Thai Digital Chart Production
and
Quality Control

By

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Abstract

Thai **H**ydrographic **D**epartment (Thai HD), founded in 1919 and under control of the **R**oyal **T**hai **N**avy (RTN), is a Thai governmental organisation whose primary mission is the provision of nautical charts, hydrographic, oceanographic and other related products and service to the RTN and private sectors concerned with maritime activities. It has traditionally produced its charts using manual production methods since it was founded. Chart production using traditional techniques is time-consuming, labour-intensive and error prone work.

Due to the efficiency and usefulness of the digital chart production being implemented in a number of national **H**ydrographic **O**ffices (HOs) worldwide, Thai HD has realised the potential of such capability. Furthermore, common agreements by the **I**nternational **H**ydrographic **O**rganisation (IHO) request that member governments have their national hydrographic office produce digital chart data and the associated updating service as soon as possible and ensure the quality of such data which will be exchanged between HOs.

Responding to these pressures, Thai HD, as a governmental charting agency and a IHO member, has recently started planning to move from manual chart production to digital production. It is expected that the new digital production will fulfil its requirements by reducing time and cost of the production and by providing more accurate and better quality charts and information related to them. Introducing such a digital production system is likely to cause organisational, legal and financial problems as well as technical ones. These should be investigated, studied and fully understood at the early stage of development. This thesis forms one of these investigations.

This thesis presents the initial move of Thai HD from the traditional chart production to the digital production. It proposes the possible digital chart production flowline to produce digital chart data, quality control procedures and quality assessment procedures to control and assure the quality of such digital chart data. These have been initially tested and proved workable. It is hoped that in a new production flow, such quality control and quality assessment procedures will be accepted and implemented within Thai HD allowing it to fulfil its requirements in the future.

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Chapter 1
Introduction

1.1 Introduction to Digital Chart Production

Nautical Chart Production is normally a responsibility of national **H**ydrographic **O**ffices (HOs). Chart production by a governmental organisation is seen as a form of guarantee of certification to permit the safe and efficient conduct of marine transportation. The production of charts provides the government with direct support to control and regulate marine transportation safety.

Chart production using traditional techniques is a time consuming, labour intensive and error prone task. Generally, a cartographer will select information from various hydrographic and topographic sources for portrayal on a chart. This information is gathered on a series of overlays which are then mosaiced to fit a final scale, projection, and datum, forming a compilation manuscript. Such a manuscript is then symbolised through scribing or drafting operations *(Strewing, Ruys and Schnier, 1983).*

The development of computer technology and its application have had a profound effect on chart production. The computer and its peripheral devices have been used to replicate traditional manual procedures, resulting in the new term *"Digital Chart Production"*. A lot of new terminologies were also introduced in cartography with the advent of the digital world and implemented in the production of nautical charts. Words like "scanner", "digitizer", "raster/vector", "plotter", "topology", and "database" are now recognised worldwide where charts are produced using computer systems in accordance with the international standards created by the **I**nternational **H**ydrographic **O**rganisation (IHO).

Utilising digital chart production many of the tedious and tiring tasks performed in traditional production (e.g. drafting, scribing, sticking up, negative engraving, and photographic processing) are either eliminated or greatly reduced in time and errors. Compilation detail is converted into machine readable form using digitising techniques and stored in a cartographic database. By maintaining such data in the database, reprints and new editions of these charts can easily be produced. In addition, the accuracy and quality of the resulting chart is equal to or better than those compiled traditionally provided the necessary care is taken. In the information age there will be a requirement for chart data to be made available in a digital form and it is incumbent upon the HOs to start planing for this eventuality now.

Thai **H**ydrographic **D**epartment (Thai HD), founded in 1919 and under control of **R**oyal Thai **N**avy (RTN), is a Thai governmental organisation whose primary mission is the provision of nautical charts, hydrographic, oceanographic and other related products and services to the RTN and private sectors concerned with maritime activities. It has traditionally produced its charts using manual production methods since it was founded. Due to the efficiency and usefulness of digital chart production being implemented in a number of national HOs worldwide, Thai HD has realised the potential capability and recently started planning to move from manual production to digital production. Introducing such a digital production system is likely to cause organisational, legal and financial problems as well as technical ones. These should be investigated, studied and fully understood at the early stage of development. This project forms one of these investigations.

1.2 The Aims of the Project

Digital chart production and awareness of data quality are the new matters for Thai HD. The first aim of this project is to study what is called "digital chart production" and to create a possible flowline for use by Thai HD. When moving from manual production to digital, the first task needing to be done is to convert chart data from the existing paper charts into the digital form which will be stored in the cartographic database. This project will primary concentrate on this stage. CARIS (**C**omputer **A**ided **R**esource **I**nformation **S**ystem), a GIS widely applied to the production of navigational charts in both paper and electronic forms, will be used to develop and evaluate procedures. A small area extracted from Thai Chart no.142 will be used as a sample chart and converted into digital form using *SAMI* (Semi **A**utomated **M**apping **I**nput) which is an on-screen digitising program available in CARIS. During the data conversion, trial methods and materials seen to be useful in order to facilitate production and control the quality of data will also be created, such as the data validation flowline, a data validation check form, a building topology flowline, the data quality specification of the digital chart, a digitising specification, and etc.

The second aim of this project is to study data quality issues and propose "quality assessment procedures" to assess the quality of the digital data initially converted by digitisation. The largest potential errors in digital map processing occurred during digitisation *(Chrisman, 1982).* Errors within cartographic data can limit the efficiency of digital chart production. It is prudent that the digital chart data captured from digitisation should be checked and its quality assessed before it will be stored in the cartographic database. In order to control and document the quality of data, quality assessment procedures and a quality assessment check form will be developed.

The third aim of this project is to evaluate the capability and efficiency of the CARIS system in digital chart production. It is one of a number of systems in which Thai HD is interested in. The experiences and familiarity gained by the author will provide useful information to Thai HD in order to evaluate the efficiency of not only CARIS but also other similar systems available worldwide.

1.3 Outline of the Thesis

This thesis outlines the initial moves within the Thai HD from manual chart production to digital production and the possible route to find the solutions which must be taken before digital chart data can be used for navigation at sea in both the current paper chart and the electronic one in the future. It comprises seven chapters. The first three chapters will introduce the project, nautical charts, the Thai HD and its traditional chart production. The last four chapters are concerned with digital chart production, quality assessment procedures and conclusion to the project.

Chapter Two presents the evolution of nautical charts and various factors (e.g. changes in shipping and technology) which have affected their production from the past until the present time. The international standardisation (International **H**ydrographic **O**ffice, IHO) and general characteristics of nautical charts will then be discussed. The definition, standardisation and progress of the **E**lectronic **N**avigational **C**hart (ENC) will be introduced at the end of this chapter.

Chapter Three gives a brief overview of Thai Hydrographic Department (Thai HD) and points to the specific aspect of Thai charts which are slightly different from international charts as specifieded by the IHO. The traditional Thai chart production and quality control procedures currently used in Thai HD to produce and control the quality of its paper charts will also be discussed. This chapter will end with the reasons why Thai HD has to move from manual production to digital production and why the quality assessment procedures for digital data are required.

Chapter Four will introduce CARIS, a GIS system used in this project as a reference software, its components, tools and programs available for the production of the digital charts. The basic mapping information available in CARIS (e.g. map projections, ellipsoids, coordinate systems and etc.) will be reviewed.

Chapter Five will concentrate on the detailed description of the proposed digital chart production flowline with CARIS. The procedures to create the digital chart data (e.g. data conversion, data editing, topology building) and to control its quality (e.g data validation, digital chart data specification, digitising specification) will be described respectively in the order of stages of work done in the pilot project.

Chapter Six will discuss the concept of data quality and its usefulness accepted by the National Institute of Standard and Technology (NIST). The five elements of data quality will be explained briefly. This chapter will then deal specifically with the quality assessment procedures created by the author and end with the results and analysis of such procedures.

Chapter Seven will propose the future developments that need to be done by Thai HD when moving from manual production to the digital one and the thesis will be summarised with the conclusion reached as a result of the study and project.

Chapter 2
The Nautical Charts

2.1 Introduction

Throughout history, the sea has been the most used long distance means of communication, travel and trade. Using a chart to plan and follow a route is one of the oldest and most important of chart functions. A Deutsches Hydrographisches Institut (DHI) working group gives the definition of chart as follows;

> "A chart is indispensable as a medium of information and as a tool for maritime traffic. It must contain all data required for both position fixing and route finding, as well as for avoidance of dangers and for the safety and ease of navigation. Information which cannot be shown on charts must be given in other nautical publications".

The term *"Chart"* has been reserved traditionally for maps used to find directions at sea and it is now similarly extended to route finding with aircraft. Presently, there are two kinds of charts appearing worldwide, the nautical chart for marine navigation and the aeronautical chart for air navigation. In the particular case of travelling by water, three requirements dominate: the need to find position at sea; the need to plan and follow the desired course; and the need to avoid danger *(Keates, 1989).* Lack of nautical charts, the most fundamental of navigation instruments, could cause dangerous navigation in unknown waters. The nautical chart is essentially a work sheet on which intended courses may be plotted, clearing lines for dangers drawn in, bearings laid off and positions established. It is not just the marine counterpart of a topographic map and is far more than a representation of physical features, seen and unseen. It is well known that the mariner has a duty nowadays with regards to nautical publications which is defined in the Safety of Life at Sea (SOLAS) Convention 1974 as follows:

> "All ships shall carry adequate and up to date charts, sailing directions, lists of lights, notices to mariners, tide tables, and all other nautical publications for the intended voyage".

This should not be any surprise as the nautical chart has a long and honourable history as the prime aid to navigation to be found on the bridge *(Maybourn, 1982).*

The compilation of a nautical chart from source information is a highly specialized job, and the result is considered to be a legal document *(Opstal, 1988).* The surveyor, engaged in a hydrographic survey, should always keep in mind that the end product based on the results of his work is intended to further the cause of safety of navigation. Charts differ from maps in that they often have to be consulted under dimmed lights and in uncomfortable circumstances. At the same time the ideal specimen shows the required information at a glance, not hidden amongst a clutter of relatively unimportant data. The hydrographic surveyor, therefore, should have a clear insight into all problems of modern navigation and should realize that the navigator makes a completely different use of a small scale chart compared to the way in which a large scale coastal or port approach chart is handled on the bridge *(Langeraar, 1984).*

Nautical charts had for many centuries a fluid relationship with topographic maps. For the modern chart, the depiction of geographical features, such as coasts, islands, estuaries, is not an end in itself, but is used as a framework for further navigational information. The contemporary chart embodies this data in a language of its own which must be mastered if the chart is to be of use. This was not always so, and many charts from the fifteenth to the nineteenth century were really dual purpose maps, showing land features too. The historical reason for this is clear. The sea charts were often the only map available for many parts of the world, especially islands, and the chart maker was fulfilling a dual role by mapping the interiors. The modern nautical chart carries so much coded data that it is perhaps closer to a technical diagram than a topographic map, and it is increasingly just one part of a technical system of navigation. The charts of the past were closer to the general map. They were more readily understood, and they served as direct geographical pictures of the coasts and islands of the world *(Whitefield, 1996).*

In summary, the nautical chart, both in the past and the present, is the mariner's road map. Effective use of a chart helps the mariners identify the best route to a destination and prevents accidents.

2.2 Evolution of the Nautical Charts

"In the year 1270, the French King Louis IX, Saint Louis, was sailing for Tunis on his last, ill-fated crusade, when a storm arose. To re-assure the king of the ship's position, the captain produced a map, and they decided to make for harbour in Sardinia" *(Whitefield, 1996).* This is the first recorded use of a chart on board a ship. Early in the following century, maritime ordinances in Spain and Italy were including a requirement for all ships to carry charts on board, and inventories from ships prove that this practice became standard *(Whitefield, 1996).* The development of charts has been greatly affected by changes in navigational techniques. For example, the Portolan charts, with their criss-crossing loxodromes (figure 2.1), developed from a need to illustrate the pilot books, called *"Portolans"* by the Italians. On these were carefully recorded bearings and distances between points of departure and arrival. As the measurement of latitude became established, the graduation of latitude began to appear on charts early in the sixteenth century. In 1569, Gerardus Mercator published his famous world map, although the general use of this projection did not take place until much later. Charts of sixteenth century showed considerable detail. The 17th century surveys of Mackenzie were of particular significance as they were based on accurate land triangulations and as a result the charts themselves were notably accurate. Numerous depths figures were shown as were the drying banks. The art of drawing a decorative title had reach its peak and drawings of ships covered any free space *(Kerr and Anderson, 1982).*

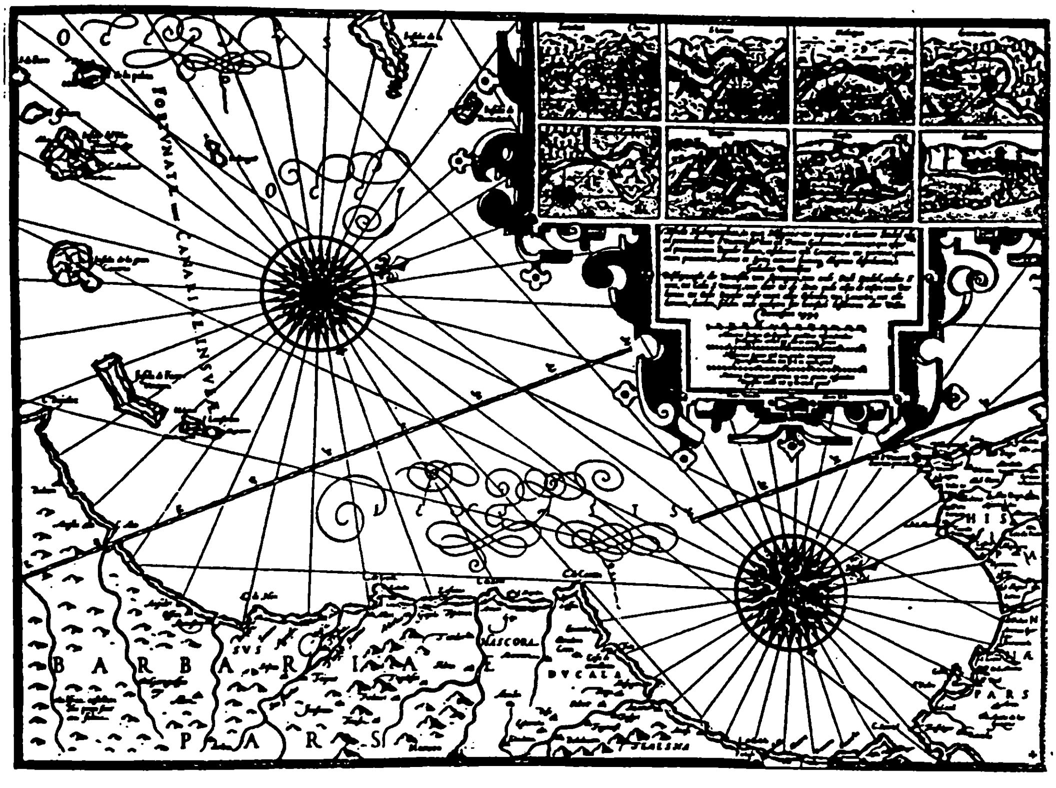


Figure 2.1 A portion extracted from a Portolan Chart in 1594 ***(Monmonier and Schnell, 1988).***

Changes in Shipping: The evolution of the chart from its early development in the thirteenth century to the middle of the nineteenth century was not significant as changes in the types and styles of shipping were also not siginificant. Ships were still powered by sail but the ships showed a slow growth in size. The latter part of the nineteenth century and the early part of the twentieth showed a remarkable change in both ship design and navigation technology. Iron replaced wood for the construction of ships in the period 1850 to 1880. The eventual end of sailing was evident by 1914 *(Kerr and Anderson, 1982).* The introduction of iron and later steel for ship construction coupled with steam and later diesel propulsion throughout the earlier part of this century resulted in a steady growth in both merchant vessel and warship size and speed. The change of ship speed was more important by 1943. It was during this period that the forerunners of the ships that had great impact on hydrographers came into being. Furthermore, the submarine first appeared about 1850 and the first oil tanker was constructed in 1886. The period since 1950 was the most remarkable in term of changes in ship design. Apart from the obvious increase in overall size, it was the huge increase in draught that caused the hydrographers concern. Whereas for most purposes the 10 fathom or 20 meter contour line had served as a danger line on charts, this was no longer sufficient with ships drawing close to 30 meters. In the military area the submarine had become supreme. The first nuclear submarine was launched in 1954 and since then submarines have increased in size and complexity. Their need for precise navigation has had considerable effect on hydrography, especially in the development of omega, transit and Global Positioning System (GPS) navigation systems. Their need for details of topography and the properties of the seafloor has had an significant effect on the hydrographic offices of the major sea powers. These historical developments of shipping show the developing complexity both of shipping and the charts which serve its needs.

Changes in Technology: Nautical charts have been affected by technological advances in two ways. Advances in navigational technology, such as radar and electronic positioning, have placed requirements for additional information on the charts, while advances in survey technology have resulted in the ability to collect far more data to be processed and displayed than in earlier years.

Advances in navigational technology: Radio direction finding and radar were developed before the Second World War. In the early fifties, the special charts used for radar were constructed. The development of electronic positioning systems has had considerable impact on chart design. Loran A, Consol and Decca Navigator were all developed during the war years followed by Loran C and Omega later. All these systems required the availability of lattice charts for ease of use. Finally, the use of satellite navigation systems in recent years is causing the navigator to question the positioning of the coastline in poorly charted parts of the world.

Advances in survey technology and cartography: The substantial impact of survey technology on chart content began with the introduction of the echo sounder which made considerably more data available than could be shown on the chart. For example, in a typical leadline surveying, 150 depth soundings would be collected and recorded on the field manuscript. Most of these soundings would be shown on the chart. With an echo sounder used in surveying, over 30,000 soundings could be recorded on the echo sounder graph. From this large data source less than 1000 soundings would be selected for processing, then a further reduction of data would be made to be shown on the manuscript *(Kerr and Anderson, 1982).* More recently, the swath sounding systems, both sonar and airborne laser systems, have the potential to collect vast amounts of digital data, and the processing of these data represents a great challenge because new procedures for processing and presentation will need to be developed. Various forms of automatic contouring have been tried, and, for processing acoustic sweep data, records have been produced using different grey tones to indicate depth bands. Electronic positioning systems for surveying developed from the navigation systems are now available with a range from precise short-range systems to less precise longer-range systems. The result has been that surveys can now be done in any weather and in some cases during day and night. Once again, the amounts of data are increased *(Kerr and Anderson, 1982).*

Automatic data collection systems are today used extensively in hydrographic surveys. Their ability to provide instantaneous correlation between position, time and depth measurement has permitted the use of faster data gathering vessels. Data processing in the field can now be more rapid, leading to overall greater efficiency. However, in cartographic offices, the high expectations of fully automated cartography in the early seventies have been replaced with the more realistic computer assisted cartography of today

2.3 International Standardisation of Nautical Charts

The production of nautical charts is mostly the responsibility of national **H**ydrographic **O**ffices (HOs), which may be either defence or civilian agencies of the government. Most countries produce charts of their own waters in the full range of scales. These national charts tend to make the fullest possible use of available hydrographic surveys, giving full cover of the national waters including the smallest ports used by the country's own coastal vessels, and by other local categories of user, such as yachtsmen and fishermen *(Newson,1983).* Other countries, with an extensive interest in maritime trade, produce chart series covering most shipping areas. Because of the degree of similarity of requirements, it often occurs that the same areas are charted by different countries at much the same scale.

Furthermore, many HOs have their own chart specifications. Different countries use markedly different paper sizes and have printing machines to suit. Language differences appear in the all important descriptions of the characteristics of navigational lights and in the quasi-legal textual notes which are very significant on nautical charts. Different series place a different emphasis on pictorialism in the symbols used and in the symbol size. Additionally, because hydrographic data changes rapidly, it is difficult to keep up to date with such changes as far as the published chart is concerned.

These differences lead to attempts to decrease the amount of duplication, to improve the interchange of chart products and to secure uniformity of charts. These have depended on reaching international agreements in relation to chart design and specification *(Keates, 1989).*

The International **H**ydrographic **O**rganization (IHO), formerly the International Hydrographic Bureau 1921-1970, is an intergovernmental consultative and technical organization working to support the safety of navigation and the protection of the marine environment. It is one of the organisations that could attempt the above mentioned international co-operation. The IHO has its headquarters in Monaco, and its membership has grown to about 62 nations including Thailand. From the outset, one of the prime objectives of the IHO was to increase the extent of standardisation in the navigational documents used by the world's shipping. Considerable progress has been made in achieving the free exchange of hydrographic data, the standardisation of symbology and the creation of an international (INT) chart series. The concept of the INT chart is that of a worldwide chart series produced to a single set of agreed specifications, with one nation producing a chart and all other nations wishing to cover the same area printing their charts from reproducibles furnished by the producer nations *(IHO, 1970).*

The work of international standaradisation by IHO began in 1967, when the 9th IHO Conference set up a six-nation Commission to obtain an agreed specification for a series of small scale international charts, with a view to sharing production among a number of hydrographic offices on a regional basis. Two separate world-wide schemes were agreed, consisting of 79 sheets altogether, sixty of them at a scale of 1:3,500,000 and the rest at 1:10,000,000 scale *(Newson, 1978),* and they were all published by 1987 *(Bunyon, 1991).* Thirteen IHO member countries currently include them as a part of their own series. Their content was quite simple, in line with their intended use for route planning or deep water navigation. The sharing of productive effort between HOs was popular and the specification was fairly easy to agree. But with the medium and large scale charts the situation is rather different.

In 1972, the IHO conference set up a new group forming the ten nation **N**orth **S**ea **I**nternational **C**hart **C**ommission (NSICC, 1972-1977) in order to investigate the application of the international chart concept to medium and large scales through a study of the north-east Atlantic area. These scales form a great bulk of charts in the various national series. They carry vastly more detail than small scale charts, much of it in national languages, and the trickiest navigation is done with their aid *(Newson, 1978).*

Resulting from these, a consistent scheme of sheetlines for the whole study area and a single comprehensive set of specification were seen to be required. By 1977, the work of NSICC on chart specifications had progressed well. Since then the international charts with INT numbers also form parts of national series. The IHO realised that the detailed specifications must logically also be applied throughout the national series. The NSICC was therefore replaced by the **C**hart **S**pecification **C**ommittee (CSC, 1977-1982) consisting of seventeen nations drawn from all continents. Its task was to expand the specification to be applied world-wide and to keep the master standardisation document up to date as changes of user requirements arose. In 1982, the official *"IHO*

Chart Specification" was formally adopted for worldwide use in all nautical chart compilation, as far as national requirements and practices permit.

Most member states are now producing their charts in conformity with these specifications. The IHO also agreed on the constitution of an international set of charts in their regions. There are agreements for the exchange of reproduction material between member states *(Opstal, 1988)*. By the end of 1990, 192 charts were produced in the medium and large scale, between 1:15,000 and 1:150,000, for the INT series, mostly lying in European waters. The world will ultimately be covered by an internationally conceived homogeneous series of 3000-4000 sheets, of managable size and on adequate scale, to suit the needs of international shipping and to be accepted without question in all parts of the globe *(Newson, 1978)*.

2.4 The General Characteristics of Nautical Charts

2.4.1 Chart Classification

The scale of a nautical chart is generally defined by the type of navigation for which the chart is intended, the nature of the area to be covered and the quantity of information to be shown. Nautical Charts are divided into different types on the basis of their principal functions, rather than their scale. Different countries have their own chart classifications which are normally based on their uses for a particular phase of navigation. Therefore, charts can be broadly classified into four main categories as follows; *(Keates, 1989)*

1) **Planning Charts** are used for general route planning and as they need to deal with oceans and seas, the scales are small, usually 1:5,000,000.
2) **Sailing Charts** are used by the navigator to plot courses in the open seas and are usually at scales of 1:500,000 and smaller.
3) **Coastal Charts** are used on approaching land and navigating in areas that contain submarine dangers, range from about 1:50,000 to 1:300,000.
4) **Harbour Charts** are at the largest scale, from about 1:10,000 to 1:25,000.

The INT Chart Specification of the IHO 1990 defines a slightly different chart classification which also links mostly to the use of the chart rather the chart scale as follows;

1) **Medium Scale:** used for passage or landfall should range from 1:1,500,000 to 1:750,000; used for coasting should range from 1:500,000 to1:150,000.
2) **Large Scale:** used for port approach, intricate or congested coastal waters should range from 1:150,000 to1:50,000; used for harbour, anchorage, narrow straits should range from 1:50,000 and larger.

2.4.2 Chart Fomat

Unlike many topographic map series which divide the entire map area into a series of regular sheets, chart schemes are apparently unsystematic in the layout of the sheet lines, as shown in figure 2.2.

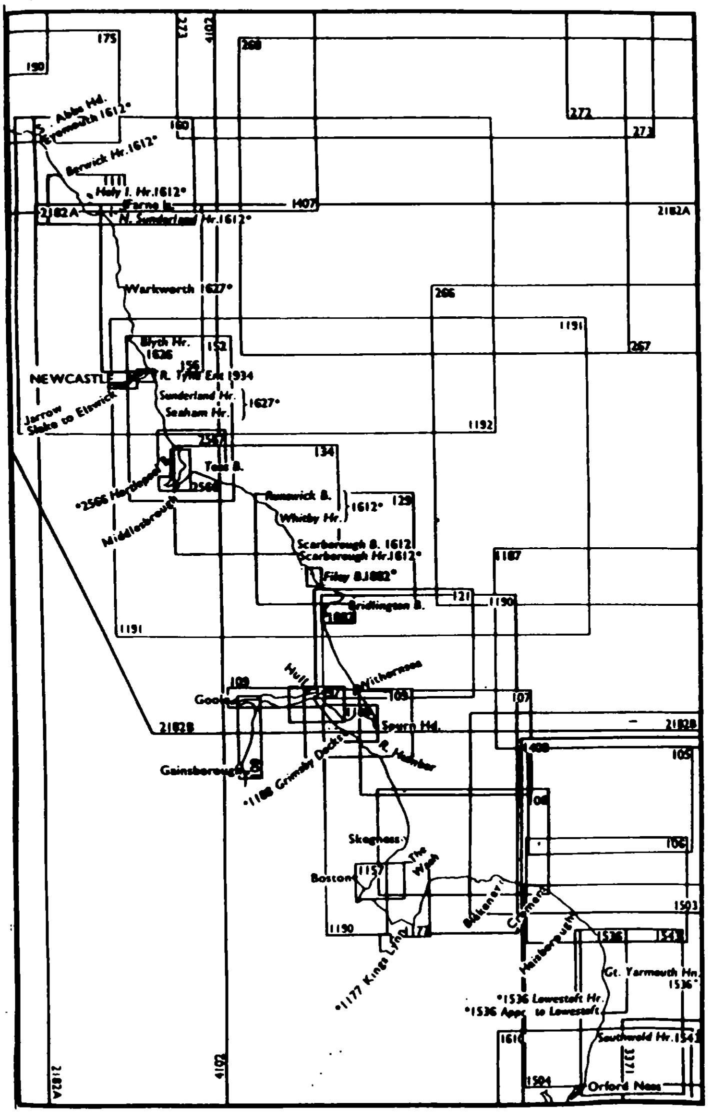


Figure 2.2 Chart Scheme of British Chart cover of eastern England 1982 ***(Newson, 1983).***

The chart users, mostly the mariners, are not interested in the exact scale of the chart because distances are measured using the latitude scale. What they require are all details for their particular phase of the journey to be shown clearly on the one chart. Both scale and size can be modified so that chart covers the area required. The chart series for coastal navigation along a particular coastline and small scale oceanic charting are frequently produced at a fixed scale, but even here the need to represent complete areas means that chart formats vary *(Keates, 1989).*

It is recommended in the IHO Specification 1990 that A0 (1189 X 841 mm.) should be the maximum paper size used for nautical charts. The neatline dimensions should ideally be either 1100 X 750 mm. or 980/1100 X 650 mm., subject to the minor variations required to locate chart neatlines on exact graduation sub-divisions.

2.4.3 Chart Projection

The nautical chart is a most significant aid to navigation on which intended routes are planned. It is the base upon which the graphical work of navigation (route planning, positioning fixing) is done. The choice of projection has, therefore, a particular importance. Since angular measurement is an important feature of dead-reckoning navigation, the use of conformal projections in navigation charts is obligatory *(Maling, 1973).* The two most commonly used conformal projections are Mercator projection and Lambert Conformal Conical projection. Additionally one projection which is not conformal, but has great significance to navigation is the Gnomonic projection. The INT Chart Specification of IHO 1990 gives the following logic for the choice of a suitable chart projection:

"A projection can generally be regarded as suitable for large scale if the chart will be identical within fractions of a millimeter to the chart that might have been drawn on any other survey projection, and any suitable grid will plot as a system of practically straight lines on the chart. This will be the case when the projection meets the conditions that its rectangular grid is a function of the earth's graticule and that it has its central meridian, standard parallel, or point of origin within a few hundred kilometers of the area charted.

Chart of scale 1:50,000 and larger may be drawn on any suitable projection, taking into account the possible advantages of using the survey projection or that used by the national mapping authorities. In latitude approaching 75° the limiting scale should possibly be larger than 1:50,000. Charts of scale smaller than 1:50,000 shall be drawn on the Mercator projection. Exceptions to this rule may be necessary in high latitudes".

2.4.4 Chart Datum

The information related to the third dimension is significantly vital to navigation. It primarily involves the soundings (depth values) and heights of objects appearing on charts such as light houses, peaks of mountains, conspicuous objects, etc. The plane which is used as a reference plane for depth values and heights should be well defined. According to IHO Chart Specification 1990, two planes are defined for measurements of the vertical distances: the Chart Datum and the Plane of Height reference.

Chart Datum is the plane of the reference to which all charted depths and drying heights (areas which are above water at low tide but under water at high tide) are related. The IHO characterised that plane as *"a plane so low that the tide will not frequently fall below it"*. It will vary from place to place in relation to the land survey datum or **Mean Sea Level** (MSL).

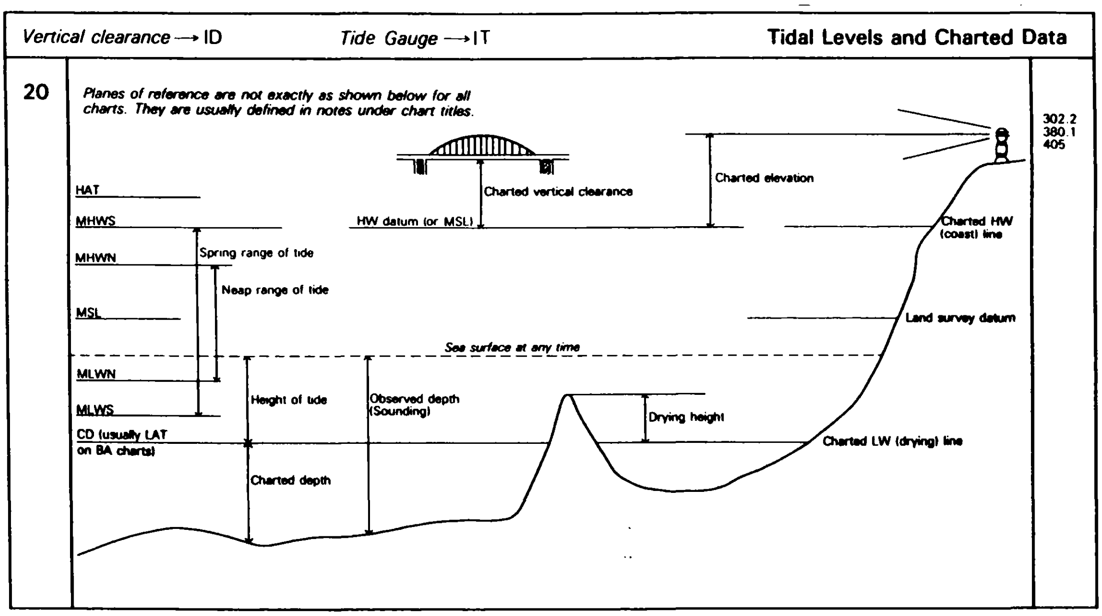


Figure 2.3 Different Plane of Reference ***(British Admiralty Chart 5011,1991).***

Normal practice is to make the chart datum equivalent to a low water level, so that the navigator finds the actual depth of water in a coastal region by adding the appropriate figure from the tide tables to the depth shown on chart *(Keates, 1989)*. As, shown in figure 2.3, the chief alternatives are between different versions of low water such as: mean low water, lowest low water if there is a double tidal range; the lowest observed, lowest possible low water; and lowest astronomical tide (based on tidal predictions). Lowest Astronomical Tide has now been adopted for all charts of British coasts. It avoids the inclusion of very unusual tidal levels, which arise under freak conditions and which can affect the lowest possible or lowest recorded tide *(Keates, 1989)*. It does not matter what chart datum will be implemented on the chart. What matters is that it should be the same datum as adopted for the prediction given in the authoritative tide tables. Thailand's chart datum is discussed in Chapter 3.

The Plane of Height Reference is defined for the measurements of all heights, except drying heights. Mean Sea Level (MSL) is normally used where there is little appreciable tide at the adjacent shoreline. It is, elsewhere, recommended that a High Water datum should be used. The connection between chart datum and land survey should not be quoted on charts, but instead, should be readily available for the use of surveyors and engineers in national tide tables *(Stefanakis, 1993)*. The chart users are recommended to read the information related to chart datum and plane of height reference used on the chart. These are normally included in the explanatory notes close to the chart title (figure 2.4).


INTERNATIONAL

CHART SERIES

BRITISH ISLES

SCOTLAND
WEST COAST

DEPTHS IN METRES

SCALE 1:500 000 at lat 55°00′

Depths are in metres and are reduced to Chart Datum, which is approximately the level of Lowest Astronomical Tide.

Heights are in metres. Underlined figures are drying heights above Chart Datum; all other heights are above Mean High Water Springs.

Positions are referred to Ordnance Survey of Great Britain (1936) Datum.

Navigational marks: IALA Maritime Buoyage System— Region A (Red to port).

Projection: Mercator.

Sources: The hydrography is derived from larger scale charts with the outer soundings being largely from lines of passage soundings.

Figure 2.4 Chart Title extracted from British Admiralty Chart 2635.

2.5 Electronic Charts

The mariners have traditionally used paper nautical charts for their maritime navigation until the present time. In the current digital age, everything is changing from conventional form into digital including the nautical chart. The representation of charts is presently moving from the tradition paper charts into a new modern form called *"Electronic Chart"*. It is a new navigation aid which is capable of providing significant benefits and safety to marine navigation and commerce. It is in reality simply the output end of an integrated navigation system which brings together different navigation sensors, in particular, the combination of radar imagery, with the digitised chart data. The idea of integrating chart and radar data goes back to the 1950s but at that time the technology had not reached a state by which digital data could be handled easily *(Kerr and Anderson, 1987)*.

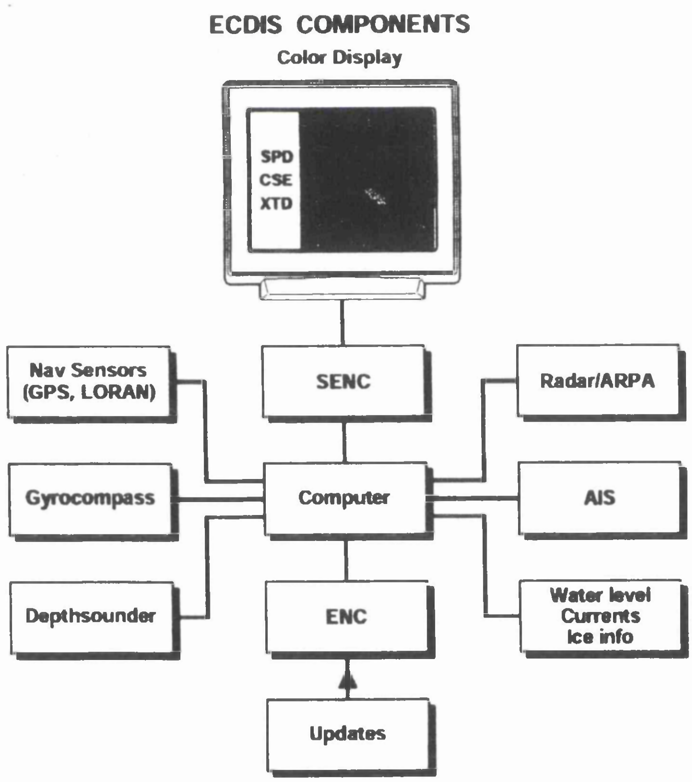


Figure 2.5 ECDIS Components ***(Alexander, 1998a).***

2.5.1 The Definition of Electronic Charts

When discussing the electronic chart, there are many terms which may initially appear to be confusing. Terms like ENC, ECDIS, SENC, ECS, and RCDS are presently used in marine community world-wide. This section will briefly indicate the meaning of these terms as defined in the International Maritime Organisation (IMO) Performance Standards for Electronic Chart Display Information System (ECDIS) as follows:

Electronic Chart Display Information System (ECDIS) means a navigation information system which, with adequate backup arrangements, can be accepted as complying with up to date chart requirement by regulation V/20 of the 1974 SOLAS Conventions, by displaying selected information from a System Electronic Navigational Chart (SENC) with positional information from navigation sensors to assist the mariner in route planning and route monitoring, and by displaying additional navigation related information if required.

Electronic Navigational Chart (ENC) means the database, standardised as to content, structure and format, issued for use with ECDIS on the authority of government authorised hydrographic offices. The ENC contains all the chart information in addition to that contained in the paper chart (e.g. sailing directions) which may be considered necessary for safe navigation.

As shown in figure 2.5, an ENC is one of the essential components of an ECDIS which has to use ENC data. It is not the ENC that is displayed but , instead, the System ENC (SENC) *(Alexander, 1998a).*

System Electronic Navigational Chart (SENC) refers to the database resulting from the transformation of the ENC by ECDIS, updates to the ENC by appropriate means, and other data added by the mariner. It is this database that is actually accessed by ECDIS for the display generation and other navigational functions, and it is the equivalent of an up to date paper chart. The SENC may also contain information from other sources.

As indicated in figure 2.5, What is actually displayed is SENC, not the ENC. Having only the ENC is not enough. It must be kept up to date for the intended voyage and then converted to an SENC *(Alexander, 1998a).*

Electronic Chart System (ECS) can be considered to be any other type of electronic chart that does not comply with the IMO Performance Standard for ECDIS. This general category can be further sub-divided into electronic charts that use either raster or vector data. Unlike an IMO-compliant ECDIS, an ECS is not intended to comply with the up to date chart requirement of V/20 of SOLAS 1974. As such, an ECS is an aid to navigation that should be always be used with an up to date chart from a government authorised hydrographic office *(Alexander, 1998b).*

Raster Chart Display System (RCDS) has been proposed as an alternative "mode of operation" for ECDIS. Recommended for adoption as Appendix 7 to the IMO ECDIS Performance Standard for ECDIS, official HO provided raster data could be used in an otherwise IMO compliant ECDIS as an interim solution until IHO S-57 ENC data (vector based) coverage becomes more widely available. However, when ECDIS equipment is operated in RCDS mode, it must be used together with an adequate folio of up to date paper charts *(Alexander, 1998b).*

2.5.2 Standardisation of ECDIS

It is recognised that the standardisation of the paper chart was not an easy job, but standardisation of the electronic chart is even more complex. Many organisations concerned with maritime activities are progressively working to establish the specification for the ECDIS. The work of such organisations is discussed below.

International Maritime Organisation (IMO) In May 1994, the draft performance standards of ECDIS were approved and forwarded to the IMO Assembly. These standards were officially adopted by IMO in November 1995 and issued as an IMO Regulation. The IMO Performance Standards permit the National Maritime Safety Administration to consider ECDIS as the legal equivalent to (i.e. as effective as) the charts required by regulation V/20 of the 1974 SOLAS Convention. IMO also requested the member governments to have their HOs produce digital nautical charts and the associated updating services as soon as possible and to ensure that manufacturers conform to the performance standards when designing and producing an ECDIS *(Alexander and Ganjon, 1995).* As a result, many HOs are currently moving from traditional chart production to the digital production in order to serve such requests. Among these, Thai Hydrographic Department (Thai HD), as a member of IMO, is also planning to move to such a new direction.

International Hydrographic Office (IHO) The IHO, while considering the IMO Performance Standard for ECDIS, developed technical standards for digital format and display. IHO Special Publication 52 (IHO S-52) is the *"IHO Specification for Chart Content and Display of ECDIS"*. It includes appendices describing the means, process for updating, colour and symbol specifications, and a glossary of ECDIS related terms. The 4th edition of IHO S-52 was issued in December 1996. IHO Special Publication 57 (IHO S-57) is the *"IHO Transfer Standard for Digital Hydrographic Data"*. Formally adopted as the official IHO standard at the XIV International Hydrographic Conference in May 1992, it includes an object catalogue, DX-90 format, an ENC Product Specification, and ENC updating profile. The current edition (Edition 3.0) was released in November 1996, and has been "frozen" for three years. Both IHO S-57 and S-52 are specified in the IMO Performance Standards for ECDIS *(Alexander, 1998b).*

The International Electronic Commission (IEC) The IEC developed its own ECDIS Performance Standard that describes the operational methods of testing and required test results for an IMO compliant ECDIS. In September 1997, Draft IEC 61174 was completed, and a Final Draft International Standard was issued on 30 March 1998. Following a formal voting process, IEC 61174 was officially published by IEC as an International Standard in August 1998. IEC 61174 is the basis for type-approval and certification process for an IMO compliant ECDIS.

The Radio Technical Commission for Maritime Service (RTCM). In United States, the RTCM recently completed work on the RTCM Recommendation Standards for Electronic Chart System (ECS). This standard was formally published by RTCM in December 1994. Unlike an IMO compliant ECDIS, an ENC is not intended to comply with the up to date chart requirement of V/20 of SOLAS 1974 *(Alexander and Ganjon, 1995).*

Not only those primary organisations mentioned above but also many other cooperative working groups were established to conduct research, develop, test, and evaluate electronic chart related technologies, such as the US-CANADA Cooperative Research whose initial objective was to evaluate the IMO provisional performance standards for ECDIS using both commercially available and prototype ECDIS tested system; the Electronic Chart Pilot project which is a joint US-Canada ECDIS program; Germany's BANET Program which involves the co-operation of the German Office of Maritime Shipping and Hydrography (BHS) in a Baltic and North Sea ECDIS Tested (BANET) project being conducted in northern Europe, Norway's ECC Program which has established an Electronic Chart Center as a regional data center for ENCs, and several HOs including Japan, Italy, France, South Africa and Spain. Whereas the vector based electronic chart data are not fully available, an Admiralty raster chart service (ARCS) has been announced by the UK's HO to provide digital (raster based) CD-ROM versions of Admiralty paper charts and a weekly updating service to be used with the ECS. In the US, the National Oceanic and Atmospheric Administration (NOAA) has begun producing digital raster version of its nautical charts for ECS, similarly to the UK HO.

Based on the insight the US Coast Guard (USCG) and NOAA have gained from working with a wide variety of mariners in the US and Canada, it is clear that when properly used, ECDIS is a significant improvement over more traditional means of maritime navigation *(Alexander and Ganjon, 1995)*.

Chapter 3

Chart Production in Hydrographic Department

3.1 Introduction to Thai Hydrographic Department

The Hydrographic Department (Thai HD), founded in 1919, is the Thai government organisation under the control of Royal Thai Navy responsible for surveying Thai navigable waterways and producing a number of official nautical charts and nautical publications in order to serve naval operations and private sectors. National responsibilities and commitments include:

- publishing and maintaining the national chart series (over 66 navigational charts)
- publishing the Thai National Tide Tables
- publishing the Thai series of Sailing Directions
- publishing the Explanation of Symbols and Abbreviations Book in Thai
- publishing the Lists of Lights and Buoys in Thai Waters Book
- compilation and maintenance of the Thai hydrographic and oceanographic data collection
- providing the Notices to Mariners service according to changes and additions to published charts
- determining the priority for national hydrographic survey requirements
- providing and maintaining aids to navigation in Thai waters
- keeping Thai Standard Time
- forecasting and broadcasting the weather in Thai waters for Thai naval warships and aircraft.

All nautical charts of Thai waters are charted by the Thai HD. Chart production by a government is seen as a form of guarantee or certification to permit the safe and efficient conduct of marine transportation. The production of charts provides the government with direct support to control and regulate marine transportation safety. Thai charts are mostly used for marine navigation purposes in Thai waters by both Thai and foreign mariners. However, they are now increasingly used for other purposes such as hydrographic and oceanographic survey; underwater cable laying, oil and gas surveying; fishery; recreation and etc. Although there is an increasingly range of chart users, they are typically well trained in the use of charts. Users have come to expect chart information to be accurate and reliable and expect charts to be high quality products.

Chart production is practically the most important work which has been done by cartographic division within HD. Most Thai nautical charts are still produced using traditional cartographic method used since HD was founded. In the last few years, HD has started planning to change the cartographic work from manual production to digital production in order to produce its charts not only in the current paper form but also in the digital one, namely the Electronic Navigation Chart (ENC), in the future. It is expected that digital production will fulfil Thai HD's requirement by reducing the time and cost of chart production and providing more accurate and better quality charts.

Thai HD is internationally a member of many organizations relating to chart production and navigation such as International Hydrographic Organization (IHO), International Maritime Organization (IMO), International Association of Lighthouse Authorities (IALA) and International Cartographic Association (ICA). As a result, all works done by Thai HD follow the regulations and standardization of such organizations. Even though Thai HD is producing charts following IHO specification, there are some specific aspects which differ slightly from IHO specification as mentioned in 3.2

3.2 Some Specific Aspects of Thai Charts

3.2.1 Chart Format

Like the chart series of the other countries, the Thai chart series has an unsystematic layout of the sheet lines, unlike the typically systematic layout of topographic map series. Both scale and sheet size are modified in order to cover the desired area at the appropriate scale. Overlaps with adjoining charts are arranged so that a conspicuous feature appears on both. The Thai chart series is shown in figure 3.1

According to INT Chart Specification of IHO 1990, it is recommended that the neatline dimensions should ideally be either 1100×750 (mm) or 980/1100×650 (mm), subject to the minor variations required to locate charts' neatlines on exact graduation sub-divisions. A0 should be the maximum paper size used for the paper charts. For Thai charts, the neatlines and paper sizes are divided into 3 sizes as shown in table 3.1

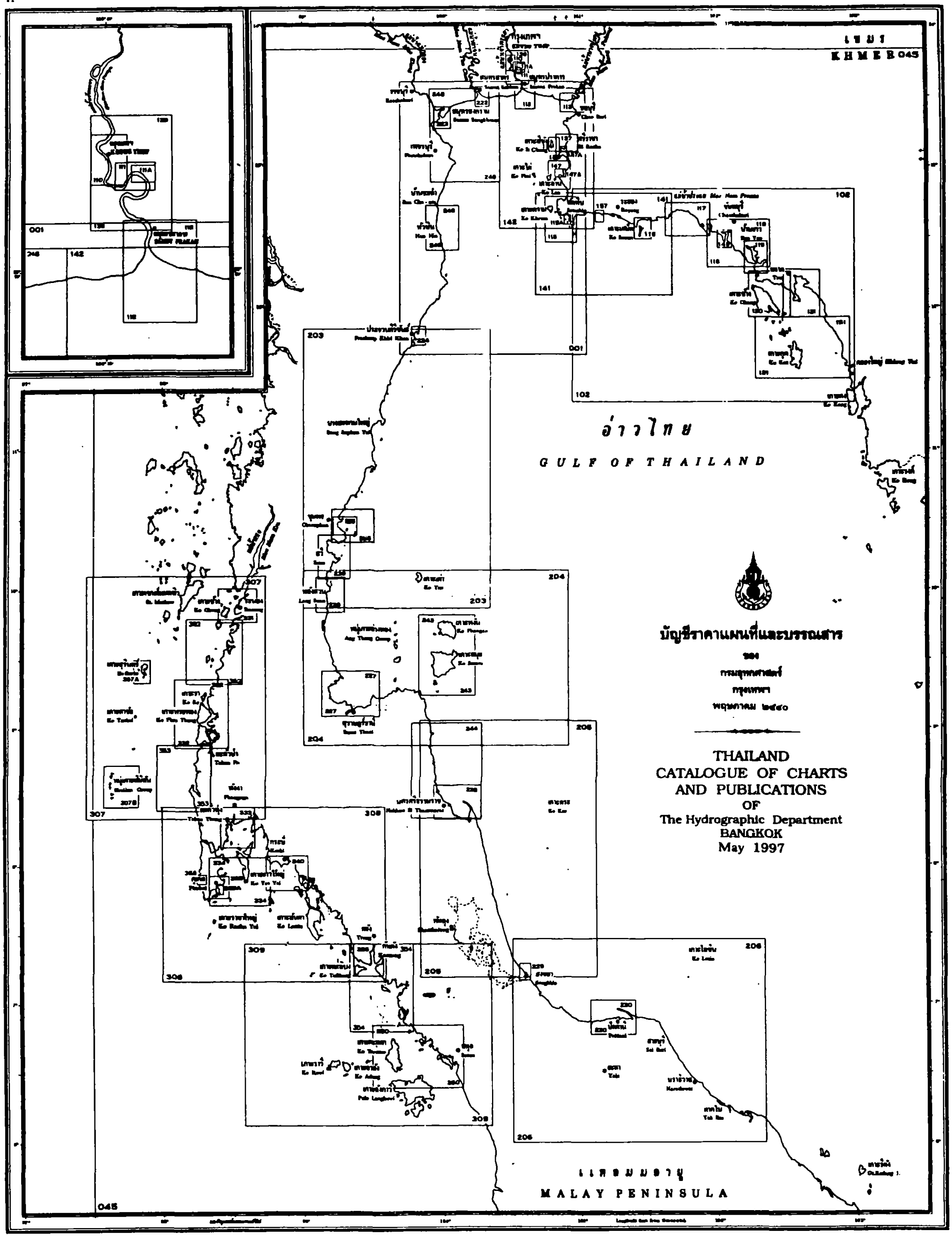


Figure 3.1 Thai chart series.

Size	Neatline Dimensions (mm)	Paper Sizes (mm)
Full Size	1000×750	1040×790
Medium Size	900×700	940×740
Small Size	850×600	890×640

Table 3.1 Standard neatline dimensions and paper sizes of Thai charts.

3.2.2 Characteristic of Thai Charts

Despite using the IHO standard, charts produced in various countries have slightly different characteristic depending on the specification of each national HO. For instance, the UK HO implements Lowest Astronomical Tide as a chart datum for depths and Mean High Water Springs as plane of height reference, whereas, French HO implements Lowest Low Water and Mean Sea Level for such information. Thai HD also has it s own standard as shown in table 3.2

Elements	Type
Projection	Mercator
Ellipsoid	Everest Spheroid
Datum	Lowest Low Water (LLW)
Plane of Height Reference	Mean Sea Level (MSL), Indian Datum 1975
Unit of Heights	Meter
Unit of Depths	Meter
Unit of Soundings	Meter
Navigational Marks	IALA Maritime Buoyage System (Region A-Red to Port)

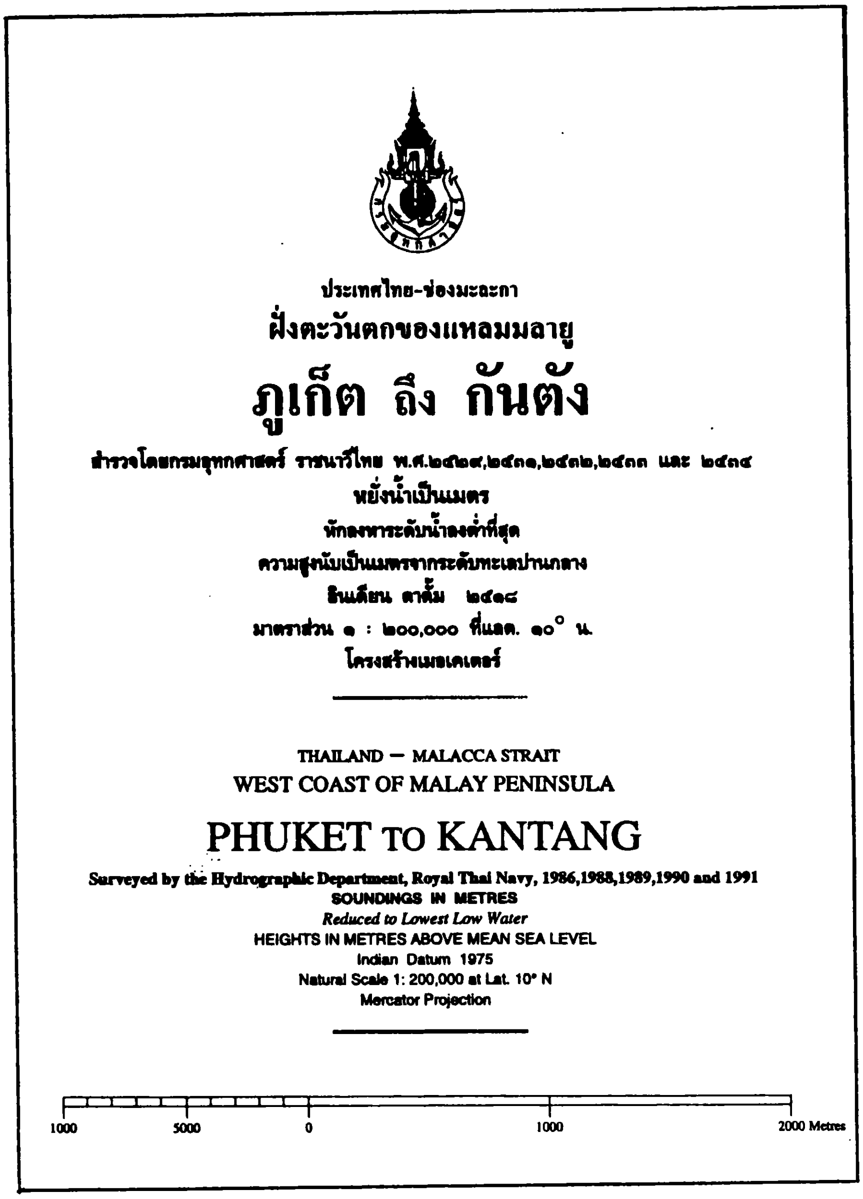
Table 3.2 Specific standard on Thai charts.

The chart user is recommended to read such information which can be found in "Chart Title" section as shown in figure 3.2

3.2.3 Names on Thai charts

Names of places, or of other phenomena related to places on the Earth's surface, are an important component of the nautical charts. They help the navigator identify the chart items. Charts are primarily produced by different national HOs which may use different languages, different alphabets, or even different scripts *(Stefanakis, 1993).*

Names of places may appear in different languages, both international form and the language of the nation publishing the charts. Thai charts are bilingual, in that there are two languages shown on them, Thai and English. The geographic names are written in both Thai and English so that not only Thai mariners but also the foreign ones will be able to use them.


ประเทศไทย-ช่องมะละกา
ฝั่งตะวันตกของแหลมมลายู
ภูเก็ต ถึง กันตัง
สำรวจโดยกรมอุทกศาสตร์ ราชนาวีไทย พ.ศ.๒๕๒๙,๒๕๓๑,๒๕๓๒,๒๕๓๓ และ ๒๕๓๔
หยั่งน้ำเป็นเมตร
หักลงหาระดับน้ำลงต่ำที่สุด
ความสูงนับเป็นเมตรจากระดับทะเลปานกลาง
อินเดียน ดาตั้ม ๒๕๑๘
มาตราส่วน ๑ : ๒๐๐,๐๐๐ ที่แลต. ๑๐° น.
โครงสร้างเมอเคเตอร์

THAILAND — MALACCA STRAIT
WEST COAST OF MALAY PENINSULA
PHUKET TO KANTANG
Surveyed by the Hydrographic Department, Royal Thai Navy, 1986,1988,1989,1990 and 1991
SOUNDINGS IN METRES
Reduced to Lowest Low Water
HEIGHTS IN METRES ABOVE MEAN SEA LEVEL
Indian Datum 1975
Natural Scale 1: 200,000 at Lat. 10° N
Mercator Projection

1000 5000 0 1000 2000 Metres

Figure 3.2 Example of Thai chart title.

Names of places are transliterated from Thai, for instance, the temple named *"Sattahip"* will be written and pronounced *"Wat Sattahip"* not *"Sattahip Temple"* because a temple is called *"Wat"* in Thai; the island named *"Si Chang"* will be written and pronounced *"Ko Sichang"* not *"Si Chang Island"* because "island" is called *"Ko"* in Thai. Examples of other geographic names commonly found on Thai charts are shown in table 3.3

English	Thai
Gulf	Ao
Creek	Khlong
River	Mae Nam
Island	Ko
Mountain	Khao
Rock	Hin
Lagoon	Bung

Table 3.3 Example of geographic names on Thai charts.

The use of such geographic names is shown in figure 3.3

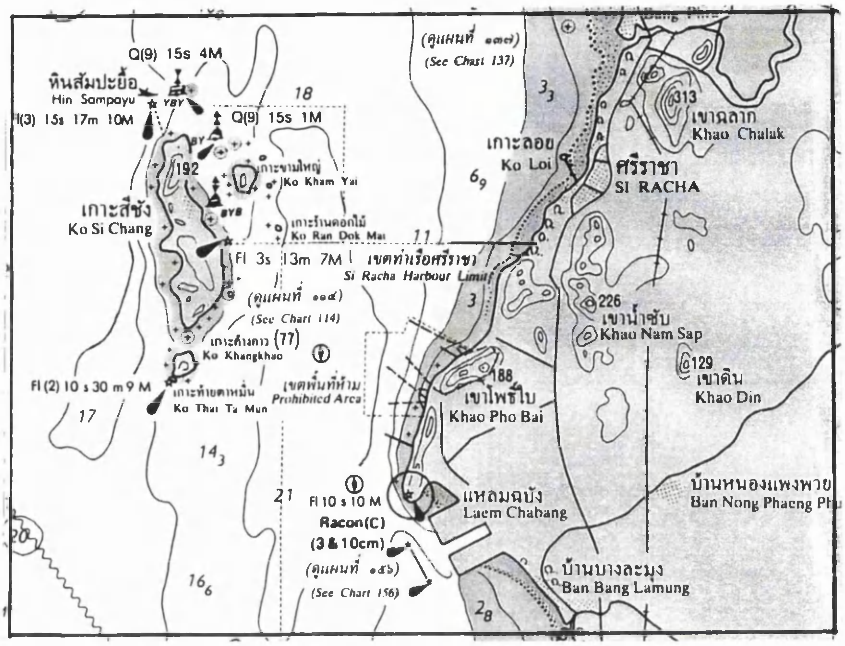


Figure 3.3 Use of geographic names on Thai charts.

3.2.4 Symbols and Abbreviation Used on Thai Charts

As mentioned above, there are some specific non IHO elements appearing on Thai Charts, such as toponyms, special symbols and abbreviations, and so on. Like the publication of *"Symbols and Abbreviations used on Admiralty Charts"*, namely "Chart No.5011 (INT 1)", the *"Symbols and Abbreviations used on Thai Charts"* has been published in order to make clear and understandable to the navigators the details of symbols and abbreviation shown on Thai charts. The first, second and the third compilations were designated "Chart No. (C)" with reference to the resolutions of IHO from 1965 to 1978 respectively.

On account of amendments and the introduction of new Symbols and Abbreviations in the 1985 IHO Resolutions, Thai HD realized that the information existing in Chart No.(C) should be updated, thus the fourth revision has been published in a booklet known as *"The Symbols and Abbreviations Used on nautical chart by The Hydrographic Department of The Royal Thai Navy 1989"*. It is based on the following principles:

1) The titles, symbols and abbreviations followed the IHO Resolution Standard Form and numbering.
2) Upright figures indicate those symbols and abbreviations which were resolved by the IHO conference or have not been resolved yet but are generally adopted.
3) Italic figures indicate those symbols and abbreviations developed for certain depictions which are different from IHO Resolutions.
4) Figures in parentheses indicate additional information in Standard form of IHO Resolutions.
5) Nautical Charts are constructed on Mercator Projection and computed on middle latitude of chart series, unless otherwise stated on charts.
6) Longitude is originated from Greenwich Meridian.
7) Soundings are shown in Meters as stated on the chart title.
8) Chart datum is generally the plane of Lowest Low Water (LLW), unless otherwise stated on the chart title.
9) Underlined figures shown on rocks, banks, and areas over water express heights in meters above chart datum.
10) Elevations are shown in Meters above Mean Sea Level except those indicated by underlined figures mentioned above. To indicate elevations of islets, cultures (e.g. chimneys), or elevation displaced from an object's position, figures in parentheses are used (*The Symbols and Abbreviations Used on nautical chart by The Hydrographic Department of The Royal Thai Navy, 1989)*.

Example extracted from Thai Symbols and Abbreviations book is shown in figure 3.4

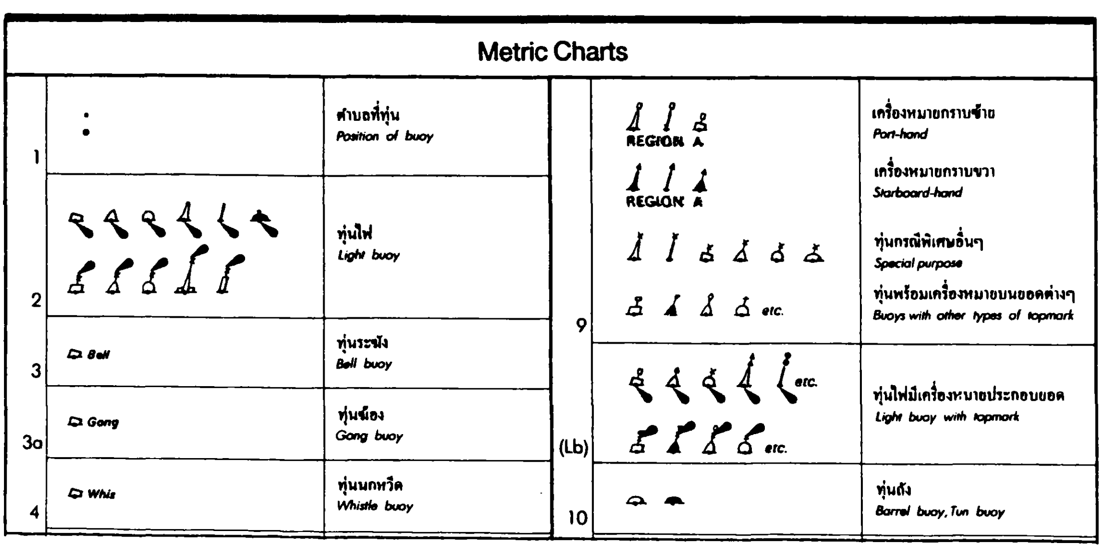


Figure 3.4 A portion extracted from Thai Symbols and Abbreviations book.

Figure 3.4 A portion extracted from Thai Symbols and Abbreviations book.

3.4Traditional Thai Chart Production

3.3.1Data Acquisition

Thai HD is still mainly gathering data using traditional Hydrographic Survey. The Survey Division is responsible for undertaking hydrographic survey to meet both defense and civil requirements. The application of aerial photography and photogrammetry have not been implemented within HD yet. As a result, the major source of data required for chart production comes primarily from hydrographic survey, whereas, the minor source comes from the existing charts, topographic maps, charts of other nations and other related organizations. Thai HD has five commissioned survey vessels which are as follows:

H.T.M.S. CHANDARA	for hydrographic survey
H.T.M.S. SUK	for oceanographic survey
H.T.M.S. SURIYA	for aids to navigation maintenance
H.T.M.S. HYDRO 2	for general purposes
H.T.M.S. HYDRO 3	for general purposes

Only one survey vessel, namely "H.T.M.S. CHANDARA", is implemented heavily for hydrographic survey. She is equipped with 6 small survey boats and modern technological equipment such as Global Positioning System (GPS), speed log, echo sounder, radar and sonar in order to perform data collection at sea effectively.

Once data collection, which is in both analogue and digital form, is completed the raw data are processed, assessed, verified into the form, sometimes called "clean data", acceptable for use by HD. When the new surveyed data arrive at HD, they are catalogued, stored, and copied for future reference.

3.3.2 Production Stage

As has been mention earlier, Thai charts are still mostly produced using traditional production, in other words, an analogue one. The traditional chart production flowline is shown in figure 3.5, and is broadly broken down into 3 stages which are data preparation stage, construction stage and reproduction stage. These are discussed below.

3.3.2.1 Data Preparation Stage

Once the cartographic division is given the order to produce charting for a specific area, the data preparation stage begins with the operations concerned with planning the required charts such as chart numbers, scales, sizes, sheet limits, details, projections to be used, and specification to be followed. Status of the existing charts are reviewed in order to determine the new and additional information that the required charts need. It includes establishment of need for hydrographic, geodetic, and topographic surveys to supply information not available from printed sources or data archives and affects the preparation of survey specifications. Data preparation also includes the collection, evaluation, and selection of source materials to be used in the chart compilation stage. Some other information sources may be required for chart construction such as older charts, topographic surveys and maps, notices to mariners, list of lights, sailing directions, and tide tables. Once planning has been completed and source materials have been selected, specifications are produced and written for cartographers (i.e. draughtsmen) who will have to select and compile the detail from available source materials.

3.3.2.2 Construction Stage

The construction stage consists of two sub-stages which are projection construction, and compilation, as discussed as follows;

Projection Construction. The basic framework must be constructed prior to the actual compilation stage. This is the construction of geographical graticule such as meridians and parallels. All data to be shown will be placed within this framework according to their geographical position respectively. For Thai charts, The Mercator Projection frameworks used to be computed and constructed manually and it was very time consuming, tiring, tedious and error prone. Principal lines were inked in black on a dimensionally stable transparent plastic sheet and further subdividing lines were added as necessary, usually in a non-photographic blue ink.

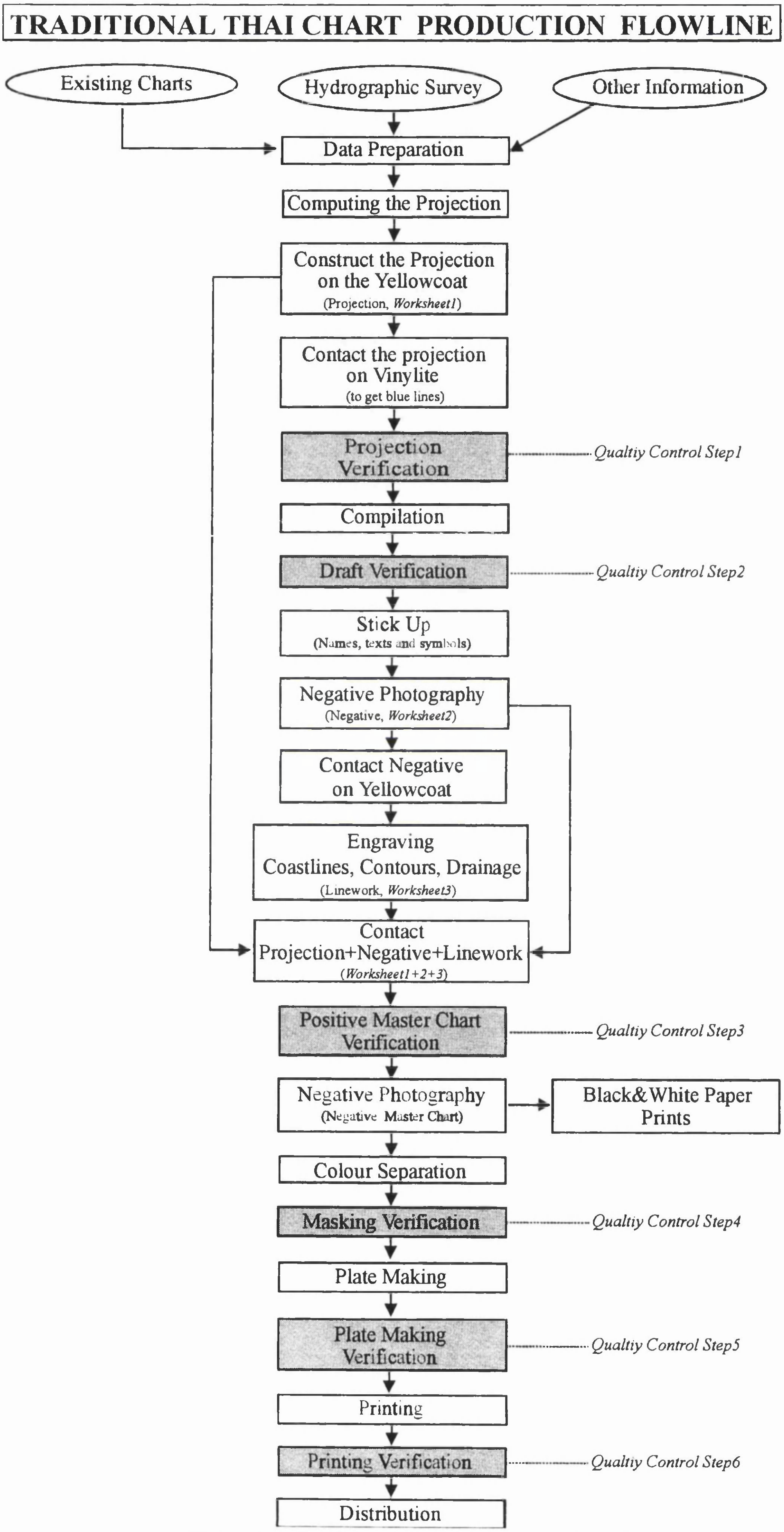


Figure 3.5 Traditional Thai Chart Production Flowline.

In the last ten years, Thai HD has started using computer technology for constructing projection frameworks. Projections are generated mathematically and drafted on *yellow coated plastic sheet (Worksheet1)* attached to a high quality flatbed plotter using scribing tools or ink pens, saving precious time and greatly increasing accuracy. Then Worksheet1 is contacted photo-mechanically on to another special plastic sheet called *"Vinylite"*, resulting in a blue line framework to be used in the compilation stage. Prior to compiling other data, the geodetic control points are plotted precisely on the framework. These are known geographic positions of features, called *"control points"*, from the field survey which are used along with the latitude and longitude lines in positioning all other cartographic data. Nowadays, the plotting of such control points can be done very efficiently by including their digitally plotted positions during the automatic graticule construction stage.

When the projection framework and geodetic control points have been plotted, the senior cartographer and the project manager examine the completeness and correctness of this worksheet *(Quality Control Step1)*. Any required changes will be made prior to the next stage.

Compilation. The objective of compilation is to select the data which may appear on the final chart from various sources and render it onto the single base. The compilation of nautical charts in HD is still purely done by hand. According to the basic cartographic rule that *"the final chart should be compiled from the larger scale one" (Robinson, et al, 1995)*, source materials have to be reduced onto positive film at the desired scale either photographically or by vertical reflecting projector. The resulting positive is used as the *"guide image"*. The desired details are then traced off on the light table directly onto the master projection sheet using both hand drawing and stripping films. Different coloured inks are used for detail to be printed in different colours. Black is used for coastline, contours, projection, soundings, names and symbols, to be shown on the black printing plate, red for compass roses and other magnetic information to be shown on the magenta plate.

Once the draughtman is sure that all desired data are placed on the *"master drafting film"* correctly, it is common practice for checking to be done before further processing. The director of the cartographic division appoints a senior draughtman and three senior cartographic officers who are not involved in the production of the document to examine and prove the master drafting film *(Quality Control Step2)*. After approval, to this master film are added names, texts, and symbols using sticking-up technique and then it is converted to a negative photographically on the film *(Worksheet2)* in order to get all data in negative form. The negative film is then contacted on another *yellow coated plastic sheet* photo-mechanically in order to get positive image for subsequent linear scribing. Linear features, such as coastlines, contours and drainage, then are traced off using the proper scribing tools resulting in finer lineworks on this worksheet *(Worksheet3)*.

Those three negative worksheets, consisting of *Worksheet1* (yellow scribecoat containing scribed framework), *Worksheet2* (negative film containing all data excluding coastlines, contours and drainage), *Worksheet3* (yellow scribecoat containing scribed coastlines, contours and drainage), require registration to ensure that the final chart composite is accurate. Two method of registrations are commonly used; registry pins and graphic registry marks.

Once registered, these three worksheets are combined using photographic method resulting in *Positive Master Film* that looks like the final chart. The positive master film is examined and proved by a project manager and those three senior cartographers again before further processing will be done *(Quality Control Step3)*. After the *Positive Master* has been approved, a contact photographic film negative is made, resulting in *Negative Master Film*. From this stage, black and white paper prints are produced for the cartographer in preparing supplementary guide sheets for the cartographic draftsmen and lithographic personnel who will make the finished drawings, reproduction negatives and printing plates.

3.3.2.3 Reproduction Stage

Area Colour Preparations. Coloured areas are produced using open-window negative masks. The idea is to make the border of the open area fall exactly on the bounding line of the region to be filled. The most common method in Thai HD is *"Cut and Peel"*. It is a convenient way to prepare open window negatives by hand using special material consisting of a thin masking film laminated to a clear polyester base. The masking material is registered over the positive master film on a light table, then the window is created by cutting around the region border with a sharp blade and then peeling the masking layer away from the base. Five colour masks are required for each charts. These are Yellow mask, Light blue mask, Dark blue mask, Black mask and Magenta mask.

Plate Making and Printing. This process includes all photography, photographic finishing, opaquing, retouching of negatives, printing plate coating, printing and high speed rotary offset press printing. Each of these steps requires the service of skilled personnel with many years of training and experience.

When the artwork is completed, it must be carefully and thoroughly checked before being sent to duplication. Because the chart is constructed from more than one worksheet, a composite of separations is used as the proofing vehicle. This composite is called a *"pre press proof"* and made prior to the actual printing. The proofing is done photo-mechanically in a laboratory setting. This proof is then examined and approved by the project manager and the three senior cartographers *(Quality Control Step4)*. After any required changes have been made to the negatives or scribed originals, printing plates are then made.

Once plate making is finished and examined *(Quality Control Step5)*, the plates are placed on the offset presses for printing. Quality control during printing process ensures that fidelity of colours and uniformity of tone and registration of colour plates meet requirements. The final printed charts are checked and approved by the head of the photo-lithographic division and project manager before the distribution *(Quality Control Step6)*.

3.4 Traditional Data Quality Assessment Procedures

As can be seen in the traditional chart production flowline summarised in figure 3.5, Quality Assessment Procedures have been carried out at every step of chart production by experienced senior cartographers and draughtmen. The products at each stage are examined and compared to the original sources and the chart specification using mainly *"visual check"* in order to check that all printed charts meet requirements and IHO specification. Any changes required will be made and reviewed until requirements are met before going to further stages.

These checks are:

- Projection Verification (*Quality Control Step1)*
- Draft Verification (*Quality Control Step2)*
- Positive Master Chart Verification (*Quality Control Step3)*
- Masking Verification (*Quality Control Step4)*
- Plate Making Verification (*Quality Control Step5)*
- Printing Verification (*Quality Control Step6)*

These verifications, or inspections, are made for the following reasons:

1) to ascertain that all existing information relevant to the chart has been considered;
2) to assure that only those sources which most clearly defined existing conditions have been used;
3) to determined that the material used has been properly generalized;
4) to assure that all symbolization conforms to standard practice and that all prominent objects and aids to navigation have been accurately plotted; and
5) to assure that the chart is produced so as to be most useful to the mariner and to meet the IHO specification.

Upon assignment of the chart production task, the examiners receive a *"Specification Sheet"* and Source Sheet. The former defines the title, limits, sounding unit, depth curve and contour interval, while the latter contains a list of all source material added to the chart by the cartographer. The examiners evaluate and verify the draughtman's selection of the critical and essential information shown on the chart. At the same time, the Source Sheet is checked so that, upon completion of the review, it becomes a record of all data pertaining to compilation.

Three qualities of good production are accuracy, completeness and clearness. Accuracy is of prime importance. The plotting of all fixed aids to navigation, landmarks, wrecks, and obstructions should be checked with their geographic coordinates. All soundings should be checked for value and their location should be true within half the width of the figure *(Bruder, 1963).* Checks are carried on all sectors, ranges, measured mile courses, and grid systems as well as dredged areas, anchorages, spoil areas, dumping grounds, cable, restricted and prohibited areas. Buoys should agree in position and characteristics with the Notice to Mariner upon which they are based.

The chart compilation should be complete. This implies that all source material relevant to the job has been considered and that the selected material has been applied in full or in part. The Source sheet should be so marked for partially applied material may be fully applied at the later date *(Bruder, 1963)*. All existing charts of the area and overlapping charts of the same series should be examined for differences which must be reconciled.

In addition to the qualities of accuracy and completeness, the chart should be clear and legible. Clarity of expression is important, since the chart is an instrument which the navigators use in order to follow the safe course. Vital information, such as the dangerous shoals and rocks, wrecks, and the aids to navigation should not be charted in an obscure or ambiguous manner. Also check to see that there are no conflicts between the various colours to be used in the final printed charts.

3.5 Future Plan for Digital Chart Production

Thai HD has been producing its charts using the traditional manual production since it was founded. Due to the economic growth in Thailand the numbers of ships navigating in Thai waters is rising, therefore the demand for charts is increasing. Not only the impact of the economic development but also the impact of technological advances in ship navigation and survey affect the production of Thai nautical charts. Technological advances have affected the nautical charts in two ways. Advances in navigational technology such as radar, Global Positioning System (GPS) and Electronic Navigational Chart (ENC) have placed requirements for additional information on the charts, while advances in hydrographic survey technology, such as echo sounder, single and multi-beam sonar image processing systems, have resulted in the ability to collect far more data to be processed and displayed than in earlier years. Furthermore, common agreements by the IHO request that member governments have their national hydrographic office produce digital chart data and the associated updating service as soon as possible and ensure the quality of such data which will be exchanged between HOs.

Responding to these pressures, Thai HD, as a governmental charting agency and a IHO member, has recently started planning to move from manual chart production to the digital production. It is expected that the new digital production will fulfil its requirements by reducing time and cost of production and by providing more accurate and the better quality charts and information related to them.

Introducing such a digital production system is likely to cause organisational, legal and financial problems as well as technical ones. These should be investigated, studied and fully understood at the early stage of development. The efficiency of various systems is being evaluated in order to find out which one is the most suitable and cost-effective for Thai HD. There are a few systems from different companies to consider; CARIS (Universals Systems), LAMPS2 (Laser-Scan), Microstation (Intergraph) and Atlas CGS (Atlas Electronik). Once one of these systems is selected, the next step of development is planning to implement this system efficiently and cost-effectively, as shown in figure 3.6. The development of digital chart production for Thai HD is discussed in Chapter 5.

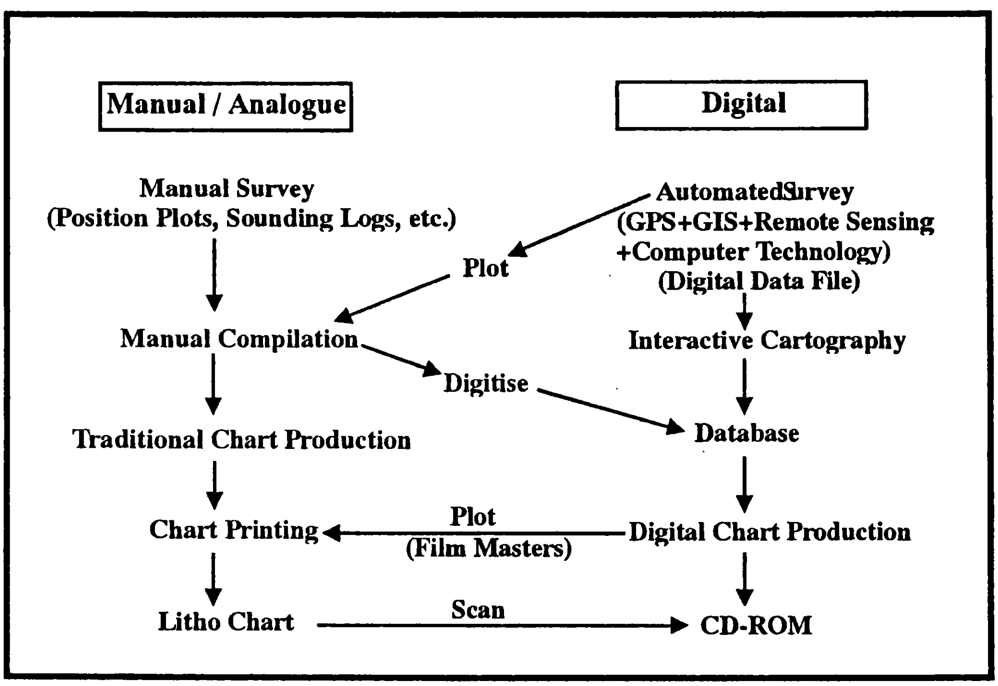


Figure 3.6 Possible Chart Production Routes.

3.6 Need for Data Quality Assessment Procedures

Thai Hydrographic Department (Thai HD), which is a government agency, is expected to be a reliable source of digital chart data in the future. Use of such data affects safety in marine navigation and the lives of mariners. Data Quality is a key aspect of the development of digital chart production. It is central to evaluating the results of digitising and any other representation. Data quality can have significant effects on the reliability of the further data processing operations.

Therefore, there are a number of reasons resulting in needs for Data Quality Assessment Procedures. Firstly, many HOs are currently in the process of converting their existing paper charts into digital form. During this process, some problems concerning the integrity of digital data may occur (e.g. the accuracy of the original chart may be lost, features may be associated with wrong attributes, etc.). Sources of these problems include software errors, procedure errors, equipment faults, or operator errors. Secondly, HOs are increasingly integrating information from a variety of sources, such as hydrographic survey, aerial photographs, photogrammetry, etc., and as a result, the data quality of these resources has different levels. Thirdly, increasingly most digital cartographic data captured from different sources are stored in a database which could be corrupted resulting in the data used for chart production being incomplete. It is prudent that the digital data used for chart production be checked and assessed to ensure that they have an acceptable "data quality". As a result, Data Quality Assessment Procedures should be constructed and implemented in the digital chart production process. The development of such procedures is discussed in Chapter 6.

Chapter 4
The CARIS Software

4.1 Introduction to CARIS

CARIS (Computer Aided Resource Information System) is Geographic Information Systems (GIS) software manufactured by Universal Systems Limited (USL) which has been developing and providing GIS and spatial information solutions for marine and land-based industries for almost twenty years. USL's headquarters are located in Fredericton, New Brunswick, with subsidiary offices in Vancouver, British Columbia, and The Netherlands.

Hydrographic Offices and Navies from over forty countries have now standardized on CARIS systems for their marine spatial information and chart production systems. These nations include Canada, United States, Germany, Russia, China, India, Indonesia, Spain, Brazil, Chile, and Argentina. This software is designed and built for a variety of applications, including municipal and resource management, hydrography and marine systems, geology, transportation and many others. It is available both on UNIX and PC (Windows NT or Windows 95) platforms.

4.1.1 CARIS for Windows Overview

CARIS is a suite of Geographic Information System software tools. It runs under Windows'95 and Windows NT, on standalone or networked PCs. A Geographic Information System (GIS) is a computer-based system for managing spatial data. Its function is to provide software tools for data capture and input, data manipulation and transformation, data query, data analysis and modelling, data visualization and data output.

The main purpose of GIS is to provide tools to aid decision-making based on a geographic database which models the real world. Uses of CARIS for Windows range from digital map and chart production, to spatial database query, analysis, and modelling. End user applications include topographic mapping, cadastral and property data mapping and management, utilities, oil and gas, municipal management, transportation, geology, forestry and agriculture applications, hydrographic charting and database management.

The CARIS for Windows product family consists of a number of packages. End users need only select the package(s) which best suits their requirements. The current packages are:

- CARIS Explorer: digitizing, editing and plotting package
- CARIS Cartographer: adds full digital cartographic support to Explorer
- CARIS Topological Mapping: adds topology capabilities to Cartographer
- CARIS GIS: fully functional GIS (includes the functions of the above packages)
- CARIS Access: GIS database query and analysis product

In addition, there are some application-specific CARIS for Windows packages:

- Semi Automated Map Input (SAMI): raster to vector data input & editing
- Network Analysis: optimum route analysis
- Digital Terrain Modelling (DTM): 3D modelling and analysis
- Image Processing: raster image import and registration
- Geological Mapping Module (GEMM): geological mapping tools for Explorer

4.1.2 The CARIS Suite

The CARIS Suite allows access to all CARIS programs and tools. CARIS Suite is started by selecting CARIS for Windows 95 and NT from the Windows *Start>Programs* menu. The programs within CARIS Suite are illustrated in figure 4.1 and are explained briefly in table 4.1.

Figure 4.1 The CARIS Suite icon.

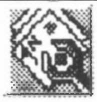
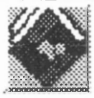
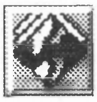
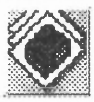
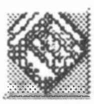
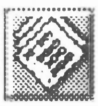
	**The CARIS Tools** is an interactive CARIS program which provides the user with various tools for managing his CARIS database.
	**The CARIS Editor** is an interactive CARIS Program which allows the user to create and edit digital maps.
	**The CARIS Information Manager** is an interactive CARIS program which allows the user to manage and query the information found in a geographic information database.
	**The CARIS Information Manager Zones** is a special version of the CARIS Information Manager with one added feature: the ability to manage and query data contained in user-defined zones.
	**The CARIS DTM Viewer** (V3D) is an interactive program that allows the user to view Digital Terrain Models in 3D.
	**The CARIS Database Manager** is a program that allows the user to manipulate the data in an attribute database and perform queries.
	**The Report Writer** is a program that accepts common data from various CARIS programs and puts it into report format.
	**CARIS Setup** is an interactive program that allows the user to create definition files that control what data the CARIS Information Manager and Database Manage will display.
	**CARIS Help** is a Windows help file that allows access to all CARIS on-line help. (Help is also available from inside individual programs.)

Table 4.1 The selected CARIS programs.

4.2 Elements of CARIS

4.2.1 The CARIS Support File

The CARIS support files contain data that affect how the data in a CARIS file will be presented on a computer screen, plotting device, or printer. Using the support files, the user can: control the colours used to represent the map features; assign symbols to particular feature types; specify patterns for symbolizing line data; control the appearance of textual data on the map, including the font, size, line type and spacing of characters. The support files affect most CARIS operations. The CARIS support files function in the following ways:

- **The Master File** contains a list of the feature codes for the features that will be used with CARIS system and some plotting instructions for lines, symbols and fonts.
- **The Symbol File** contains more plotting instructions for symbols and fonts.
- **The Text specification File** contains the font, size, line weight, and spacing of text used in CARIS files.
- **The Colour Map** contains information defining the colours available in CARIS in terms of hue, lightness, and saturation.
- **The Colour Table** assigns colours which are defined in the colour map to feature codes, theme numbers, and other feature tags.

CARIS provides two versions of each of the support files, one for *hydrographic (marine based)* applications and one for *topographic (land based)* usage. CARIS can be used without modifying these support files, but they can be changed if necessary. The following table shows the names of the support files provided with the CARIS system. The topographic files are assigned as defaults at installation time.

File Type	Topographic	Hydrographic
Master	tp_maste.txt	ih_maste.txt
Symbol	tp_symbo.bin	ih_symbo.bin
Text Specification	tp_texts.txt	ih_texts.txt
Colour Map	tp_colou.cma	ih_colou.cma
Colour Table	tp_color.col	ih_color.col

Table 4.2 CARIS Support files.

4.2.1.1 The Master File

A master File is a text file (extension.txt) containing a list of feature codes and instructions for plotting features on a map or chart. The master file is sorted alphabetically by feature code. The master file controls the appearance of map data. It may contain instructions for patterning lines, combining symbols to form composite symbols, presenting text and masking overlapping features.

The master file consists of a number of main records and sub records. Each feature code described in the master file is represented by one main record and, optionally, one or more sub records. Each main record or sub record occupies one line of text which can be up to 80 characters in length. A main record contains 13 fields. Field 4 of a main record contains comments. If field 2 contains the letter L, S, T, or M, it is a subrecord, which contains four fields. Field 4 of a subrecord contains instructions. The following shows a record extracted from a default master file:

```
!00---------------------------------------------------------------------------
!01 FCODE  = Feature code. Maximum of 12 characters.
!02 T      = Subrecord type. L=line pattern, M=mask, T=text S=symbol.
!03 N      = Subrecord sequence number. Always start with 0. Maximum is 9.
!04 COMMENT = Feature description. Maximum of 36 characters.
!05 CS     = Colour separation flag (feature colour).
!06 P      = Peel coat file flag: Symbolize/leave Unsymbolized/Not on peel.
!07 FD     = Flash F followed by D or R. Draw D followed by D or R.
!08 CA     = Symbolization case number.
!09 LW     = Line weight in thousandths of an inch. Eg. 05 means 5/1000
!10 DS     = Disk and symbol number for flashed symbols.
!11 M      = Magnification factor for flashed symbols value: 0 to 9
!12 LS     = Line smoothing value: 00 to 99. Not presently used.
!13 DC     = Data code, 4 maximum: 1,3,7,8,A(=10),B(=11).
!14 PATTERN = Line pattern. Columns 16 to 80 of up to 9 subrecords.
!15---------------------------------------------------------------------------
!16FCODE  T N COMMENT                              CS P  FD  CA LW DS M LS DC

  NPFP      0 Fishing Prohibited Symbol/limit left PR N  DR  03 06          13
  NPFP    L 0 BMx.032, NMF.75,
  NPFP    L 1 (DFx. 028, DFx.028/ROT90/OFF.015,DFx.028,NBx.034)
  NPFP    L 2 DFx.028,DFx.028/ROT90/OFF.015,DFx.028,BNx.034
  NPFP    M 0 0.15NPIL
```

Figure 4.2 A record extracted from the Master File.

The main record is on the seventeenth line and the sub records describing how the line is patterned are on subsequent lines.

4.2.1.2 The Symbol File

A symbol file is a file containing point features, fonts and composite symbols. Point features are symbols, such as picnic tables, marshes, telephone poles, survey monuments, or manholes. Fonts are sets of characters and numbers. CARIS has a number of predefined fonts. User defined fonts extend the capability of the system by allowing foreign and special purpose character sets. Composite symbols are symbols which are combined from two or three symbols to become a new symbol. Using predefined symbols can save time because a single reference draws a series of lines. Otherwise, the symbols must be digitized by hand each time.

Symbols are described in the master file but the symbol coordinates are stored in the symbol file. The symbol file has three forms, **an ASCII source version** with extension .dat and **a compiled binary version**, with extension .bin. An ASCII source version can be accessed and modifiedby the user, but the .bin file can be used only by CARIS programs. In order to edit a symbol or add a new one, edit the symbol coordinates in the ASCII symbol file then compile it using the *Build CARIS Symbol File* tool. A third file with the same name as the symbol file and the extension .ibm cross-references the symbols with a bitmap image. This bitmap image, if it exists, will appear when a feature code of the symbol is selected before adding a symbol in the CARIS Editor.

4.2.1.3 The Text Specification File

The text specification file is a text file (extension.txt) which contains parameters that define the appearance of text. It ensures that map text specifications are followed during map production. There can be up to 1000 entries in the text specifications file. The text specification file consists of **keys** representing the font, the style, and the point size and **parameters** defining the font number, size, line thickness, and the spacing for a font. The following table describes the function of each field in the default text specification file.

Field	Column	Description
Key	1-12	A 12-character key used to identify the font.
Size	13-19	The size of the upper-case A of the font expressed in millimeters
Font	20-26	A number representing the font. CARIS fonts are numbered 1 to 26 for font A to Z. Non-CARIS fonts such as PostScript and True Type fonts are given numbers greater than 26.
Line Weight	27-34	The line thickness expressed in millimeters
Spacing	35-	The distance between characters expressed in millimeters, where block = calculated as the distance between the centers of the characters proportional = calculated as half the width of a character, plus half the width of the next character, plus the spacing value

Table 4.3 Fields in the default Text Specification File.

A number of fonts are available when CARIS is installed, but new fonts can be defined up to a total of 26 in the symbol file. An unlimited number of True Type or PostScript fonts can also be used. The key can be included in the master file as a subrecord of a feature code. Text associated with that feature code has the appearance defined by the parameters associated with the key. Figure 4.3 shows an extracted fields from the text specification file.

Key	Size	Font	Line Wt	Spacing
CB4.5	1.039	23	0.152	0.51
CM16	3.727	23	0.508	1.65
IB	2.892	6	0.813	1.76
IM4.5	1.064	6	0.127	0.48
IM14	3.197	6	0.508	1.45
UB6.5	1.466	1	0.254	0.73
UM9	2.128	1	0.254	0.90

Figure 4.3 Example of Text Specification File.

4.2.1.4 The Colour Map

A colour map defines the colours for the maps. It has the extension.cma and consists of: **index numbers** defining colours, **parameters** defining the hue, the lightness, and the saturation (figure 4.4).

<colour_number>
<colour_spec>=(<value1>,<value2>...<valueN>)
where:
<colour_number> is the integer colour number
<colour_spec> is the colour system specification (RGB, HLS, or CMYK)
<value1>, etc. integers representing values defining the colour; the number of values will depend on <colour_spec>.
RGB, and HLS require 3 values, CMYK requires 4.

Example:
!testfile
0 RGB=(255,0,0)
1 RGB=(0,0,255)
2 HLS=(100,100,100)
3 HLS=(10,50,50)
4 RGB=(10,0,255)
5 CMYK=(0,100,0,0)
6 CMYK=(100,0,0,0)
7 RGB=(9,9,9)

Figure 4.4 Example of the Colour Map.

CARIS provides a colour bar that displays the defined colours at the top of the screen. The colour map can be displayed using the CARIS Editor menu item *Options>Display> Colour>Show Colour Map*. In order to edit the colour map use *Options>Display> Colour>Edit Colour Table/Map*. A new colour map can be created and used by referencing with environment variable *uslXcmap*. Each line in a colour map defines one colour.

4.2.1.5 The Colour Table

The colour table defines a default colour set and assigns colour map index numbers to CARIS data features. The colour table can be edited using *Options>Display>Colour> Edit Colour Table/Map.*

The colour table is a text file with the extension .col. It consists of the following .

- **Comments**: The comment field is added to describe the purpose of the colour table. The comment fields of the default colour table file provides a brief explanation of the file use and a list of legal keywords. Legal keywords state the conditions controlling the assignment of a colour in a complex colour entry.
- **Complex colour table**: The complex colour table specifies conditions that must be met before a colour is assigned to a feature or group of features. These conditions are associated with legal keywords.
- **Simple colour table**: The simple colour table associates feature codes with colour numbers. User can define up to 100 entries in the table. The same colour number may be assigned to more than one feature code.
- **Default colour**: The default colour number (normally 1) is the colour number used to represent all features except those associated with entries in the simple and complex colour tables.

Table 4.4 describes the function of each field in the colour table; and figure 4.5 shows the example.

Components	Description
comments	Comment lines starting with a "!" character
complex table	An index number followed by an "=" and a two-letter code, where FC = Feature code UN = User Number ID = Source ID FL =flag (1-sel,2-bak,3-sel+bak,4-sup, 5-sel+sup,6-bak+sup, 7-masked)
simple table	An index number followed by a feature code
default colour	An index number
Note sel=selected, bak=background, sup=suppressed, masked=masked	

Table 4.4 The function of each field in the Colour Table.

```
! IHO Colour Table Example
!
! This file is used to match features to a colour number in
! order to draw it. If a feature satisfies more than one of
! the criteria in the colour table, then the first applicable
! colour will be chosen.
!
! USAGE:

! On exiting this colour table from the editor via a CARIS
! graphics module a file will be written called
! "filename.COL". On invoking a CARIS graphics command in
! the future on this file, this colour table will be used. If
! a .COL file is not found then the colour file given by
! uslXcolor will be copied to "filename.COL"
!
! The table consists of two parts: 1) Complex colour table
! 2) Simple colour table.
!
! NOTE: All lines beginning with exclamation marks ("!") are
! treated as comments.
!
! 1) 'COMPLEX' TABLE:
! **************
! This table associates a colour with features according
! to one of their general characteristics.
!
! 3 TS=(1990 01-JAN 10:00:00,1990 21-JAN 10:00:00) UN=1
! 4 LD=MD12
! 3 YF=CLOSE
! 5 LF=ARC
!
!*****************************************************************
7 IN42
7 IN13
7 IN60D2
7 IS24
6 IS21
6 IS22
6 IS23
7 IS31
7 IS32
7 IS33
7 IS34
7 IS35
4 IS41
4 IS42
7 TRIFILL
!
! If no match is made above the feature will be drawn in the
! default color which is:
1
```

Figure 4.5 Example of the Colour Table.

4.2.2 Setting Up the CARIS Support Files

CARIS provides two sets of support files, one for hydrographic (marine-based) applications and one for topographic (land-based) applications. In order to set up the CARIS support files before making a map or chart for a specific site, the following steps are required.

From Windows, click *Start>Run>Open>C:\CARIS\SYSTEM\Ih_setup.bat (or Tp_setup.bat)*. This file is executed to set up the environment for hydrographic (or topographic) applications. The hydrographic file includes the IHO symbol file and the appropriate definitions for use with them. Once the selected *Ih_setup.bat* file is run, the main support files will be used by being referenced with the environment variables (begin with **uslX**) as shown the following table;

Variables	Directory\Support Files
uslXsymbol_5	$carisXsys_bin\ih_symbo.bin
uslXmaster	$carisXsys\ih_maste.txt
uslXcolor	$carisXsys\ih_color.col
uslXtext_spec	$carisXsys\ih_texts.txt
uslXcmdmac	$carisXsys\ih_macro.dat
uslXcmap_plot	$carisXsys\ih_col_p.cma
uslXcmap	$carisXsys\ih_color.cma

Table 4.5 Variables and the main Support Files in *Ih_setup.bat.*

New support files can be edited or even created, but before using them, they need to be set by referencing with the appropriate variables. For instance, the support file called *"ih_maste2.txt"* is created and then set using *Set Environment Variable* tool in the *Environment Control* module of CARIS Tools. As a result, the variable *"uslXmaster"* is set from *"$carisXsys\ih_maste.txt"* to *"$carisXsys\ih_maste2.txt"*.

4.3 CARIS Mapping Basics

CARIS provides computer tools to store, manipulate and display map-related information commonly found on a paper map. Generally, paper maps are used to convey information about the earth and the features on its surface. In order to indicate the exact location on the surface that the map represents, special map related information (e.g.

scale bar, coordinate grid) is used. To more easily distinguish between the various types of features on the map (e.g. roads, rivers, buildings), different combinations of colours, symbols and patterns are used. For example, a thick red solid line may be used to represent a four lane highway and an orange dashed line may be used to represent a loose surface, dry weather road.

A digital map is a computerized version of a traditional map and it can also include additional information about the features found on the map. For example, a digital map may represent a property map showing the locations of properties in a city. Information associated with the properties, such as appraised value, owner and type of dwelling, may be also part of the digital map.

This information is called *"attribute data"*. CARIS stores the visual (graphic) part of a digital map in a special computer file called *"a CARIS file"*. The map features which are stored in a CARIS file are called *"CARIS features"*. Graphic data usually depicts a part of the earth, and is represented by the X,Y(and sometimes Z) coordinates of points on the earth. Because of this relationship to the earth, this part of the CARIS database is called *"the geographic database"* and graphic data is referred to as *"geographic data"*. The term spatial data is sometimes also used.

In addition to the features on a digital map, a CARIS file also contains general mapping information which defines the coordinate system used to represent the features. This information makes it possible for CARIS to know where the map is on the earth (geographic origin and extent), how the earth was flattened to make the map (map projection), and the scale of the map. Attribute data is usually not graphic and thus not represented by coordinates. Attribute data is usually stored in tables created and maintained by a database package. INGRES, dBASE, and Paradox are all examples of database packages which can be used to store attribute information.

CARIS uses a "key" to identify a feature. A key is a name consisting of up to 12 alphanumeric characters with no blanks between the characters. The key provides the link between the geographic data and the attribute data.

The CARIS database can be broken into two components, **geographic database** and **attribute database**, as shown in figure 4.6.

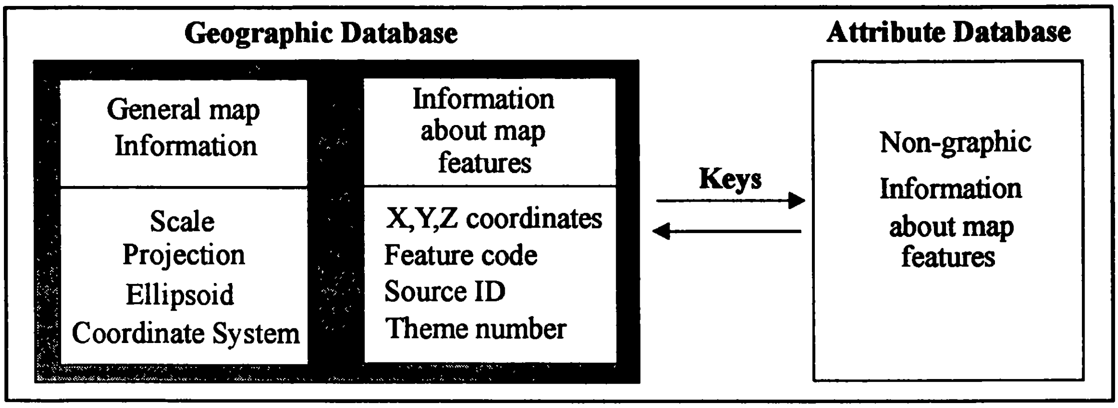


Figure 4.6 Components of a CARIS Database.

The geographic database contains coordinates of points used to represent map features, special names and numbers used to group and identify features and general mapping information that defines the coordinate system used to represent the map features.The attribute database contains data which is not represented by coordinates (i.e. non-positional).

4.3.1 General Mapping Information

General mapping information includes scale, projection, ellipsoid, coordinate system and resolution of the map data.

4.3.1.1 Choosing the Scale

The scale is important in CARIS because it provides a guide to selecting the resolution at which data will be stored in the CARIS file and determines the amount of detail that can be presented on a digital map. It is recommended the map data should be represented on the scale which best suits the data to be displayed. More detail can be presented on large scale maps than on small scale maps.

4.3.1.2 Choosing the Map Projection

A map projection is a way of representing an area of the earth's surface on a flat surface. Projecting features of a spheroidal earth onto a flat map usually causes some or all of the features to be distorted. For example, the features may be stretched in one direction, or they may appear relatively larger than features in other areas of the map. Different kinds of projections are available to control the distribution of these distortions. CARIS provides for the following projections:

- Lambert Conformal Conic
- Mercator
- Polyconic
- Rectified Skew Orthomorphic
- Transverse Mercator (including UTM)
- Cassini
- Stereographic (including polar)
- Gnomonic
- Gauss Krueger

The map projection is commonly printed on the map. The map projection must be well defined before being used as the base map (the framework to which all data will be referenced).

4.3.1.3 Choosing the Ellipsoid

The earth is not a true sphere. This must be taken into account if accurate measurements are to be made from maps. For the purpose of mathematical calculations, an ellipsoid is used as a best estimate of the earth's surface. This allows for the conversion between geographic latitude and longitude, and the projection's X and Y coordinates. Mapping people often refer to X coordinates as eastings and Y coordinates as northings. Projections are calculated on the most appropriate ellipsoid for a local area. Maps of an area using the same projection on different ellipsoids are not the same.

Ellipsoidal information is contained in a text file called the CARIS datum file. CARIS provides the following ellipsoids.

- Clarke,1866
- International
- ATS77
- NAD83
- Bessel (1841)
- Colosofsci Ellipsoid 1940
- Australian Geodetic 1966 and 1984
- Australian National ellipsoid
- European 1950 and 1979
- Everest ellipsoid
- Everest ellipsoid, revised Kertau datum
- Geodetic Datum 1949
- Geodetic Reference System 1980 (ellipsoid)
- International ellipsoid — same values as Hayford
- Borneo Rectified Skew Orthomorphic Grid
- North American Datum 1927 and 1983
- World Geodetic System 1972 and 1984

If the required geographic data is represented on a series of maps with different projections and different ellipsoids, it can be converted to a common one using CARIS software. A general transformation from one ellipsoid to another, and from one projection to the other, can be performed using the CARIS tool *Transform a Map*.

4.3.1.4 Choosing the Coordinate System

A horizontal coordinate system (grid) is a system of horizontal and vertical lines, as shown in figure 4.7. It is used to describe the locations of points on a map. One point in the coordinate system is chosen as the origin and assigned coordinate values of 0,0.The horizontal and vertical distance of a point from the origin is known as its coordinates.

They are usually referred to as Eastings or X in an easterly direction and as Northings or Y in a northerly direction.

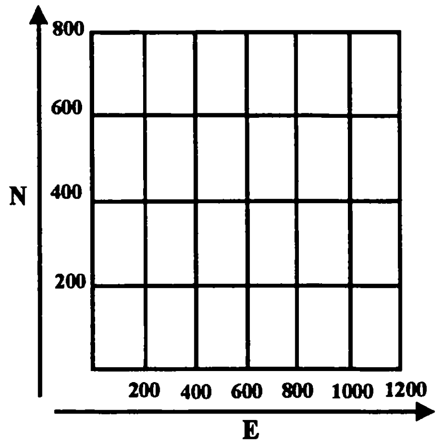


Figure 4.7 Northings and Eastings.

A vertical coordinate system has only one axis. One point on the axis is designated as the origin, or vertical datum, and is assigned a coordinate value of 0. Other points will have a vertical coordinate equal to distance from the origin. Mean Sea Level (MSL) is commonly used as a vertical datum. Hydrographic charts often use other vertical data. CARIS software supports four horizontal coordinate systems as follows;

- Northing and Eastings in Metres (NEMR)
- Non Registered in Metres (NRMR)
- Latitude and Longitude in Degrees (LLDG)
- Chart in Metres (CHMR)

In CARIS, The map data must be represented with one of these coordinate system which is appropriate the desired application. The following table describes each coordinate system.

Coordinate System	Characteristics
NEMR	Coordinates are expressed as northings and eastings in metres on the ground, referenced to a map projection. If the positions of the features on the map are based on a map projection, this coordinate system should be used.
NRMR	Coordinates are expressed in metres on the map and have no reference to location on the ground. This coordinate system is used when the information necessary for relating the map to the real world (control points) is not available.
LLDG	Coordinates are expressed in latitude and longitude in decimal degrees on a reference ellipsoid. This coordinate system is useful for storing data based on a global coordinate system. User can add data to a CARIS file based on an LLDG coordinate system using keyboard entry. User can also digitize a map in another coordinate system (e.g. NEMR) and convert it to LLDG.
CHMR	This coordinate system is used primarily for hydrographic charting. Coordinates are expressed in metres on the chart, based on an origin at the lower left corner of the chart. The latitude and longitude of the chart origin are known, providing a reference to the real world.

Table 4.6 Four Coordinate Systems available in CARIS.

4.3.1.5 Choosing the Resolution

The resolution of the data is the smallest possible distance that can be measured between two points on the map. Two points which are separated by a distance less than the resolution are considered to be coincident. For example, if the resolution of data is one metre at ground scale, two points less than a metre apart cannot be distinguished. The location of points will be rounded to the nearest metre as depicted in figure 4.8, where the dashed line is the true position of points and the solid line is the rounded position of points.

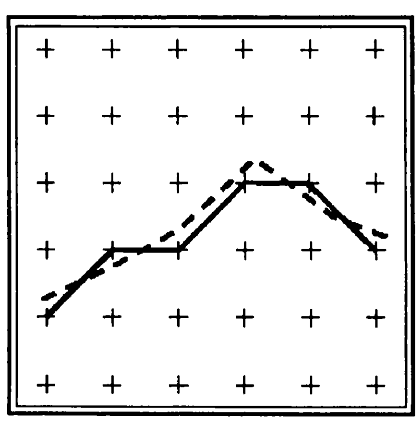


Figure 4.8 The resolution of the map data.

When choosing the resolution at which data will be captured, the following should be considered:

- the accuracy of the data coordinates required in the project
- the amount of storage available for the applications. The higher the chosen resolution, the more storage required for lines whose detail is extremely fine.
- the appearance of text and symbols on the final output

The level of accuracy of data varies according to the way the data are collected. The coordinate accuracy of data taken directly from a stereo plotter is generally higher than that taken from a paper map, assuming that the scales are similar; a list of surveyed coordinates is likely to be the most accurate of all *(Universal Systems Ltd.,1997).*

Curved lines collected at a fine resolution require more disk storage space than straight lines. If the cartographic appearance is important, a fine resolution may be required to retain the smooth appearance of a line. A coarse resolution will result in *"jagged lines"* on a plot. Choosing too fine a resolution may also result in a non-smooth line, showing the *"shakiness"* of the digitizing operator's hand.

4.3.2 Types of CARIS Data

CARIS supports various types of map data. These are the following.

- **Stream lines:** Stream lines are lines which contain points at regular intervals. Stream lines are used to represent irregular features such as rivers and coastlines.
- **Dashed lines:** Dashed lines consist of a series of dashes.
- **Point to point lines:** Point to point lines are lines which contain points only when the line changes direction. Point to point lines are used to represent regular features such as buildings and subdivision lots.
- **Positioned text:** Positioned text, sometimes referred to as notes, are strings of alphanumeric text which have an associated position.
- **Raster:** Raster data refers to a collection of pixel values, such as an image.
- **Names:** Names are strings of alphanumeric text.

- **Symbols:** Symbols are point features which have meaningful graphic representations.
- **Soundings:** Soundings are point features which represent water depth.
- **Spot heights:** Spot heights are point features which are represented by symbols and contain elevation information.
- **Text blocks:** Text blocks consist of one or more strings of alphanumeric characters which are treated as a block.

4.3.3 Classifying CARIS Data

CARIS stores two types of information for each feature at the time of data entry. These are X, Y, Z coordinates and tags which allow user to group features (e.g. the type of feature, the thematic layer to which it belongs, etc.)

If the map feature is not given the feature tag at the time of data entry, CARIS will tag the features with default values which may have to be changed at a later time to values suitable to the application. It is recommended that user classify the data in advance so that appropriate values can be assigned at data entry. CARIS feature tags are briefly defined in the following table:

Tag	Definition
Feature Code	The feature code is a 12-character alphanumeric code which identifies real world objects such as rivers, roads, houses, fire hydrants, shopping centres.
Source ID	The source ID is a 12-character alphanumeric code which identifies details about the source of the data.
User Number	The user number is a numerical identifier assigned to features with common characteristics. It may range between 1 and 2,000,000,000 (2-billion).
Theme Number	The theme number identifies the thematic layer to which a map feature belongs. It is a numerical identifier whose initial value is based on the user number.
Key	The key is a 12-character alphanumeric identifier which is used to relate spatial features to their attribute data in a textual database. If each map feature has unique attribute data, then the key will be unique.

Table 4.7 CARIS Feature Tags.

4.3.4 Map Display

This section describes how to control the display in CARIS graphics programs. This includes how to selectively display certain features, and how to assign colours to map/chart features.

4.3.4.1 Display Visibility Parameters

Data identifiers are used to control which data is displayed by the CARIS Editor via the visibility parameters. When the graphics screen is redrawn, the visibility parameters are checked and only those features referenced are drawn. This is useful in allowing only the map/chart features of interest to be drawn at any time.

Within the CARIS Editor, CARIS Information Manager, CARIS SAMI, orV3D, select the menu item *Options> Display> Visibility Parameters* or click on the visibility parameters icon. Set the appropriate parameter(s) then redraw the CARIS file using the *Refresh* icon. The display visibility parameters dialogue is shown in figure 4.9.

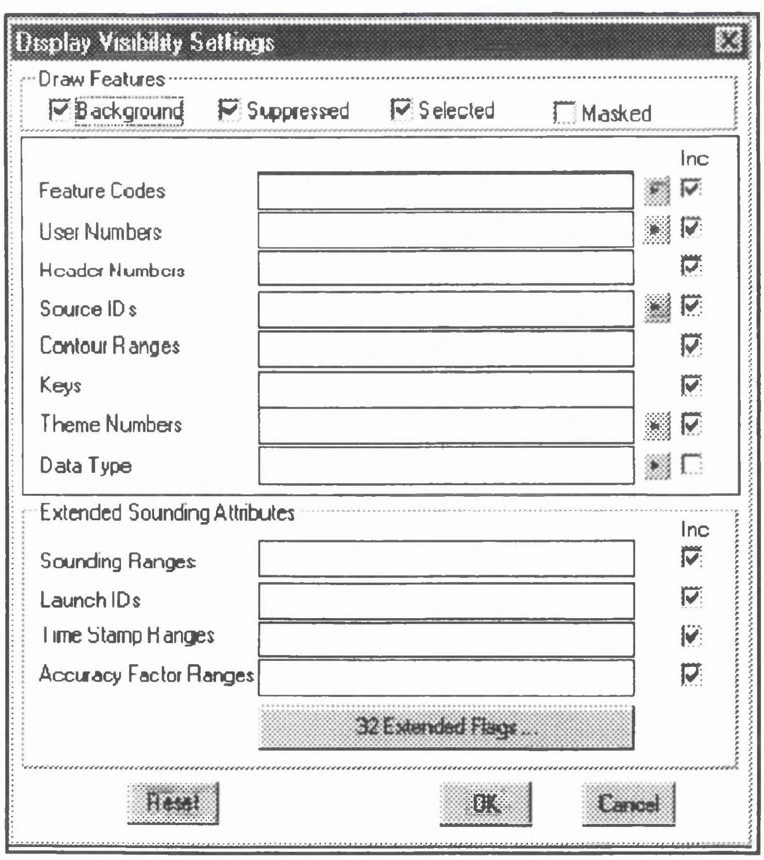


Figure 4.9 Display Visibility Parameters.

The feature to display can be restricted by using one or more categories (e.g. by feature code and by user number). For feature codes, user numbers, source IDs, and theme numbers, they can be selected by clicking on the *Select* button and selecting from a list of available identifiers. If more than one category is selected, features will be drawn only if they match both categories. The features can also be displayed according to its compilation status or whether it is masked or not by selecting or deselecting the appropriate options. If a different subset of features or all map (chart) features are required to be displayed again, the visibility parameters must be reset. In order to clear or change a particular setting, simply remove or add the appropriate values. To restore all settings to the default, click on the *Reset* button.

The visibility parameters are remembered from one CARIS Editor session to the next. This includes the last area that was zoomed in on (if applicable). The same visibility parameters settings are used by the different CARIS graphics programs when viewing the same CARIS map file. Visibility parameters can also be used to restrict processing in CARIS batch programs. For example, the CARIS tool *Extract Part of a Map* can be restricted to extract only the features referenced in the visibility parameters, rather than every feature in the file.

4.3.4.2 Colour Table and Colour Map

Two text files are used to control colours in CARIS, colour table and colour map. Colour table assigns colours to features in a CARIS map/chart, where colours are defined by numbers starting at 0 (the background colour). Colour map defines the actual colours using the HLS (hue, lightness, and saturation) colour system.

The set of colours currently available can be viewed by choosing the *Show Colour Map* menu item from the *Options>Display>Colour* menu in any graphics program. To edit the colour table or the colour map, select *Options>Display>Colour>Edit Colour Table/Map* or click on the colour editor icon. The interactive colour editor will appear. If the advanced settings of the colour editor is used to assign colours to polygons, colour-filled polygons can be displayed in both the *CARIS Editor* and *CARIS Information Manager* by clicking on the *Enable colour fill* icon.

As mentioned earlier, CARIS, a GIS software system, provides two versions of support files for different purposes, one for hydrographic applications and one for topographic usage. These support files are originally well defined to facilitate the operator doing mapping operation. They can, if required, be modified to meet specific requirements. CARIS also provides different kinds of mapping information (e.g. map projections, ellipsoids, horizontal coordinates, etc.) to serve different purposes of map production. Different map data in a CARIS file can be selectively presented by using *Display Visibility Parameters*, Colour Map and Colour Table. Using these support files, mapping information and facilities available in CARIS, digital map (or chart) production can be performed effectively. Digital Chart Production with CARIS is discussed in the next chapter.

Chapter 5
Digital Chart Production with CARIS

5.1 Proposed Digital Chart Production Flowline

As mentioned in chapter 3, Thai Hydrographic Department (Thai HD) is in the process of moving from manual chart production to digital production. The idea is to use digital data from a cartographic database to produce the digital chart file in support of paper chart production initially and electronic charts in the future. Therefore, the digital data is primarily required to serve such production. The first task that has to be done necessarily is converting the existing charts from paper form into digital form. The chart production procedure has to be modified or even recreated in some stages. As a result, the new proposed "Digital Chart Production Flowline" has been developed in order to display the whole process of digital chart production, as shown in figure 5.1

5.2 Data Validation

Due to the various sources of information used for chart production, it is impossible to use and store all information in the cartographic database. Only the useful, up to date and accurate data, or in other words "clean data", will be input and stored in the database. Currently, Thai HD does not have the proper process in place to deal with data validation. As a result, the proposed "Data Validation Flowline" is required in order to review, assess, validate and determine the usability and accuracy of such data. The proposed "Data Validation Flowline" and "Data Validation Check Form (DVCF)" are shown in figure 5.2 and appendix 5.1. The concept of this process is that all new documents entering the Thai HD are routed through the validation stage, where a comparison is made with any current projects in validation, field surveys, and chart production. The reviewer examines the document for its usefulness and that all necessary information is available. If it is not useful, the document is discarded and assigned *to "Unuseful Information"* with the document number. If the document has already been received, it will be again discarded and assigned to *"Duplicate Information"* with the document number.

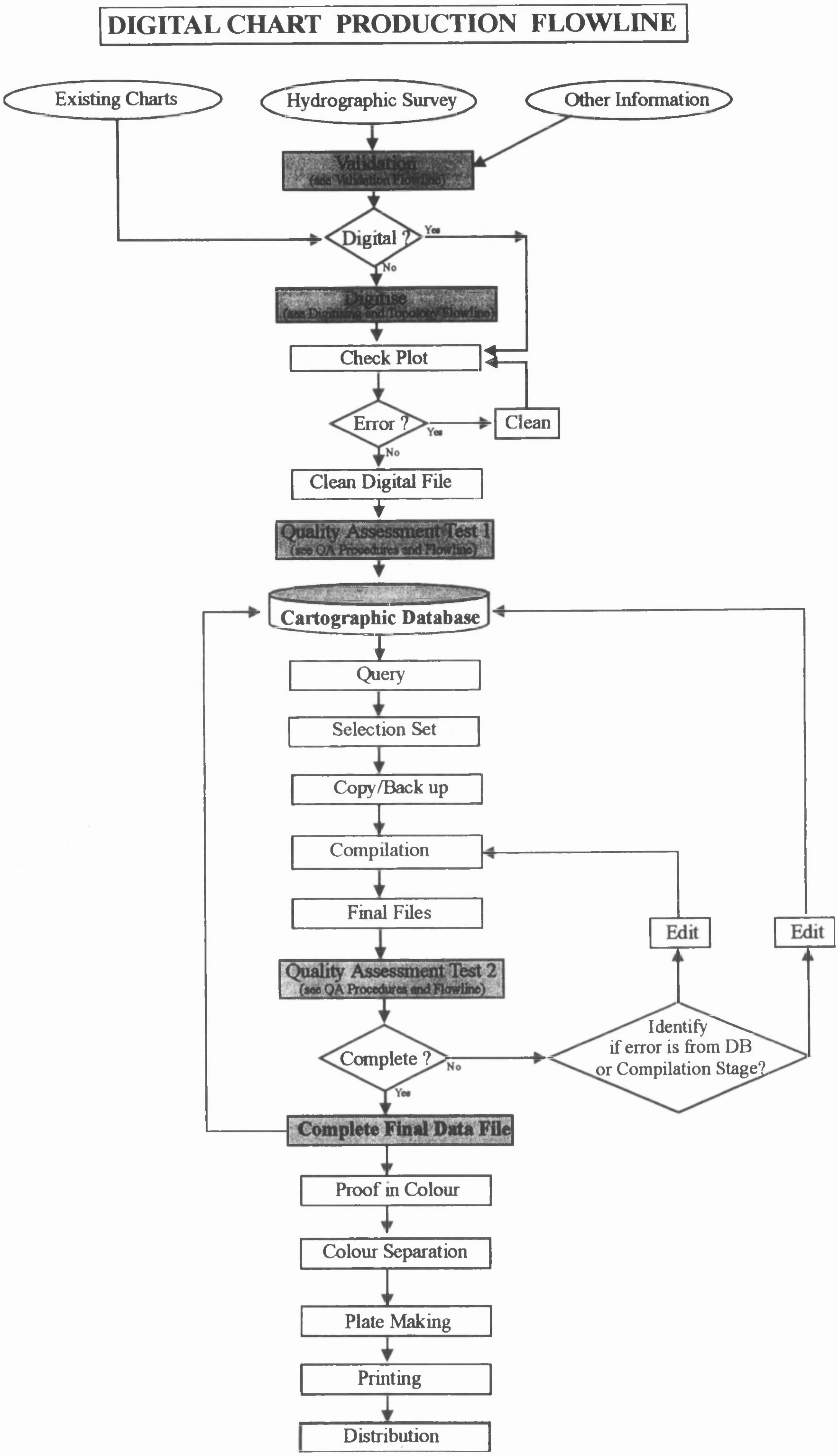
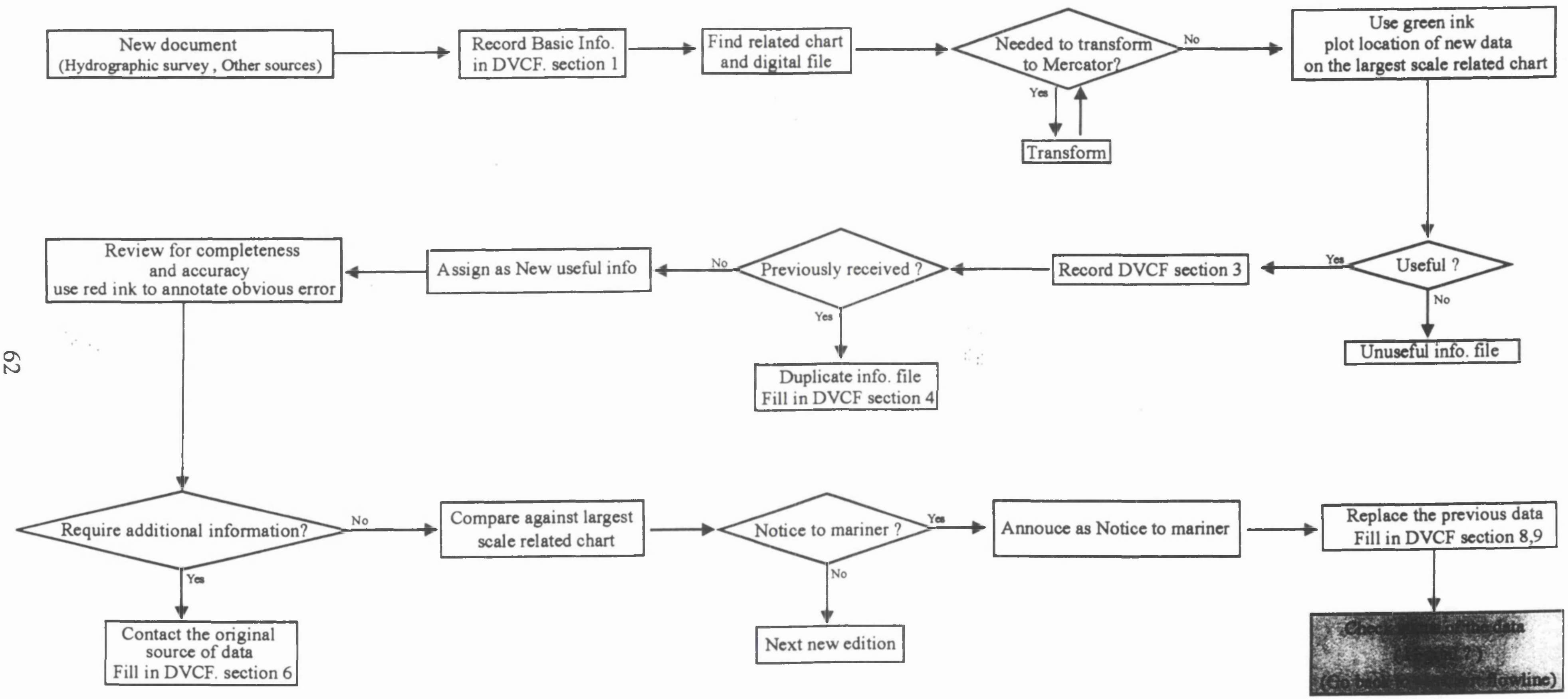


Figure 5.1 Proposed Digital Chart Production.

Data Validation Flowline



Note DVCF=Data Validation Check Form

Figure 5.2 Data Validation Flowline.

But if the document is determined to be useful, the document is then assigned to *"Useful Information"* with an appropriate document number and compared against the largest scale chart to determine what action is the most appropriate for disseminating the information. It is the reviewer's requirement to determine which information may cause a hazard to navigation, or conversely, which benefit commerce. When a potential Notice to Mariner exists, a request for action is sent to the navigation instrument division. A comparison of the document against the existing data is carried out. The decision to supersede or keep data depends on scale, data, changes in the data itself and usefulness for charting purposes. For examples, small scale data may supersede large scale if dates are very different (e.g. 1970,1:25,000 chart may be superseded by 1998,1:50,000). The new data should supersede the old data. Newer data should never be superseded with older data. Once assigned to *"Useful Information"*, the new document is checked to see if information is available in digital form. If not, data conversion of such a document from the original form into a digital one is performed and stored in the cartographic database for further operation.

5.3 Data Quality Specification of Digital Charts

In order to check if the final digital data meets the requirement, there should be a standard to be referenced against. In this project, such a standard was created and called "Data Quality Specification of Digital Charts". This specification is intended to facilitate the production of digital chart files, digitised from existing charts. This specification deals primarily with the structure of digital files. Thai HD has been traditionally concerned with the visual presentation of chart information using a paper form. In the digital world, it is critical that the underlying data is correct and unambiguous in terms of file coding, attribution, organisation and structure. The data must be strictly defined and predictable at the non-graphic or database level. Assuming CARIS or a similar digital production system will be used, in order to achieve these requirments the proposed "Data Quality Specification for Digital Charts" was developed by the author. Before discussing this specification, some discussion of terminology is needed. "Integrity" means "reliability", such as there being no conflict in the database and "correct" means "the same as", for example the attribute of features in digital charts are the same as those of the original. Criteria used by the author are:

1) Header of the digital chart must be correct using "Making Header Procedure".
2) Digitising must follow Digitising Flowline, Digitising Specification, THAI HD Cartographic Manual, THAI HD Symbols and Abbreviations used on Thai Charts and CARIS Hydrographic Symbology.
3) User Number and Theme Number (UN/TN)
    - must be the same.
    - must not = 0
    - of the final Digital Chart File should contain the following UNs/TNs 10, 20, 30, 31, 32, 33, 34, 40, 50, 60, 70, 71, 80, 90, 100, 110, 120, 121, 130, 140, 160, 170, 180, 190, 200.
    - requiring fill colour must have topology.
4) Feature Code (FC)
    - must be valid, up to date and associated with the correct features.
    - of each category must be in the correct UN/TN.
    - with Z value must be correct.
5) Features must not be digitised twice or duplicated.
6) Topology
    - in topological theme number, Network, Polygon Topology and Polygon Label must be all "COMPLETE".
    - should use Standard Polygon Label.
7) Source ID must be valid and associated with correct features using the Standard Source ID.
8) Compilation Status of all features must be "SELECTED".
9) Soundings – 100 % must be correct, with a maximum locational error not exceeding 1.0 mm. at chart scale
10) Aids to Navigation
    - must have 100% correct attributes, with a maximum locational error 1.0 mm. at chart scale.
    - should, if possible, use the latest information.
11) Dangers
    - 100% of dangers to navigation should have the correct attributes, with maximum locational error 1.0 mm. at chart scale.
    - If possible, use the latest information for this matter.

12) Texts

- Names and Other texts must have the correct attributes (spelling, font size, font style, positioning)
- Bottom Quality must be digitised as TEXT not SYMBOL.
- Abbreviation of colour of buoys must be digitised as SYMBOL not TEXT.

13) Positional Accuracy

- Registration accuracy should have RMSE $\leq$ 0.3 mm. at chart scale.
- All features should have a maximum locational error not exceeding 1.0 mm. at chart scale.

14) Final Digital Chart File must be in CARIS format (.DES) and importable and exportable into NTX, ASCII, DXF, DLG format without loss of information.

5.4 Digital Chart Production with CARIS

5.4.1 Feature Tags

As mentioned in 4.3.3 (Classifying CARIS Data), each feature entered in a CARIS file will be stored with two types of information, one is X,Y,Z coordinates and the other is feature tags. The feature tags are used to: associate digital data with real world features and with other digital data; classify data and link it to external information in attribute databases; control which features are displayed in the graphics area and assign colours to features based on combinations of the feature tags. Data can be processed, analysed, and retrieved conveniently using the feature tags. The CARIS feature tags that are used are Feature Code (FC), Source Identification (Source ID), User Number (UN) and Theme Number(TN),

5.4.1.1 Feature Code (FC)

The feature code is a 12-character alphanumeric code which is used to classify lines, points (symbols), and names on a map or chart into groups of real world features such as coastlines, contours, roads, rivers, or buildings. The feature codes are used in CARIS to determine the colours of features and their symbolised appearance on the map or chart. The operator will be prompted for the feature code before adding features to the CARIS file. The feature code can be changed using *Edit>Features>Set Feature Code* menu item in SAMI or CARED. The features can be assigned different colours according to their feature codes and the code itself can be retrieved interactively by pointing at a feature. The feature codes are stored in the master file. CARIS provides two version of each master files, one for hydrographic (marine-based) applications and one for topographic (land-based) usage. In this project the former, namely "*ih_maste.txt*", was used. In order to facilitate the operator, CARIS also provides a document called "CARIS Hydrographic Symbology" that contains all feature codes based on IHO INT1 Standard. For instance, the feature code begins with AL indicates artificial land features (e.g. ALBD=building, ALROMO=motorway), the feature code begins with CL indicates coastline (e.g. CLSL=surveyed coastline, CLSLSDLT=sandy shore). If there is a wide variety of features, it may be useful to group them and assign feature codes to groups. If, for example, all coastline features began with CL, it would be possible to use the asterisk as a wildcard (CL*) to mean all feature codes beginning with CL. An example of the feature codes in CARIS Hydrographic Symbology is shown in appendix 5.2.

5.4.1.2 Source IDs

The source ID is a 12-character alphanumeric code which identifies information about the source from which a feature was captured. The source ID can be assigned to the features using *Options>Features>Source ID* and can be changed or edited using *Edit>Feature>Set Source ID*. The features can be assigned different colours according to their source ID and the ID itself can be retrieved interactively by pointing at a feature. The source ID can consist of letters, numbers, and underscores only. It is recommended not to use characters such as slashes, brackets or dollar signs. The source ID should be assigned to each real world feature in the database that reflects information about its source. For this project, in order to have the source ID clearly identify the source, a standard for source IDs was created as shown in table 5.1. The source ID "TCH_1998_045" (row 2) indicates that the data associated with this source ID comes from Thai chart, produced in 1998, chart number 045.

SOURCE OF DATA	FORMAT	EXAMPLE
Field Survey	SUR_YYYY_NNN	SUR_1998_001
Thai Chart	TCH_YYYY_NNN	TCH_1998_045
Thai Topographic Map	TTM_YYYY_NNN	TTM_1998_025
Notices to Mariners	NTM_YYYY_NNN	NTM_1998_001
Other Sources	OTS_YYYY_NNN	OTS_1998_001
Note Y=Year of issued data, N=the order of issued data in such a year		

Table 5.1 The proposed Source ID Standard.

5.4.1.3 User Number (UN)

A user number is a number ranging from 1 to 2 billion and assigned at the time of data capture to groups of features sharing common characteristics. It operates in the same manner as "layer" in Corel draw and "level" in Microstation. It is a good idea to group all the real world features in the database into appropriate themes or categories and assign each category a user number. This will facilitate the operator in subsequent operation. For example, in a digital chart file, coastlines and hydrographic contours are contained in UN=200, Aids to navigation are contained in UN=120, soundings are contained in UN=160 and so on. When some soundings need to be changed, only UN=160 is retrieved to edit the desired soundings. All UNs don't have to be retrieved unnecessarily in order to do such an operation. The user umber can be assigned to the features using *Options>Feature>User Number* and can be changed using *Edit> Feature>Set Feature Code.*

5.4.1.4 Theme Number (TN)

A theme number is a number ranging from 1 to 2 billion and assigned by CARIS to groups of features that have topology. The user number assigned at data entry automatically becomes the initial theme number. The user number and theme number are separate entities. It is recommended that they should be treated as one number. The same feature should not be assigned a different user and theme number. The building of network topology and polygon topology is based on theme numbers. Groupings of features assigned to a particular theme number can be overlaid on other themes to produce a new layer of information with a new theme number. When themes are later merged or renumbered, the user number will not be changed. It will act as a record of the original theme. A new theme number should be assigned only when combining existing themes or renumbering a theme.

5.4.2 Data Capture

Data can be captured to a CARIS file in three basic ways, depending on the source of the data. If the data is on a paper or mylar map/chart sheet, data can be added using a digitizing table or tablet with the **CARIS Ed**itor (Cared). If the data has been scanned (1-bit TIFF), data can be added using the raster-following functions of CARIS **SAMI**

(Semi-Automated Mapping Input). If the data is in the digital format of a CAD program or another GIS program, data can be converted to CARIS format using one of the tools in the *Import & Export Map Data* module.

Due to the fact that the Thai HD's first task of digital production is converting the existing paper charts into digital form, the second method which is entering data using the raster-following functions of CARIS SAMI seems to be the most likely method to be implemented for such a task. As a result, this method was selected for this project. The "Digitising Flowline" was created and is shown in figure 5.3. Entering data using SAMI can be divided into three stages. These are Pre-processing, Data Entry processing and Post-processing

5.4.2.1 Pre-Processing

Pre-processing involves scanning the required chart, converting the scanned chart into CARIS raster object format and thinning the raster data into1-bit. The original should preferably be a mylar chart but, to test the production process a paper chart was used. The selected area extracted from Thai chart number 142, scale 1:120,000, coverage latitude 13-00-00 N to 13-12-00 N, longitude 100-46-00 E to 100-59-00 E (180 mm. × 184 mm.), was to be utilised as the original chart in this project, as shown in figure 5.4.

Scanning Chart: The original chart was scanned using a "Black Widow" flatbed scanner, model Scan Pro 4800 SP, resolution 400 dpi, colour mode, together with "Paint Shop Pro 5" software. It was then decreased in colour depth into 2 colours (B/W) and saved in TIFF format (uncompressed). It is recommended that the chart should be scanned at the coarsest resolution giving the acceptable result. The finer the resolution of the scanned image, the greater the processing time. Therefore, some testing may be required to determine which resolution is optimal *(Universal Systems Ltd., 1997)*.

Converting TIFF image (.tiff) into CARIS raster object format (.des): The TIFF image was converted to CARIS raster object format in order to be used in CARIS SAMI, using the *TIFF Image Format* program in the *Import & Export Map Data* module in *CARIS Tools* as shown in figure 5.5.

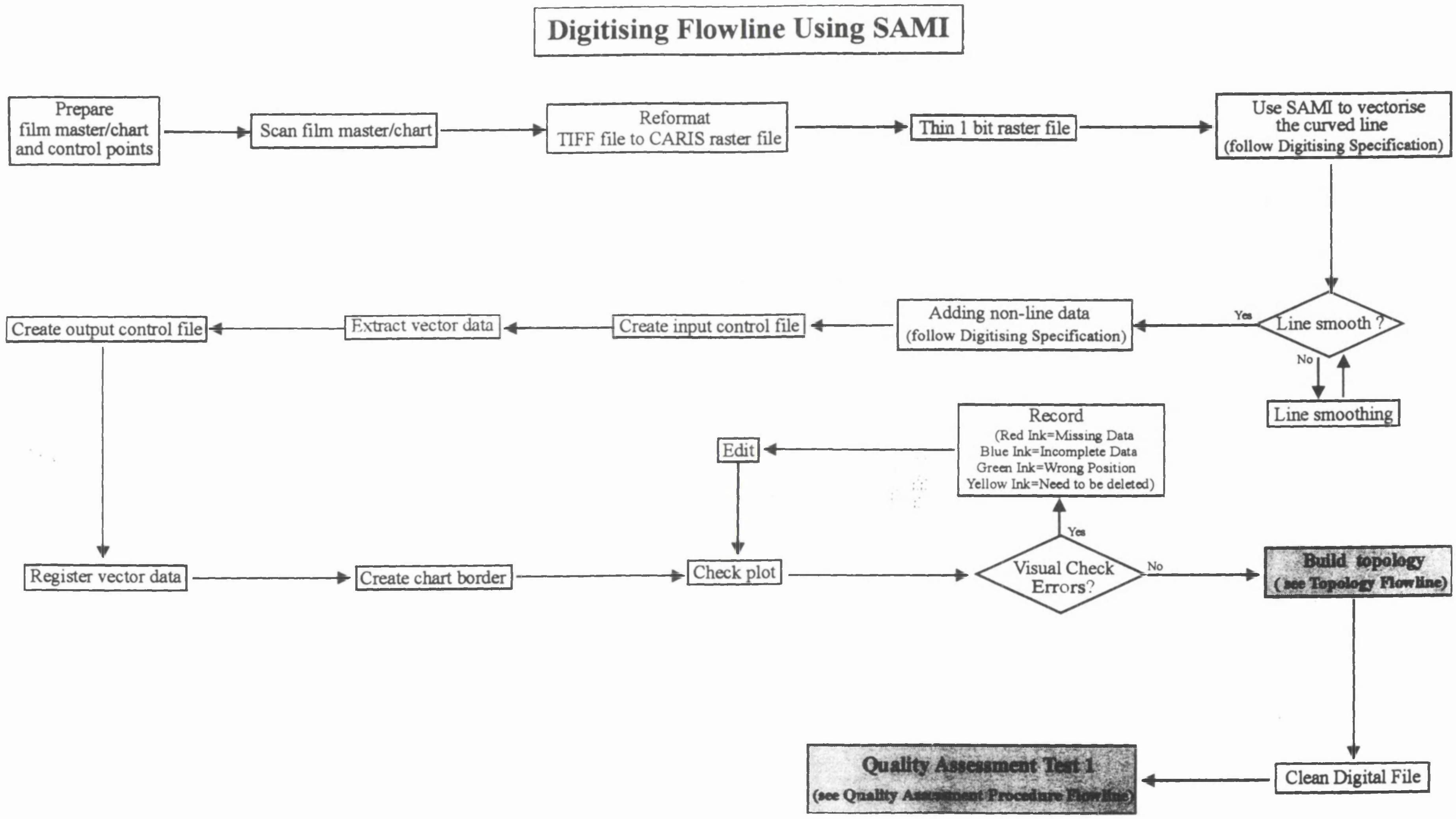


Figure 5.3 Digitising Flowline using SAML

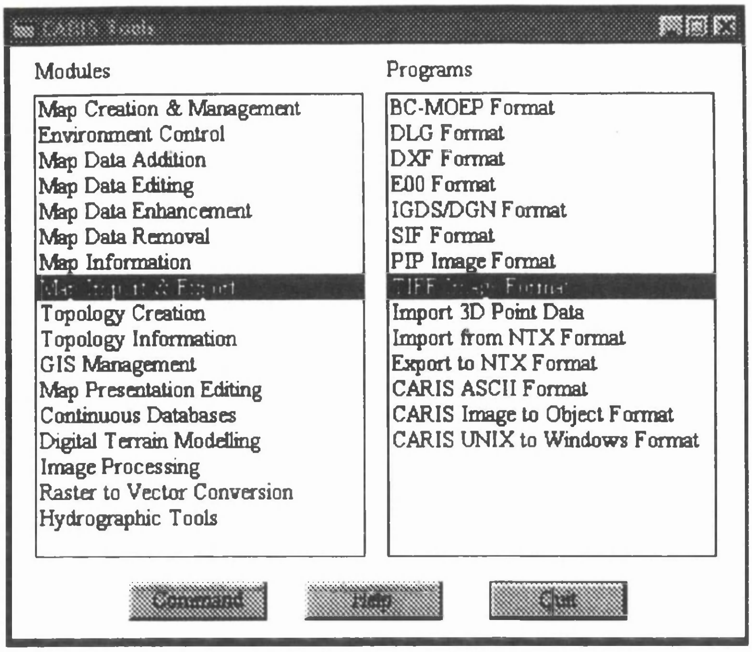


Figure 5.5 The *CARIS Tools*.

Thinning the raster data: The CARIS raster object format was then thinned in order to speed up line following in SAMI. *The Thin 1-Bit Raster Data* tool created a new layer of CARIS raster object data in a CARIS file by thinning the existing raster object data in that CARIS file. The original raster object data will remain unchanged in the CARIS file. The thinned raster is given the feature code THINRAST and user number 9999 by default. The *Thin 1- Bit Raster Data* process can be very time consuming. It is recommended that if a large detailed chart is to be thinned, this process should be run overnight or at other off-peak times *(Universal Systems Ltd.,1997)*.

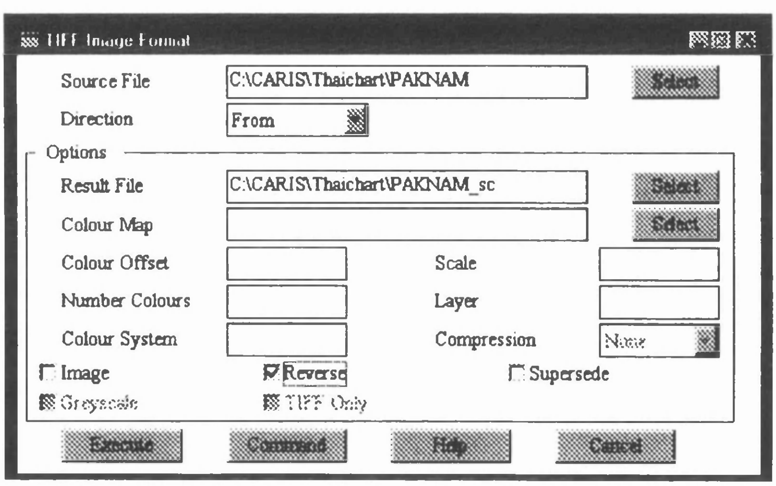


Figure 5.6 The option window of *TIFF Image Format* program.

Thin 1-Bit Raster Data is an iterative process. During each iteration, the whole file is processed to remove pixels from lines that have thickness greater than one pixel. The thinned raster data is now ready to be captured in SAMI.

5.4.2.2 Processing

5.4.2.2.1 CARIS SAMI

CARIS SAMI is a computer-assisted digitizing system. It converts raster data into vectorised line data semi-automatically. It also enables fast manual digitization of text, symbols, soundings and spot heights. It does not require a digitizing table; only a mouse is required. SAMI avoids inaccuracy due to tracking errors in conventional digitizing tables and reduces digitizing time drastically. SAMI can be started by clicking the *CARIS SAMI* icon from the *CARIS Suite*. Once started, SAMI window and SAMI tools icon panel appear as shown in figure 5.7.

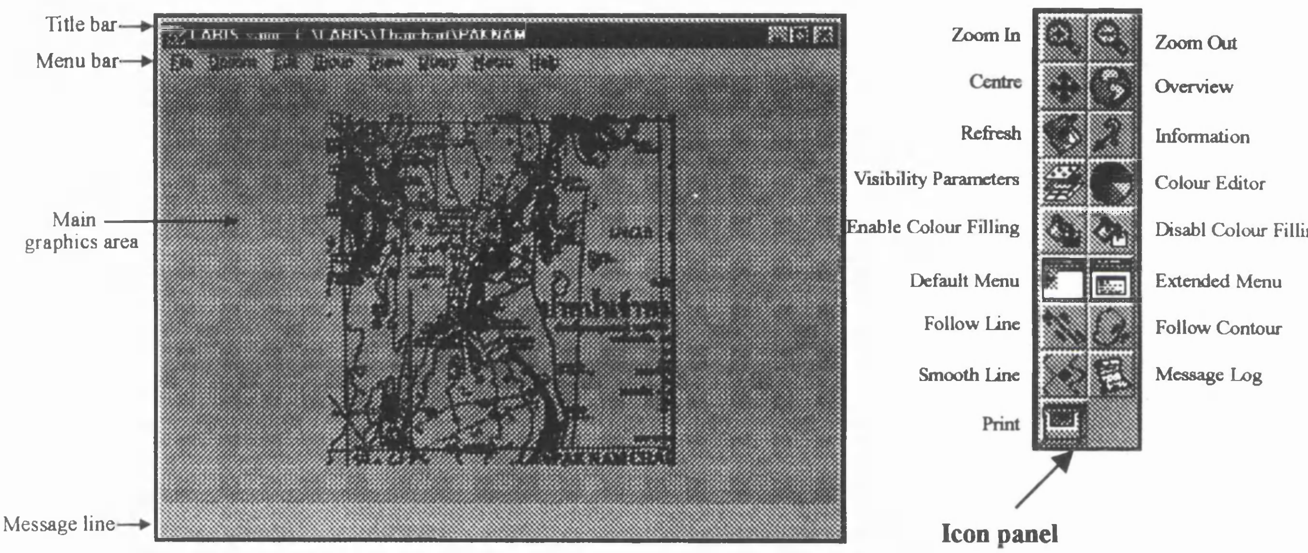


Figure 5.7 CARIS SAMI window and *SAMI tools* icon panel.

In SAMI (and also CARED) there are three basic ways to communicate with the commands: using menu bars; macro commands; and the icon panel.

Menu Bar consists of a number of textual items called “menu titles”. Each menu title contains drop-down menus and cascading menus. The menu can consist of many cascading menus which branch out in hierarchicies to form a menu tree (figure 5.8). In subsequent descriptions, the “greater than” symbol (>) is used to separate the different levels in this menu tree. For example, *Edit>Line>Add>Contour Follow* refers to *Contour Follow* item in the cascading menu *Add* which in turn is an item in the *Line* menu.

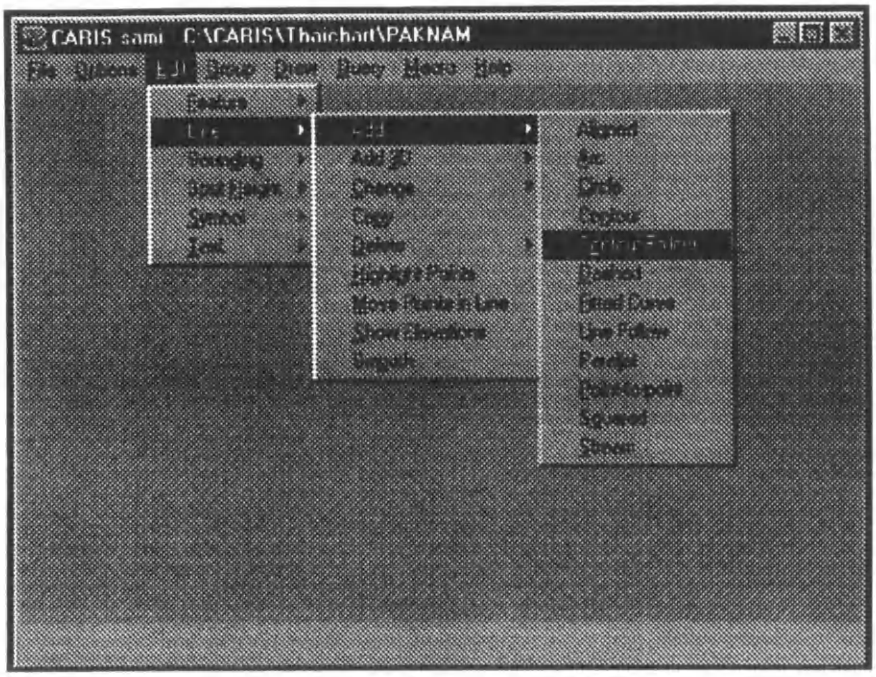


Figure 5.8 The Menu Tree.

Macro Command can be used by typing macro names which access the actual commands behind the menu interface of CARIS programs. CARIS allows the operator to design his own CARIS macros to replace the system menus. CARIS macros are equivalent to the menu items. Some users may prefer activating commands by entering macro commands rather than clicking several cascading menus. When typed, the macro will appear on the message line of main SAMI graphic window, then <*Enter*> is pressed to activate the desired command. Examples of standard macro commands are shown in table 5.2.

Macro	Description	Equivalent Menu Items
LIAA	add an arc	Edit>Line>Add>Arc
LICI	add a circle	Edit>Line>Add>Circle
LICO	add a contour line	Edit>Line>Add>Contour
LIAS	add a stream line	Edit>Line>Add>Stream
LICL	clip line	Edit>Line>Change>Clip
LIEX	extend line	Edit>Line>Change>Extend line
LIDE	delete line	Edit>Line> Delete
NACH	change the attributes of name	Edit>Text>Change
SOCH	change the sounding's depth value	Edit>Sounding>Change

Table 5.2 Example of standard macro commands in CARIS.

Icon Panel contains icons which provide shortcuts to frequently used commands. For example, selecting the *Zoom In* icon is the same as selecting the *Draw>Zoom in* menu item.

Mouse Button Functions are mainly used for digitising purpose. They function in two modes, Normal operation mode and Verifying mode.

- *Normal operation mode:* The left button is used to select menu item or digitise a point, the middle button is used to enter search or snap mode (type "S" instead in case of 2 button mouse) and the right button is used to quit the current command (or "Q").
- *Verifying mode:* The left button is used to accept or Yes ("Y"), the middle button is used to not accept or No (type "N" in stead in case of 2 button mouse), and the right button is used to reject or cancel or quit.

Before starting the operation, the hydrographic environment is set in order to get the hydrographic CARIS Support File (e.g. ih_maste.txt, ih_symbol_5.bin, ih_colour.col). This is achieved by running *ih_setup.bat* via *Start>Run>C:\CARIS\System\Ih_setup .bat>OK*. Once selected, the Support files for hydrographic applications are available for further operations.

SAMI is started by clicking on the *CARIS SAMI* icon in the *CARIS SUITE* and selecting the CARIS file containing the sample scanned chart to be used for on screen digitising. The raster scanned chart is displayed in the main graphic window.

The TIFF data (FC=TIFF) and the thinned raster data (FC=THINRAST) are initially both displayed in *black* in UN 9999. As mentioned earlier, the thinned raster was required for digitising purpose because it could speed up the operation. To differentiate those two raster data sets, the thinned raster data was assigned to *red* colour in *Colour Map & Table Editor* (figure 5.9) by either selecting *Options>Display>Colour> Edit Colour* or clicking the *Colour Map & Table Editor icon*. This results any feature code with FC=THINRAST to be drawn in the red colour. The vector lines, as they were added consequently, are drawn in black by default.

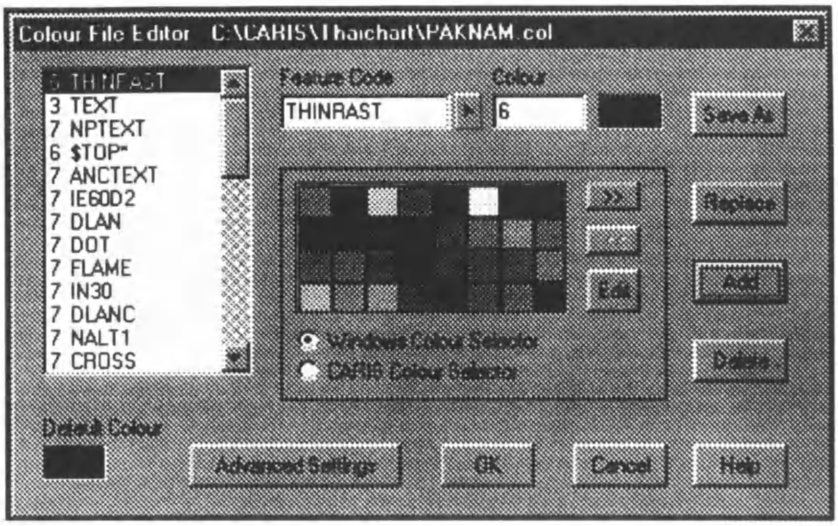


Figure 5.9 Assigning colour by FC in the *Colour Map & Table Editor*.

Only the thinned version of the raster image needs to be displayed on the screen. To do so, the thinned data is selected by using either *Options>Display>Display Visibility Parameter>Feature Code>Thinrast>Include>OK* (figure 5.10) or the *Display Visibility Parameter* icon and selecting Thinrast to be shown. Now the thinned data is ready to be traced on screen.

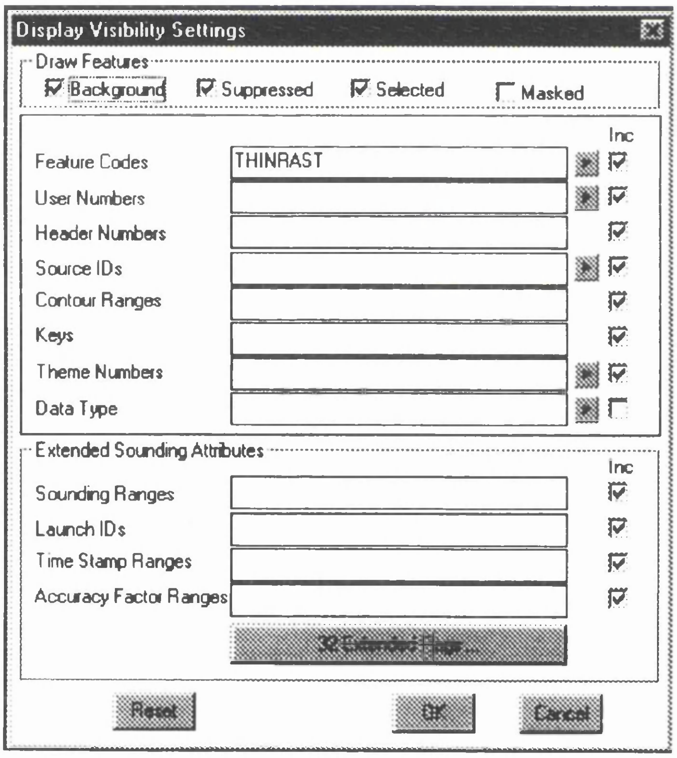


Figure 5.10 Setting the *Display Visibility Parameters*.

All features to be added in the CARIS file have to be assigned a feature code and user number (feature tags) in order to access them for data manipulation in the further processes. It is useful to organise the feature tags for each feature in advance. As a result, the proposed "Digitising Specification" (table 5.3) was created in order to determine which feature code is suitable for the feature to be added and in which user number.

This specification is based on three referenced documents, "Thai Chart Production Manual", "Symbols and Abbreviations used on Thai Chart" and "CARIS Hydrographic Symbology". It is intended to assist the operator in assigning the correct feature tags to the feature added. For instance, if the operator wants to add a wharf on the digital chart, he can see that the wharf is in the Ports and Harbours Category of Symbols and Abbreviations used on Thai Chart, it has to be in UN=110 from the Digitising Specification and it has to have FC=AWPR from CARIS Hydrographic Symbology. The proposed "Digitising Specification" is shown in table 5.3. For data quality assessment purposes discussed in the next chapter, all feature codes, user numbers theme numbers and texts associated with all features captured in this project are required to be filled in on the "Quality Assessment Check Form" which will be used for checking the data quality of the final digital chart file. More details about quality assessment procedures will be discussed in the next chapter.

By using the proposed Digitising Specification, it is expected that the digital data will be added into the digital chart file systematically and the digital chart file, as a result, will be structured logically.

DIGITISING SPECIFICATION				
No.	**Category**	**User No.** (Theme No.)	**DataType**	**Example**
1	Chart Border, Neatline, Lattice	10	Line	See -Thai HD Manual Chapter 4 (Chart Format, Dimension and Grid)
2	Title Block, Bar Scale	20	Text\Line	See -Thai HD Manual Chapter4 (Tittle)
3	Name of places and Islands (Province, Amphur, District, Street and etc.)	30	Text	See -Thai HD Manual Chapter 7 (Geographical Name)
	Text of Aids to Navigation	31	Text	See -Symbols and Abbreviations Book Index K, L, N, p17-24, 26 (Lights, Buoys Beacons and Fog Signals)
	Purple Text	32	Text	See -Thai HD Manual Chapter 7 (Geographical Name)
	Text of Miscellaneous Station	33	Text	See -Symbols and Abbreviations Book Index J, p16 (Miscellaneous Station)
	Text of Radio and Radar Station	34	Text	See -Symbols and Abbreviations Book Index M, p25 (Radio and Radar Station)

No.	Category	User No. (Theme No)	Data Type	Example
4	Building	40	Text\Line\ Symbol	See -Symbols and Abbreviations Book Index I, p14-15 (Building)
5	Artificial Features	50	Text\Line\ Symbol	See -Symbols and Abbreviations Book Index H, p12-13 (Artificial Features)
6	Control Points and Spot Height	60	Symbol	See -Symbols and Abbreviations Book Index D, p7 (Control Points)
7	Topographic Contour	70	Line	See -Thai HD Manual Chapter 7, Symbols and Abbreviations Book Index C, p5-6, (Land Topography)
	Topographic Contour Label	71	Text	See -Symbols and Abbreviations Book Index C, p5-6, (Land Topography)
8	Natural Features	80	Text\Line\ Symbol	See -Symbols and Abbreviations Book Index C, p5-6, (Land Topography)
9	Miscellaneous Station	90	Text\ Symbol	See -Symbols and Abbreviations Book Index J, p16 (Miscellaneous Station)
10	Radio and Radar Station	100	Text\ Symbol	See -Symbols and Abbreviations Book Index M, p25 (Radio and Radar Station)
11	Ports and Harbours	110	Line\ Symbol	See -Symbols and Abbreviations Book Index G, p10-12 (Ports and Harbours)
12	Aids to Navigation	120	Text\Line\ Symbol	See -Symbols and Abbreviations Book Index K, L, N, p17-24,26 (Lights, Buoys and Beacons and Fog Signals)
13	Dangers	130	Symbol	See -Symbols and Abbreviations Book Index O, p27-29 (Dangers)
14	Various Limits	140	Text \Line	See -Symbols and Abbreviations Book Index P, p30-33 (Various Limits and etc.)
15	Coasline Characteristic	150	Line	See -Symbols and Abbreviations Book Index A,B, p1-4 (The Coastline and Coast Features)
16	Sounding	160	Soundings	See -Symbols and Abbreviations Book Index Q, p34-35 (Soundings)
17	Bottom-Quality	170	Symbol	See -Symbols and Abbreviations Book Index S, p37-39 (Bottom-Quality)
18	Tides and Currents	180	Text\Line	See -Symbols and Abbreviations Book Index T, p 40-41 (Tides and Currents)
19	Hydrographic Contours Label	190	Text	See -Symbols and Abbreviations Book Index A, B, R, p1-4, 36 (The Coastline and Coast Features)
20	Coastline, Low water Line, Hydrographic Contours, Polygon Label	200	Line	See -Symbols and Abbreviations Book Index A, B, R, p1-4, 36 (The Coastline and Coast Features) See -Polygon Label Standard
<u>Note</u> For Feature Codes of features see CARIS HYDROGRAPHIC SYMBOLOGY				

Table 5.3 The proposed Digitising Specification.

On the sample scanned chart, there were three types of features to be captured, lines (curved and straight), points (point symbols), and texts. A standard procedure should be used in order that each feature to be digitised is done so accurately and completely.

5.4.2.2.2 Data Capture of Lines

Data capture of lines can be done using the *Edit>Line>Add* menu as shown in figure 5.5. SAMI provides various command to capture different types of lines according to their characteristics. The three most common used frequently in this project are Line Follow Contour, Line Follow and Point to Point Line, discussed below.

Line Follow Contour is used to capture curved lines with elevation such as contours and the low water line. It creates the vector lines from raster data by following the raster data. This process is sometimes called "tracing". With fully automatic tracing the raster conversion program normally decides itself which way to go when two lines cross or meet (e.g. street junction) but with this tool in SAMI (Semi Automated Map Input), as the name implies, the decision is the operator's. This means that it takes more time to create the vector data, but probably less time to edit it later. Once this tool is selected, the user input window appears to prompt the operator to define a data source to follow as shown in figure 5.11.

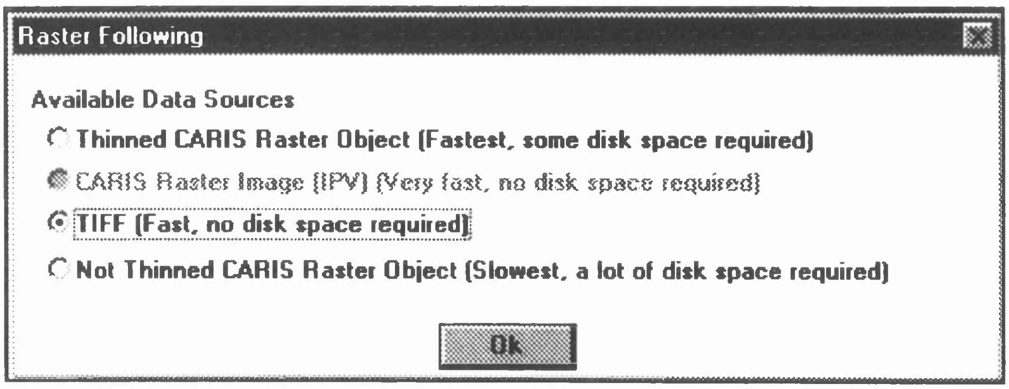


Figure 5.11 Defining of data source for *raster following.*

Having followed the steps outlined above, three data source are available, thinned raster data (N), unthinned raster data (R) and TIFF file (T). Thinned raster data is preferred because it will speed up the line following. After thinned raster data is selected by typing "N", the crosshairs appear in the graphic area. Whenever the crosshairs are visible, whether the operator is starting a new line or in the middle of following a line, the following softkeys options are displayed (these softkeys are also available in CARED). These options allow the operator to;

Quit – Pressing <Q> (or the right mouse button) tells the program that the operator wants to quit line following mode, then it will prompt the operator for a feature code.

Intermediate Point – Pressing <I> allows the operator to directly enter a point. This is useful if the raster image is so cluttered that the operator cannot easily select the proper point, or if the contour following reaches a decision point, and proper point is missing because of overlapping text. The operator can add intermediate points until reaching the next raster line.

Extend – Pressing <X> allows the operator to extend an existing vector line. This is useful for long lines that do not fit into a convenient zoom window. When working on a large chart or map, the operator will not be able to see all of it at once. The operator may have to vectorise only the part of a line that is visible, then extend the line after shifting the display to the next part of the line.

Close – Pressing <C> allows the operator close a closed shape such as a building outline or polygon without having to select the first point in the shape a second time.

Data Source – Pressing <D> allows the operator to change the data source as described above.

Options – Pressing <O> allows the operator to change two options, pixel value of the raster source to follow (either 0 or 1) and On-screen tracking (Yes or No)

A raster line is followed from the beginning of the section the operator points to until a position where a decision must be made. This could be the end of the line, an intersection, or a gap. Prior to follow the next section of raster line, the section of the previous vectorised line will be highlighted and the operator is asked if it is satisfactory. If the operator is satisfied, the left mouse button is clicked to answer "Yes" and accepted it, or click the middle button to answer "No" (Type "N" in case of 2 buttoned mouse). Once accepted, the vectorised portion of the line is redrawn in black on top of the red raster line. The operator continues to select the appropriate section of the raster line until the end of the line is reached or until no more of the line is visible at the current Zoom level. The vectorising is ended by clicking the right mouse button. The user input window appears to prompt the operator for feature code and elevation (depth value) for the vectorised line.

When vectorising a chart, two factors should be considered when deciding how far to zoom in; readability and screen refresh time. The operator should be far enough out to distinguish which line is which, but not so far out because screen refresh time is annoyingly slow when lots of data is displayed.

According to the Digitising Specification, coastlines (CLSL), low water lines (CLLW) and hydrographic contours (CODTMR) have to be in the same UN (layer) for building topology in order to create colour fills later in the process. Due to the number of hydrographic contour lines with different depth values, confusion can occur during vectorising because they are all *black*. To avoid such confusion, it is recommended that colour table is created in order to distinguish the coastlines, low water lines and hydrographic contours during vectorising. By doing this, the operator is able to do line following more correctly and more accurately. A new colour table, called "samihydro contour.col", was created in *Colour Map & Table Editor* and assigned different colours to the curved lines by depth values as shown in table 5.4. The thinned raster data, originally assigned to *red*, is reassigned to *black* in order to contrast the other colours. From the author's point of view, this works very well. For the topographic contours, the same idea is applied but another colour table called "samitopocontour.col" may be utilised in stead.

Feature Code	Z value	Colour
THINRAST	-	Black
CLSL	-	White
CLLW	0	Red
CODTMR	2	Green
CODTMR	5	Yellow
CODTMR	10	Blue
CODTMR	15	Orange
CODTMR	20	Magenta
CODTMR	30	Pink
CODTMR	40	Brown
CODTMR	50	Light blue
CODTMR	100	Black
CODTMR	200	Light green
CODTMR	500	Grey

Table 5.4 Colours assigned to contours by depth value in "samihydrocontour.col"

Line Follow (LIRF) is used to capture the curved lines in same manner as the contour follow. The difference between these two tools is that the former is used to capture the line without elevation, whereas, the latter is used to capture the line with elevation. The coastline, the characteristic of coastlines (e.g. rocky shore, sandy shore) are captured by the line follow tool in the same manner as contours. In case of the characteristic of coastline, they are captured as normal curved line. When vectorised, they do not appear as rocky and sandy shore symbols as shown on the raster backdrop. However, once symbolised, they would be displayed as seen on the chart. More about symbolisation will be mentioned later.

Point to Point Line was used to capture straight lines between digitised points. It is utilised to capture the linear features along which the linear symbols are formed, such as roads, railroads, jetties, wharfs and various limits. Like the case of characteristic of coastlines, these linear symbols are vectorised using the raster backdrop as a guide in the same manner as a straight line. After symbolisation, they are shown as on the chart. Again, more about symbolisation will be mentioned later. In the case of the neatline, it is critical to capture it as accurate as possible because all features would be added to this framework. There are some techniques worth mentioning. Using this tool, the neatline could be added by pointing at the four corners (the intersections of graticule) of the raster backdrop in the same Zoom in level but the resultant neatline is not precise due to it being too difficult to point exactly at the corners at this level of zoom.

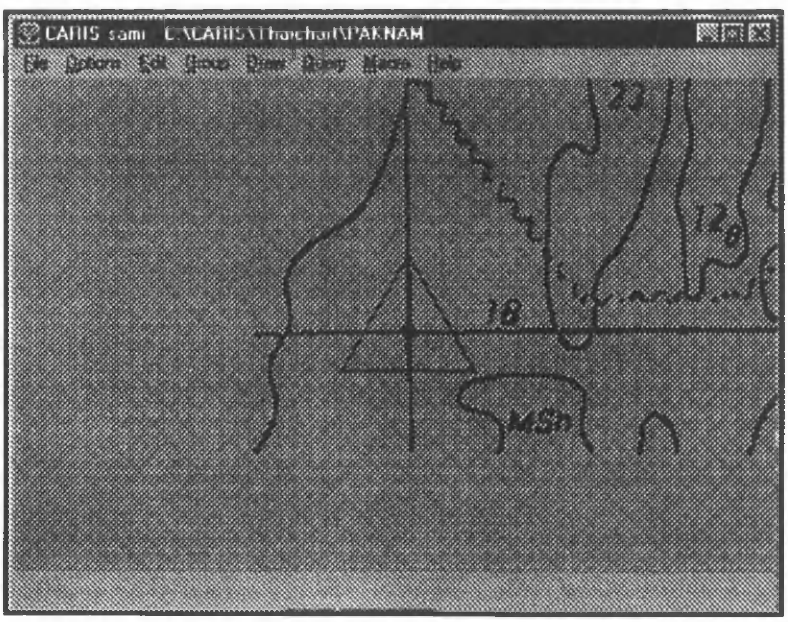


Figure 5. 12 Data capture of neatline using symbol snapping technique.

In order to digitise the neatline precisely, it is recommended to zoom in at each corner close enough to see intersection of the raster graticule clearly, then added a conspicuous symbol (e.g. triangulation point, FC=ALTS, shown in figure 5.12) by pointing at the corner as accurately as possible. This is repeated for all four corners. By drawing an overview showing these four symbols, add point to point line (*Edit>Line>Add>Point to point*) by snapping (middle mouse button or "S") the digitised points to the created symbols. Using this technique, the neatline is constructed correctly and precisely. The point symbols may then be deleted.

5.4.2.2.3 Data Capture of Text

Names or text features of many kinds occur on charts to identify places, phenomena, etc. The text involved in this project are generally the names of places (e.g. district names, island names and the descriptive names associated with symbols (e.g. abbreviation of lights, buoys). The primary task is to establish attributes of text for the digital chart as close as possible to the original chart. These attributes involve the text fonts, the text sizes, and line weight. As mention in chapter 3, the texts on Thai charts are shown in two languages, both Thai and English. Unfortunately, the current version of CARIS does not support Thai fonts yet. As a result, only English text would be captured in this project. The fonts provided by the system are adequate to cover all texts on the sample chart. The text can be captured using the *Edit>Text>Add* menu as either straight name or along a curve as shown in figure 5.13.

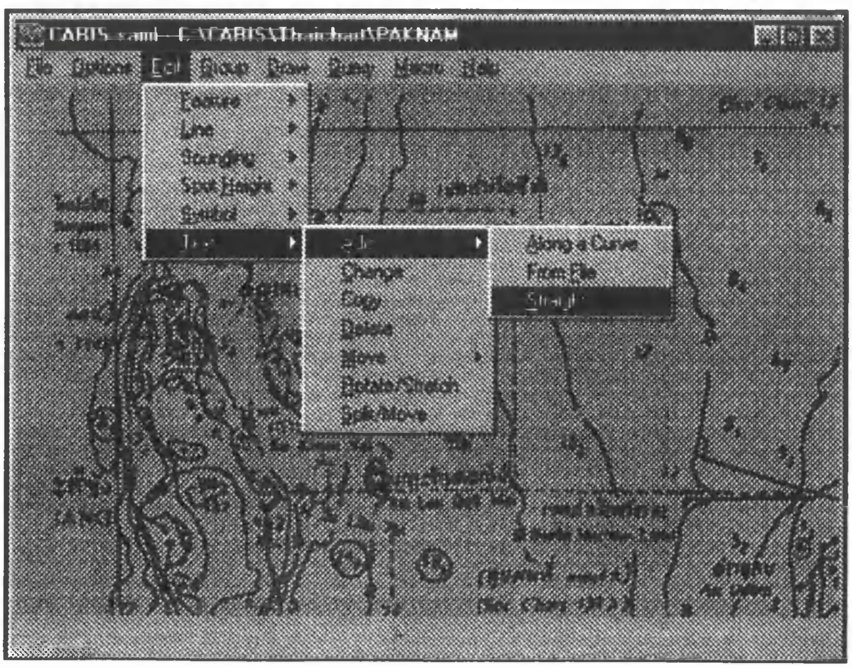


Figure 5.13 The *text menu* item.

Once activated, the "add a name" window appears to prompt the operator for feature code, text attributes (e.g. font number, font size in mm., line weight in one thousandth of an inch) and the actual name required to add to the digital chart file. In CARIS, the name has an associated referent point which is used for defining the location. When a name is added, the referent point is set to the top-left location of first character in the name. Names can be placed correctly using the raster backdrop as a guideline.

One problem encountered when adding names is that the size of some names added were not shown exactly as specified. For example, a name was specified as 2 mm. size when added but, when measured, the size on screen using *Option>Distance between two points*, it s size was shown as only 1.3 mm. at chart scale. As a result, some experiments were required to find out what were the proper values to result in the correct displayed size (e.g. input 3 mm. for 2 mm. displayed size, 2.3 mm. for 1.5 mm). It is not clear from the CARIS documentation why this occurs. The text and their attributes used on this project are shown in table 5.5. The soundings and the abbreviation of the buoy colours (e.g. *YBY* =Yellow Black Yellow) were treated as symbols and will be mentioned in the next section.

Type of text	Font Number	Font Size (mm)	Line Weight (1/1000 inch)
Names of Amphur and important islands	60	2 (3)	16
Names of District, islands, mountains and buildings	60	1.5 (2.3)	12
Names of rocks	1	1	6
Text of various limits (big)	62	2 (3)	12
(small)	62	1.5 (2.3)	12
Text of aids to navigation	1	1.5	4
Text of radio and radar station	1	1.3	4
Text of bottom quality	6	1.5	4
Note 2 (3) means input 3 mm for 2 mm displayed size.			

Table 5.5 The text and their attributes used in this project.

5.4.2.2.4 Data Capture of Points

The symbols, soundings and spot height were captured as the digitised points. They are added via *Edit>Symbol (Sounding, Spot Height)>Add* menu item. Once activated, the "add a symbol" window appears to prompt the operator for the symbol attributes (e.g. feature code, size, angle). The symbol feature codes are associated with bitmap images of the symbols to be added, as shown in figure 5.14.

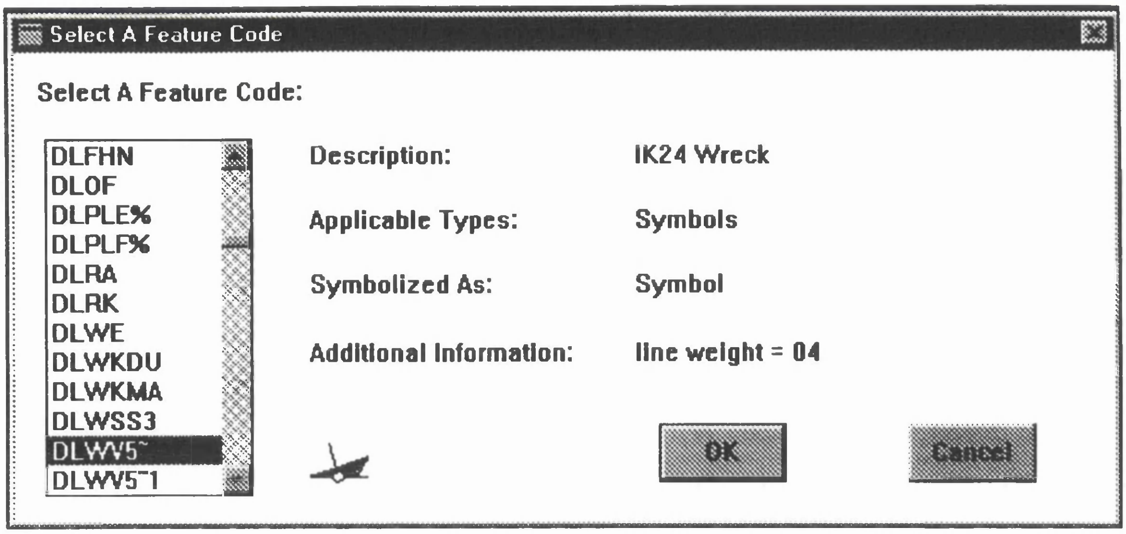


Figure 5.14 The symbol feature codes associated with the bitmap images.

Adding point data is very similar to adding text. They are digitised by specifying a single point representing the reference point which is normally at the bottom-center of the symbol. Hydrographic soundings display values to the right of the decimal point as a subscript. Spot heights consist of a spot height value, sometimes called "label", and an optional symbol. Again, the raster backdrop of these point features was used as a guideline for point data placement. As mentioned earlier, the attributes of these point data (e.g. feature code, type of data, line thickness) are specified in the ih_maste.txe and "CARIS Hydrographic Symbology" that meets the IHO specification.

5.4.2.2.5 Data Editing

Although SAMI provides facilities for capturing all the required data and following the above procedures should result in a clean data file, often there will be a need to carry out some editing of the data. CARIS provides a wide range of editing tools.

Editing line data is achieved by using *Edit>Line>Change* menu item. CARIS provides a number of commands for line editing functions. The most commonly used commands implemented in both digitising and editing were clip line, extend line, join line, split line, copy line, delete line, mask and unmask line. Use of these commands is vital to ensure that the digital data is accurately located and consistent at common nodes or arcs, and that polygons are properly closed. The correct use of these commands throughout the data capture and editing process will reduce data compatability errors and save valuable time during the topology building process.

Editing texts can be done using *Edit>Text* menu item. Texts can change their attributes (e.g. font number, font size, line weight), or be copied, deleted, rotated, stretched, or moved. Texts can be moved by either individual letters or the whole name. In addition, the reference point of text can be moved to a new position without moving the actual text. This is useful when positioning polygon labels into the polygon for building polygon topology due to the CARIS rule that the reference point of the polygon label must be within the polygon regardless of the position of the actual text.

Editing point data such as symbols, soundings and spot heights is done using *Edit> Symbol (Soundings, Spot heights)* menu item. They can change their attributes (e.g. sizes, angles), and be deleted or moved. In the case of spot heights, the spot height value (label) can be moved without moving the spot height symbol. This is useful for the improving the legibility of spot height values without any interruption of the other data.

Editing groups of features CARIS allows the operator to select a group of features and process them all at once. This is called "defining a lasso". The features can be moved or deleted within the lasso. The lasso can be defined by drawing a polygon around the features of interest using the *Group>Define Group* menu item. The *Group* menu can also be used to change feature tags (e.g. feature code, user number, etc.), delete, move, copy, and paste groups of features, mask and unmask groups of lines. When the lasso is defined, the program prompts the operator to specify whether the user wants an inclusive (I) lasso (features inside), or an exclusive (E) lasso (features outside) and whether the linear features which intersect the lasso boundary are to be clipped. If the clip line option is selected, curved and point to point lines will be clipped at the point where they crossed the lasso boundary. The lasso proved very useful when large numbers of features required to be edited.

5.4.2.3 Post-Processing

After vectorising, the vectorised data was post processed to register it to the chart projection system. This process is called "registration", which can be done either in SAMI or in CARED. The registration is the process of transforming data from one coordinate system (e.g. NRMR of the vectorised data on the scanned chart) to another one (e.g. CHMR of the final digital chart) so that it relates to the real world. In SAMI, registration can be done either before vectorising (register the TIFF file to the appropriate coordinate system first, then vectorise the registered data) or after vectorising (vectorise the unregistered data, then register to the appropriate coordinate system). In this project, the latter was performed.

The registration consists of applying a number of equations to unregistered data to make it conform to a registered coordinate system. The equations are applied to the coordinates of "control points" in both coordinate systems. The control points coordinates are contained in a special text file called the "control file". The control file is a text file which contains the point IDs and the coordinates for a numbers of control points. These control points are the locations for which the ground coordinates are known. Two control files are required, one contains the locations of the control points in the unregistered chart, another one contains the location of the same points in the registered coordinate system. The process of registration is shown in figure 5.15

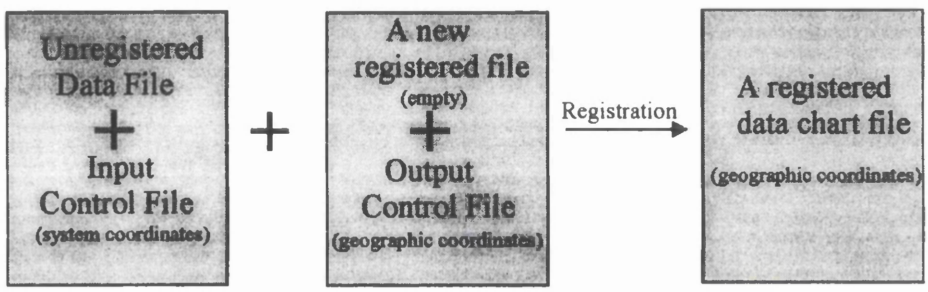


Figure 5.15 The Overview of Registration.

Registration involves creating the input control file, extracting the unregistered vectorised data from the scanned chart, creating a registered new empty chart file, creating the output control file and registering the unregistered vectorised data into the registered new empty chart file.

Creating input control file is done via *File>Create control file* in SAMI (CARED). Once activated, the user input window appears to prompt the operator for the name of control file (.con) and the control point number. The location of the control point is found by pointing at the desired conspicuous point. In this project, eleven control points were used which were the four corners of the neatlines and seven conspicuous symbols (e.g. triangulation point, spot height and fixed lights on the land). The more control points used, the more accurate the registration. The input control file (.con) is actually saved as a text file as shown in figure 5.16

!Control !Point ID	X	Coordinates Y	Z
1,	0.01060,	0.00787,	0.00000
2,	0.19088,	0.00991,	0.00000
3,	0.18790,	0.19380,	0.00000
4,	0.00730,	0.19215,	0.00000
5,	0.01613,	0.16396,	192.00000
6,	0.14630,	0.18332,	0.00000
7,	0.12313,	0.12998,	226.00000
8,	0.09811,	0.11208,	201.00000
9,	0.07969,	0.06706,	0.00000
10,	0.08414,	0.05842,	0.00000
11,	0.03334,	0.02832,	0.00000

Figure 5.16 Example of the input control file.

Extracting the unregistered vectorised data from the scanned chart. Once vectorising is complete, the raster data is no longer required. The vectorised data need to be extracted from the file containing both the raster and vector data and registered to a new CARIS chart file. Using *Display Visibility Parameter*, the raster data (TIFF and thinned raster data) were deselected (not drawn). Only the vector data were then drawn with the overview zoom to ensure that all vector data required are displayed, then SAMI is exited. Extracting vector data is done by using *Extract Part of a map* tool from the *Map Creation & Management* Module. This program creates a new CARIS file containing only the vector data that was set as visible in the input file.

Creating a registered new empty file: Before registering, a new CARIS file registered to the correct header of the final chart (e.g. Mercator projection, Everest ellipsoid, final scale and etc.) must be created and used as a template for the unregistered vector file. This can be done using *Create a new map* program from *Map Creation & Management* Module in CARIS Tools. The parameters required for the final Thai chart were defined in the header as shown in figure 5.17. In order to facilitate the operator in making a new CARIS chart, the proposed "Making a header for Thai chart procedure" was created as shown in appendix 5.3

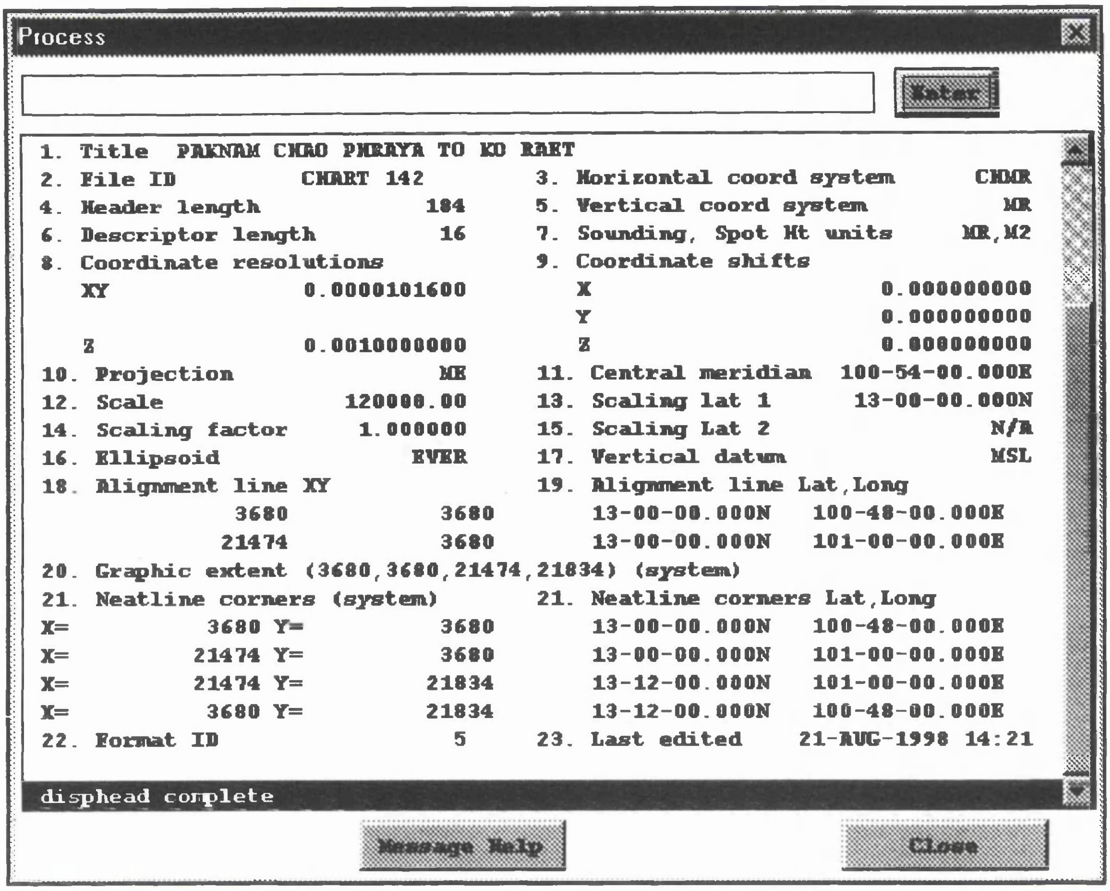


Figure 5.17 Header of the final digital chart file.

Creating the output control file: This file contains the control points which the ground coordinates are known (latitude and longitude). It could be created using either *File>Create>Control file* in SAMI (CARED) or a text editor. It is recommended that it may be more accurate to create this output control file in a text editor by copying the input control file in a new name and replacing the x,y coordinates with the known geographic coordinates of the final chart for each point in turn. The output control file is shown in figure 5.18

!Control !Point ID	Coordinate Latitude	 Longitude	 Z
1,	13-00-00.000N,	100-48-00.000E,	0.0000
2,	13-00-00.000N,	101-00-00.000E,	0.0000
3,	13-12-00.000N,	101-00-00.000E,	0.0000
4,	13-12-00.000N,	100-48-00.000E,	0.0000
5,	13-10-08.875N,	100-48-28.926E,	192.0000
6,	13-11-21.000N,	100-57-11.500E,	0.0000
7,	13-07-50.144N,	100-55-41.969E,	226.0000
8,	13-06-45.000N,	100-54-00.000E,	201.0000
9,	13-03-48.000N,	100-52-36.000E,	0.0000
10,	13-03-10.000N,	100-52-58.000E,	0.0000
11,	13-01-18.000N,	100-49-30.000E,	0.0000

Figure 5.18 Example of the output control file.

Registering the vector data file is done using *Register a map* program from *Map Creation & Management* module. Once executed, the four necessary files created above (the unregistered vector data file, the input control file, the registered empty chart file with correct header and the output control file) are required input to the *Register a map* window. A new name for the registered file may be specified. The result is a registered vector data file complete with the correct header. The resultant file should be checked for the registered coordinates using *Query>Point location* menu item. The registered coordinates should be equal or very close to their actual values.

5.4.3 Building Topology

Topology is defined as the spatial relationship between connecting and adjacent map features relative to each other but independent of distance and direction *(ESRI Inc., 1993; Raper and Green, 1989)*. It describes the geometrical relationship between the features in the digital chart. The raster data has no spatial intelligence whereas the vector data is recognised as having three data models, spaghetti, chain node and full topology *(Ley, 1992)*. Full topology is required if the digital data is to be used at some stage later as an input to GIS.

In CARIS, Topology is required to allow areas to be colour filled and possibly permit many types of analysis in the future. Topological elements include nodes, arcs, polygons and polygon display labels. The process of computing topological relationship is called "Building Topology". Topology is built theme by theme. A theme is defined as a topologically consistent layer of data, or in other words, a user number with topology. In this project, there are two themes which need topology for colour fill. These are theme number 40 containing the buildings to be colour filled in *black* and theme number 200 containing land areas to be colour filled in *yellow (buff)*, low water area to be colour filled in dull *green (olive)*, shallow water zone between 0-5 meter contours to be colour filled in *blue* and 5-10 meter contour zone to be colour filled in *light blue*. Building topology can be performed either in CARED or in Topology Creation Module in CARIS Tools. The former will be discussed in this project.

CARIS Editor (CARED) is an interactive program used to create and edit the digital map or chart. Its funtionality (e.g. menu items, using soft keys, macro commands) is very similar to CARIS SAMI. The distinctive difference between these two programs is that SAMI is used to capture data on screen whereas CARED is used to capture data via digitising tablet, edit data and build topology.

Building topology is an iterative process, often requiring commands to be repeated. Some steps are automated using either CARED or CARIS Tools, others are interactive using CARED. Building topology involves first building network topology and then building polygon topology. A flowline for building topology is shown in figure 5.19.

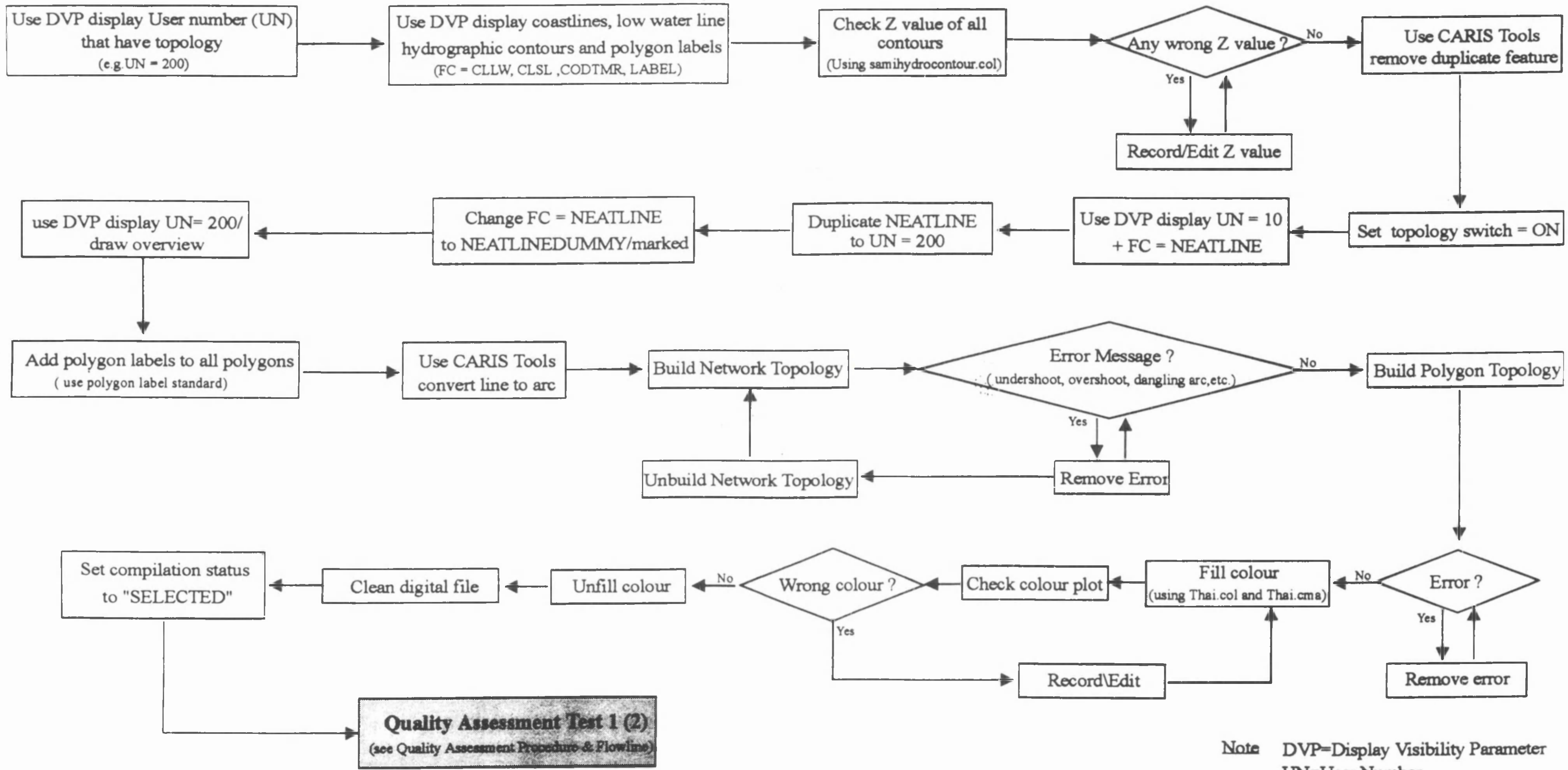
5.4.3.1 Building Network Topology

Building network topology concerns only nodes and arcs. In the data capture process, the data were probably digitised with some gaps (undershoots), overlaps (overshoots) and duplicated. Network topology removes these errors. The theme numbers (TN 200, 40) required to build network topology must have their own neatlines, as a result, the neatline in UN 10 must be copied and placed in UN 200 with FC=neatlinedummy. Building network topology consists of converting lines into arcs, locating arc intersections, cutting the arcs at intersections and subsequently deleting overshoots. These operations are performed in CARED using *Topology>Step by step topology* (or *Topology>Fast topology building* if the user is familiar with this process already).
When the build network topology program is executed, the process window appears to report the result with some error message numbers and quantities remaining, as shown in figure 5.20.

Typical error message numbers usually found are 75 (overlapping arc), 126 (dangling arc) and 127 (pseudonode). The meanings of errors and remedies can be found by clicking the *Message help button* at the bottom of the process window and entering the message numbers required.

The errors from building network topology can be removed both automatically and interactively. Firstly, automatic removal may be used to remove many duplicates, overshoots, undershoots and pseudonodes using *Topology>Step by step topology> Remove duplicates (and other errors).* Then the network topology needs to be unbuilt and rebuilt again in order to find out if there are any errors remaining. The errors remaining must then be removed interactively. CARED provides a special menu item to highlight, examine, list and clear the errors via *Topology>Error checking*.

Building Topology Flowline



Note DVP=Display Visibility Parameter
UN=User Number
FC=Feature Code

Figure 5.19 Building Topology Flowline.

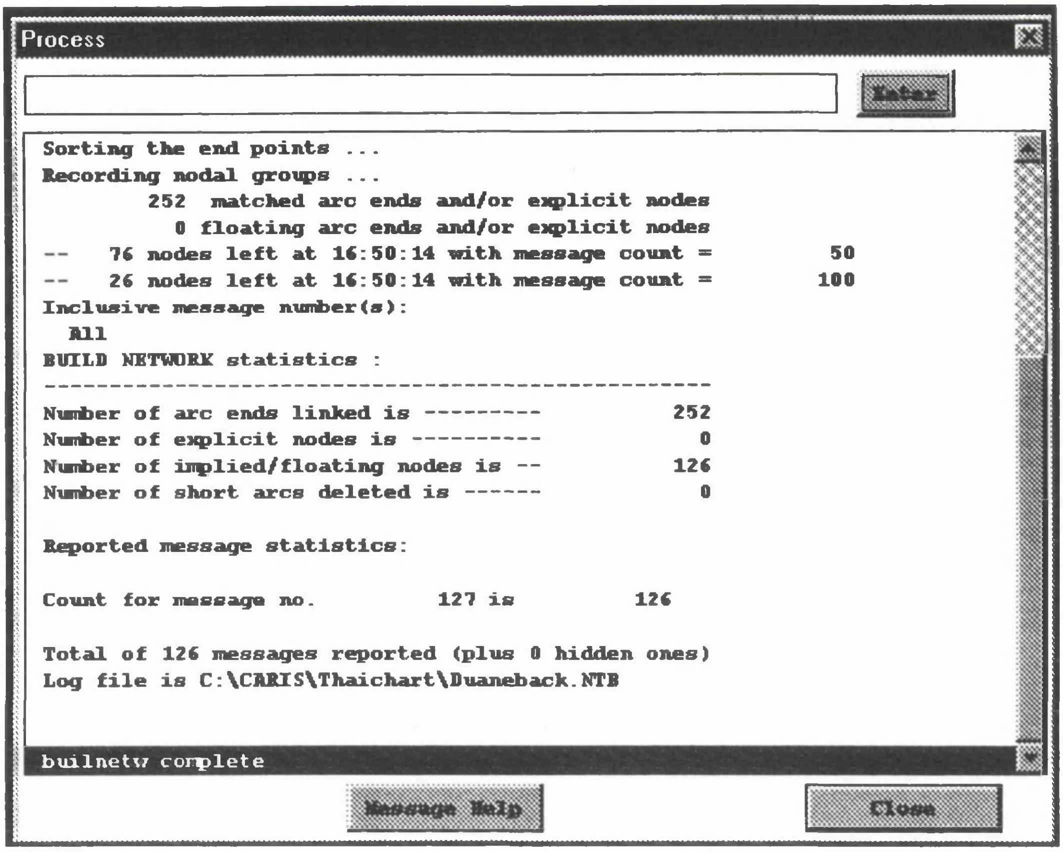


Figure 5.20 The process window of *Build network topology* program.

This is proved useful because it is very difficult to examine errors using visual checks performed by the operator. Using *Topology>Error checking>Examine Errors*, the operator is prompted to enter the error number to scan (e.g. 126=dangling arc). The cause of the error is reported and one arc involved highlighted. It is sometimes not really an error (e.g. a dead-end street), therefore the operator has to decide if it is really error. After being identified, errors are corrected using typical *Edit* menu items as usual. Network topology needs to be unbuilt and rebuilt every time the data is edited. These process are repeated until no error is reported. In practice, some types of errors may be ignored (e.g. 127=pseudo node).

5.4.3.2 Building Polygon Topology

Building polygon topology is performed after network topology is created and error free. It builds polygons from connected polygon arcs. These polygons can have attributes assigned to them and can be used to generate thematic layers and colour fills for the digital chart. Prior to building polygon topology, polygon labels need to be added within the closed polygons. The display polygon labels are names which lie inside the polygons and have been converted into the display polygon labels. They are used to identify polygons when assigning attributes to them in a database or when assigning the colour fills. In order to have unique polygon display labels, the proposed "Polygon Display Label Standard" was created as shown in table 5.6.

POLYGON LABEL	DESCRIPTION
LANDLB	Land polygon label
WATERLB	Water in land polygon label
0M	Polygon composed of coastline and low water line
0_2M	Polygon composed of low water line and 2m contour line
2_5M	Polygon composed of 2m and 5m contour line
5_10M	Polygon composed of 5m and 10m contour line
10_15M	Polygon composed of 10m and 15m contour line
15_20M	Polygon composed of 15m and 20m contour line
20-30M	Polygon composed of 20m and 30m contour line
30-50M	Polygon composed of 30m and 50m contour line
50-100M	Polygon composed of 50m and 100m contour line
100-200M	Polygon composed of 100m and 200m contour line
200_500M	Polygon composed of 200m and 500m contour line
500_1000M	Polygon composed of 500m and 1000m contour line
1000_2000M	Polygon composed of 1000m and 2000m contour line

Table 5.6 The proposed Polygon Display Label Standard.

The polygon display labels are added as the same manner as adding text using *Edit>text>add* menu, then converted to polygon display labels using *Topology>Step by step topology>Convert Names into Labels.*

The polygon topology is built via *Topology>Step by step topology>Build Topology.* Once executed, the process window displays the result and error message numbers and quantities. Typical error message numbers usually found are 83 (tiny polygons caused by digitising errors), 89 (multiple labels in the same polygon), 95 (no polygon label) and 128 (non-unique polygon labels in the file). The information on message error numbers and remedies can be retrieved by clicking on the *Message help* button in the process window.

The errors from building polygon toplogy are removed interactively in the same way as those for network topology. Topological error checking can also be performed. Most of errors from building polygon topology are concerned with polygon labels. These can be corrected using *Edit>text* menu item as usual. Polygon toplogy needs to be unbuilt and rebuilt after removing errors. If any errors still remains, the process is repeated until none remains. In practice, some errors may be ignored such as error number 113 (adjacent polygons have the same key) because the same key (display polygon labels) may be added to several polygons. If any arc was edited while cleaning polygon topology, the network topology must be rebuilt before rebuilding polygon topology.

5.4.3.3 Checking Topology

After building topology is complete, topological status should be checked using *List Theme* program from *Topology information* in *CARIS Tools*. Once executed, the process window displays the topological status of the digital chart. There are three possibilities reported, *None* (no topology with this theme), *Partial* (some topology has been built but is not error free) and *Complete* (complete toplogy has been built on this theme). According to proposed "Data Quality Specification of Digital Charts", the topological status of the network topology, polygon topology and polygon label of the themes that have topology (TN 40, 200) must be read *"Complete, Complete, Complete"* as shown in figure 5.21.

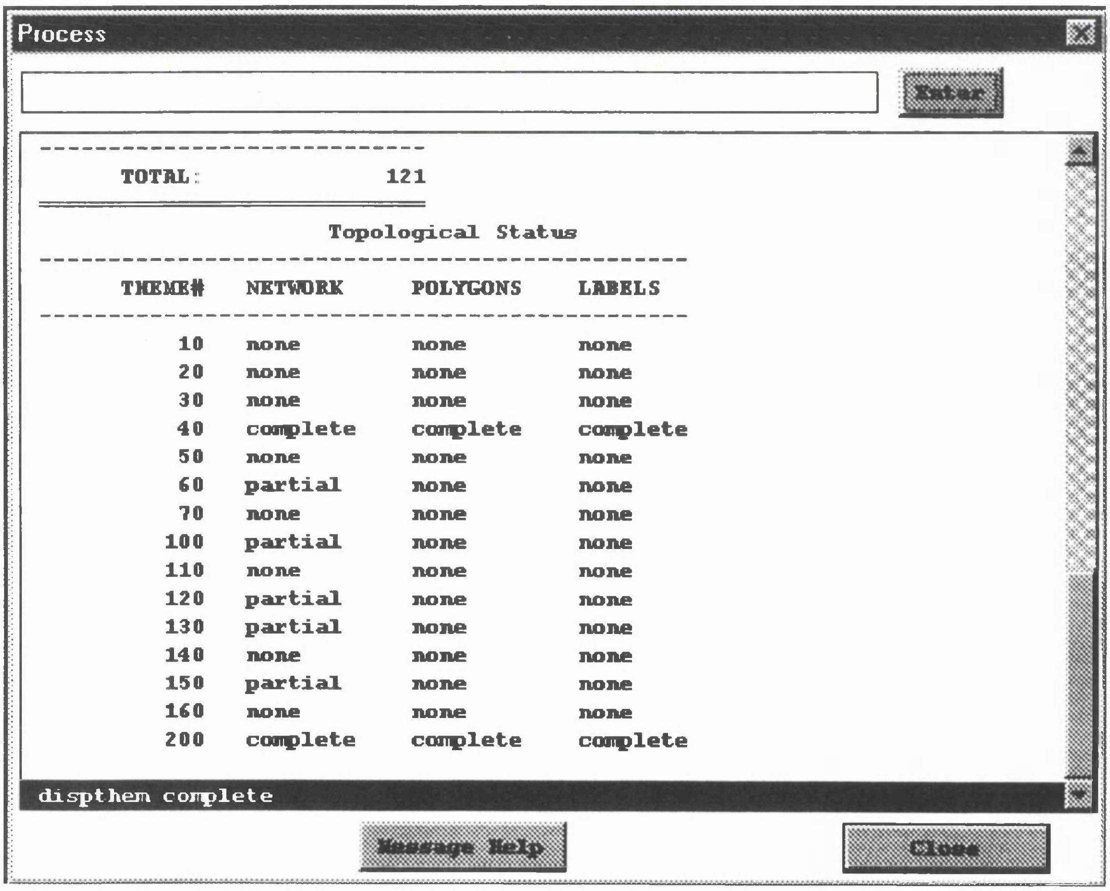


Figure 5.21 The process window of the *List Theme* program.

5.4.4 Adding Colour to the Digital Chart

As mentioned earlier, there are two text files used to control colours in CARIS the colour table (.col) and the colour map (.cma). In this project, a new colour table called "Thai.col" and a new colour map called "Thai.cma" were created. Thai.col is used to assign colour numbers to the features and polygon areas that need to be colour filled but the actual colours in term of RGB solution are maintained in Thai.cma. The features are assigned colour numbers by feature code via *Colour Map & Table Editor* using the simple colour table. For instance, the black features (e.g. coastlines, contours, railway and etc.) are assigned to colour number 31 (e.g. 31 CLSL) which is black in Thai.cma (e.g. 31 RGB=(0,0,0)) whereas the magenta features (various limits, the flares of lights and etc.) are assigned to colour number 7 (e.g. 7 NPML) which is magenta in Thai.cma (7 RGB=(184,52,203)).

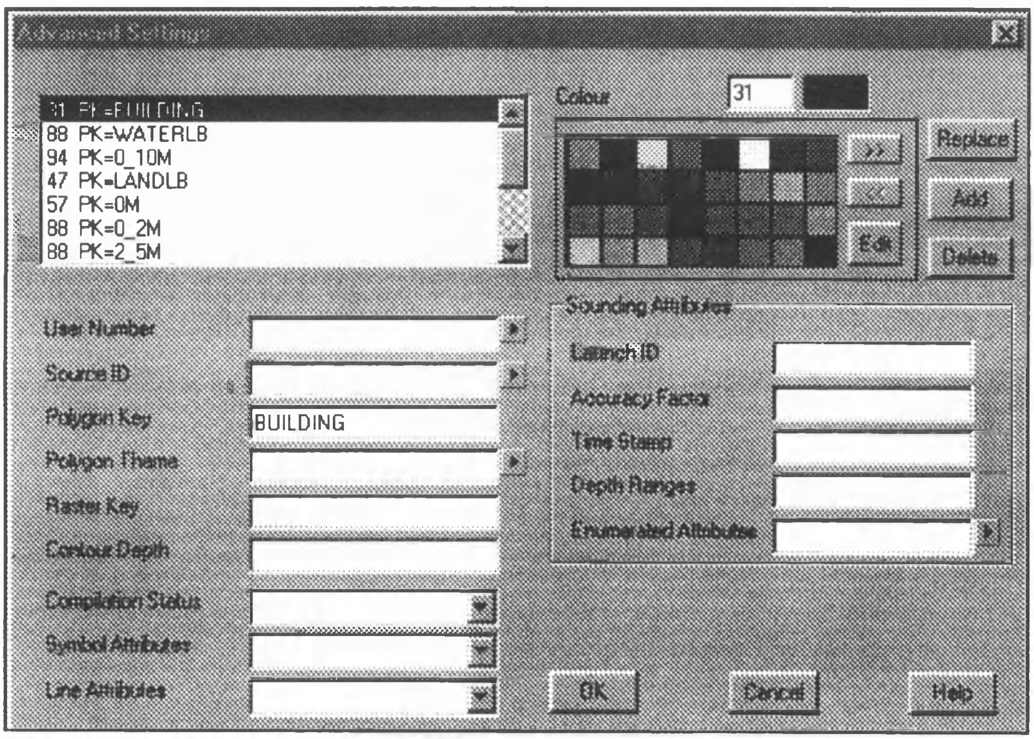


Figure 5.22 Assigning colours to polygon by polygon keys.

For polygon areas, colour numbers are assigned by their polygon keys (polygon display labels) using advanced settings. For instance, the land area was assigned to colour number 47 (e.g. 47 PK=LANDLB) which is *yellow* in Thai.cma (47 RGB=(255, 209, 51)), the drying area is assigned to colour number 57 (e.g. 57 PK=0M) which is *dull green* in Thai.cma (57=(167,230,136)) and so on, as shown in figure 5.22.

After creating the colour table and the colour map (Thai.col and Thai.cma). These two files were replaced in the digital chart file *using Options>Display>Colour>Replace Colour Map (Table).* All features and polygon areas are shown with colours similar to those of the original chart.

5.4.5 Symbolisation

Symbolization is the process of replacing basic point line and area features with more meaningful symbols or patterns. Unsymbolized data is easier to add to a digital chart because the features being traced are less complex that their actual appearances. In addition, unsymbolized features require less computer disk space for storage. In this project, some features, such as various limits, rocky shore, sandy shore, jetties and railtrack, were captured as the normal points and lines, and needed to be symbolized before printing. For instance, the railroad line was represented on the original chart as a single line with tiny crossbars at frequent interval. Digitising each of those crossbars would be time consuming and error prone. When captured, it is digitised as a simple line. After symbolization, it was displayed and plotted with the crossbars. Symbolization can be performed via *Option>Display>Symbolize during draw.* The screen then needs to be refreshed in order to see the actual appearance of the features. Once refreshed, all features are symbolized and shown as seen on the paper chart. A plot of resultant digital chart is shown in figure 5.23.

As is shown by this chapter, The Digital Chart production can be done effectively using CARIS software. CARIS provides the variety of tools, programs and support files to facilitate the operator during the operation. CARIS also offers the operator various methods of operation. For example, data capture can be performed either using digitising tablet in CARED or using semi-automated digitising on screen in SAMI which is less time consuming and less error prone. Data can be edited conveniently using the editing tools available both in CARED and SAMI. Feature codes associated with the features are well defined by their attributes (e.g. types of data, line weight, line pattern, symbolization) in the master file that meets the IHO Specification. The operator does not have to be concerned with specifying the attributes of such features. What he has to know is what feature code and user number should be used for the feature to be captured by consulting the proposed digitising specification and CARIS Hydrographic Symbology.

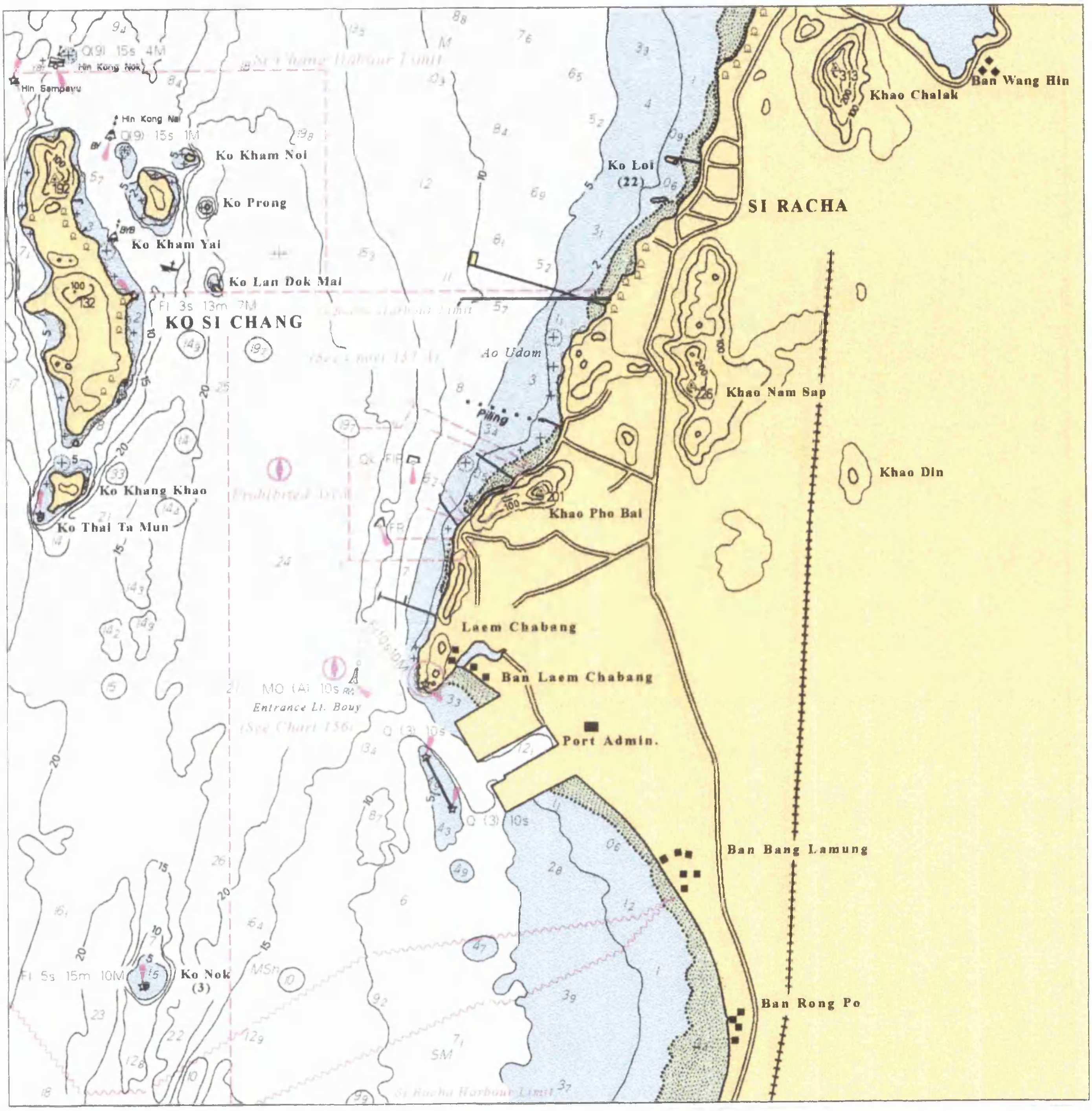


Figure 5.23 The final chart produced in this project using proposed Digital Chart Production.

Topology can be built automatically and and topological errors can be removed both automatically and interactively. Different colour tables and colour maps can be used at various stages, such as samihydrocontour.col may be used for digitising hydrographic contours whereas Thai.col is used for the final colour fill. By fully utilising such capabilities, digital chart production with CARIS can be performed successfully. During production, however, some errors may occur in the digital chart file, such as some features may be associated with wrong feature codes, wrong user numbers, wrong Source IDs and wrong positions; some features may be missing on the plotted chart;

topological themes may be not complete; etc. In order to ensure that the final digital chart file is complete and meets the proposal Data Quality Specification for Digital Charts, data quality assessment is required as discussed in the next chapter.

Chapter 6

Data Quality Assessment Procedures

6.1 Introduction to Data Quality

It is, in the future, expected that Thai Hydrographic Department (Thai HD), which is a government agency, be a reliable source of digital chart data. Use of such data affects safety in marine navigation and the lives of mariners. The first task of Thai HD necessary for digital charting is to convert the existing paper charts into a digital form which will be stored in a cartographic database. During the data conversion process some problems concerning the integrity of digital data may occur. Sources of these problems include software errors, procedure errors, equipment faults, or operator errors. Maintenance of data integrity is an essential part of digital chart production. It is prudent that the digital data captured from the paper charts be checked and assessed to ensure that they have an acceptable "data quality". Data Quality is a key aspect of the development of digital cartography. It is central to evaluating the results of digitising and any other representation. Data quality can have significant effects on the reliability of the further data processing operations.

Data about positions, attributes and relationship of features in space are often termed "spatial data" *(Guptill and Morrison, 1995)*. In 1982, in the United States a National Committee on Digital Cartographic Data Standards (NCDCDS) was established under the auspices of the American Congress of Surveying and Mapping (ACSM). Over a five year period, this committee deliberated and produced a report entitled "A Draft Proposal Standard for Digital Cartographic Data" *(Moellering, 1987)*. This perhaps represents the first comprehensive statement on spatial data quality in the electronic age. Quoting from the report's statement of spatial data quality:

> "The purpose of the Quality Report is to provide detailed information for a user to evaluate the fitness of the data for a particular use. This style of standard can be characterised as "truth in labelling" rather than fixing arbitrary numerical thresholds of quality. These specifications therefore provide no fixed levels of quality because such fixed levels are product dependent. In the places where testing is required, several options for different levels of testing are provided. In this environment the producer provides the quality information about the data and the user makes the decision of whether to use the data for a specific application"
>
> *(Moellering, 1987, p.8)*

In the Moellering report the specification of the components for reporting data quality is divided into five sections. The International Cartographic Association (ICA) Commission on Spatial Data Quality, along with other groups, has accepted these five elements as important aspects of spatial data quality. Since 1987, a modified version of the proposal standard for exchange of spatial data created by the Moellering committee has been accepted by the National Institute of Standard and Technology (NIST) as the Federal Information Processing Standard-173 (FIPS-173) *(Guptill and Morrison, 1995)*.

This standard defines data quality as the information that a producer should present to a potential user to allow the user to make a determination of fitness for some particular use. The vehicle for this information is a quality report in five parts as follows:

> 1) **Lineage:** "The lineage portion of a quality report shall include a description of the source material from which the data were derived, and the methods of derivation, including all tranformations involved in producing the final digital files. The information shall include the dates of the source material and the dates of ancillary information used for update. The lineage portion shall also include reference to the specific control information used, and describe the mathematical transformations of coordinates used in each stage from the source material to the final product" *(NIST, 1994, p.21)*.
>
> 2) **Positional Accuracy:** "The quality report portion on positional accuracy shall include the degree of compliance to the spatial registration standard. It includes measures of the horizontal and vertical accuracy of the features in the data set. It must consider the effects on the quality of all transformations performed on the data and report the results of any positional accuracy testing performed on the data *(NIST, 1994, p.21)*.
>
> 3) **Attribute Accuracy:** "covers the fidelity of the non-spatial data. The use in analogue technology of reliability diagrams to display attribute accuracy must have an equivalent in the electronic age using digital technology. It is now deemed crucial to the use digital data that the accuracy of any and all attributes tied to an earth position be specified along with the values for these attributes" *(Morrison, 1995)*.
>
> 4) **Completeness:** "The quality report shall include information about selection criteria, definitions used and other relevant mapping rules. For example, geometric thresholds such as minimum area or minimum width must be reported. The report on completeness shall describe the relationship between the objects represented and the abstract universe of all such objects. In particular, the report shall describe the exhaustiveness of a set of features" *(NIST, 1994, p.24)*.
>
> 5) **Logical Consistency:** "The report on logical consistency shall describe the fidelity of the relationship encoded in the data structure of the digital data. Logical

> consistency describes the number of features, relationships, or attributes that have been correctly encoded in accordance with the integrity constraints of the feature data specification. Test could be both graphic or visual and topological" *(NIST, 1994, p.23).*

The five elements mentioned above were implemented as a guideline for developing the proposed "Data Quality Assessment Procedures" in this project which is discussed in the next section.

6.2 The Proposed Data Quality Assessment Procedures

As shown in the proposed "Digital Chart Production Flowline" (figure 5.1), there are two Quality Assessment Tests included, "Quality Assessment Test 1" and "Quality Assessment Test 2". Quality Assessment Test 1 is designed for checking data quality of the digital chart files captured from the existing charts using *SAMI* before they are stored in the cartographic database. Quality Assessment Test 2 is ideally included for checking data quality of the digital chart files compiled from the cartographic database during subsequent chart production. Due to the fact that this project is primarily concerned with converting data from the paper charts into digital form, that there is currently no cartographic data base, and the restricted time available to the author, the Quality Assessment Test 1 will be focused on and Quality Assessment Test 2 discussed briefly later on.

6.2.1 Quality Assessment Test 1

It is assumed that the digital data set captured as described in chapter 5 will be stored in the cartographic database. This data set should be tested in order to assure that its data quality meets the proposed "Data Quality Specification of Digital Chart" mentioned in chapter 5.3 and it is a clean data set, prior to being entered into the cartographic database. As a result, the "Quality Assessment Test 1 Procedures" are required. Prior to creating such procedures, all tools and programs available in CARIS, equipment and peripherals available in house (Department of Geography and Topographic Science) were evaluated and selected in order to be implemented in such procedures.

The quality assessment is carried out in the CARIS environment supported by one A4 laser printer, two colour printers (A4 and A3 subsequently). A light table is required for comparing check plots against the original chart. After selecting the necessary equipment, the proposed "Quality Assessment Test 1" was created. It consists of three main parts: Quality Assessment Flowline, Quality Assessment Check Form (QACF) and Quality Assessment Procedure Manual (QAPM).

The Quality Assessment Flowline (figure 6.1) expresses an overview of the Quality Assessment Procedures showing what is to be tested in the digital file and for what purpose. **The Quality Assessment Check Form** (appendix 6.1) was designed following the concept of "truth in labelling" to assist in the assessment and recording of the quality of the digital file. All information added into the digital chart file (e.g. header, user numbers, source IDs, etc.) during the data capture process are entered in the *Input* section of each check by the operator capturing the data. Such *Input* information will be checked against the *Output* section by the operator doing the checks. On the basis of this information aspects such as the quality of the feature codes, or the completeness of the features, can be derived. This form may, in the future, be stored by the information system builder as a quality field in the cartographic database to be assessed at will by the users. *(Drummond, 1994)*

The Quality Assessment Procedure Manual (appendix 6.2) was also created, which if followed would result in the correct completion of the QACF. This manual explains the procedures in a step by step manner which is expected to be followed and understood by the operator. The procedures cover the five main areas related to digital data quality mentioned earlier. These are lineage, attribute accuracy, positional accuracy, logical consistency and completeness. These procedures are explained briefly. More details can be found in QAPM itself.

1) Lineage: concerns checking of the description of source material used and methods of derivation, including mathematical tranformations of coordinates. The source chart reflects the lineage of the data. Information concerning lineage, in this project, can be found in both the Source IDs associated with the features and Header of the digital file. Both of them are checked by considering the digital chart file. There is no attempt to check the quality of the source chart due to the limitation of the availability of such information. Where new surveys are incorporated into the charting process more detailed lineage information can be captured and stored.

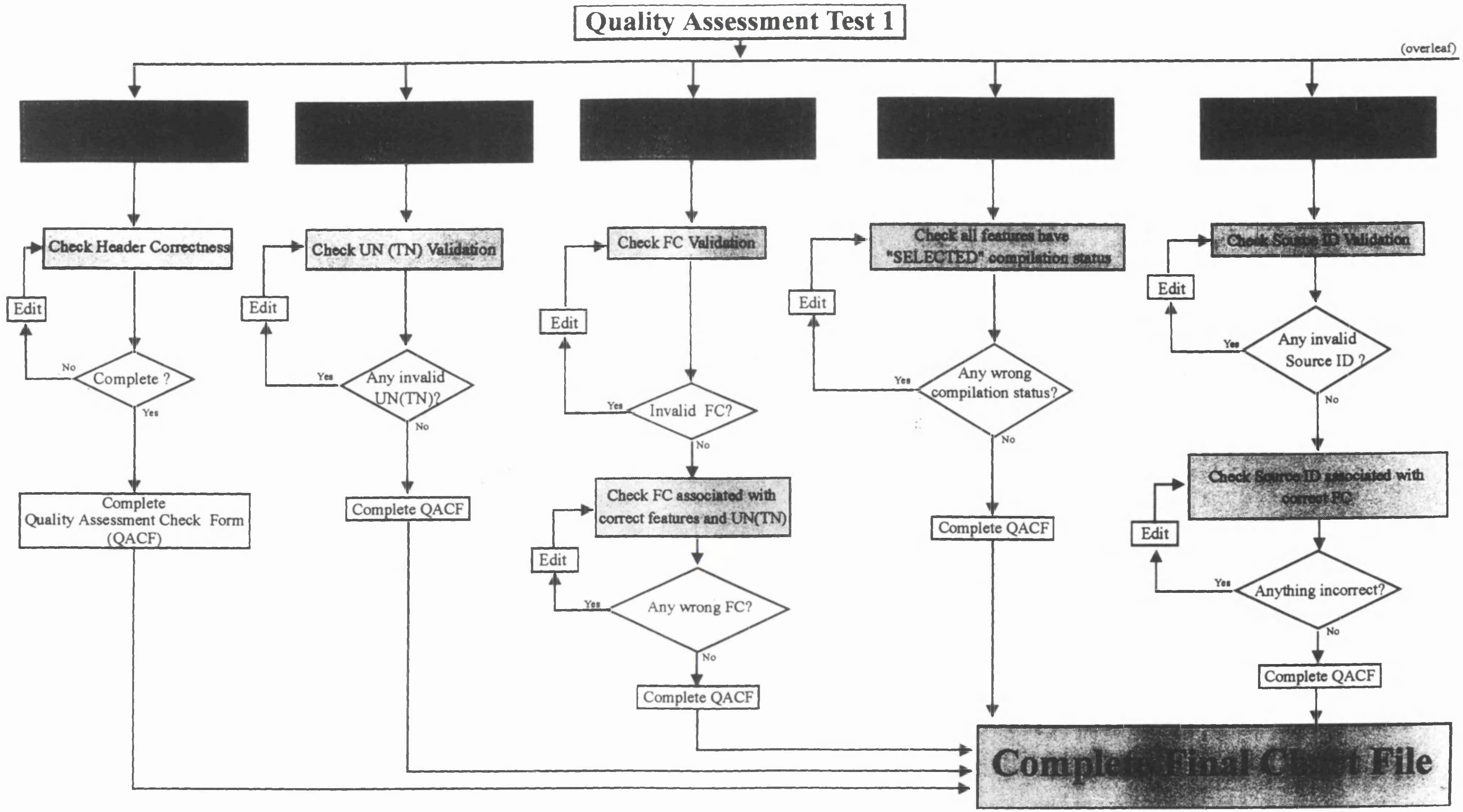


Figure 6.1 Quality Assessment Test 1 Flowline.

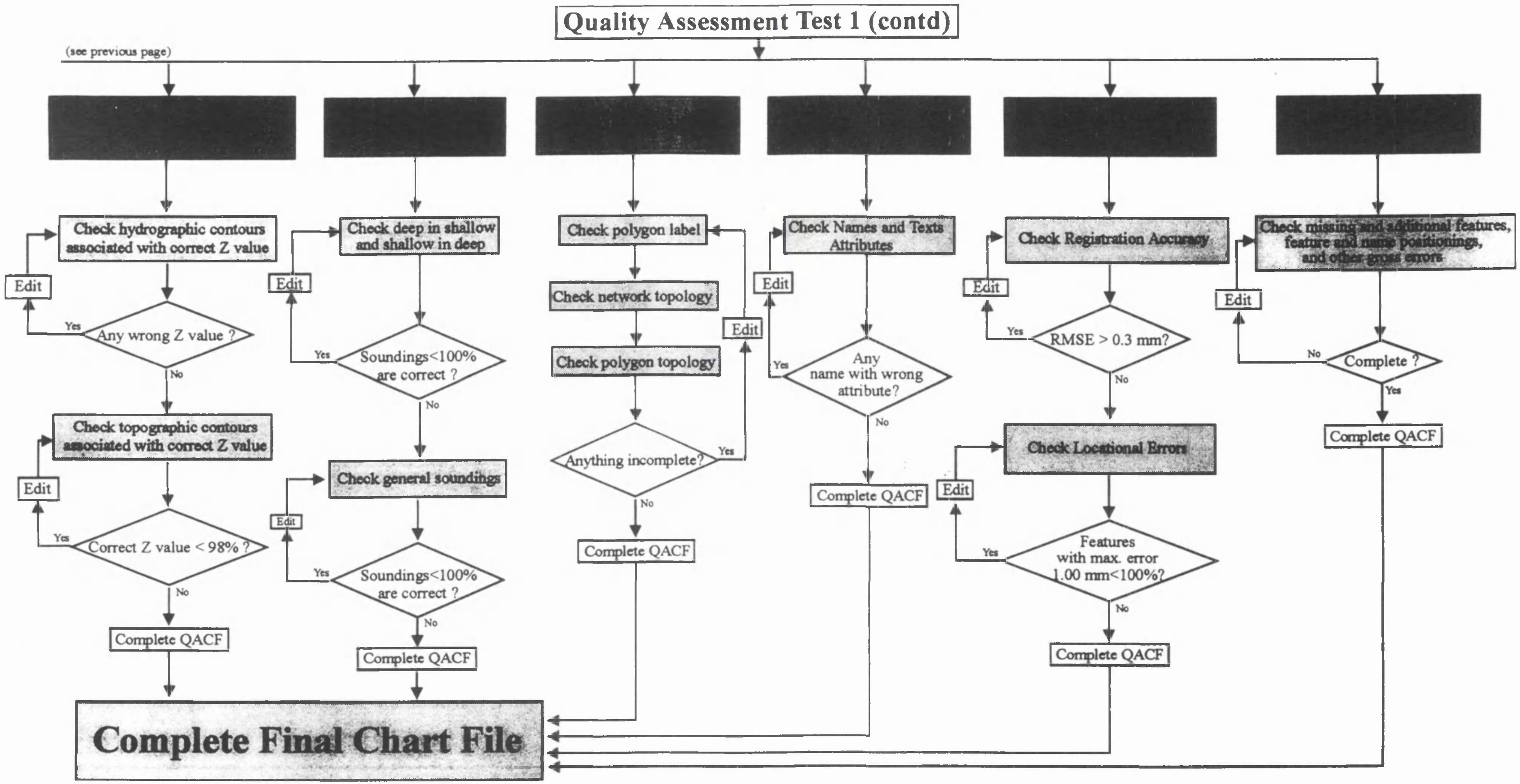


Figure 6.1 Quality Assessment Test 1 Flowline (contd).

Source IDs provide the codes, in other words "lineage codes", which identify information about the source from which features are captured. The Source IDs are vital to good data management and analysis in the latter processes. They are a means of keeping track of many sources of information used in building the cartographic database. They may contain, in the future, information about chart scale of the original data, the kind of chart, etc. If there is a dispute or question about the integrity of the data, the source can be traced and consulted.

In the production used in this project, all features are assigned the same Source ID (TCH_1995_142) according to the proposed "Source ID Standard" because they are all captured from the same original chart. Checking the Source ID is done for two purposes, one for the Source ID Validation and another for association with the correct feature codes. The Source ID Validation is checked using *List Source IDs* program available in *CARIS Tools*. All Source IDs in the digital file are displayed on screen (figure 6.2). Due to the fact that there is no cartographic database in this project, the Source IDs in digital file are checked against the input Source IDs in QACF instead of those in the cartographic database. Any invalid Source IDs are corrected.

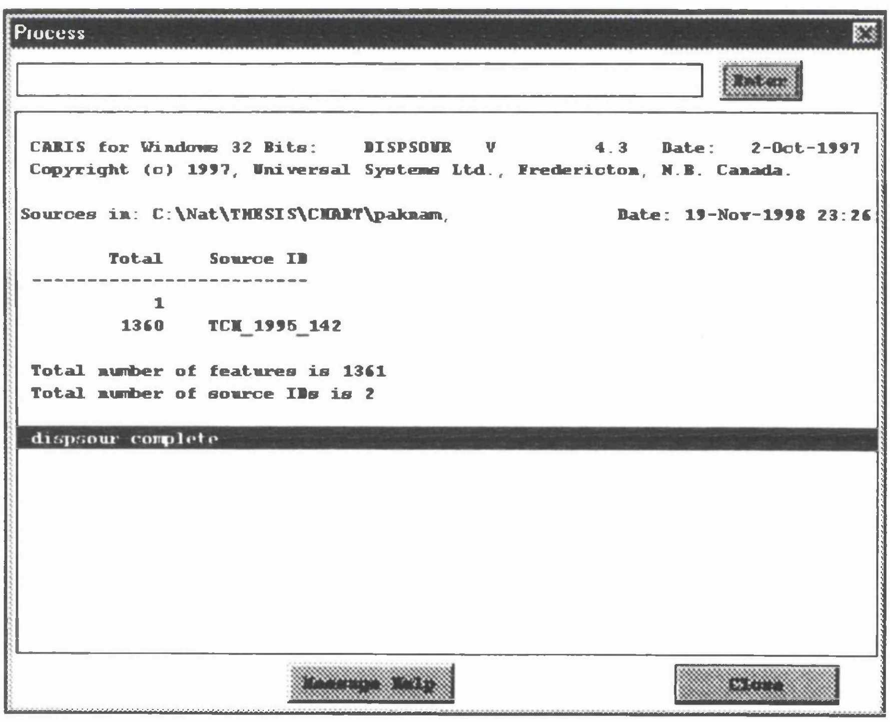


Figure 6.2 The process window of *List Source IDs* program.

Checking the association of Source ID with the correct feature codes is done by using *Display Visibility Parameter* to display each Source ID inclusively and feature codes belonging to it exclusively (not drawn). Nothing should be drawn. If any features are drawn they must have the wrong Source IDs and need to be changed to the correct one.

HEADER: The header of the digital chart file contains many fields of quality related information such as title of chart, scale, horizontal co-ordinate systems, vertical datum, projection, unit of soundings and spot heights, etc. This information reflects the lineage of data in the digital chart file. These fields were defined during the data capture operation. Errors in the header are primarily caused by keying mistakes during data entry. Header integrity is checked on screen using *List Map Header* program available in *CARIS Tools*. The fields in the header of the digital file are displayed (figure 5.17) and then checked against the input fields recorded in QACF. Any incorrect fields are corrected.

2) Attribute Accuracy: This is concerned with the attribute information associated with the features in the digital chart file. In this project, all features are assigned generic attributes but, some features also have specific ones. For example, all features are assigned a feature code, user number, compilation status and source ID but the hydrographic contours are assigned a specific depth value as well as generic attributes.

The following information concerning attribute accuracy is checked: feature codes; user numbers; compilation status; z values of the hydrographic and topographic contours; names and text attributes; and soundings.

Feature Codes: are checked by considering the digital file for two purposes, one for feature code validation, another for association with the correct features and user numbers. Feature code validation is done by using *List Feature Codes* program available in *CARIS Tools*. All feature codes in the digital file are listed on screen (figure 6.3) and checked against those of the master file. Any invalid feature codes found are corrected.

Checking for association of feature codes with correct features is done by displaying each user number and each feature code belonging to it, feature code by feature code on screen. The features displayed are then checked against the original chart and the input feature codes in the QACF. Any missing or excessive features found are corrected.

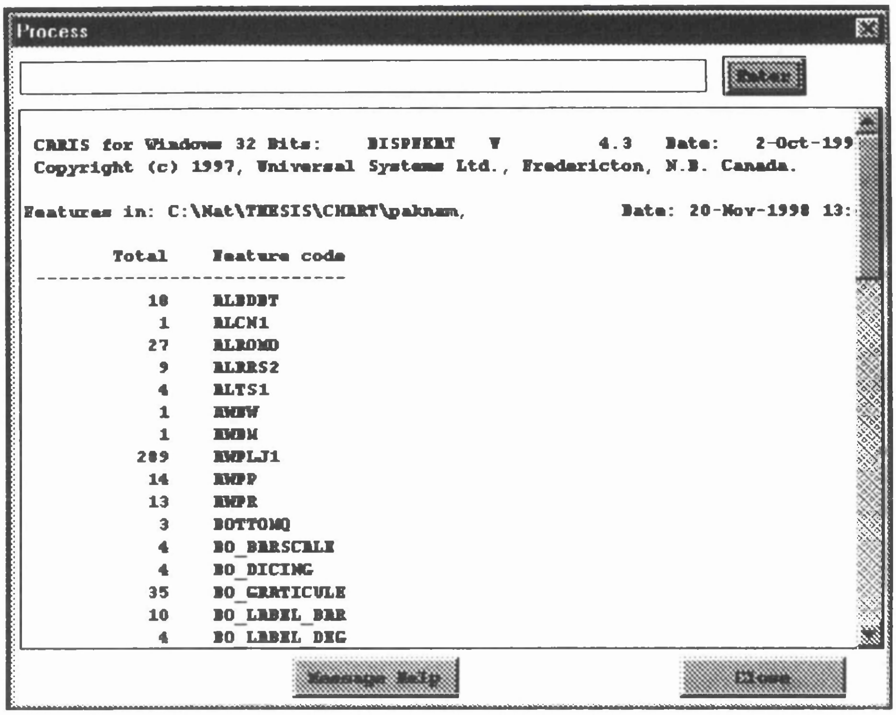


Figure 6.3 The process window of *List Feature Codes* program.

User Numbers: are checked for user number validation by considering the digital file. This is done by examining the user numbers available in *Available List* in *Display Visibility Parameter* (figure 6.4) against the input user numbers in QACF. Any invalid user numbers found are displayed on screen and the features in such user numbers are corrected to their valid one.

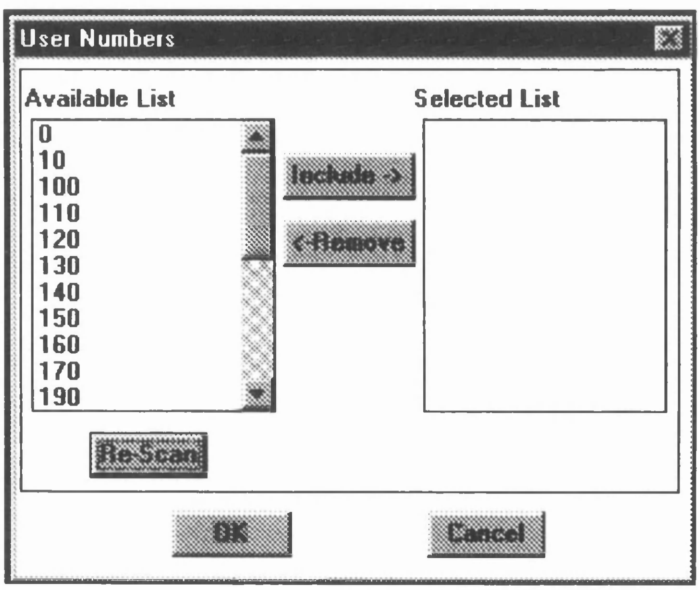


Figure 6.4 The example of User Numbers found in *Available List* of *Display Visibility Parameters.*

Compilation Status: All features in digital chart file can be assigned three different setting of compilation status available in CARIS. These are *"Background"*, *"Selected"* and *"Suppressed"*. According to the proposed "Data Quality Specification of Digital chart File", all features are required to have *"Selected"* compilation status. This is checked by considering the digital file. All features with *"Selected"* compilation status are excluded from drawing on the screen. Nothing should be drawn. Any features drawn means that they have the wrong compilation status and need to be corrected.

Z values of low water lines, hydrographic and topographic contours: Low water lines and hydrographic contours were assigned depth values (Z) during data entry. These depth values are checked by considering the check plot. The low water line, hydrographic contours and their contour labels are displayed with a minimum of the other features (e.g. coastlines) to provide reference points. The standard colour table is then replaced by one named "samihydrocontour.col to temporarily assign different colours to low water lines and hydrographic contours according to depth value. A check plot is produced and compared to the original chart on the light table. Any hydrographic contours missing or with wrong depth values are marked and corrected. In the case of topographic contours, unlike hydrographic ones, the z values are checked by considering the digital file. The topographic contours are displayed on screen with a minimum of the other features (e.g. coastlines) to provide the reference points and randomly checked by using the *Information Icon* in CARED to point to the sample topographic contours to get z values. These z values are recorded and checked against those on the original chart. The percentage of correctness is computed. If this is less than 98%, the correction is made.

Soundings: are checked by considering the digital file in two ways, one for deep soundings in shallow water and shallow soundings in deep water, the other for general soundings. All soundings are displayed on screen with a minimum of the other features (e.g. coastlines, low water lines and hydrographic contours) to provide reference points. The deep in shallow and shallow in deep soundings are checked randomly against those of the original chart. The percentage of correctness is computed. If this is less than 100%, corrections are made. The same procedure is also applied to check general soundings.

Names and Texts: The attributes of names and texts concern spelling, font number (font type and style), font size and line weight. These are checked by considering the digital file. Names and texts in this project are classified into 5 categories: names of places and islands; text of aids to navigation; purple text; text of miscellaneous stations; text of radio and radar stations; and text of bottom quality.

DISPNAME -file=C:\CARIS\Thaichart\Paknam -output=C:\CARIS\Thaichart\Paknam.lis -scope.display_file

Display for: C:\CARIS\Thaichart\Paknam, Date: 08-Sep-1998 22:04:21

Font	Size	Lwt.	Name	Lat	Long
1	1	1	Hin Sampayu	13-11-11.752N	100-48-11.815E
60	2.3	1	Ko Thai Ta Mun	13-06-26.051N	100-48-30.914E
60	2.3	1	Ko Khang Khao	13-06-51.076N	100-48-55.962E
1	1	1	Hin Kong Nok	13-11-25.033N	100-48-43.215E
1	1	1	Hin Kong Nai	13-10-51.928N	100-49-18.621E
60	2.3	1	Ko Kham Yai	13-09-27.554N	100-49-20.159E
60	3	1	KO SI CHANG	13-08-47.545N	100-49-27.523E
60	2.3	1	Ko Nok	13-01-14.034N	100-49-44.842E
60	2.3	1	(3)	13-01-18.319N	100-50-02.646E
60	2.3	1	Ko Lan Dok Mai	13-09-00.551N	100-50-26.601E
60	2.3	1	Ko Prong	13-09-53.922N	100-50-23.768E
60	2.3	1	Ko Kham Noi	13-10-29.725N	100-50-13.531E
60	2.3	1	Laem Chabang	13-05-26.679N	100-53-07.040E
6	1.3	5	Piling	13-07-37.039N	100-53-19.058E

Figure 6.5 Example of report file of *List Text* program.

Names and texts of each category including their attributes are listed in the report file, which is a text file with the extension.lis (figure 6.5), using *List Texts* program available in *CARIS Tools*. Such names and texts then are checked against the input names and texts attributes in the Names and Texts Check Form (NTCF, appendix 6.3). Any names or texts with the wrong attributes are corrected. For positioning and legibility of names and texts, these will be checked in completeness checking simultaneously.

3) Topological Integrity: This has implications on both positional and attribute quality of the data. Gathering and retaining node-area-line relationships must be positionally and qualitatively accurate. Lines must begin and end at nodes and no lines may intersect (cross) without the presence of a node. Left and right area must be indicated and appropriately coded. Two theme numbers (TN=40,200) in the digital file have topology built during data entry in order to allow colour fills. Topological integrity checks of these two themes are performed by considering the digital data. This is done automatically using *List Themes* program available in *CARIS Tools*. Three different types of topological status of all themes are reported on screen (figure 5.21). These are network topology, polygon topology and polygon labels. Topology status of the themes required to have topology, should be all read *"Complete"*. If any of such topological themes were read *"None"* *"Incomplete"* or *"Partial"*, such topological themes need to be edited and topology rebuilt until free of errors.

4) Positional Accuracy: This indicates the degree of compliance to the spatial address standard, including information on control surveys and the accuracy of spatial addresses in the final product determined by deductive estimate, internal evidence, comparison to source, and (or) tests using independent sources of higher accuracy. There are two checks concerning the positional accuracy: checking for registration accuracy and checking for locational errors.

Checking for registration accuracy: The data set captured using SAMI was first stored in system coordinates (NRMR). After vectorising, it was registered to the chart coordinate system (CHMR) which is related to the real world. The registered coordinates of the digital data set should be equal or very close to their actual values within the specified criteria. The registration accuracy, as a result, needs to be checked. This is performed by considering the discrepancies between the coordinates of registered control points, used in registration process, and those of the original (true coordinates). The triangulation symbols (FC=ALTS) are added in the digital chart file with true coordinates of those control points. The discrepencies of the control points and their true coordinates (triangulation symbols) are then measured digitally on screen using *Query>Distance between two points* tools (figure 6.6) available in CARED and recorded in QACF.

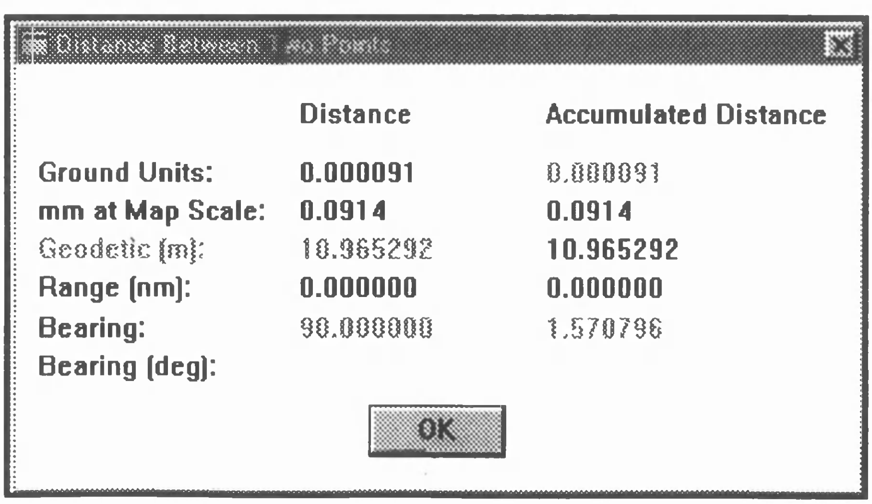


Figure 6.6 The resultant window of *Distance between two points* tools.

The Root Mean Square Error (RMSE) is computed and compared to the criteria. If it exceeds 0.3 mm. at chart scale, a new registration must be performed to improve the situation, if deemed appropriate.

Checking for locational errors: This is performed by considering the check plot. produced on the stable base material. Sample well defined points are checked against the original on the light table to determine the positional quality of data. The discrepencies are visually measured and recorded in QACF. Any locational errors greater than 1.0 mm. are marked. The percentage of sample points with discrepency less than or equal 1.0 mm. is computed. If this is less than 100%, any further action to be taken would be decided by the supervisor in charge of the validation procedure.

5) Completeness: This indicates the concept that the digital file should contain the same level of information shown on the original chart. This is checked by considering the check plot. All features in the digital file excluding low water line and polygon labels are displayed and symbolised. The colour table, named "Thai.col", and colour map, named "Thai.cma" are used to assign colours to the features and to colour fill polygons resulting in a plot similar to the original chart. All information including positioning and legibility of names and texts are checked against the original on the light table. Any missing, excessive features and gross errors are marked and corrected.

6.2.2 Quality Assessment Test 2

Quality Assessment Test 2 is included in the digital chart production flowline for checking the digital chart file compiled from the cartographic database once this has been established. Most of its procedures are likely to be similar to those of Quality Assessment Test 1 but, there may be some procedures which are slightly different. Of particular note is the identification of the source of errors. Errors found in Quality Assessment Test 1 can be identified as primarily resulting from the digitising process, whilst errors found in Quality Assessment Test 2 may come from either the compilation stage or from cartographic database itself (i.e. they were not identified in Quality Assessment Test 1). Therefore, some procedures concerning identification of sources of errors should be developed and included in Quality Assessment Test 2. These will check not only the quality of data on the chart but also the intregrity of cartographic data base simultaneously. Once the source of errors are identified, such errors will be corrected according to their source. This is especially important for errors found in cartographic data base, which if overlooked and not corrected, will occur repeatedly and cause unnecessarily time wasting.

The example mentioned above is just a simple difference in the procedures between the two Quality Assessment Tests. There may be some other procedures which need to be modified or even further tests included in Quality Assessment Test 2. However, without the cartographic database, it is difficult to create and test such procedures. Once the database is designed and created, Quality Assessment Test 2 is likely to be developed more easily and effectively using experience gained from building the database and using Quality Assessment Test 1.

6.2.3 Testing and Analysis of Quality Assessment Test 1

The procedures described in the previous section were tested in a pilot project. Although these procedures were designed in combination with quality assessment, quality control and corrective editing, they are practical and workable. The procedure allows a data set, such as one captured as described in chapter 5, to have its quality assessed for both the positional and attribute data using the source chart, check plots and automatic procedures which looked at the digital data for correct datatypes, attributes, projection and coordinate system, geometry and logical consistency. It should be noted that there is no procedure at this time for assessing the quality of the source chart.

By implementing tools and programs available in CARIS and facilities available in house, the Quality Assessment Procedures were created, tested and proved that they are practical and workable. However, this is just the first step by Thai HD concerning digital chart production and quality assessment of data produced by such a production system. Although the Quality Assessment Procedures are feasible there remains scope for future developments, such as more automated procedures (e.g. automated feature codes, compilation status and source IDs validation checkings).

The final form of the cartographic database needs to be determined and Quality Assessment Test 2 finalised. The equipment and methods used in the Quality Assessment Tests need to be assessed (e.g. the accuracy of scanners and plotters). Some of these aspects are discussed in the next chapter.

Chapter 7

Future Developments, Recommendations and Conclusion

"Rome was not built in one day". This proverb is absolutely true. Everything takes time to achieve its purpose. The primary aims of this project are to study the possibility of moving from traditional chart production to digital production and to develop quality assessment procedures for Thai HD. A major element in the chart production process is the conversion of the detail appearing on the hand draw chart compilation into the reproduction quality images which will appear on the printing plates. When performed using traditional manual methods, this activity is both time consuming and labour intensive. Using the digital flow line, compilation detail is converted into a machine readable form using scanners and digitising tables. A verification plot of the data is then produced and examined for errors, which are subsequently corrected using interactive editing equipment. It has been shown that digital chart production and data quality assessment with CARIS is feasible but there remain questions and further developments as discussed below.

7.1 Future Developments and Recommendations

7.1.1 Evaluation of the Other Systems

CARIS, the reference software used in this project, is a powerful system which is capable of producing digital charts and checking data quality of such charts successfully, but it is only one of various systems currently available in the field of Marine Information System (MIS) which is GIS technology applied to the production of navigational charts, both paper and electronic. There are a number of similar systems which should be evaluated in the same manner to CARIS (e.g. LAMPS2, Microstation MGE, Atlas CGS, etc.) in order to find out which system is the most suitable for Thai HD. Change in production will cause organisational, technical as well as financial problems. Therefore, the selection of the appropriate system is the most important matter to be considered from the author's point of view. This is due to the fact that it is a significant move by Thai HD from manual chart production to digital, and that such a system will be very costly and thus must justify the investment of both time and money.

As a result, Thai HD should evaluate the efficiency of various systems in order to get the most cost-effective system which is able to fulfil its requirements.

7.1.2 Creation of Cartographic Database

The cartographic database is a digital data base containing the information required to produce the published charts. It is a key factor of digital chart production. As Thai HD is moving to digital chart production, the future requirements for the creation and maintenance of digital chart information in such a database should be considered simultaneously. The design phase of the database requires many basic decisions concerning data source materials, accuracy requirements, possible database methodologies, levels of structuring, digitising techniques, processing systems, formats and means of maintaining the database. These must all be considered and well defined. The database should be designed not only to have the functional capability and capacity to handle the requirements of digital chart production, but also meet the needs of other users for nautical charting data. It is likely that this database will assist not only in the production of new charts and new editions but also in the handling of incoming hydrographic data, both analogue and digital and the development of electronic chart products.

For "truth in labelling", resulting from Quality Assessment Check Form (QACF), to be useful, the quality values supplied with the digital data have to be incorporated into the cartographic database. The database designers have to take this into consideration. This can be called *"Information Quality Sub-system"* allowing the providers of data to supply not only the data but also information on data quality. As yet such sub-systems are not standard but, however, proposals exists for their design and it is to be expected that soon they will become standard *(Drummond, 1994)*.

7.1.3 Creation of Quality Assessment Test 2

As mentioned in 6.2.2, Quality Assessment Test 2 will be included in the digital chart flowline for assessing the quality of the digital chart file compiled from the cartographic database. It is expected to check not only the quality of data from the compilation stage but also the intregrity of the database. This test has not been developed fully in this project due to the fact that there is no cartographic database available and that inadequate time is available to the author. Once the cartographic database is designed, created, and implemented, Quality Assessment Test 2 should be created using the experiences gained from implementing of such a database.

7.1.4 Modification of Quality Assessment Test 1, Equipment and Documentation

Although the performance of Quality Assessment Test 1 procedures is initially satisfactory, most of procedures are done manually. This could slow the work and may be error prone. Therefore, more automated procedures are required to speed up the process and minimize the errors. For example, checking for feature code validation is currently done by visual comparison of the input feature codes against the master file containing all feature codes available in CARIS. This could be done automatically by writing a program to do this work instead of the operator. The same idea can be similarly applied to checking of user number, source ID, names and texts. The Quality Assessment Check Form (QACF) is currently filled by hand. This could lead to errors and shortcutting. The automatic generation of QACF should be made possible to avoid such problems. Shortcutting can also be avoided if it is impossible for data to be described as quality assessed if it has not been done. Procedures to ensure this remain to be investigated *(Drummond, 1994)*. The equipment and peripherals implemented in digital chart production and data quality assessment should be more efficient and accurate. The accuracy and cost effectiveness of scanners, plotters, digitising tables and printers should be evaluated. If these devices are insufficiently accurate, they could become another source of unexpected errors. All documents and instructions relating to digital chart production and data quality assessment (e.g. software documentation, procedure manuals, quality assessment check form, etc.) should be improved, standardised and maintained systematically.

7.1.5 Convincing Staff about the Importance and Usefulness of Data Quality

Data Quality is a key requirement that must be considered at the earliest stage of system design. This is particularly true for all digital production systems.*(Kennedy-Smith, 1986)*. In Thailand, the public's awareness of quality matters has recently been raised by various organisations advertising their recent ISO 9000 series accredition. As a governmental charting organisation, Thai HD is expected to be concerned about quality but, in fact, this matter is not well known and considered as much as it should be. It is the author's intention to raise the importance, awareness and usefulness of digital data quality to staff of Thai HD with hope that they will agree and proceed with introducing digital production based upon quality before quantity. It should be recognised that the requirement for data quality is a key factor in the overall system design. In the initial of development both the requirement for data quality and the mechanisms to support it should be fully understood.

7.1.6 Staff Training

The human resource is the most significant mechanism of any organisation. Without this resource, the goals of such organisations will never be accomplished. Digital chart production and data quality are the new matters for Thai HD. Most staff in Thai HD are familiar with manual chart production. They are experienced cartographers with excellent cartographic skills but lack information technology (IT) knowledge. This knowledge is essential for digital production which is computer based technology. As a result, some training concerning IT, digital chart production, data quality and etc. needs to be prepared and given to such cartographers in order to prepare them for performing a new, challenging job. Such training could be given both in the form of a training course and on the job training.

7.2 Conclusion

The Thai Hydrographic Department (Thai HD), Royal Thai Navy, is a governmental organisation whose primary task is the provision of hydrographic, oceanographic and other related products and services to the Royal Thai Navy. Unclassified navigational charts and other publications are offered for sale to the private sector concerned with the maritime activities.

Thai HD has been producing its charts using the traditional manual production since it was founded. Due to the efficiency and usefulness of digital chart production being implemented in a number of national HOs worldwide, Thai HD has realised the potential capability. Furthermore, common agreements by the IHO request that member governments have their national hydrographic office produce digital chart data and the associated updating service as soon as possible and ensure the quality of such data which will be exchanged between HOs.

Responding to these pressures, Thai HD, as a governmental charting agency and an IHO member, has recently started planning to move from manual chart production to digital production. It is expected that the new digital production will fulfil its requirements by reducing time and cost of the production and by providing more accurate and the better quality charts and information related to them.

As a result, the efficiency of various systems is being evaluated in order to find out the most suitable and cost-effective one for Thai HD. Among these systems, CARIS is a system in which Thai HD is interested. As stated already, It is a Marine Information System (MIS) which is GIS technology applied to production of navigational chart both paper and electronic one. Fortunately, with the kind assistance and support of Universal Systems Limited (USL), the system manufacturer, CARIS has been used in this project to develop and evaluate possible production procedures.

In addition to this initial aim for the project, consideration has also been given to the quality of data being produced by the proposed digital production system and suitable quality assessment procedures developed. It has also given the author a unique insight into the problems faced by Thai HD in moving to digital production.

A small area extracted from Thai chart number 142 has been used in the creation of the digital chart production flowline and data quality assessment procedures using programs, tools available in CARIS and equipment available in the *Department of Geography and Topographic Science*. The successful creation of this sample chart indicates that the methods developed are practical and can achieve the desired results.

Although the results of this project show a move to digital production is feasible, this is only the Thai HD's first significant step to be taken on the way to international standards. It can be seen that the problems of introducing a digital chart service are organisational, legal, and financial as well as technical. It is the aim of the author to assist in finding answers to these questions, having as its overriding consideration the safety and convenience of the mariners. The procedures need more research and extensive field experience before reaching international acceptance.

The author hopes that the digital chart production and data quality assessment procedures will be accepted and implemented within Thai HD, resulting in benefits to the author's beloved Royal Thai Navy. If so, it could be said that the digital chart production and awareness of data quality have been introduced into the Thai HD.

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APPENDIX 5.1

Data Validation Check Form (DVCF)

1) Receive\Record Basic Information

   Incoming new information no.______________________________

   Date received____

   Source of information_____________________________________

      Address____

      Telephone no.____________________________________

      Fax no.____

   What is the new information? (e.g. new port, wreck, new survey, etc.)_____

   Area of new information___________________________________

   Affected charts____

   Scale____

   Projection____

   Ellipsoid____

   Datum____

   Unit of heights____

   Unit of soundings_______________________________________

2) Needed to be transformed to Mercator Projection, Everest Spheroid, Metric Unit (meter) and the same scale as the largest scale of related chart ?

   ☐Yes, Transform

   ☐No, Go to 3.

3) Plot new information (green ink) on the largest scale of related chart, Useful?

   ☐Yes, Go to 4.

   ☐No, Assign to "Unuseful information no.________________"

4) Check if information has been previously received or duplicated ?

   ☐Yes, Assign to " Duplicated information no.______________"

   ☐No, Assign to " New useful information no.______________"

5) Check for error, Error?

☐Yes, Annotate errors and corrections (red ink)

☐No, Go to 6.

6) Required additional information ?

☐Yes, Contact the original of source data.

Contacted date_______________

Responded date______________

☐No, Go to 7.

7) Should be " Notice to Mariners ? "

☐Yes, Send to Navigational Instrument Division to annouce as NTM.

☐No, Store in " Next new edition file "

8) Reason for replacement of older date (eg. newer, more details, more accurate and etc.)

9) Conclusion

Useful?	☐Yes, new useful info.no.___	☐No, unuseful info.no.__
Duplicated?	☐Yes, duplicated info. no.___	☐No
Should be NTM?	☐Yes	☐No

Inspected by 1.________________________________

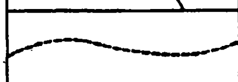
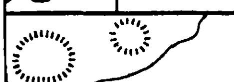
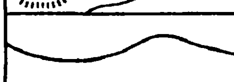
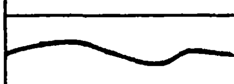
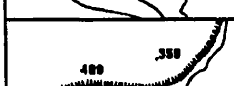
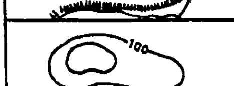
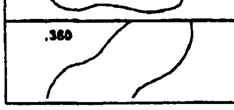
2.________________________________

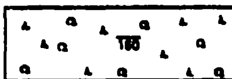
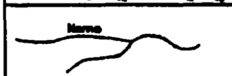
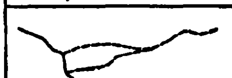
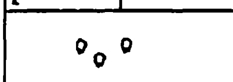
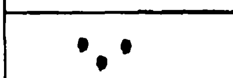
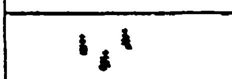
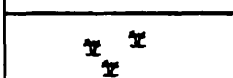
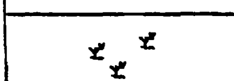
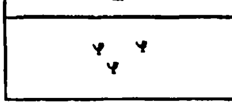
3.________________________________

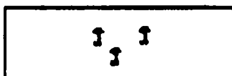
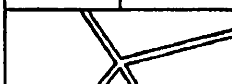
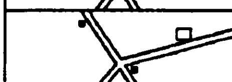
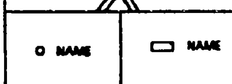
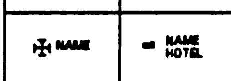
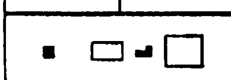
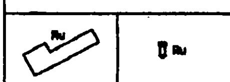
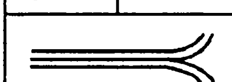
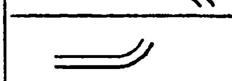
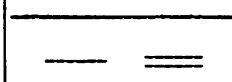
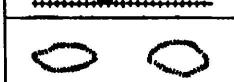
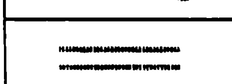
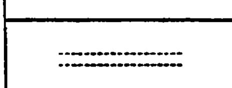
Date of inspection________________________________

APPENDIX 5.2

Example of CARIS Hydrographic Symbology

▲	IB20 ALTS	Triangulation point
⊕	IB21 ALOS	Observation spot
⊙	IB22 ALFP	Fixed point
	IB23 ALBM	Benchmark
	IC1 CLSL	Coastline . surveyed
	IC2 CLIK	Coastline . unsurveyed
	IC3 NFSCLT NFSCLTME NFSCLTSM	Steep coast . Steep coast with rock cliffs . Cliffs
	IC4 NFHLLT	Coastal hillocks
	IC5 CLSLFT	Flat coast
	IC6 CLSLSDLT	Sandy shore
	IC7 CLSLGRRT TEXT	Stoney shore . Shingly shore
	IC8 NFSD NFSD3 TEXT	Sandhills . Dunes
	IC10 COTPMR COTPIX COTPLB	Contour lines with spot heights
	IC11 NFSU	Spot heights
	IC12 COTPIK	Approximate contour lines with approximate height
	IC13 COTPFMLT COTPFMHV	Form lines with spot height

	IC14 NFWDU NFWDT (Spot height using 'T')	Approximate height of top of trees (above height datum)
	IC20 CLRI	River . Stream
	IC21 CLRIR	Intermittent river
	IC22 NFRP	Rapids . waterfalls
	IC23 CLLR	Lakes
	IC24 NFSP TEXT	Salt pans
	IC25 NFGL	Glacier
	IC26 NFLF	Lava flow
	IC30 NFWDT NFWDU TEXT	Wood . in general
	IC31.1 NFWSDTM	Deciduous tree
	IC31.2 NFWSEVN	Evergreen (except conifer)
	IC31.3 NFWSCNK	Conifer
	IC31.4 NFWSPLL	Palm
	IC31.5 NFWSNPI	Nipa palm
	IC31.6 NFWSCAJ	Casuarina
	IC31.7 NFWSFIO	Filao

	IC31.8 NFWSEUP	Eucalypt
	IC32 NFMNG2RT IC32 CLSL	Mangrove
	IC33 NFMSPK TEXT NFMSS1MS NFMSS2MS	Marsh
	ID1 AWUA AWUAHL	Urban area
	ID2 AWUA AWUAHL ALBD ALBDFI	Settlement with scattered buildings
	ID3 AWSETX ALSH1 ALBDFI	Settlement (on medium and small scale charts)
	ID4 AWINTX ALBD CHV	Inland village
	ID5 ALBD ALBDFI ALBDBL	Building
	ID8 ALRC TEXT ALWTWT	Ruin . Ruined landmark
	ID10 ALROMO ALROMOIN	Motorway
	ID11 ALRODL ALRODLT	Road (hard surfaced)
	ID12 ALTR ALTRDL	Track . Path (Loose- or unsurfaced)
	ID13 ALRR ALRRS1 ALRRS2 (ALBD)	Railway . with station
	ID14 ALCTLT ALCTRT	Cutting
	ID15 ALEMLT ALEMRT	Embankment
	ID16 ALTU	Tunnel

APPENDIX 5.3

Making a Header Procedure for Thai Chart

1) Use *CARIS Tool>Map Creation & Managemant>Creat a New Map*
2) Type CARIS File *(e.g. C:\CARIS\Thaichart\Chart334), EXECUTE*
3) Type in 1. Enter file title *(e.g. PHUKET HARBOUR and APPROACHES)*
   2. Enter file ID *(e.g. CHART334)*
   3. Enter horizontal coordinate system *(e.g. CHMR)*
   4. Enter Projection *(e.g. ME)*
   5. Enter

corner 1	Latitude	*(e.g. 07-55-00.00 N)*
	Longitude	*(e.g. 98-25-00.00 E)*
corner 2	Latitude	*(e.g. 07-55-00.00 N)*
	Longitude	*(e.g. 18-30-00.00 E)*
Corner 3	Latitude	*(e.g. 08-00-00.00 N)*
	Longitude	*(e.g. 98-30-00.00 E)*
Corner 4	Latitude	*(e.g. 08-00-00.00 N)*
	Longitude	*(e.g. 98-25-00.00 E)*

   6. Enter central meridian *(e.g. Press Enter)*
   7, Enter scaling latitude (7-55-00.000N) *(e.g. Press Enter)*
   8. Enter scale denominator *(e.g. 50,000)*
   9. Enter ellipsoid *(e.g. EVER)*
   10. Enter chart resolution (in metres) (0.00001016) *(e.g. press Enter)*
   11. Enter resolution for elevation (in metres) (0.001) *(e.g. Press Enter)*
4) CARIS will display full header, check any field need to be corrected.
   If Yes Type field number to change and type the correct value.
   If No Record all fields input above including Vertical Coordinate System, Soundings, Spot Heights Unit and Vertical Datum in Quality Assessment Check Form (QACF)
5) Type Q to quit and Close.

APPENDIX 6.1
Quality Assessment Check Form (QACF)

Digital Chart No. ____
Chart Title____

1. HEADER

Field	1.1 Input	1.2 Output	1.3 Correct?
1. Chart Title (item1)			
2. File ID (item2)			
3. Horizontal co-ordinate system (item3)			
4. Projection (item10)			
5. Corner 1. Latitude (dd-mm-ss.00N) (item21)			
Longitude (dd-mm-ss.00E)			
2. Latitude			
Longitude			
3. Latitude			
Longitude			
4. Latitude			
Longitude			
6. Central Meridian (item11)			
7. Scaling latitude (item13)			
8. Scale denominator (item12)			
9. Ellipsoid (item16)			
10. Chart resolution (in meters) (item8)			
11. Resolution for elevation (in meters) (item8)			
12.Vertical Coordinate System(item5)			
13.Soundings, Spot Height Units (item7)			
14.Vertical Datum (item17)			

1.4 Header ☐ Complete ☐ Incomplete Why?__________

2. USER NUMBER\THEME NUMBER (UN\TN)

2.1 Input UN (TN)____

2.2 Output UN (TN)____

2.3 User Number Validation ☐ Complete ☐ Incomplete Why?_____

3. FEATURE CODE (FC)

1.Chart Border, Neatline, Lattice				
Feature Code	**3.1 FC Validation**	**3.2 Correct Feature**	User No. (Theme No.)	**3.3 Correct UN? (TN)**
2. Title Block, Bar Scale				
3. Names				
4. Buildings				
5.Artificial Features				
6.Control Points				
7.Topographic Contours, Topographic Contours Labels				
8.Natural Features				
9. Miscellaneous Station				

10. Radio and Radar Station				
Feature Code	**3.1 FC Validation**	**3.2 Correct Feature**	User No. (Theme No.)	**3.3 Correct UN? (TN)**
11. Ports and Habours				
12. Aids to Navigation				
13.Dangers				
14. Various Limits				
15. Coastline Characteristics				
16. Soundings				
17. Bottom Quality				
18. Tides and Currents				

19. Hydrographic Contour Label				
Feature Code	**3.1 FC Validation**	**3.2 Correct Feature**	User No. (Theme No.)	**3.3 Correct UN? (TN)**
20. Coastlines, Low Water Lines, Hydrographic Contours and Polygon Labels				

3.4 FC Validation ☐ Complete ☐ Incomplete Why?________________

3.5 FC associated with correct features and UN\TN

☐ Complete ☐ Incomplete Why? ________________

4. COMPILATION STATUS

4.1 All features have "SELECTED" compilation status?

☐ Yes ☐ No Why? ______________________

5. SOURCE ID

Source ID	**Description**	**5.1 Source ID Validation?**	**Feature Code**	**5.2 Correct FC?**
1.				
2.				
3.				

5.3 Source ID Validation ☐ Complete ☐ Incomplete Why ?__________

5.4 Source ID associated with correct FC

☐ Complete ☐ Incomplete Why?__________

7. SOUNDINGS

7.1 Check deep in shallow and shallow in deep

Sample Soundings No.	**7.1.1 Expected sounding value**	**7.1.2 Displayed sounding value**	**7.1.3 Correct?**
1.			
2.			
3.			
4.			
↓	↓	↓	↓
50.			

7.1.4 Percentage of sample deep in shallow and shallow in deep with correct soundings value = ________%

7.1.5 =100 %?

☐ Yes ☐ No Why? ______________________________

7.2 Check general soundings

Sample Soundings No.	**7.2.1 Expected sounding value**	**7.2.2 Displayed sounding value**	**7.2.3 Correct?**
1.			
2.			
3.			
4.			
↓	↓	↓	↓
50.			

7.2.4 Percentage of sample soundings with correct value = _____%

7.2.5 =100 %?

☐ Yes ☐ No Why? ______________________________

8. TOPOLOGY

Topological Theme No.	**8.1 Network Topology**	**8.2 Polygon Topology**	**8.3 Labels**

8.4 Topology Status ☐ Complete ☐ Incomplete Why? __________

9. NAMES and TEXTS

9.1 Names and Texts Attributes *(Checked in Names and Texts Check Form)*

Texts of	9.1.1 Spelling	9.1.2 Font Number (Type & Style)	9.1.3 Font Size	9.1.4 Line Weight
1. Names of places and islands				
2. Aids to Navigation				
3. Purple Text				
4. Text of Miscellaneous Stations				
5. Text of Radio and Radar Stations				
6. Text of Bottom Quality				

9.1.5 Names and texts have correct attributes

☐ Yes ☐ No Why? ______________________

10. POSITIONAL ACCURACY

10.1 Check registration accuracy

Control Point (CTP) No.	10.1.1 CTPs of Original Chart		10.1.2 CTPs of Digital Chart		10.1.3 Differences (V)
	Latitude	Longitude	Latitude	Longitude	
1. (SW)					
2. (SE)					
3. (NE)					
4. (NW)					
5.					
↓	↓	↓	↓	↓	↓
Last control point					

10.1.4 RMSE of control points = ________ ≤ 0.3 mm. at chart scale?

☐ Yes ☐ No Why? ________________

10.2 Check locational errors

Sample Point No.	**10.2.1 Discrepency (V)**	**10.2.2 ≤ 1.0mm?**
1.		
2.		
3.		
4.		
5.		
↓	↓	↓
50.		

10.2.3 Percentage of the sample points with discrepency ≤ 1.0mm =____%

10.2.4 =100%?

☐ Yes ☐ No Why? ________________

11. COMPLETENESS

11.1 Completeness of the final chart

☐ Complete ☐ Incomplete Why?________________

12. CONCLUSION

12.1 This Digital Chart File No._____ ☐ **Pass** ☐ **Fail Why?** ________

12.2 Date of inspection____

12.3 Comment or recommendation____________________________________

12.4 Inspectors

12.4.1 ____

12.4.2____

12.4.3____

APPENDIX 6.2
Quality Assessment Procedure Manual (QAPM)

1. HEADER

1.1 Record Digital Chart Number and Chart Title on the top of Quality Assessment Check Form (QACF).
1.2 Use *CARIS Tools>Map Information>List Map Header>select the digital chart file to be displayed chart header>Execute*.
1.3 Record Output Fields in (QACF) section 1.2,>*Close process window.*
1.4 Compare the Input (1.1) and Output Fields (1.2), Use pencil tick √ for the correct fields and X for the incorrect ones in section 1.3.
1.5 Check in section 1.3, any incorrect fields?

□ Yes, → Use *CARIS Tools>Map Data Edition>Edit Header>select the digital file to be edited>Execute.*
→ Enter field number to change until no error.
→ Type Q to quit,>*Close process window.*
→ Repeat 1.2-1.5 until No.

□ No, → Fill in QACF section 1.4.

2. USER NUMBER\THEME NUMBER (UN\TN)

2.1 Use *CARED>select the digital chart to be checked.*
2.2 *Display Visibility Parameter (DVP)>click at User Number (UN)> Re-Scan>look at Available List.*
2.3 Record UNs (TNs) avalable in section 2.2,>*OK.*
2.4 Compare Input UNs (2.1) and Output UNs (2.2).
2.5 Check any invalid UNs?

□ Yes, → *DVP to display invalid UN.*
→ *Group>Define Group>draw Lasso to surround features in invalid UN.*
→ *Group>Change>UN to valid one.*
→ Repeat 2.2-2.5 until No.

□ No, → Fill in QACF section 2.3.

3. FEATURE CODE (FC)

3.1 Check Feature Code Validation

3.3.1 *CARIS Tools>Map Information>List Feature Codes>select the digital file to be checked>Execute.*
3.3.2 In Process Windows, check displayed FCs against section 3 Feature Code column, use pencil tick √ for valid FC and X for invalid FC in section 3.1, >*Close process window.*

3.3.3 Check in section 3.1, any invalid FCs?

□ Yes, → *CARIS Tools>Map Data Editing>Edit Feature Codes> select the digital file to be changed FC>Option>New Feature Code=Type new FC>Change=Yes>Old Feature Code=Type invalid FC to be changed.*
→ Repeat 3.3.1-3.3.3 until No.

□ No, → Fill in OACF section 3.4 (FC Validation).

3.2 Check association of Feature Code with correct feature and UN.

3.2.1 *CARED>select the digital file to be checked.*
3.2.2 *DVP>display each UN and each FC belongs to that UN on screen sequentially.*
3.2.3 Visual check against the original chart, tick √ for FC associated with correct feature and UN and X for incorrect one in section 3.2, 3.3.
3.2.4 Any missing or excessive feature?

□ Yes, → *Edit>Feature>Set Feature Code (or User Number)>point to wrong feature and change to correct FC (or UN)*
→ If too many features to be changed *Group>Define Group> draw Lasso to surround wrong feature>Change to correct FC (or UN).*
→ Repeat 3.2.2-3.2.4 until No.

□ No, → Repeat 3.2.2-3.2.4 for the rest of FCs until all FCs are checked. Go to 3.2.5.

3.2.5 Fill in QACF section 3.5.

4. COMPILATION STATUS

4.1 *DVP>Draw Features>do exclusive draw at "SELECTED".*
4.2 Anything is drawn? (nothing should be drawn).

□ Yes, → *Edit>Feature>Set Compilation Status>SELECTED>point to feature with wrong Compilation Status.*
→ If too many features to be changed>*use Lasso.*
→ Repeat 4.1- 4.2 until No.

□ No, → Fill in QACF section 4.1, >*Exit CARED.*

5. SOURCE ID

5.1 Check Source ID Validation

5.1.1 *CARIS Tools>Map Information>List Source ID>select the digital file to be checked>Execute.*
5.1.2 In process window, Check the displayed Source ID against section 5 in Source ID column, tick √ for valid Source ID and X for invalid one in section 5.1, >*Close process window.*
5.1.3 Check in section 5.1, any invalid Source IDs?

□ Yes, → *CARED>select the digital chart to be changed.*
→ *DVP display invalid Source ID.*
→ *Edit>Feature>Set Source ID>point to feature with invalid Source ID>Change to valid one.*
→ If too many features to be changed>*use Lasso.*
→ Repeat 5.1.1-5.1.3 until No.

□ No, → Fill in QACF section 5.3.

5.2 Check association of Source ID with correct FC.

5.2.1 *DVP display each Source ID+all FCs belongs to it>Do exclusive draw at FC.*
5.2.2 Anything is drawn? (nothing should be drawn).

□ Yes, → tick X for FC with incorrect Source ID in section 5.2.
→ *Edit>Feature>Set Source ID>point to feature with wrong Source ID>Change to valid one.*
→ If too many features to be changed>*use Lasso.*
→ Repeat 5.2.1-5.2.2 until No.
□ No, → tick √ for Source ID associated with correct FC in section 5.2.

5.2.3 Fill in QACF section 5.4.

6. Z value of Hydrographic and Topographic Contours.

6.1 Check association of Z value with correct hydrographic contour.

6.1.1 *DVP Display FC=CLLW,CODTMR, CLSL, COLB, NEATLINEDUM +UN=190, 200.*
6.1.2 *Options>Display>Colours>Replace Colour Table>Select samihydrocontour.col (This colour table assigns the different colours to contours by Z values as following table below)*

Feature Code	Z value	Colour
CLSL	-	White
CLLW	0	Red
CODTMR	2	Green
CODTMR	5	Yellow
CODTMR	10	Blue
CODTMR	15	Orange
CODTMR	20	Magenta
CODTMR	30	Pink
CODTMR	40	Brown
CODTMR	50	Light blue
CODTMR	100	Black
CODTMR	200	Light green
CODTMR	500	Grey

6.1.3 Check Plot on the film, check against the original chart on the light table by order of Z value.
6.1.4 Any wrong Z values?

□ Yes, → tick X for contour associated with wrong Z value in section 6.1.1.
→ Use green ink to mark contour with wrong Z value and annotation.
→ Use red ink to mark missing and incomplete contour
→ *CARED>DVP display FC=CODTMR+Contour range = wrong Z value.*
→ *Edit>Line>Change>Contour Elevation>point to contour with the wrong Z value and change to the correct one.*
→ Repeat 6.1.1-6.1.4 until No.

□ No, → tick √ for contour associated with correct Z value in section 6.1.1.

6.1.5 Fill in QACF section 6.1.2.

6.2 Check association of Z value with correct topographic contour.

6.2.1 *DVP>display UN=70, 71, 200.*
6.2.2 *Information icon>Random check Z value of topographic contours against the original chart by pointing to contour and get information> Record Z value in section 6.2.1, 6.2.2.*

6.2.3 Compare Z value of 6.2.1 and 6.2.2 and tick √ for correct one and X for incorrect one in section 6.2.3.
6.2.4 Compute percentage of sample topographic contours with correct Z values and fill the result in section 6.2.4.
6.2.5 Z values of sample contours are correct < 98 %? (should be correct ≥ 98%)

□ Yes, → *Edit>Line>Change>Contour Elevation>point to contour with the wrong Z value and change to the correct one.*
→ Repeat 6.2.1-6.2.5 until No.

□ No, → Fill in QACF section 6.2.5.

7. SOUNDINGS

7.1 Check correctness of deep in shallow and shallow in deep.

7.1.1 *DVP>display UN=160, 200.*
7.1.2 Random check deep in shallow and shallow in deep on screen against the original chart.
7.1.3 Record results in 7.1.1, 7.1.2.
7.1.4 Compare sounding values of 7.1.1 and 7.1.2 and tick √ for correct ones and X for incorrect ones in section 7.1.3.
7.1.5 Compute percentage of sample soundings with correct values and fill the result in section 7.1.4.
7.1.6 <100 % correct? (should be correct=100 %).

□ Yes, → *Edit>Sounding>Change sounding value by pointing to sounding with wrong value and change to correct one.*
→ Repeat 7.1.1-7.1.6 until No.

□ No, → Fill in QACF section 7.1.5.

7.2 Check general soundings.

7.2.1 *DVP>display UN = 160, 200.*
7.2.2 Random check general soundings on screen against the original chart.
7.2.3 Record results in 7.2.1, 7.2.2.
7.2.4 Compare sounding values of 7.2.1 and 7.2.2 and tick √ for correct ones and X for incorrect ones in section 7.2.3.
7.2.5 Compute percentage of sample soundings with correct value and fill the result in section 7.2.4.
7.2.6 <100 % correct? (should be correct =100 %)

□ Yes, → *Edit>Sounding>Change sounding value by pointing to sounding with wrong value and change to correct one.*
→ Repeat 7.2.1-7.2.6 until No.

□ No, → Fill in QACF section 7.2.5, *>Exit CARED.*

8. TOPOLOGY

8.1 *CARIS Tools>Topology Information>List Themes>select the digital file to be checked>Execute.*
8.2 Look at topoligical TM in process windows, record the results in section 8.1, 8.2, and 8.3.
8.3 Anything read "incomplete", "None" or "partial"?
(Topological Status should read "complete, complete, complete")

☐ Yes, → Go to Topology Flowline to edit topology
→ Repeat 8.1-8.3 until No.

☐ No, → Fill in QACF section 8.4, *>Close process window.*

9. NAMES and TEXTS

9.1 Check Name and Text Attributes.

9.1.1 *CARED>select the digital file to be checked.*
9.1.2 *VP>display UN=30 (names of places and islands)>Exit CARED.*
9.1.3 *CARIS Tools>Map Information>List Texts>select the digital file to be checked>Report File-type the name of report file(.lis)>Scope-Display >Execute.*
9.1.4 Check all names (or texts) on report file against Names and Texts Check Form, record Output of text attributes in Names and Texts Check Form section 1.1, 1.2, 1.4, 1.6 (Spelling, Font Number, Font Size, Line Weight).
9.1.5 Compare Input and Output, tick √ for text with correct attributes and X for incorrect ones in section 1.3, 1.5, 1.7.
9.1.6 Any names (or texts) with incorrect attributes?

☐ Yes, → *CARED>select the digital file to be edited.*
→ *Edit>Text>Change by pointing to name (or texts) to be change>Type in the correct attribute.*
→ Repeat 9.1.2-9.1.6 until No.

☐ No, → Do the same to texts of aids to navigation, purple texts, miscellaneous station, radio and radar station, bottom quality sequentially (UN = 31, 32, 33, 34, 170).

9.1.7 Fill in QACF section 9.1.1, 9.1.2, 9.1.3, 9.1.4 and 9.1.5.

9.2 Check positioning and legibility of Names and Texts.

This will be checked in 11 (Completeness Checking).

10. POSITIONAL ACCURACY

10.1 Check registration accuracy.

10.1.1 Prepare true geographic coordinates of the control points used in registration process of the original chart, record in 10.1.1.

10.1.2 *CARED>select the digital file to be checked VP>display all FCs except FC=CLLW, LABEL>OK.*

10.1.3 Add triangulation symbols (FC=ALTS, size 2 mm) with true geographic coordinates of control points using *Edit>Add>Symbol* and by pressing K, the *User Input Box* will appear, then type in their true coordinates of control points subsequently (e.g. /GE= 13-00-00 N, 100-48-00 E).

10.1.4 Read the coordinates of the control points of digital file using *Query>Point location* point to each control points accurately (using snap mode, press S), record in 10.1.2.

10.1.5 Measure the differences (V in mm. at chart scale) between the coordinates of the control points in digital file and those of the original one (triangulation symbols) using *Query>Distance between two points* (using snap mode, press S), record V in 10.1.3.

10.1.6 Compute RMSE using formula;

$$RMSE = \pm\sqrt{\sum V^2/(N-1)}$$

When V = the differences between the coordinates of the control points in digital file and those of the original chart.
N = the numbers of sample points.

10.1.7 Record RMSE in section 10.1.4.

10.1.8 RMSE ≤ 0.3 mm. at chart scale?

☐ Yes, → Fill in QACF section 10.1.4.

☐ No, → Consult supervisor in charge

10.2 Check locational errors.

10.2.1 Prepare the original chart with 50 well defined points (4 corners+46 sample points).

10.2.1 *CARED>VP* display all FCs and Uns except FC= CLLW, LABEL.

10.2.2 *Options>Display>Colour>Edit colour table/Map* to assign all FCs in red.

10.2.3 *Option>Display>Symbolise during draw>Refresh.*

10.2.4 Plot the whole chart on the film.

10.2.5 Compare the printed chart against the original one on the light table, measure and record the discrepencies of the sample points in 10.2.1 using blue pen mark-up any feature with discrepency>1.0mm, while searching if any missing features, additional features, and other gross errors found, mark them up with the red pen (this will be used to assist in completeness checking later on).

10.2.6 Tick √ for the sample points with discrepency ≤1.0mm and X for the sample point with discrepency >1.0mm in section 10.2.2.

10.2.7 Compute percentage of sample point with discrepency ≤1.0mm and record in 10.2.3.

10.2.8 All sample points with discrepencies ≤1.0mm=100% ?

☐ Yes, → Fill in QACF section 10.2.4

☐ No, → Consult supervisor in charge.

11. COMPLETENESS

11.1 *CARED>DVP>display all FC and UN except FC = CLLW, LABEL.*

11.2 *Options>Display>Colours>Replace colour map>select Thai.cma.*

11.3 *Options>Display>Colours>Replace colour table>select Thai.col.*

11.4 *Option>Display>Symbolise during draw>Enable colour fill>Refresh.*

11.5 Plot the whole chart on the film.

11.6 Do visual check against the original charts on the light table carefully, look for missing features, additional features, names and texts positioning and other gross errors.

11.7 Any errors?

☐ Yes, → Use red ink mark and annotate errors.
→ Edit errors by following the test procedures of each test.
→ Repeat 11.1-11.7 until No.

☐ No, → Fill in QACF section 11.

12. CONCLUSION

12.1 Fill in section 12.1-12.4.

APPENDIX 6.3
Names and Texts Check Form (NTCF)

1. Names of Places and Islands (UN = 30)										
Name	1.1 Spelling	Font (Type and Style)			Font Size (mm.)			Line Weight (Lwt.) (mm.)		
		In put	1.2 out put	1.3 OK?	In put	1.4 out put	1.5 OK?	In put	1.6 out put	1.7 OK?

2. Texts of Aids to Navigation (UN = 31)										
Name	2.1 Spelling	Font (Type and Style)			Font Size (mm)			Line Weight (Lwt.) (mm)		
		In put	2.2 out put	2.3 OK?	In put	2.4 out put	2.5 OK?	In put	2.6 out put	2.7 OK?

3. Purple Text (UN = 32)										
Name	3.1 Spelling	Font (Type and Style)			Font Size (mm)			Line Weight (Lwt.) (mm)		
		In put	3.2 out put	3.3 OK?	In put	3.4 out put	3.5 OK?	In put	3.6 out put	3.7 OK?

4. Texts of Miscellaneous Station (UN = 33)										
Name	4.1 Spelling	Font (Type and Style)			Font Size (mm)			Line Weight (Lwt.) (mm)		
		In put	4.2 out put	4.3 OK?	In put	4.4 out put	4.5 OK?	In put	4.6 out put	4.7 OK?

5. Texts of Radio and Radar Station (UN = 34)										
Name	5.1 Spelling	Font (Type and Style)			Font Size (mm)			Line Weight (Lwt.) (mm)		
		In put	5.2 out put	5.3 OK?	In put	5.4 out put	5.5 OK?	In put	5.6 out put	5.7 OK?

6. Texts of Bottom Quality (UN = 170)										
Name	6.1 Spelling	Font (Type and Style)			Font Size (mm)			Line Weight (Lwt.) (mm)		
		In put	6.2 out put	6.3 OK?	In put	6.4 out put	6.5 OK?	In put	6.6 out put	6.7 OK?