec_no
and meas_doc like  "*ebb*" and
position.samp_date like "*97*"
order by  STATION_LOC.STATION DESC;
UNION SELECT station_loc.station,
station_loc.lat, meas_doc, station_loc.lon,
POSITION.samp_time, POSITION.rec_no,
RESULTS.rec_no, RESULTS.parameter,
POSITION.samp_depth_m,
RESULTS.pract_value
FROM station_loc, POSITION, RESULTS
WHERE station_loc.station =
POSITION.station
and POSITION.rec_no = RESULTS.rec_no
and meas_doc = 'az' and position.samp_date
like "*97*"
ORDER BY STATION_LOC.STATION DESC;
```

respectively.

The temporal criteria requested is for the 1997, particularly for the measurement document type of ebb and az. Eventually the result is a single query view or table with all the necessary information display in a descending order sorted.

A union query parses for the attribute type definition to execute the SQL statements. Hence the attributes that occur in the different tables are meeting the criteria of the query and data types.

```
SELECT  * FROM Location where MSLINK in
(select MSLINK from results where parameter
= 'sand' and pract_value< 5)
```

The query includes the feature id and MAPID in most case to execute the query and permit triggering the QUERY, LOCATE, REVIEW, and ATTACH, FIRST, LAST, NEXT, PREVIOUS buttons. Retrieves all the records associated to the feature by the MSLINK which full fills the criteria i.e., sand value < 5.

```
SELECT * FROM LOCATION WHERE
STATION IN (SELECT STATION
FROM RESULTS WHERE PARAMETER =
'ppddt' AND                    PRACT_VALUE<
(SELECT AVG (PRACT_VALUE) FROM
RESULTS WHERE PARAMETER = 'ppddt')
OR          samp_depth_m >(SELECT AVG
(SAMP_DEPTH_M) FROM RESULTS
WHERE SAMP_DEPTH_M BETWEEN 15
AND 20)) AND (LOCATION.AREA > 15);
```

It parses the LOCATION table its Identifier which references in the table results for the measured PPDDT value which is less than the average of PPDDT and samp_depth_m greater than the average of the individual sample depth in meters which ranges between 15 and 20 meters representing area > 15.

```
SELECT * FROM LOCATION WHERE
STATION IN (SELECT STATION FROM
RESULTS WHERE PARAMETER = 'lead'
AND PRACT_VALUE> (SELECT AVG
(PRACT_VALUE) * 2 FROM RESULTS
WHERE PARAMETER = 'lead') AND
samp_depth_m > (SELECT AVG
(SAMP_DEPTH_M) FROM RESULTS
WHERE SAMP_DEPTH_M BETWEEN 0 AND
5)) AND (LOCATION.AREA > 5);
```

Select all the attributes in the Location table and reference the station attributes to the station in the table results. The parameter LEAD is selected and compared ageist all those greater than 2 times average and samp_depth_m is compared to that greater than average forrange depth between 0 and 5 for area greater than 5.

```
SELECT * FROM LOCATION WHERE
STATION IN (SELECT STATION
FROM RESULTS WHERE PARAMETER =
'ppddt' AND pract_value <
(SELECT AVG (PRACT_VALUE) FROM
RESULTS WHERE PARAMETER = 'ppddt')
OR samp_depth_m >(SELECT AVG
(SAMP_DEPTH_M) FROM RESULTS
WHERE SAMP_DEPTH_M BETWEEN 15
AND 20)) AND (LOCATION.AREA > 15);
```

It parses the LOCATION table its Identifier which references in the table results for the measured PPDDT value which is less than the average of PPDDT and samp_depth_m greater than the average of the individual sample depth in meters which ranges between 15 and 20 meters representing area > 15.

```
SELECT * FROM LOCATION WHERE
STATION IN (SELECT STATION FROM
RESULTS WHERE PARAMETER = 'salinity'
AND pract_value < (SELECT AVG
(pract_value) FROM RESULTS WHERE
PARAMETER = 'salinity') AND
samp_depth_m > (SELECT AVG
(SAMP_DEPTH_M) FROM RESULTS
WHERE samp_depth_m BETWEEN 0 AND
15)) AND (LOCATION.AREA >5);
```

Retrieves locations where salinity less than the averages and samp_dep_m is less than the average depth per station only for the depth between 0 and 15 m and locational area > 5 sq km.

```
PARAMETER [Beginning Date] DateTime,
[Ending Date] DateTime;
SELECT DISTINCTROW POSITION.station,
Format (samp_Date,"dd-mm-yyyy") AS [Year],
Format$(samp_time,"hh:nn:ss") AS MTime,
Results.parameter, RESULTS.pract_value,
results.SI_value
FROM [position], results
WHERE (((Results.parameter)="sand") AND
((POSITION.rec_no)=[results]. [Rec_no])
AND ((position.samp_date) Between
[Beginning Date] And [Ending Date]));
```

It requests the user the beginning date and ending date of measurement, then selects the stations, measured attributes and the value of analysis from the position and results tables respectively. The value of the attribute is equated to sand for the data only for those between the beginning and ending date. The final results are displayed in format as Mtime for the sampling time and as a Year for the sampling year.

```
SELECT DISTINCTROW STATION_LOC.
MAPID, STATION_LOC.MSLINK,
RESULTS.parameter,
Results.pract_unit, Max
(RESULTS.pract_value) AS AVG_PRCT,
position.samp_date, position.samp_time_e,
position.samp_time, DateDiff ("s",
[samp_time], [samp_time_e])/60 AS Time
Elapsed, STATION_LOC.station,
Station_Loc.lon, Station_Loc.lat
FROM [position], STATION_LOC, RESULTS
WHERE
(((STATION_LOC.station)=[POSITION].
[STATION]) AND
((POSITION.rec_no)=[RESULTS].
[REC_NO]) AND
((RESULTS.parameter)="MERCURY") AND
((Position.samp_date) Between #4/8/1996#
And #4/6/1997#))
GROUP BY STATION_LOC. MAPID,
STATION_LOC.MSLINK,
RESULTS.parameter, Results.pract_unit,
position.samp_date, position.samp_time_e,
```

Calculates the measured values of mercury between the time elapsed for measurement 1 and measurement 2 in terms of minutes The search of the data includes three tables in which the Master table is associated with spatial features and checks for all samples which have last measurement time represented by measurement samp_time_e.

position.samp_time, STATION_LOC.station, Station_Loc.lon, Station_Loc.lat HAVING (((position.samp_time_e) Is Not Null));	
SELECT samp_date, DateDiff ("yyyy", now (), samp_date) AS time difference FROM [position];	*Retrieves the information between the present and date of measurements*

Appendix 3: GIS Database Terminology

Term	Meaning
ATTRIBUTI	*It is a column name that describe a specific entity*
GEORELATIONAL_TABLE	*An out put of an associated attribute and feature tables*
DDL	*An acronym for data definition language used by SQL*
DML	*An acronym for data manipulation language used by SQL Statement to define the database components*
ENTITY	*Table related to its affiliated attributes*
NOLOT	*Non Lexical Object (Entity)*
LOT	*Lexical objects (attribute)*
DATABASE DESIGN	*A process where the conceptually established data model is implemented in a specific database.*
RELATIONAL JOIN	*The relating of two or more tables in a relational database on the basis of a common item or field*
LINKED TABLE	*A Table or flat file linked to a database for viewing or editing*
DATA TYPE	*Data type a reference to the type of an attribute's content. For instance to handle numerals as numbers or simply as character data and are utilized in ensuring data integrity within a database.*
NORMALIZATION	*A process in a data modeling method used as a database design tool for relational databases.*
3NF	*Every attribute is unique + pk, + non transitively - dependent on the pk*
2NF	*Every attribute is unique + functionally dependent on pk*
1NF	*Every attribute is unique*
CREATE TABLE	*Defining the database table components using a data definition language*
INSERT INTO	*An SQL statement function used to populate a table using the SELECT data*

	manipulation part of SQL
SELECT	*It is an SQL statement workhorse command which is designed to return a Table upon execution*
SQL	*Relational database language utilized for implementing the DDL and DML.*
QUERY	*An SQL statement expressing a set of conditions that forms the basis for the retrieval of information from a structured database.*
TUPLE	*A distinct database row stored in a relational database table pertaining to the different attribute name of the table composed of one data item each.*
PRIMARY KEY	*A unique column or column designed to identify a tuple in a relational database table*
REFERENTIAL KEY	*A unique column or column designed to identify a tuple in another relational database table*
ONE TO MANY	*A relation in which one attribute value in a table is related to many attribute values in another table.*
MANY TO MANY	*A relationship between two entity sets in an Entity-Relationship Model, in which many entities of one entity set are related to many entities in the other*
ONE TO ONE	*A relation in which one attribute value in a table is related to one attribute values in another table.*
REFERENTIAL INTEGRITY	*Capability of ensuring information integrity. For instance, a table will not be given a foreign key value unless it is a primary key value in other table.*
REDUNDANCY	*Un necessary repetition of data in a system*
MANDATORY ATTRIBUTE	*An attribute utilized to reference the a tupel*
INFORMATIVE ATTRIBUTE	*The non mandatory attribute of a table*
TEMPORAL DATABASE	*A database containing information indexed by time. Time/ date which can either be represented as discrete steps, or as a continuous variable*
OPEN DATABASE CONNECTIVITY (ODBC)	*A standard API (application program interface) used to communicate with database management systems, developed by Microsoft.*
ATTRIBUTE TABLE	*(GIS context): Data structured in a tabular file containing rows and columns, which are in most cases associated to geographic features. Every tuple or row represents a geographic feature identified by a geographic identifier.*
ASPATIAL	*Attributes structured to be associated to describe the spatial elements*
VALIDATING TEXT	*Definition of a textual message to indicate on how data are entered or displayed*
RAW DATA	*Data which has not been exposed to any processing*
NON GRAPHIC DATA	*Data related to non geometric objects*
PRIMARY DATA	*Data that represent certain originality. E.g. fresh rock of an in situ sample*

SECONDARY DATA	Resampled data. E.g. converting paper map to electronic file for building the GIS
SYSTEM GENERATED ENTITIES	Special tables generated by the spatial engine to work coherently with an external data model
USER DEFINED ENTITIES	Structured relational database tables which could be joined to system generated tables by means a migrating key
MEASURED_RESULTS	Multidisciplinary data structured systematically to have a common a common identifiers for easy access and retrieval process
LITHOLOGY-DATA	Raw data related to geologically distinctive lithologic attributes
TECTONIC-DATA	Attributes related to the tectonic structure for instance, fault trends, strike and dip angles
CAMPAIGNDATEDATA	An entity composed mainly of temporal parameters
LOCATION-DATA	An entity containing georefrencing data sources
AMALGAMATION	The fusing of different structured tables to reduce the number join tables and facilitate the retrieving (a process of demoralization)
CASCADE UPDATES	The possibility to enable a referential integrity constraint changes despite the defined referential integrity to update
CASCADE DELETIONS	The possibility to enable a referential integrity constraint changes despite the defined referential integrity to delete
SPATIAL BUILDING BLOCK ENTITIES	Entities that compose the GIS associated feature tables.
SQL SYNTAX DIFFERENCE	The difference of utilizing SQL statement to return values in form a query view.
INDEXING	A process of creating keys that helps to increase the speed of accessing and retrieving the data
HIERARCHICAL DATA STR. (HDS)	The data model is based on the required constraint that a child record is not supported to have a multiple parents. Hierarchical data models represent data in a tree like structure, with one data type providing the root (initial map) to which all others are linked via parent/child relationships with hidden pointer.
NETWORK DATA STRU. (HDS)	Network data model were constructed to compensate the weakness of a hierarchical model by allowing different parents to point to a single child or a child point to a different parents
RELATIONAL DATA STRU. (RDS)	A relational database model based on tables (relations), fields and rows. Operations based on structured tables are easily implemented based on common values that can be easily corrected and identified in case of system failures.
DATABASE	The possibility and ability of different software systems to exchange information

COMMUNICATION	*and requests, using methods such as object linking or translation of different feature.*
NESTED SQL (SUBQUERY)	*A query that reference a second query by means of IN key word to retrieve related information*
CROSS TAB QUERY	*Special select type query that output results in a spread sheet format*
ASPATIAL ANALYSIS	*Analysis performed on data stored in an attribute database, without associating to spatial features*
UNION OPERATION	*A query used to create the union of two or more tables*
INTERSECTION	*A query employed to generate the common attribute values of the two or more tables*
LIST BOX	*A List display of table's results in a visual basic form*
ZONAL CORRELATION	*Spatial correlation based on different zone in a regional/ local environment*
ANOMALIES	*Abnormal display of certain measured or analyzed values*
ENTITY RELATIONAL MODEL	*A logical way of describing entities and their relationships within relational databases, in most cases diagrammatically*
TRANSFORMATION	*Process of rectification, typically involves rotation and scaling of grid cells during a projection system.*

Appendix 4: Geographic Objects Generation (A,B,C,D and E)

A	***Geographic Objects (MapInfo)***
Set Obj = Create line (LonDegDec, LatDegDec, LonDegDec2, LatDegDec2)	*Purpose: Create a line object based on the starting and ending points of coordinates.* *Requirements: MapBasic and .tab file (MapInfo GIS)* *Specific Projection system (case study PASDA56)*
Update LocationPoint *Set Obj = Create Circle (LonDegDec, LonDegDec, Unit)* *The Point Object is converted into a circle with a specific filed radius in U (unit*	*Purpose: Create a circle object based on Point and it's a radius* *Requirements: MapBasic and .tab file (MapInfo GIS)* *Specific Projection system (case study PASDA56)*
Update Circle Object *Set obj= Create Point (Centroid (Obj)), (Centroid (Obj))*	*Purpose: Creates a point by reversing a circle object into a point.* *Requirements: MapBasic and .tab file (MapInfo GIS)* *Specific Projection system (case study PASDA56)*

1. Mslink Integer ; 2. LonDegDec Float ; 3. LatDegDec Float ; 4. Area Float ; 5. Perimeter Float ; 6. Myimage Char (45) ; 7. Begin_Metadata 8. "\Activeobject" = "" 9. "\Activeobject\Expr" = "Myimage" 10. "\Activeobject\Mode" = "Hotlink_Mode_Both" 11. "\Activeobject\Relative" = "True" 12. "\Isreadonly" = "False" 13. End_Metadata	*A spatial object and object generating code.* *Steps 1 defines an object identifier* *2 and 3 are coordinates* *4 and 5 defines possible dimensions of the object* *6 variable for the meta data object path* *7 defines the meta object creations* *Requirements:* *.tab file* *MapBasic* *Specific projection system*

B Geographic object (MBE): Polyline (lstring object)

```
 Defining type and objects
Sub Main
Dim MaxNorthing   As Double
Dim MaxEasting   As Double
Dim scaleNorthing  As Double
Dim scaleEasting  As Double
Dim InString   As String
Dim PointCount  As Integer
Dim point()   As MbePoint
Dim ThisPoint  As MbePoint
Dim I         As Intege
MbeSendCommand "SUPPRESSED NOECHO"
MbeWriteCommand "DRAWING Graph"
MbeWriteStatus "Graph on work...
MaxNorthing  = 0.0
MaxEasting   = 0.0
PointCount  =  0
'Pointing to the data file
Open "path" For Input Access Read As #1
'--------------------------------------------------------------------
' Reading the Provided values  into array
' the loop
While NOT EOF(1)
Line Input #1, InString
thisPoint.X = Val(Item$(inString,1,1,","))
thisPoint.Y = Val(Item$(inString,2,2,","))
PointCount = PointCount + 1
Redim Preserve point(pointCount)
point(pointCount) = thisPoint
If thisPoint.X > MaxNorthing Then
MaxNORTHING = thisPoint.X
End If
If thisPoint.Y> MaxEasting Then
                    maxEasting = thisPoint.Y
End If
Wend
Close #1
'----------------------------------------------------
scaleNorthing = Northing / MaxNorthing
```

```
scaleEasting = Easting / maxEasting
'Scaling the array
For      I = 1 to pointCount
point(i).X = point(i).X * scalenorthing
point(i).Y = point(i).Y * scaleeasting
Next I
'Drawing the limiting axes
MbeSendCommand "PLACE LSTRING SPACE"
MbeSendDataPoint 0,7,0
MbeSendDataPoint 0,0,0
MbeSendDataPoint 9,0,0
MbeSendReset
   'Generating the GEG
   Mbesendkeyin "place point"
 'MbeSendCommand  "PLACE LSTRING SPACE"
For      I = 1 to pointCount
MbeSendKeyin "XY=" + Cstr(point(i).X) + "," + Cstr(point(i).Y)
        Next I
 MbeSendReset
MbeWritePrompt ""
MbeWriteCommand ""
MbeWriteStatus "Finished - GEG"
MbeSendCommand "ECHO"
End Sub
```

C Geographic Objects :	**Points and shape on 3d Seed File**
SUB MAIN Dim startPoint As MbePoint Dim point As MbePoint, point2 As MbePoint MbeSendCommand "ACTIVE COLOR 12" MbeSendCommand "ACTIVE STYLE 0" MbeSendCommand "ACTIVE WEIGHT 0" MbeSendKeyin "place circle radius" MbeSendKeyin "1.2" MbeSendCommand "ACTIVE level 12" Mbesendkeyin"xy=613.928,9781.452,-11.00" '1 Mbesendkeyin"xy=628.344,9770.452,-4.000" '4 Mbesendkeyin"xy=625.346,9763.399,-5.500" '2 Mbesendkeyin"xy=626.588,9761.000,-7.000" '3 Mbesendkeyin"xy=624.575,9756.538,-11.000" '5 Mbesendkeyin"xy=626.990,9750.894,-8.000" '6 Mbesendkeyin"xy=630.013,9742.306,-9.600" '6.6 Mbesendkeyin"xy=628.162,9733.231,-12.500" '7 Mbesendkeyin"xy=625.986,9724.401,-8.600" '8A Mbesendkeyin"xy=622.475,9714.884,-7.000" '9A MbeSendKeyin "1.6" Mbesendkeyin"xy=623.991,9698.232,-6.46" '10 Mbesendkeyin"xy=608.492,9706.722,-7.000" '11 MbeSendKeyin "1." Mbesendkeyin"xy=598.066,9704.592,-12.000" '12 Mbesendkeyin"xy=596.181,9704.824,-4.1000" '12A Mbesendkeyin"xy=586.601,9703.875,-13.300" '13 'Mbesendkeyin"xy=582.071,9695.929,-5.500" '13_1 Mbesendkeyin"xy=583.613,9703.875,-3.500" '13A MbeSendKeyin "1.6"	*Purpose: Create a an ellipsoid shape around point of measurement* *Requirements:* *3D seed file (MicroStation Environment)* *Preferable with a specific Projection (case study SAD1956)* *Z value viewer tool (Accurate draw tool.* *A Macro that generates point bounded by user defined radius (zone) of interest and measurement depth in a given unit.* *A map is generated within a georeferenced grid map* *The values of the x, y and z are referenced from within the Geodatabase* *The comments characters with the left single quotation mark indicate* *A label of the site of interest.* *Flexibility: It is possible to modify the symbology of the features and the dimension of the given semi circular*

Mbesendkeyin"xy=592.981,9712.216,-13.6000" '14 Mbesendkeyin"xy=604.487,9721.383,-7.000" '15 Mbesendkeyin"xy=608.617,9733.221,-10.700" '16 MbeSendKeyin "1.4" Mbesendkeyin"xy=616.258,9743.769,-19.000" '17 Mbesendkeyin"xy=621.742,9747.027,-14.000" '19 Mbesendkeyin"xy=619.031,9749.013,-17.000" '18 Mbesendkeyin"xy=617.491,9753.064,-19.000" '20 MBESENDRESET mbeSendKeyin "place point" MbeSendCommand "ACTIVE COLOR 10" MbeSendCommand "ACTIVE STYLE 0" MbeSendCommand "ACTIVE WEIGHT 3" MbeSendCommand "ACTIVE level 10" Mbesendkeyin"xy=613.928,9781.452,-11.00" ' 1 Mbesendkeyin"xy=628.344,9770.452,-4.000" '4 Mbesendkeyin"xy=625.346,9763.399,-5.500" '2 Mbesendkeyin"xy=626.588,9761.000,-7.000" '3 Mbesendkeyin"xy=624.575,9756.538,-11.000" '5 Mbesendkeyin"xy=626.990,9750.894,-8.000" '6 Mbesendkeyin"xy=630.013,9742.306,-9.600" '6.6 Mbesendkeyin"xy=628.162,9733.231,-12.500" '7 Mbesendkeyin"xy=625.986,9724.401,-8.600" '8A Mbesendkeyin"xy=622.475,9714.884,-7.000" '9A Mbesendkeyin"xy=623.991,9698.232,-6.46" '10 Mbesendkeyin"xy=608.492,9706.722,-7.000" '11 MbeSendKeyin "1.2" Mbesendkeyin"xy=598.066,9704.592,-12.000" '12 Mbesendkeyin"xy=596.181,9704.824,-4.1000" '12A MbeSendKeyin "1.2" Mbesendkeyin"xy=586.601,9703.875,-13.300" '13 'Mbesendkeyin"xy=582.071,9695.929,-5.500" '13_1 Mbesendkeyin"xy=583.613,9703.875,-3.500" '13A Mbesendkeyin"xy=592.981,9712.216,-13.6000" '14 Mbesendkeyin"xy=604.487,9721.383,-7.000" '15 Mbesendkeyin"xy=608.617,9733.221,-10.700" '16 Mbesendkeyin"xy=616.258,9743.769,-19.000" '17 Mbesendkeyin"xy=621.742,9747.027,-14.000" '19 Mbesendkeyin"xy=619.031,9749.013,-17.000" '18 Mbesendkeyin"xy=617.491,9753.064,-19.000" '20 MBESENDRESET END SUB	*values.* *The feature point is created and associated to shape geographic element via MbeSendCommand "CREATE CENTROIDS " MbeSendCommand "FEATURE ATTACH " and provided that the MbeSendCommand "ACTIVE FEATURE name= Category.featureName.Element type" the database records associated MbeSendCommand MbeSendCommand "ASSOCIATE LINKAGES "*

D	Bottom channel morphology Profile Generation
SUB MAIN Dim startPoint As MbePoint Dim point As MbePoint, point2 As MbePoint MbeSendCommand "ACTIVE COLOR 12" MbeSendCommand "ACTIVE STYLE 0" MbeSendCommand "ACTIVE WEIGHT 6" MbeSendKeyin "place line" Mbesendkeyin"xy=613.928,9781.452,-11.00" Mbesendkeyin"xy=621.136,9775.952,-7.500" Mbesendkeyin"xy=628.344,9770.452,-4.000" Mbesendkeyin"xy=625.346,9763.399,-5.500" Mbesendkeyin"xy=625.967,9762.203,-6.250" Mbesendkeyin"xy=626.588,9761.000,-7.00" Mbesendkeyin"xy=625.582,9758.772,-9.00"	*Purpose: Generates cross sectional profile across the different estuary channels based on the measurements points. Depth profile visualized by customizing the left, right or front. MicroStaion 3D viewing tools*

Mbesendkeyin"xy=624.575,9756.538,-11.00" Mbesendkeyin"xy=625.783,9753.716,-9.500" Mbesendkeyin"xy=626.990,9750.894,-8.000" Mbesendkeyin"xy=628.502,9746.600,-8.600" Mbesendkeyin"xy=630.013,9742.306,-9.600" Mbesendkeyin"xy=628.162,9733.231,-12.500" Mbesendkeyin"xy=627.074,9728.816,-12.800" Mbesendkeyin"xy=625.986,9724.401,-8.600" Mbesendkeyin"xy=624.231,9719.643,-9.000" Mbesendkeyin"xy=622.475,9714.884,-7.000" Mbesendkeyin"xy=624.989,9711.317,-11.000" MbeSendCommand "ACTIVE COLOR 4" MbeSendCommand "ACTIVE STYLE 0" MbeSendCommand "ACTIVE WEIGHT 6" Mbesendkeyin"xy=630.854,9722.300,-8.000" Mbesendkeyin"xy=635.721,9720.199,-11.000" Mbesendkeyin"xy=638.675,9708.345,-6.500" MbeSendCommand "ACTIVE COLOR 3" MbeSendCommand "ACTIVE STYLE 0" MbeSendCommand "ACTIVE WEIGHT 6" Mbesendkeyin"xy=623.991,9698.232,-16.100" Mbesendkeyin"xy=616.242,9702.477,-10.500" Mbesendkeyin"xy=608.492,9706.722,-7.000" Mbesendkeyin"xy=603.279,9705.657,-9.000" Mbesendkeyin"xy=598.066,9704.592,-12.000" Mbesendkeyin"xy=597.124,9704.708,-8.000" Mbesendkeyin"xy=596.181,9704.824,-4.100" Mbesendkeyin"xy=592.334,9704.234,-9.500" Mbesendkeyin"xy=586.601,9703.875,-13.300" Mbesendkeyin"xy=585.107,9703.875,-8.000" Mbesendkeyin"xy=583.613,9703.875,-3.500" MbeSendCommand "ACTIVE COLOR 11" MbeSendCommand "ACTIVE STYLE 10" MbeSendCommand "ACTIVE WEIGHT 6" Mbesendkeyin"xy=589.791,9708.046,-9.000" Mbesendkeyin"xy=592.981,9712.216,-13.600" Mbesendkeyin"xy=604.487,9721.383,-7.000" Mbesendkeyin"xy=608.617,9733.221,-10.700" Mbesendkeyin"xy=612.438,9738.495,-14.5000" Mbesendkeyin"xy=616.258,9743.769,-19.000" Mbesendkeyin"xy=617.645,9746.391,-18.000" Mbesendkeyin"xy=621.742,9747.027,-14.000" Mbesendkeyin"xy=620.387,9748.020,-16.000" Mbesendkeyin"xy=619.031,9749.013,-17.000" Mbesendkeyin"xy=619.617,9750.046,-16.500" Mbesendkeyin"xy=617.491,9753.064,-19.000" Mbesendkeyin"xy=619.637,9772.426,-8.000" mbesendreset END SUB	*Requirements to run the main-* *3D seed file (MicroStation Environment)* *Preferable with a specific Projection (case study SAD1956)* *Z value viewer tool (Accurate draw tool)* ………………………………………………………………. *Flexibility: It is possible to modify the symbology of the features and the dimension of the given semi circular values.* ……………………………………………………………… *The feature point is created and associated to shape geographic element via MbeSendCommand "CREATE CENTROIDS " MbeSendCommand "FEATURE ATTACH " and provided that the MbeSendCommand "ACTIVE FEATURE name= Category.featureName.Element type" the database records associated MbeSendCommand MbeSendCommand "ASSOCIATE LINKAGES "*

E	3D Seed file Multiple Features Generator
SUB MAIN Dim startPoint As MbePoint Dim point As MbePoint, point2 As MbePoint MbeSendCommand "ACTIVE COLOR 12" MbeSendCommand "ACTIVE STYLE 0" MbeSendCommand "ACTIVE WEIGHT 0" MbeSendKeyin "place circle radius" MbeSendKeyin "1.2"	

Mbesendcommand "ACTIVE COLOR 2" *Mbesendkeyin"Xy=613.93,9781.45,-0.20" '1* *Mbesendkeyin"Xy=613.93,9781.45,-5.00" '1* *Mbesendkeyin"Xy=613.93,9781.45,-6.00" '1* *Mbesendcommand "ACTIVE COLOR 3"* *Mbesendkeyin"Xy=625.35,9763.40,-0.20" '2* *Mbesendkeyin"Xy=625.35,9763.40,-3.50" '2* *Mbesendkeyin"Xy=625.35,9763.40,-4.90" '2* *Mbesendcommand "ACTIVE COLOR 4"* *Mbesendkeyin"Xy=626.59,9761.01,-0.20" '3* *Mbesendkeyin"Xy=626.59,9761.01,-4.70" '3* *Mbesendcommand "ACTIVE COLOR 5"* *Mbesendkeyin"Xy=628.34,9770.45,-0.20" '4* *Mbesendkeyin"Xy=628.34,9770.45,-1.20" '4* *Mbesendkeyin"Xy=628.34,9770.45,-3.00" '4* *Mbesendcommand "ACTIVE COLOR 6"* *Mbesendkeyin"Xy=624.58,9756.54,-0.20" '5* *Mbesendkeyin"Xy=624.58,9756.54,-5.00" '5* *MBESENDRESET* *Mbesendkeyin "Place Point"* *Mbesendcommand "ACTIVE COLOR 12"* *Mbesendcommand "ACTIVE STYLE 0"* *Mbesendcommand "ACTIVE WEIGHT 0"* *Mbesendcommand "ACTIVE Level 10"* *Mbesendkeyin"Xy=613.93,9781.45,-0.20" '1* *Mbesendkeyin"Xy=613.93,9781.45,-5.00" '1* *Mbesendkeyin"Xy=613.93,9781.45,-6.00" '1* *Mbesendkeyin "Place Line"* *Mbesendkeyin"Xy=613.93,9781.45,-0.20" '1* *Mbesendkeyin"Xy=613.93,9781.45,-5.00" '1* *Mbesendkeyin"Xy=613.93,9781.45,-6.00" '1* *MBESENDRESET* *Mbesendkeyin "Place Point"* *Mbesendcommand "ACTIVE COLOR 3"* *Mbesendkeyin"Xy=625.35,9763.40,-0.20" '2* *Mbesendkeyin"Xy=625.35,9763.40,-3.50" '2* *Mbesendkeyin"Xy=625.35,9763.40,-4.90" '2* *Mbesendkeyin "Place Line"* *Mbesendkeyin"Xy=625.35,9763.40,-0.20" '2* *Mbesendkeyin"Xy=625.35,9763.40,-3.50" '2* *Mbesendkeyin"Xy=625.35,9763.40,-4.90" '2* *MBESENDRESET* *Mbesendkeyin "Place Point"* *Mbesendcommand "ACTIVE COLOR 4"* *Mbesendkeyin"Xy=626.59,9761.01,-0.20" '3* *Mbesendkeyin"Xy=626.59,9761.01,-4.70" '3* *Mbesendkeyin "Place Line"* *Mbesendkeyin"Xy=626.59,9761.01,-0.20" '3* *Mbesendkeyin"Xy=626.59,9761.01,-4.70" '3* *MBESENDRESET* *Mbesendkeyin "Place Point"* *Mbesendcommand "ACTIVE COLOR 5"* *Mbesendkeyin"Xy=628.34,9770.45,-0.20" '4* *Mbesendkeyin"Xy=628.34,9770.45,-1.20" '4* *Mbesendkeyin"Xy=628.34,9770.45,-3.00" '4* *Mbesendkeyin "Place Line"* *Mbesendkeyin"Xy=628.34,9770.45,-0.20" '4* *Mbesendkeyin"Xy=628.34,9770.45,-1.20" '4* *Mbesendkeyin"Xy=628.34,9770.45,-3.00" '4* *MBESENDRESET*	*Purpose: Creates an ellipsoid shape, point of measurements and vertical line feature to indicate the depth variation of measurement point.* *Requirements to run the main* *3D seed file (MicroStation Environment)* *Preferable with a specific Projection (case study SAD1956)* *Z value viewer tool (Accurate draw tool)* ………………………………………………………………………. *A Macro that generates point bounded by user defined radius (zone) of interest and measurement depth in a given unit.* *The different layers are visualized within the same xy coordinates but different vertical zones of information.* *A map is generated within a georeferenced grid map* *The values of the x, y and z are referenced from within the Geodatabase* *The comments characters with the left single quotation mark indicate* *A label of the site of interest.* *Flexibility: It is possible to modify the symbology of the features and the dimension of the given semi circular values.* *The feature point is created and associated to shape geographic element via MbeSendCommand "CREATE CENTROIDS "* *MbeSendCommand "FEATURE ATTACH " and provided that the MbeSendCommand "ACTIVE FEATURE name= Category.featureName.Element type" the database records associated MbeSendCommand MbeSendCommand "ASSOCIATE LINKAGES "*

```
Mbesendkeyin "Place Point"
Mbesendcommand "ACTIVE COLOR 6"
Mbesendkeyin"Xy=624.58,9756.54,-0.20"  '5
Mbesendkeyin"Xy=624.58,9756.54,-5.00"  '5
Mbesendkeyin "Place Line"
Mbesendcommand "ACTIVE COLOR 6"
Mbesendkeyin"Xy=624.58,9756.54,-0.20"  '5
Mbesendkeyin"Xy=624.58,9756.54,-5.00"  '5

MBESENDRESET
Mbesendcommand "ACTIVE COLOR 12"
        Mbesendcommand "ACTIVE STYLE 0"
          Mbesendcommand "ACTIVE WEIGHT 0"
              Mbesendkeyin "Place Circle Radius"
                  Mbesendkeyin "1.2"
Mbesendcommand "ACTIVE COLOR 2"
Mbesendkeyin"Xy=613.93,9781.45,-0.20"  '1
Mbesendkeyin"Xy=613.93,9781.45,-5.00"  '1
Mbesendkeyin"Xy=613.93,9781.45,-6.00"  '1
Mbesendcommand "ACTIVE COLOR 3"
Mbesendkeyin"Xy=625.35,9763.40,-0.20"  '2
Mbesendkeyin"Xy=625.35,9763.40,-3.50"  '2
Mbesendkeyin"Xy=625.35,9763.40,-4.90"  '2
Mbesendcommand "ACTIVE COLOR 4"
Mbesendkeyin"Xy=626.59,9761.01,-0.20"  '3
Mbesendkeyin"Xy=626.59,9761.01,-4.70"  '3
Mbesendcommand "ACTIVE COLOR 5"
Mbesendkeyin"Xy=628.34,9770.45,-0.20"  '4
Mbesendkeyin"Xy=628.34,9770.45,-1.20"  '4
Mbesendkeyin"Xy=628.34,9770.45,-3.00"  '4
Mbesendcommand "ACTIVE COLOR 6"
Mbesendkeyin"Xy=624.58,9756.54,-0.20"  '5
Mbesendkeyin"Xy=624.58,9756.54,-5.00"  '5

MBESENDRESET
end sub
```

Appendix 5: Building Aspatial Interface Embedded Program

Figure 8-8 :
Retrieving by station and Zone

```
Private Sub Combo4_Click()
Dim mysql As String
mysql = "select attributes from attributes"
Dim GISent As String
Combo4.SetFocus
GISent = Combo4.SelText
If GISent = Combo4.SelText Then
Combo4.ControlTipText = [Forms]![form3]![Combo4].SelText
List6.Requery
```

```
End If
If List6.Visible = True Then
List6.ControlTipText = "selected entity's attributes"
List6.ForeColor = vbBlack
END SUB
```

Obj. Name: *cobmo4*
CONTROL TIP: *location*
ROW SOURCE:

```
Select Qentities.Entityname
From Qentities;
Obj.name: Xlist6
ROW SOURCE: SELECT ATTRIbutes.attributes
FROM ATTRIbutes
WHERE (((ATTRIbutes.entityname)=
[forms]![form3]![combo4].[seltext]));
```

Location coordinate driven results based on label object

Obj.Name = lblstation1

Event Procedure:

```
Private Sub lblstation1_Click()
Const strlonlat1 As String = "79:58.68,1:58.65"
Dim mysql As String
cmbstations.SetFocus
cmbstations.Text = "1"
List65.Requery
List69.Requery
lblstation1.ControlTipText = strlonlat1
End Sub
```

name : Cmbstations
Row source :

```
SELECT DISTINCTROW STATION_LOC.station,
STATION_LOC.lon, STATION_LOC.lat
FROM STATION_LOC;
```

Obj name List 65
ROW SOURCE:

```
SELECT DISTINCTROW qrypositionformap.samp_date,
 qrypositionformap.samp_time, qrypositionformap.station
FROM qrypositionformap
WHERE
(((qrypositionformap.station)=[Forms]![Form4]![Combo121].[SelText]
Or
(qrypositionformap.station)=[Forms]![Form4]![cmbstations].[SelText]));
```

Obj name : list 69
Row source

```
Select Distinctrow Qryresultsmap.Parameter, Qryresultsmap.Pract_Value,
Qryresultsmap.Pract_Unit, Qryresultsmap.Station
From Qryresultsmap
Where (((Qryresultsmap.Parameter)="Gravel")
And ((Qryresultsmap.Station)=[Forms]![Form4]![Combo121].[Seltext]))
```

```
 Or (((Qryresultsmap.Parameter)="Sand") And
((Qryresultsmap.Pract_Value)<45) And
((Qryresultsmap.Station)=[Forms]![Form4]![Combo121].[Seltext]))
 Or (((Qryresultsmap.Parameter)="Silt") And
 ((Qryresultsmap.Station)=[Forms]![Form4]![Combo121].[Seltext])) Or
(((Qryresultsmap.Parameter)="Clay") And
((Qryresultsmap.Station)=[Forms]![Form4]![Combo121].[Seltext]))
 Or
(((Qryresultsmap.Station)=[Forms]![Form4]![Cmbstations].[Seltext]));
```

Figure 8-10 : Event cmdClickStation

Purpose of the program: -
Retrieve and display the geodatabase information via clicking a button. Stations, georeferencing parameters, date and results of analyses based on the specified underlying query. It displays in a list-based form

Object Names : Text2, Xlist1, Ylist31

```
Private Sub cmdlocation17_Click () ' event on button
 Text2.SetFocus              'event cursor indicate location present

Text2.Text = "17"            'control (constant) assigned station number
Xlist1.Requery               'list4 is required for station display
YList31. Requery             ''list31 is requeried
End Sub                      'end of this specific operation
```

```
SQL: - list 1: Row source lstposition
     SELECT STATION_LOC.station, STATION_LOC.lon,
     STATION_LOC.lat' from station_loc where
     (((STATION_LOC.station)=
     [Forms]! [TEST]! [Text2]. [Text]));

SQL: - list 2: row source Query 12
     SELECT DISTINCTROW Results.station,
      Results.meas_no, Results.rec_no,
     Results.parameter,
      Results.SI_value,'RESULTS.SI_UNIT
     FROM RESULTS WHERE
      (((Results.station)=[Forms]! [TEST]! [Text2]. [Text]));
```

Figure 8-13: On timer Event Procedure

```
Private Sub Form_Timer()
Graph10.Requery
    If Me!pract_value < 1 * ((0.45)) And Me!parameter = "MERCURY" Then
            Me![lbl].Caption = "safe"
            Me![lbl].ForeColor = Me![pract_value].ForeColor = vbBlue
           Me![pract_value].ForeColor = vbBlue
           Me![Label3].ForeColor = vbBlue
           Me![Label1].ForeColor = Me![Label3].ForeColor
          ElseIf Me.pract_value > 2 * ((0.45)) And Me!parameter = "MERCURY"
   Then
               Me![lbl].Caption = "unsafe"
```

```
Me![lbl].ForeColor = Me![pract_value].ForeColor = vbRed
Me![pract_value].ForeColor = Me![lbl].ForeColor
ElseIf Me.pract_value > 3 * ((0.45)) And Me!parameter = "MERCURY" Then
Me![lbl].Caption = "dangerous"
Me![lbl].ForeColor = Me![pract_value].ForeColor = vbBlack
Me![pract_value].ForeColor = Me![lbl].ForeColor
Else: Me![Graph10].BorderColor = vbBlue
End If
If Me!pract_value < 1 * ((0.95)) And Me!parameter = "CADMIUM" Then
Me![pract_value].ForeColor = vbBlack
Me![lbl].ForeColor = Me![pract_value].ForeColor = vbBlack
Me![lbl].Caption = "safe"
ElseIf Me.pract_value > 2 * ((0.95)) And Me!parameter = "CADMIUM" Then
Me![pract_value].ForeColor = vbBlue
Me![lbl].ForeColor = Me![pract_value].ForeColor = vbBlue
Me![lbl].Caption = "unsafe"
ElseIf Me.pract_value > 3 * ((0.95)) And Me!parameter = "CADMIUM" Then
Me![pract_value].ForeColor = vbRed
Me![lbl].Caption = "dangerous"
Me![lbl].ForeColor = Me![pract_value].ForeColor = vbRed
Else: Me![Graph10].BorderColor = vbRed
End If
If Me!pract_value < 1 * ((8.4)) And Me!parameter = "LEAD" Then
Me![pract_value].ForeColor = vbBlack
Me![lbl].Caption = "safe"
ElseIf Me.pract_value > 2 * ((8.4)) And Me!parameter = "LEAD" Then
Me![pract_value].ForeColor = vbBlue
Me![lbl].Caption = "unsafe"
ElseIf Me.pract_value > 3 * ((8.4)) And Me!parameter = "LEAD" Then
Me![pract_value].ForeColor = vbRed
Me![lbl].Caption = "dangerous"
Else: Me![Graph10].BorderColor = vbRed
End If
If Me!pract_value < 1 * ((10.7)) And Me!parameter = "COPPER" Then
Me![pract_value].ForeColor = vbBlack
Me![lbl].Caption = "safe"
ElseIf Me.pract_value > 2 * ((10.7)) And Me!parameter = "COPPER" Then
Me![pract_value].ForeColor = vbBlue
Me![lbl].Caption = "unsafe"
ElseIf Me.pract_value > 3 * ((10.7)) And Me!parameter = "COPPER" Then
Me![pract_value].ForeColor = vbRed
Me![lbl].Caption = "dangerous"
Else: Me![Graph10].BorderColor = vbRed
End If

If Me!pract_value < 1 * ((7.96)) And Me!parameter = "ZINC" Then
Me![pract_value].ForeColor = vbBlack
Me![lbl].Caption = "safe"
ElseIf Me.pract_value > 2 * ((7.96)) And Me!parameter = "ZINC" Then
Me![pract_value].ForeColor = vbBlue
Me![lbl].Caption = "unsafe
ElseIf Me.pract_value > 3 * ((7.96)) And Me!parameter = "ZINC" Then
Me![pract_value].ForeColor = vbRed
Me![lbl].Caption = "dangerous"
```

```
Else: Me![Graph10].BorderColor = vbRed
End If

If Me!pract_value < 1 * ((8.7)) And Me!parameter = "CHROMIUM" Then
    Me![pract_value].ForeColor = vbBlack
    Me![lbl].Caption = "safe"
ElseIf Me.pract_value > 2 * ((8.7)) And Me!parameter = "CHROMIUM" Then
    Me![pract_value].ForeColor = vbBlue
    Me![lbl].Caption = "unsafe"
ElseIf Me.pract_value > 3 * ((8.7)) And Me!parameter = "CHROMIUM" Then
    Me![pract_value].ForeColor = vbRed
    Me![lbl].Caption = "dangerous"
    Else: Me![Graph10].BorderColor = vbRed
End If

On Error GoTo Err_Command116_Click
    DoCmd.GoToRecord , , acNext
Exit_Command116_Click:
Exit Sub

Err_Command116_Click:
    MsgBox Err.Description

    Resume Exit_Command116_Click
    DoCmd.DoMenuItem acFormBar, acEditMenu, acUndo, ,
    acMenuVer70
End Sub
```

Row source

```
Transform Max(Subquery1.Pract_Value) As Maxofpract_Value
Select Subquery1.Parameterfrom Subquery1
Where (((Subquery1.Discipline_Name)="Heavy_Metal"))
Group By Subquery1.Parameter
Pivot Subquery1.Station;
Link Child Field = Station
Link Parent Field  = Station
Obj.Name:  Graph 10
Time Interval : 3000
Has A Module : True
```

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