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MODEL FOR DETERMINATION OF CARTOGRAPHIC AND HYDROGRAPHIC PRIORITIES

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Abstract

The determination of priority zones for hydrographic surveys and charting is based on manual and empirical methods permitting only to consider a limited number of factors with the tools that are used.

A model composed of about twenty variable layers and typical parameters to the maritime field, to hydrography and to cartography is proposed in order to provide a base to a computerized system on microcomputer spreadsheet.

The problem, the present methodology, the model, the informatics environment, the application, the data are described and the analysis of a real life example of utilization is presented.

1. PROBLEM

The Canadian Hydrographic Service (CHS) is responsible for providing nautical information (nautical charts, tide tables, sailing directions and so on) to mariners in order to ensure navigational safety. The role of the CHS is, therefore, to collect, process and manage data and transform it into nautical information products for distribution. This is a long, complex and costly process. The products are ever-changing and dependent on morphological site changes, the construction of new port facilities or changes in transportation methods. Given limited resources and the significant costs associated with field operations and charting, the medium-and long-term planning of hydrographic work is essential.

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Mariners' needs vary according to the type of navigation (commercial, pleasure boating, fisheries), developments in naval construction (greater draft), navigational instruments (digital data) and the construction of new port facilities. Economic considerations related to maritime activities, as well as the dynamic of the morphology of the sea floor are criteria which must be considered, in addition to the state of the raw data and the quality of their representation. It is, therefore, essential to have an effective decision-making tool to systematically compare and consider the numerous factors affecting the planning of hydrographic projects.

2. CURRENT METHODOLOGY

To date, hydrographic activities have been planned using a few simple criteria, various manual evaluation tools and a level of expertise which hydrographers have developed over time. In terms of hydrographic surveys, the principal criterion used is the age of the surveys. Those sectors for which the raw data are more than a few years old are given priority over sectors with recent, metric surveys, beginning with the sectors with higher maritime traffic. Sectors which have never been charted, such as rivers used by pleasure boaters, are also identified in order to carry out surveys that will result in the production of charts. A scheme for the delimitation of charts is established and a five-year plan is developed on the basis of these results.

In those sectors which have undergone major changes, charts are periodically revised through new editions or reprints. The chart series are revised in accordance with the five-year plan and survey deposit. The representation is then standardized by representing the bathymetric data in metric units, and the toponymy and notes in bilingual format. Because the work of collecting and processing data represents a considerable task, only the criterion of replacing outdated surveys with new, metric surveys is applied, the other criteria are evaluated only when they are of critical importance in planning decisions. These factors are often related to planners' personal knowledge of the environment and are rarely based on a systematic planning tool. Moreover, political decisions can easily influence the incomplete analyses used as a basis for planning.

3. INCOMPLETE CRITERIA

The criterion of replacing old data (sextant and plumb line) with new surveys itself provides a sound basis for planning.

However, in terms of rationalizing and optimizing resource utilization, other important criteria must now be considered, namely the economic importance of maritime activities, the complexity and dynamics of the morphology of the sea-floor, the amount of new data available from other agencies, the density of the data acquired, the need for revisions based on the traffic on maritime routes and so on. In the past, these criteria were based solely on the personal and undocumented knowledge of planners. It is very likely that their analyses referred to these factors at one point, but the latter were not always systematically evaluated in order to support their decisions.

Given the fact that the requests and needs of users of hydrographic data (clients and the public) are varied, and that their requests are becoming increasingly urgent, planning must, of necessity, adjust to this new reality and take into consideration all the criteria which could affect the production of nautical documents. It becomes essential to be able to justify the criteria which underlie decisions regarding the surveying and charting choices and priorities. Since the proposed model uses an automated planning tool, it makes it possible to support planners' decisions by providing them with a systematic analysis of the variables affecting navigational safety and, hence, to analyse requests as a function of the priorities derived from the model.

4. GEOGRAPHIC LAYOUT

The geographic sector being analysed (in this case, the Quebec Region of the CHS) was divided into rectangular zones with sides measuring approximately 50-60 km, in order to cover all navigable waterways. Each of these zones was then subdivided into cells with sides measuring approximately 1 km. Each zone was then identified by a unique reference number. A graphic index indicating the relationship between the zone and the territory covered was created to provide a geographic reference for easy access (Fig. 1).

5. PROPOSED MODEL

The model contains three primary layers: the first, **state of the site**, is characterized by economic and morphological variables; the second, **state of the data**, contains variables pertaining to the degree of reliability of the bathymetric data; and the third, **presentation**, refers to the status of existing nautical charts. The primary layers are subdivided into secondary layers which are in turn subdivided into tertiary layers, for a total of nineteen variables (Fig. 2).

Because of its flexibility, the model can be manipulated either to define the overall characteristics of the territory by consulting the entire layer of all the variables, or to analyse them at a more specific level, such as surveys or charts.

6. DESCRIPTION OF THE LAYERS

1. State of the site

1.1 — Economic activities. This layer makes it possible to quantitatively evaluate the economic importance of maritime activities. An economic study

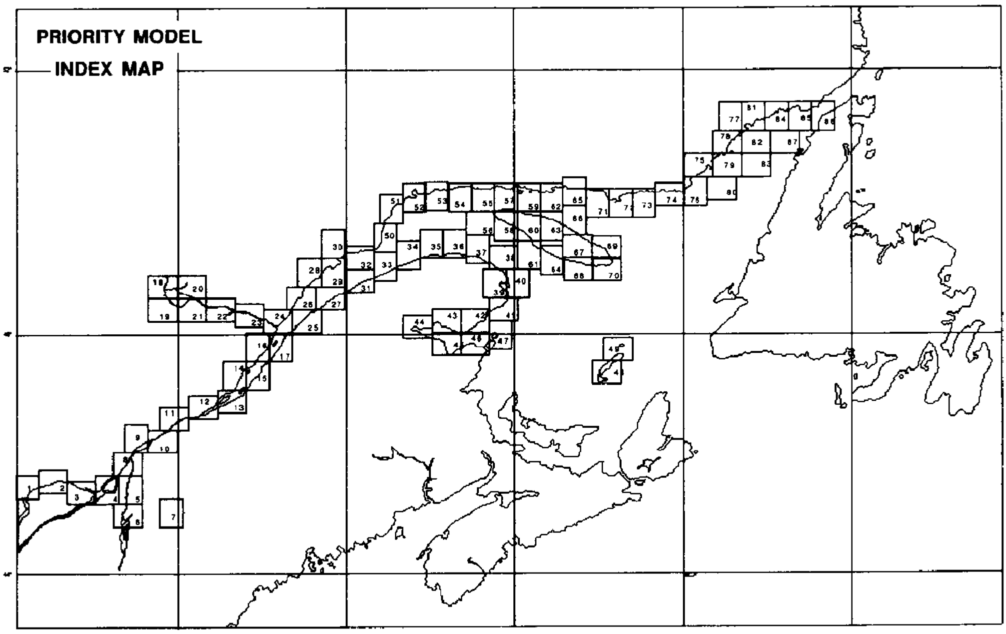

FIG. 1.— The Quebec Region of the Canadian Hydrographic Service.

carried out by the Economic Services Division of the Department of Fisheries and Oceans, Quebec Region, was needed in order to provide the CHS with an economic evaluation method it could use. The economic value of fisheries, maritime transport, pleasure boating, and ferry activities was calculated as a function of factors which are specific to these activities, thereby making it possible to give a dollar value to their importance. This evaluation takes into consideration the value of the vessels, the value of the goods they are carrying and the value of the people on board (for insurance purposes).

1.1.1. — *Maritime transport.* The economic value of maritime transport was evaluated by calculating the sum of the values of the goods being shipped, that of the fleet and that of travel in navigable zones. These values were then encoded and represented on 43 base maps divided into 132 subregions.

Fleet value: takes into consideration the value of vessels, the number of which was estimated on the basis of Canadian Coast Guard data. The value of goods being shipped was established using Statistics Canada data to establish (in tonnes) the volume of goods on board and in transit. Cargo value was calculated on the basis of the average price per tonne for various categories of goods being shipped. The value of vessel traffic in the study takes two factors into consideration: the vessels' average number of days at sea and the number of crew members on board. Canadian Coast Guard statistics were used to estimate the number of vessels in each of the zones in which maritime traffic is monitored. The number of crew members was deduced on the basis of maritime transportation statistics, which give the average number of crew members per vessel as eight.

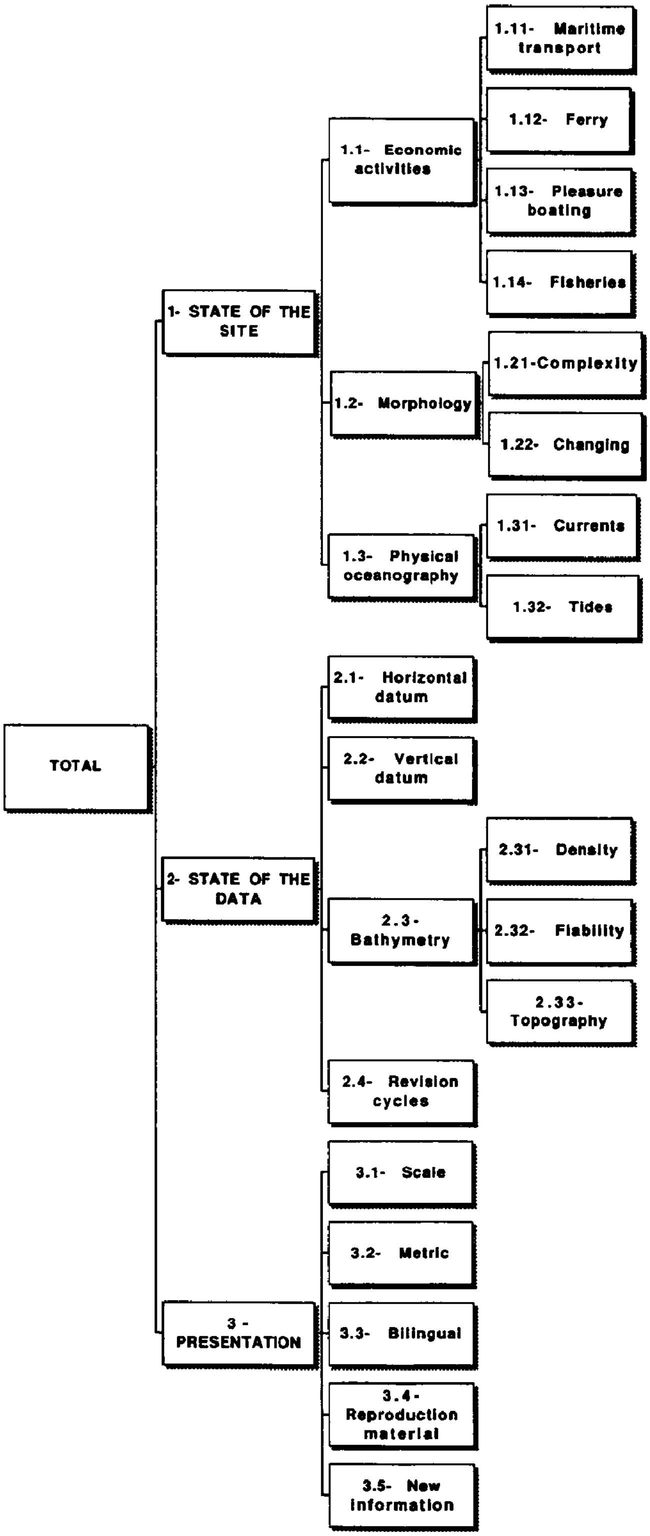

FIG. 2.— Proposed Model.

1.1.2. — *Ferries.* The economic evaluation of the value of ferry activities takes into consideration the value of the ferry fleet, the value of traffic and that of the operations. The Fleet value of certain vessels was determined by the Quebec Department of Transportation; for the others, a value was established using an investment ratio based on the capacity and size of the vessels. Traffic includes the transportation of vehicles and passengers, and travel by crew members. The value of the activity generated by the ferries was taken to be the sum of the operating costs before the amortization of the vessels.

1.1.3 — *Pleasure boating.* The pleasure activities included in the study were pleasure boating, sport fishing and marine mammal observation activities. Fishery and commercial activities, as well as ferry activities, all of which are covered in other categories, were excluded.

The 1983 Canadian Coast Guard census was used to determine the total number of boats, their value and the average number of passengers during outings for each of the communities.

1.1.4 — *Fisheries.* Commercial fishery activities were estimated on the basis of landings, the value of the plants, the value added to the fish by the plants, inshore and midshore fleets, traffic, the value of service infrastructures, the value of aquaculture facilities, the value of fishing banks and the value of the corridors linking the banks to ports of landing.

1.2 — Morphology. This secondary layer takes two factors into consideration: the complexity of the bottom profile and changes due to the movement of sediment. The portfolio of nautical charts was used to evaluate these variables.

1.2.1 — *Complexity.* In order to assess the complexity of the bottom, depth (a limiting factor for navigational safety) was considered first in order to separate the sectors which are less than 30 m deep from the deeper sectors. The deep sectors were assigned a low rating which was independent of the bottom profile. However, for sectors less than 30 m deep, the bottom profile was taken into consideration. In a shallow area, a flat bottom is less dangerous than an uneven bottom; therefore, the latter would be given a higher rating.

1.2.2 — *Changes.* In terms of the dynamics of the bottom profile, a sandy bottom would be assigned a high rating under the model, while a rocky bottom would receive a low rating.

1.3 — Physical oceanography. This secondary layer consists of two physical variables, namely currents and tides.

1.3.1 — *Currents.* This variable was assessed by consulting data found on up-to-date nautical charts. Sectors with currents exceeding 4 knots were assigned a high rating, sectors with currents between 2 and 3 knots were assigned a medium rating, and those with currents measuring less than 2 knots were assigned a low rating. Once analysed, this criterion remains stable as long as there are no major changes to the coastline.

1.3.2 — *Tides.* Tides had to be considered because tidal zones are more dangerous to navigate than sectors with no tides. Tide tables were used to divide the territory according to tidal amplitude. In the model, sectors in which the tidal amplitude can reach 6 m were given a high rating, a zone with average tides reaching a height of approximately 2 m was given a medium rating, while a zone with low small tides reaching a height of approximately 1 m was assigned a low rating.

2. State of the data

The evaluation of the state of the data is one of the most important factors, because bathymetric surveys have not, over the years, been carried out according to the same methods or using the same instruments. Every factor affecting the reliability of the data must be taken into consideration.

2.1 — Horizontal datum. The hydrographic data must be linked to a horizontal reference system in order to confirm them in a reliable manner. The co-ordinate system must be known in order to be able to transfer the positions of all of the bathymetric data gathered using the same reference system. The possibility of linking the data to a known horizontal reference was used as a parameter when analysing this variable.

2.2 — Vertical datum. Bathymetric data are gathered from vessels equipped with various types of acquisition systems.

The collection of data during surveys must be done in relation to a known vertical reference system. During processing, the data are reduced to one common reference level which is the chart datum. The sectors in which it is impossible to relate the data gathered to the chart datum, owing to lack of information on the plan or lack of control in the field during collection, are assigned a higher rating than the others.

2.3 — Bathymetry

2.3.1 — *Density.* Survey density is a very important factor, however, until now most of the data gathered provided only a profile of the bottom rather than complete coverage. In order to evaluate this variable, the scale of the survey was considered, since the distance between sounding lines is directly related to it. Sectors for which the scale was larger than 1:5,000, that is, where the distance between the sounding lines was 25 m or less, were assigned a low rating under the model (this would also be the case for a total coverage survey). Sectors in which the survey scale was smaller than 1:5,000 were assigned higher ratings since the sounding lines were further apart and the probability of a shoal being located between two sounding lines was greater.

2.3.2 — *Reliability.* The reliability criterion takes into consideration the types of positioning systems and the method of depth sounding used during data collection. Since these factors have changed as the technology evolved over the years, the year in which the survey was carried out was used to evaluate this criterion. Pre-1945 surveys using rudimentary systems such as sextants and plumb lines were assigned a high rating, while surveys done between 1945 and 1970, primarily using echo sounders, were assigned a medium rating, and recent surveys using electronic systems were given a low rating.

2.3.3. — *Topography.* The topographic coverage criterion was evaluated on the basis of the availability of topographic documents. These are considered adequate for charting, particularly when they are available at scales of at least 1:20,000. If this is the case, they are assigned a low rating. If sector charts are available only at 1:50,000, a medium rating is assigned; if no information is available for the sector or the scale is smaller than 1:50,000, a high rating is assigned.

2.3.4 — *Revision cycle.* Between comprehensive hydrographic surveys, it is necessary to update the information at varying intervals in order to keep nautical charts up-to-date. In frequently travelled sectors such as the marked channel of the St. Lawrence, port facilities are more affected by changes than those in outlying sectors which are not as frequently travelled (North Shore). The evaluation of this variable takes into consideration the number of years that have passed since the last revision survey for each geographical sector. In order to be more realistic in the assignment of ratings for this criterion, the territory was divided into three distinct regions representing the sectors which change significantly and require biennial revision cycles (commercial channels, approaches to ports), sectors which change moderately and require revisions every five years (around channels, less important ports) and sectors with low traffic (Fig. 3).

3. Presentation.

The presentation phase is the phase during which hydrographic and cartographic data are actually used. The planning of hydrographic surveys is therefore closely related to the updating of cartographic coverage. The following variables are considered under the model to assess the quality of cartographic coverage: the scale of the charts; the presentation in metric and/or bilingual format; the quality of the reproduction material and the number of new documents available affecting the updating of charts.

3.1 — Scale. This sub-layer is used to evaluate whether the current scale of Canadian Hydrographic Service charts is adequate for navigational purposes. The sectors for which no chart is available are assigned a high rating, as are those for which existing coverage of the charts is inadequate for safe access to anchorage and moorage. Sectors for which the scale of the charts is acceptable or require only a minor improvement are assigned an average rating. Sectors for which the cartographic coverage is adequate for navigational purposes (adequate coverage is defined as a small or medium scale for outlying sectors and a large scale for access to ports) were assigned a low rating.

3.2 — Metric system. This layer is evaluated simply on the basis of the delimitation of the current charts in the portfolio. If the charts were metric a low rating was assigned; if they were not, a high rating was assigned.

3.3 — Bilingualism. Several years ago, the Canadian Hydrographic Service set itself the goal of updating its portfolio of nautical charts to reflect Canadian standards on bilingualism. When the portfolio of nautical charts was reviewed, charts that were already bilingual where given a low rating and those that were available only in English were given a high rating.

3.4 — Reproduction material. It is necessary to analyse this variable in order to determine the amount of work needed to touch up the negatives used to print new editions. When a new edition of a chart is printed, changes are made to the plates without completely redrawing them. Comprehensive surveys for the

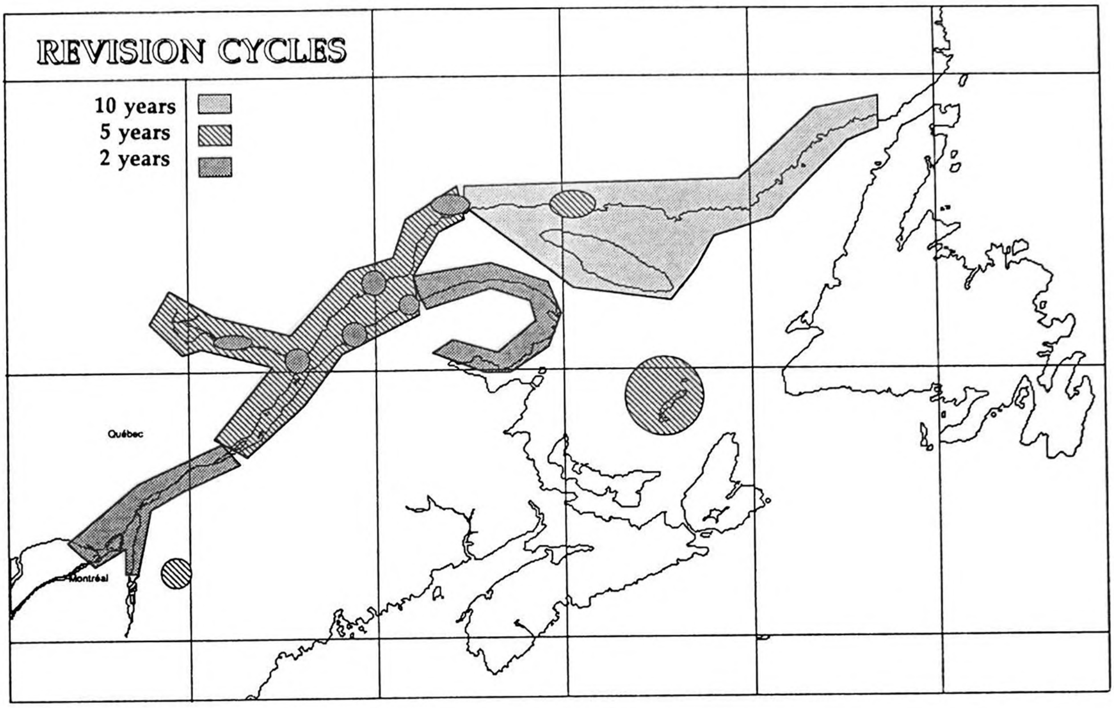

FIG. 3.— Revision Cycles.

production of new charts are carried out only about every forty years. In between, changes are distributed to mariners in the form of new editions or reprints. The reproduction process eventually causes the negatives to deteriorate; after several editions, the negatives must be extensively repaired before they can be re-used. Since the material used to reproduce new editions and reprints deteriorates over time, charts which have had more than two new editions since they were first printed were assigned a high rating, charts which have had one or two new editions were assigned a medium rating and new charts were assigned a low rating.

3.5 — New information. This criterion refers to the dynamic nature of nautical charts. It is very important because it deals with a factor which is very dangerous for mariners, namely change. The area covered by a nautical chart continues to change after the chart has been put on the market. Each week, Notices to Mariners are published in order to enable mariners to amend their charts to indicate hazards identified since the date of purchase. These may result from new survey schemes, the construction of new port facilities or the repositioning of a navigational aid. Other information which is less dangerous in terms of navigation is retained by the CHS for inclusion in new editions of nautical charts. All of this information is recorded using a point system according to which the importance of new data affecting each of the charts in the portfolio is assessed. The results are used to evaluate this variable of the model.

7. AUTOMATION

In order to be able to use the model as effectively as possible, it was decided to integrate it into the Apple-Macintosh environment in order to have access to an infinite number of possibilities such as updating/manipulating various scenarios and unlimited graphic outputing in various formats.

An electronic spreadsheet software (Wingz) was chosen in order to make it possible to integrate the zone into spreadsheets, with the cells of the electronic spreadsheet to the cells of the model (1 km^2) and the various layers to spreadsheets dynamically linked by means of the software. The calculation capabilities of linked spreadsheets enable us to do calculations integrating the data for one zone over several or all layers, or calculations of mosaics in order to cover several zones when analysing results. The ability to assign colours to the values of the spreadsheet cells makes it possible to directly chart the results using the electronic spreadsheet software (Fig. 4).

The hardware used is an Apple-Macintosh FX (8 MB of RAM) with a 19" colour monitor and a Hewlett-Packard PaintJet printer for colour printouts.

8. INTEGRATION AND WEIGHTING OF THE LAYERS

The main reason for using an electronic spreadsheet system to support the priority model is to be able to do calculations to integrate the various layers in order to being out extremes and nuances which make it possible to graphically interpret these results on a geographic basis.

These integration calculations are done by digitally combining the values of each cell in each zone with the values of the corresponding cells in the various layers of the same zone. This integration is carried out by means of calculations integrating all the layers while at the same time making it possible to weight the layers in relation to each other.

The purpose of each of the layers described above is to evaluate the variables affecting navigational safety. It is important to note that their relative importance varies from the point of view of navigational safety. The structure of the model takes this fact into consideration and makes it possible to assign a different weight to each of the variables in the primary, secondary and tertiary layers.

The weights can be determined fairly easily by the system operator, with a view to performing various calculations to simulate conditions, calibrate the model or interpret the results.

In order to weight each of the variables, it is important for the planner to test the model in a restricted sector where the interaction of the various variables is well known. The result obtained during these tests can then be applied to the whole of the territory covered by the model. Once the model is properly

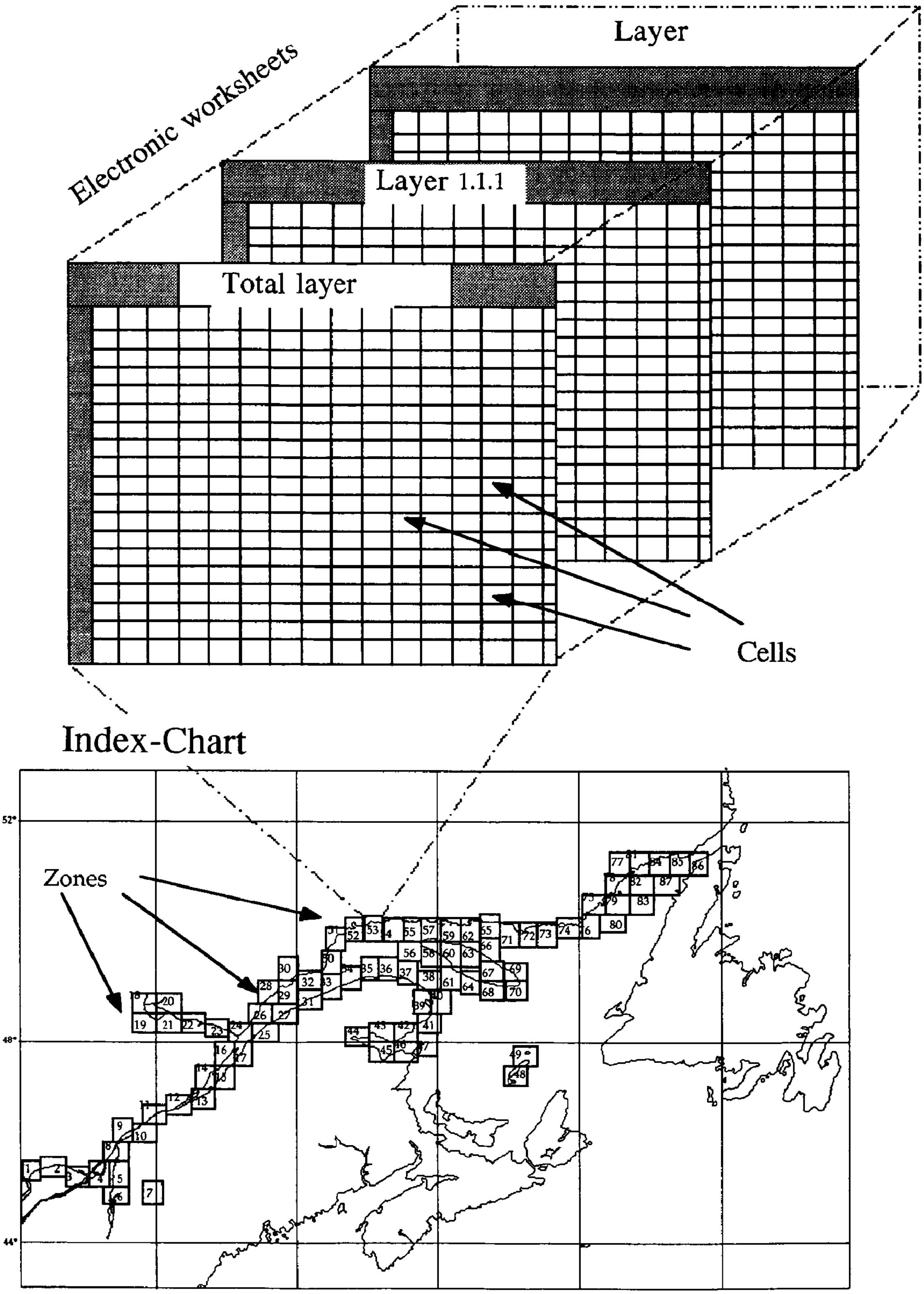

FIG. 4.— Electronic Spreadsheet.

calibrated, it should not be necessary to change these weights.

Tests were carried out in order to determine what weight to assign to each of the model's 19 variables. In the first test, identical weights were assigned within each category of variables. In the second test, some variables were weighted intuitively to reflect knowledge of these variables. After several tests, optimal weights were identified.

The weighted values used are:

1 — STATE OF THE SITE: 34%
Economic activities: 34% (commercial: 50, ferries: 20, pleasure boating: 20, fisheries: 10)
Morphology: 33% (complexity: 50, changes: 50)
Physical oceanography: 33% (currents: 50, tides: 50)

2 — STATE OF THE DATA: 33%
Horizontal datum: 10%
Vertical datum: 15%
Bathymetry: 50% (density: 20, reliability: 70, topography: 10)
Revision cycle: 25%

3 — PRESENTATION: 33%
Scale: 10%
Metric: 10%
Bilingual: 10%
Reproduction material: 35%
New information: 35%

The system also allows new layers to be added to the model. If new variables were found to have an effect on the planning of hydrographic projects (for example, an environmental variable or parameters identified by clients during public consultations), it would be possible to add a new layer to the model.

The results of the calculations are combined in a new spreadsheet (known as the results spreadsheet) which can describe overall results (all the layers), primary results (secondary layers by primary level: 3 results) or secondary results (all the tertiary layers by secondary level: 4 results).

Hence, the relevant cells of the results spreadsheet have a calculated value which is colour-coded so that it can be graphically represented to facilitate interpretation of the reuslts.

9. DATA

1.1 — Collection and entry. Data collection was a major task. The data pertaining to the economic criteria were evaluated and encoded right away by the authors of the economic study. They prepared base maps which were then digitized into various electronic spreadsheets. The collection of information pertaining to the state of the data and their graphic presentation was carried out by the Canadian Hydrographic Service based on the consultation of reference indexes, the portfolio of nautical charts and the system for evaluating changes to nautical charts.

Tools such as command macros and menus were developed in order to facilitate these operations by simplifying the work of the data-entry operators as much as possible. The volume of data could become quite significant and could, in the case of the Quebec region of the Canadian Hydrographic Service for example, represent hundreds of spreadsheets and an equal number of zones, each containing 19 interrelated spreadsheets, thereby resulting in a total of approximately 2,000 different electronic spreadsheets. This requires the standardization of the worksheet names as well as a sound archiving structure.

1.2 — Validation. Tools were developed to facilitate the validation of the digitized data into the spreadsheets. Hard copy printouts identical to the data collection sheets can be generated by the system in order to allow the operator to carry out a visual verification by superimposing the two documents.

1.3 — Updating. Of course, this planning tool can be reliable only if it is regularly updated to reflect changes in the various variables in the secondary and tertiary layers. As far as the economic variables are concerned, a study should be carried out every five to ten years in order to update or completely replace the values in the model. Cycle of this kind makes it possible to reflect changes in maritime activities, namely growth or decline.

Some variables, such as currents, tides and the complexity of the sea-floor, are not subject to rapid changes. Therefore, it is not necessary to change the model over the years for these three variables.

On the other hand, variables dealing with the state and presentation of the data must, ideally, be updated at least once a year. An updating plan should be put into place so that changes affecting these variables can be collected during the years and entered into the system before the planning exercises for hydrographic projects.

Tools have also been developed to facilitate the updating operations using several basic commands.

10. RESULTS

The priority model is an instrument which can accurately reflect reality to the extent that the raw data were carefully collected and digitized into electronic worksheets, and that quality was controlled during these operations. Users of the model must realize that the model is a planning tool and not a magical decision-making recipe. The tool itself is a means of verifying the interaction of a great number of variables, a task which would not easily be accomplished using manual evaluation methods. It has become an aid for planners by supporting their decisions with systematic analyses. Use of this tool will enable them to more effectively prioritize their work to take into account limited resources and contentious choices, while at the same time ensuring that all of the known physical and economic parameters have been considered.

11. AN ACTUAL CASE

The Montreal sector was chosen to illustrate the results that this model can produce. It was chosen because the graphic representation is easy to interpret. The Island of Montreal is bordered on the south by the St. Lawrence River and the Seaway; Jésus Island is bordered on the south by the Rivière des Prairies and on the north by the Rivière des Mille Iles.

A comparison of the results of the model with the manual analyses taken from various databases reveals that the weighting applied to the model accurately reflects reality. A detailed analysis of the three primary layers makes it possible to identify the preponderant variables in each of the layers.

By analysing the **state of the site** layer, it is possible to clearly determine that commercial navigation activities take place there since the commercial channel is easily identifiable. Pleasure activities are also very important in the Lac Saint-Louis sector. Verification with the base data reveals that the weight assigned to the model seems to accurately describe reality.

The results of the compilation of the **state of the data** layer highlight the Rivière des Mille Iles sector. This is explained by the fact that there is no bathymetric data available for this region. A maritime sector for which there is a lack of data will be given priority so that corrective action can be taken. The Rivière des Prairies is not highlighted, because recent surveys are available for that sector. It should be noted that that sector of the St. Lawrence, with the exception of the rapids, received a fairly high rating.

The model also provides quite an accurate representation of reality for the **presentation** layer. In fact, the Rivière des Prairies and the Rivière des Mille Iles sectors were given fairly high ratings because these sectors had not yet been charted at the time of data entry. These zones must, therefore, be given a higher priority than the sector of the St. Lawrence River for which charts already exist.

By performing the calculations for the three principal layers described above (Fig. 5), it is possible to draw the following conclusions for the Montreal sector from the automated model: the importance of maritime activities (commercial navigation in the channel and pleasure boating on Lac Saint-Louis) stand out in the overall results, especially in the Lac Saint-Louis sector. The Rivière des Mille Iles is also identified as a priority zone owing to the fact that there are no navigational data or charts available for this region. Sectors containing the Rivière des Prairies sector and the St. Lawrence downstream from Montreal and outside the channel have been assigned a fairly high rating, but have less priority than the above-mentioned sectors.

Based on the analysis of the results of the model for the Montreal sector, it can be concluded that comprehensive surveys should first be carried out in the Lac Saint-Louis sector. Moreover, the Port of Montreal sector, which includes the commercial channel, should be redone, as should the Rivière des Mille Iles.

Reviewed within the real life context of planning, the prioritization resulting form this model might be slightly different. For example, the decision to carry out

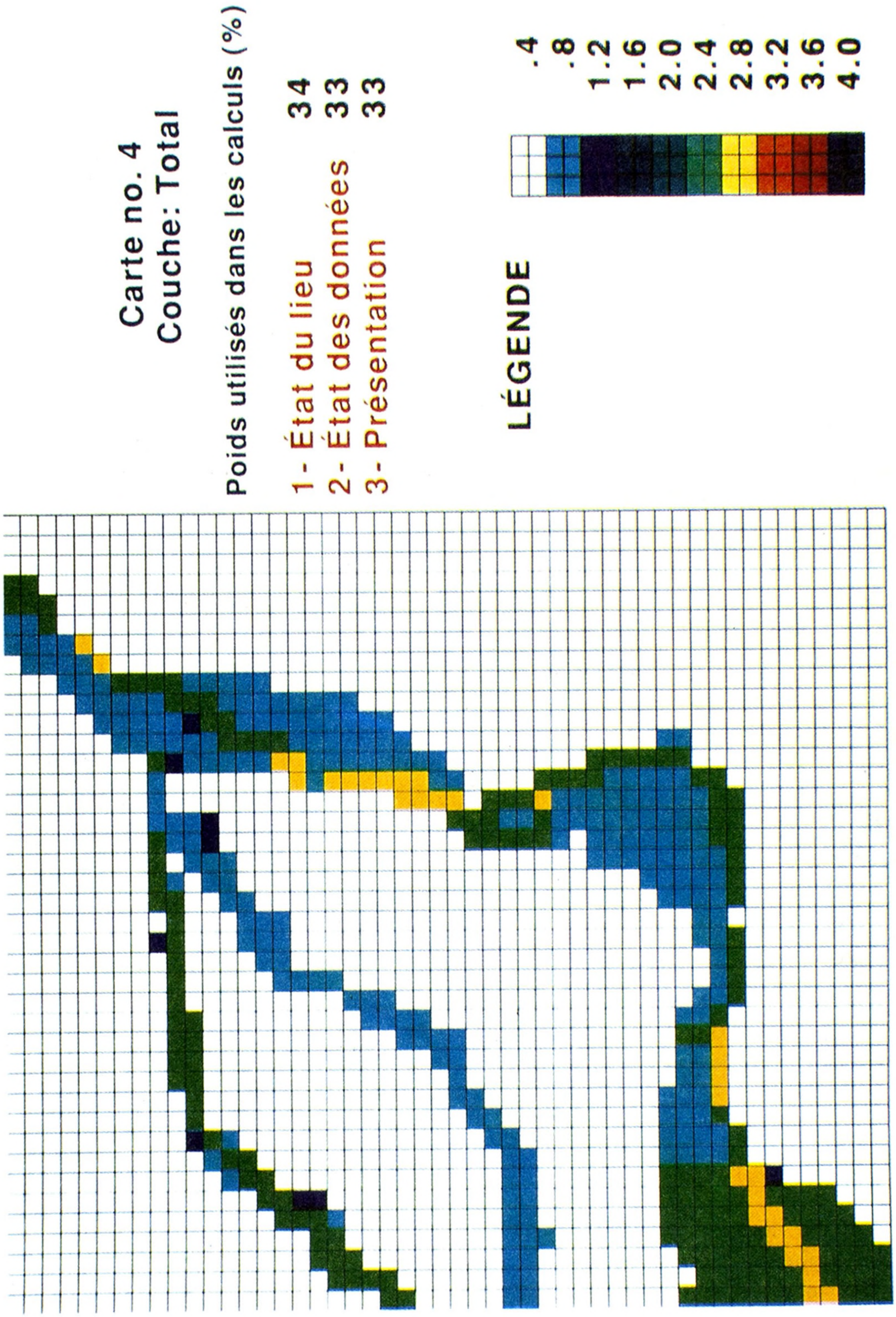

FIG. 5.— The Montreal Sector.

surveys for the Rivière des Mille Iles could be questioned, because the model highlighted this region at the level of the **state of the data** layer because no data or charts were available for this section. This does not in any way signify that this expanse of water should be given priority or even charted. The river is partially navigable by vessels with small drafts. This consideration should play a part in the final planning decision. The purpose of the automated model is to support and confirm planners' decisions, not replace them. It is, therefore, important to be able to put the findings of the model back into a real geopolitical context. It becomes necessary to consider the various parameters present in the system to aid in prioritizing and decision-making, as illustrated in the following diagram (Fig. 6).

12. MOSAICS OF THE TERRITORY

This automated system also makes it possible to construct mosaics which can be used to analyse the entire territory, thereby making it possible to compare zones or regions.

In this way, the overall view of the Montreal/Quebec sector makes it possible to identify which areas should be a priority in terms of surveying or charting (Fig. 7).

By carrying out a detailed analysis of the mosaics of the three primary layers (state of the site, state of the data and presentation) we noted that, in the state of the site layer, the economic activities were differentiated from each other, and even clearly indicated the areas of the channel in which they were the most important. The same was true of morphological factors such as currents and tides.

The analysis of the state of the data mosaic very clearly identified the sectors for which no survey existed. The sectors for which recent surveys were available were also identified.

When the mosaic of the presentation layer was analysed, the status of the nautical charts provided very interesting results. For example, the sectors for which recent surveys are available, but new charts are not, were clearly indicated. The boundaries of the charts are well marked and it is easy to determine the relative age of the charts on the basis of colour. The comprehensive mosaic of the three layers places the interaction of the variables back into an overall perspective.

On the comprehensive mosaic, the state of the site layer is identifiable in that the commercial channel is indicated along the St. Lawrence. The Rivière des Mille Iles sector is indicated because it has never been surveyed and no current chart exists for this sector. This is the combined result of two of the primary layers, namely the state of the data and presentation. The Lac Saint-Louis and Sorel regions are indicated as priorities on the map because the integration of the three layers indicates that the relevance of the variables affecting navigation is higher than elsewhere.

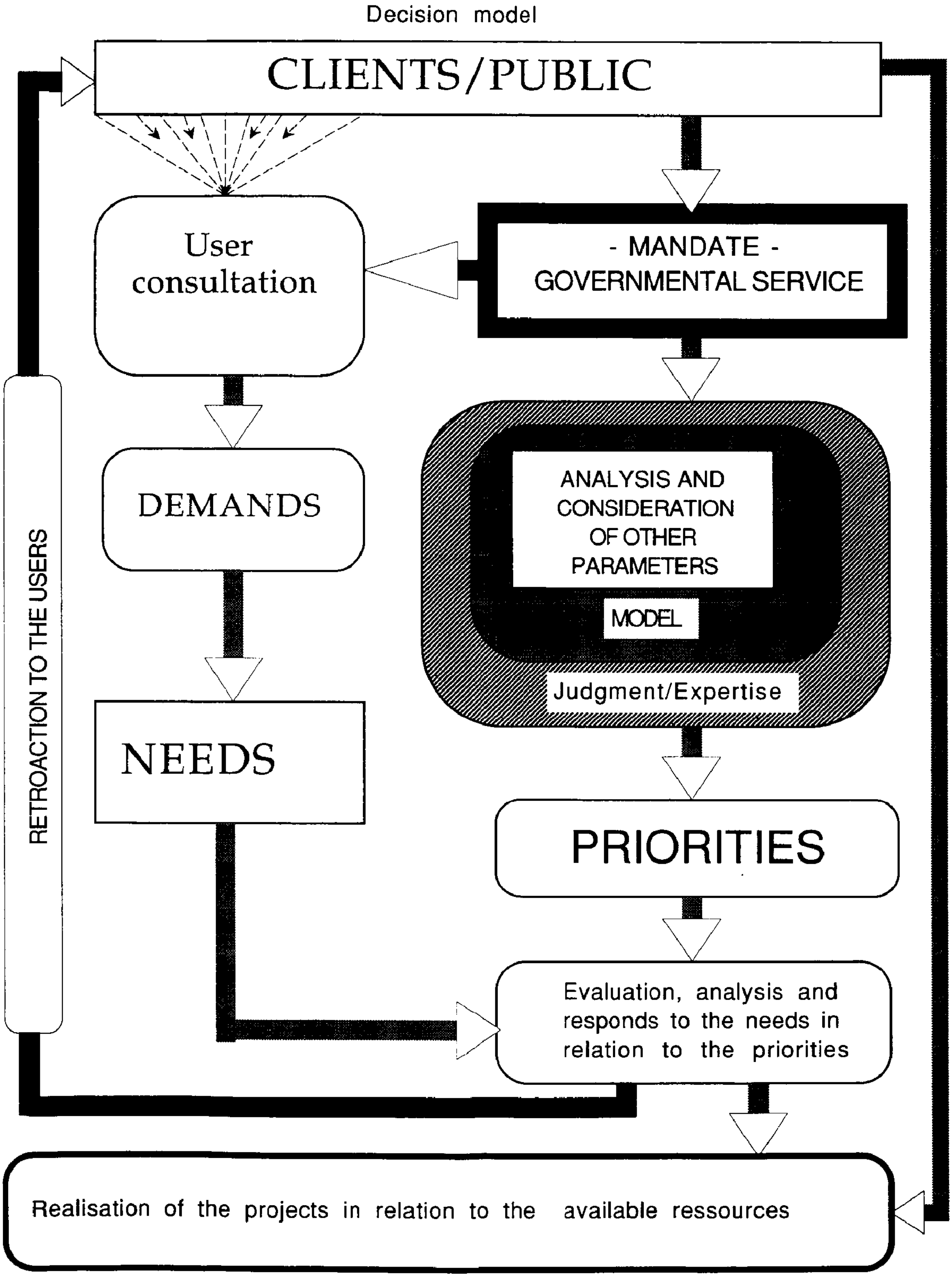

FIG. 6.— Decision Model.

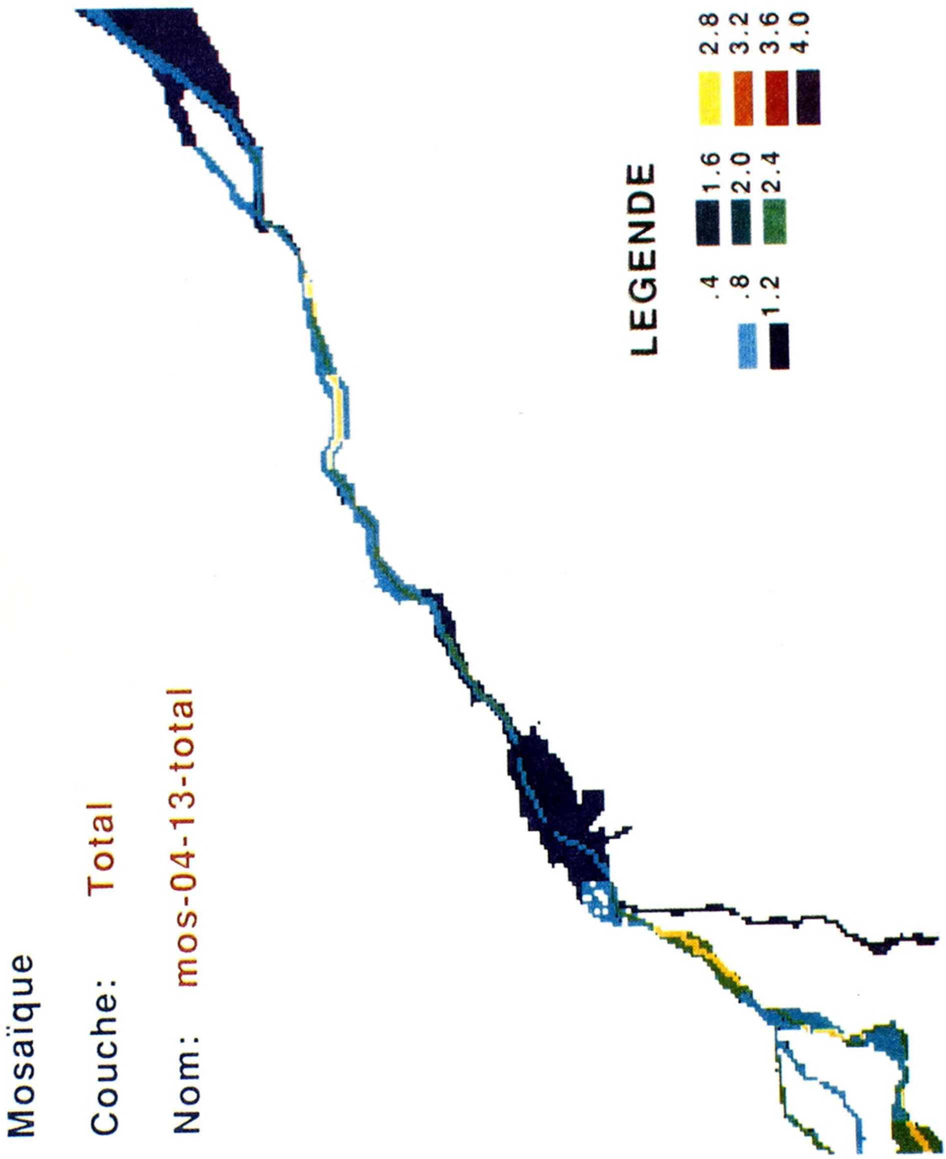

FIG. 7.— Mosaics of the Territory.

13. CONCLUSION

The analysis of the results for an actual case clearly indicates the validity of the model and automated system developed to apply it. The weighting realistically highlights the variables in question and the overall results seem quite promising for this planning tool.

The use of an automated tool interrelating several important variables allows planners to systematically take into consideration all of the factors which determine the priority of hydrographic projects. The overall analyses which can be carried out from this model make this tool significantly more useful than conventional planning methods.

The priority model is an indispensable aid; however, judgement must be used so that the model supports planners' decisions rather than replaces them.

In terms of consultation and improved service to the client, the evaluation of needs is one of the most important stages of the planning process. During this process, the needs identified are assessed in relation to the priorities of the model. It is very important to ensure that hydrographic activities consider all the variables that affect them, on the basis of their relative importance. Once properly calibrated, the priority model will enable planners to make better choices in order to meet various user needs.