

A COMPILER'S OBSERVATION CONCERNING THE IMPLEMENTATION OF IDPF

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ABSTRACT:

Technological advances generally lead to new applications which improve existing methodologies. The National Ocean Service, Coast and Geodetic Survey (C&GS), Photogrammetry Branch is now facing the challenge of implementing a fully electronic system to extract the data on aerial photographs for digital map compilation. Known as the Integrated Digital Photogrammetric Facility (IDPF) this system will revolutionize photogrammetry as practiced at C&GS. This paper will present, from a photogrammetric cartographer's point of view, observations on the implementation of IDPF.

KEY WORDS: Analytical, Photogrammetry, Mapping, Integrated System.

1. INTRODUCTION

Applying new technologies may not be as difficult or challenging as developing new software and hardware, but learning and using new ways of doing things does offer its own special class of little challenges. The Coast and Geodetic Survey (C&GS), Photogrammetry Branch (PB) is now in the process of implementing a fully electronic system to extract data from aerial photographs for digital map compilation. The center piece of this effort is the Integrated Digital Photogrammetric Facility (IDPF). IDPF is a C&GS developed photogrammetric software package which controls analytic stereoviewers and utilizes data base technologies for analytic aerotriangulation and digital map compilation (Snyder, 1991). The "integrated" structure is more than a description of the software and hardware configuration. It is also being reflected in the way PB goes about its business of compiling maps photogrammetrically, affecting the compilation process and the bureaucratic structure of the branch.

2. HISTORICAL REVIEW

The basic process by which PB produced maps from aerial photographs was officially codified in the 1949 version of the Topographic Manual Part II (Part I was never published). The Manual contains "...the requirements and detailed procedures for all photogrammetric operations..." (Swanson, 1949). Attempts were made to maintain the currency of the procedures outlined in the Manual through the issuance of formal updates known as Photogrammetric Instructions and less formally through a series of office memorandums. As can be easily imagined, the effort to maintain the documentation became more and more convoluted with advances in technology. The Topographic Manual is being replaced by a new document known as the Coastal Mapping Program Operations Manual. Although the Topographic Manual and its amendments is being superseded, PB is just now gaining the baseline of experience needed to establish new criteria for digitally generated products.

As outlined in the Topographic Manual, the map compilation process in the PB was a rigid and linear process. The Bureaucratic structure of the Branch was a mirror of the work flow (Planning Unit, Field Unit etc. Fig 1). Work on a particular project moved in one direction. Each unit performed their specific tasks required to complete their phase of the work. Once a unit had determined its phase of the operation complete, the project was passed down the line. The compilation phase was responsible for tying together all loose ends. The linear work flow system created a separateness among the various units, especially between aerotriangulation and compilation.

Aerotriangulation to support compilation on analog instruments is a multistage task at a variety of instruments and locations. Before instrument work begins, project photographs are inspected for proper overlap (endlap and sidelap for photos taken in parallel strips). Control points, which have been marked by targets on the ground, are identified and marked on contact prints.

Locations for the placement of pass points along strips of photographs and tie points between strips are also selected. This is an important step. Except for the first and last photographs of a strip, image points should be measured on three photographs. Given 1:50,000 scale photographs typically acquired at C&GS, and certain areas being mapped (rugged Alaskan shoreline) good images for transfer between photos are not always readily identifiable. The difficulty of clearing parallax in areas of steep slopes, forest of tall trees, featureless tundra etc., results in an inability to precisely measure images in every photograph.

The quality of an analytical aerotriangulation adjustment is, to a large extent, a function of how well the same image can be identified on different photographs. In the PB, a stereo point transfer device (the Wild PUG) was used to unambiguously mark points (pass points and tie points) in the common area of overlapping photographs by drilling a small hole in the emulsion of film diapositives. The correct use of the point transfer device required: patience to properly clear parallax; constant mechanical adjustment to insure that the drill hole was concentric with the floating mark; and neatness so that the marks drilled were not obliterated by dust or dirt. For strips of photographs, the mark was made on the middle photograph of three so that the mark would fall on two adjoining stereomodels. For photographs from parallel strips, a mark would be made on both photographs. Typically, five or six models would be marked in a day.

Once all photographs had been "PUG'ed", the aerotriangulation process continued with photo-coordinate measurement on a stereocomparator (the Wild STK). All stereomodels created during the point transfer process would have to be reestablished on the stereocomparator; all image positions measured. The stages of the stereocomparator were "powered" by manually turning hand cranks. Attempting to work too quickly could cause both mental and physical fatigue. Unique identifiers, entered by hand, were assigned to each of the image points as they were measured. Four or five models could be expected to be measured in a day.

Processing of the measured data proceeded strip by strip to edit the data and look for blunders, such as the same identifier assigned to two different points. Finally, a simultaneous block adjustment of all photographs resulted in the computation of camera station parameters and X,Y,Z positions for all measured points. The horizontal positions determined in the aerotriangulation process were plotted on a stable base mylar map sheet (known as a T-sheet). A particular mapping project was usually subdivided into a number of T-sheets with a geographical coverage of 10 minutes by 10 minutes. The scale of the map sheet and its coverage were initially determined in the planning stage. Factors considered in the scale of a T-sheet were the mapping objectives, physical nature of the area to be mapped, the scale of the source photographs, and the mechanical limitations of the equipment used to draw the map (flatbed plotters,

analog stereoplotters). Compilation would receive from aerotriangulation the marked photographs and the corresponding T-sheets with the plotted positions of the control points determined in the aerotriangulation process. Models were then set by analog methods on a stereoplotter. Each model was absolutely oriented to the T-sheet by matching the mark on the photograph (the PUG hole) to its corresponding position plotted on the T-sheet.

3. OBSERVATIONS ON THE USE OF IDPF

With the implementation of IDPF, a system based on automated analytical methods (vs analog methods), the manner in which PB operates has changed radically. Although conceptually IDPF is hardware independent, from a practical point of view its use is tied to the analytical machines it controls and the computers in which it resides. In implementing IDPF, the photogrammetric cartographer of the PB faces two new challenges. First, changing the mental conception as to the work process. Second, becoming physically attuned to the hardware employed by IDPF. In the past, these two items were very much inter-related. The mental processes and steps conceived to solve a photogrammetric mapping problem were a function of the equipment to be used. Similarly, using IDPF will alter the approach PB uses to compile maps from aerial photographs. Following are some observations concerning the implementation of IDPF at PB.

3.1 Efficiency The nature of the PUG / STK system was such that it was difficult to correct for faulty measurements with the STK, or poor point marking with the PUG. As a consequence, a redundant number of points would be marked and measured on photographs to allow questionable points to be withheld from the block adjustment without degrading the geometry of the solution. This essentially doubled the amount of work necessary for aerotriangulation. With IDPF, point transfer and measurement are a single operation. When an image is to be transferred to a new stereomodel, IDPF pre-positions the measuring mark to the approximate location of the image on the new photograph. The time saving in aerotriangulation mensuration has been tremendous. For example, before the introduction of IDPF, a two strip block of 12 photographs (6 in each strip) could be expected to take 5 days in the mensuration process. Two days to mark image points, 3 days to measure with the stereocomparator. With IDPF, the mensuration of that same block would be completed in a single day!

The vertical adjustments in an analytical system are more critical than in an analog system. On an analytical plotter, the operator must use the vertical solution determined by the aerotriangulation adjustment. PB personnel have noted through the years that people perceive the floating mark differently. Thus, while one person will perceive the dot to be "on the ground", another person will perceive it to be slightly floating, while still another will see it as slightly "buried". In the IDPF system it is not possible to "tweak" the solution to fit one's personal preference as can be done with an analog machine.

3.2 Compilation Although T-sheets were drawn to the same standards, when maps are drawn by hand it is possible to detect individual drafting styles. This artistic expression, though limited, was a source of pride to cartographers of the PB who knew that their work would become part of the historical record of the United States and stored in the National Archives. When a graphic map is the final expression of the data compiled, editing and corrections can be achieved with an eraser and a pen. When cartographic information is stored in a digital data base, what may seem to be small changes can become quite complex requiring assistance from experts in computer files and data base structures.

In IDPF, the expression of digital data is limited to cartographic codes contained in the software.

Thus, due to present software constraints, IDPF will not plot a simple dotted line (.....). The dotted line would be used to represent the low water line on a T-sheet. Within IDPF the low water line would be distinguished by an attribute in a digital file, not by a graphic symbol.

When compiling with an analog instrument onto a mylar base map, the selection of detail to be compiled is related to the scale of the map. One guide used in the PB for the selection of detail to be compiled was the "rule of thumb". Area features, such as lakes and ponds, which could be covered by one's thumb on the manuscript would not be compiled (this guide did not apply to features which were critical or required to be mapped). With the mylar sheet replaced by a graphic CRT which can display mapped data at a variety of scales, the cartographer must pay close attention that the selection of detail remains appropriate for the project being compiled and consistent throughout the mapping project.

Compiling data using IDPF has not yet demonstrated any time advantage over the analog system. In fact, the time spent on the instrument in the collection of data has increased. The primary cause for delay is the tagging of data with the correct cartographic codes. Compilation must stop every time a new feature is encountered so that the previous feature may be written to the data base and the new feature tagged with the correct cartographic code. However, the time saved by IDPF in the elimination of hand drafting more than compensates for the increased instrument compilation time.

3.3 Superimposition Superimposition is a feature of the IDPF system which inserts compiled graphic data back into the optical train of the analytical plotter so that the graphic data appears "superimposed" on the models. This is a tremendous aid in editing and reviewing compiled data since it is possible to see what has and has not been compiled by looking at the stereomodel. As a consequence, compilation can be reviewed "on line". Previously, compilation would be evaluated by comparing the manuscript to photographs enlarged to the approximate scale of the manuscript.

3.4 Accuracy Standards Standards of accuracies for mapped data are expressed by how well a point can be plotted or scaled from a map. Statistical programs which are part of the IDPF system (Elassal, 1991) allow an analysis of the digital data at a level far greater than can be determined from a graphic product. The introduction of IDPF is opening a discussion within the PB as to how accuracies for digitally generated products should be expressed.

3.5 Data security When working with a computer network data base system, the possibility exists for someone gaining access, inadvertently or otherwise, to a project data base and altering the data therein (the digital equivalent of spilling coffee on a manuscript). The PB has appointed a data base manager who is responsible for the security of digital data. Restricting access to the data through a data base manager is a good idea. However, cartographers must maintain close coordination with the data base manager to insure access to their own projects.

3.6 Hardware Work on IDPF comes to a halt during thunderstorms and periods of high winds, which cause electrical disruptions that could seriously damage the computer hardware. IDPF hardware requires a controlled temperature environment. Most operators find that the optimal temperature for the equipment to be uncomfortably cool. Sweaters are worn and hands are cold even in the middle of summer. The hum of cooling fans from all the various pieces of equipment creates a constant level of noise which is annoying when compared to the relative quiet of compiling with an analog instrument.

4. PRACTICAL EXAMPLE

Recently, PB completed a prototype mapping project of the New Buffalo, Michigan area. This

project was a rigorous test of the integrated approach to mapping that is now possible in the PB. The New Buffalo area is being studied by a consortium of academic, Federal and Local government groups concerned with flooding and erosion in sensitive areas of the Great Lakes. PB will provide baseline surveys in these areas which will be used to monitor change through the years. As part of this effort, PB will provide topographic data (the compilation of contours) as well as planigraphic data (horizontal positions). Experience gained with the New Buffalo prototype map will be used to evaluate and refine methods and procedures for digital mapping in the PB (FIG's 2 & 3).

Photographs of the New Buffalo area were of excellent quality and were being used to train personnel in aerotriangulation with IDPF. Personnel in charge of training were well experienced in the art of aerotriangulation as practiced before the introduction of IDPF. Normally, strips would be measured in line with tie points between strips measured every three or four models. For planimetric mapping this system was entirely satisfactory. However, an analysis of the aerotriangulation statistics for the New Buffalo project found that the vertical accuracies necessary for 1 meter contours from 1:10,000 scale photographs would not be met (the vertical root mean square [RMS] for all points measured as computed through error propagation was 0.45 meters). Since the residual errors of the image point measurements were very low, there was no reason to suspect a problem with the film or operator error. When set on the analytical plotter models were clear of any visible parallax, but models from different strips showed marked differences in elevation of common features. The solution to this problem was not difficult to perceive, and with IDPF not difficult to execute. Models between strips needed to be more "tightly" tied together.

Under the old system of aerotriangulation used in the PB the task would have been much more difficult and labor intensive. Photos from adjacent strips would have to be reset on the PUG, parallax cleared and images marked in both photographs. Image points which had previously been marked on a photograph could not be transferred to a new photograph because the marking process destroyed the image to be transferred. Once all new tie points had been established their photo coordinates would then be measured on the STK.

In a digital photogrammetric system such as IDPF the task is much simpler. With analytical plotters it is possible to measure images from parallel strips. Image points are not physically marked on the photographs, but are stored as coordinates based on a reference system defined by the fiducial marks on the photographs. Increasing the tie point between the strips of the New Buffalo photographs was simply a matter of registering the photographs from adjacent strips onto the analytical plotter, recalling the image from one photograph (a pass point) and stereoscopically measuring that image on the adjacent photograph (creating a new tie point).

The net result of this process to increase the ties of the New Buffalo photographs was an improvement in the RMS by a factor of 2 (0.22 meters). It cannot be emphasized enough what a daunting task the above procedure would have been before the introduction of the IDPF system. It is interesting to note that the improved adjustment was not the result of identifying new image points, but rather taking image points already identified and measuring them in more combinations. Clearly, most persons familiar with aerotriangulation block adjustments would know that this would be the case. However, given the emphasis on planimetric mapping in the PB and with the PUG being the weak link in the aerotriangulation process (Tewinkel, 1968), the procedure of tieing only every third to fourth model of parallel strips became the standard PB practice. Additionally, by using a B-8 stereoplotter, each stereomodel would be leveled to vertical control independently, i.e.

aerotriangulation would provide horizontal control for models; vertical control for models would be provided from an independent source, such as a field survey or a USGS topographic map, not from elevations determined in the aerotriangulation adjustment.

Collecting features with an analytical plotter is very similar to using an analog plotter. Objects to be mapped are identified in the stereo model and traced with the reference mark. However, the data collected is written to a digital file, displayed on a graphic CRT, and superimposed back into the model. Notes which would have been written by hand on a manuscript, are now a sequence of numbers, called cartographic codes, which associate attributes to the feature being mapped. In compiling the New Buffalo map, the cartographer had to be certain to monitor the cartographic codes lest the wrong attribute be assigned to the feature being compiled. Since the symbolic display of data is more limited with the IDPF system (i.e. the same symbols represent different features), these attributes are critical for interpreting mapped data.

The superimposition of data collected is an indispensable feature of the IDPF system. The collection of contours for the New Buffalo map would have been impossible to keep track of without superimposition.

5. CONCLUDING REMARKS

Using IDPF replaces much of the physical dexterity in using analog equipment with learning new skills such as key board manipulation. Servo motors replace the hand powered cranks of the STK. No more reaching with two hands to maneuver two diapositives on the stages of the PUG to create a stereo image to mark a pass or tie point. After marking a point, attempting to move both photos in unison to another location, tediously clearing parallax and marking again.

The hardware and software configuration of IDPF permits aerotriangulation and compilation at one location, known as a Photogrammetric Work Station. When aerotriangulation was a separate function at PB, personnel executing adjustments did not view the models based on their adjustments. Cartographers in compilation had no involvement in the aerotriangulation process. IDPF creates not only an integrated work station but is also leading to an integrated work force. The formerly separate Aerotriangulation and Compilation Units have been combined into one Photogrammetric Unit. With IDPF, once an adjustment has been completed, the photogrammetric cartographer can quickly set models on the analytical plotter to check the quality of the aerotriangulated adjustment. If necessary new points can be easily added to the adjustment by switching back to the comparator mode.

To more effectively exploit the capabilities of the IDPF system, PB personnel should not confine themselves to thinking and executing aerotriangulation using methods and procedures designed to minimize the shortcomings of a semianalytic analog system, but rather, take advantage of the digital environment which allows a wide latitude of possibilities for data manipulation.

The impact of IDPF on map compilation is just now being explored. IDPF has heightened the photogrammetric skills and broadened the photogrammetric horizons of PB personnel, drawing them out of the niches to which they were confined in the old routine and allowing them to see the big picture while simultaneously providing access to minute details of the raw data through a digital data base system.

The sense of loss in the artistic aspect of creating a map by hand will have to be replaced by the more abstract creative process of digital data manipulation.

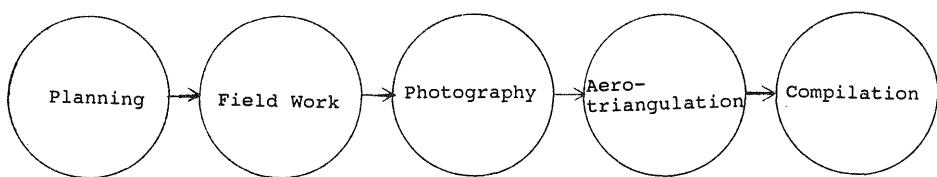


Figure 1

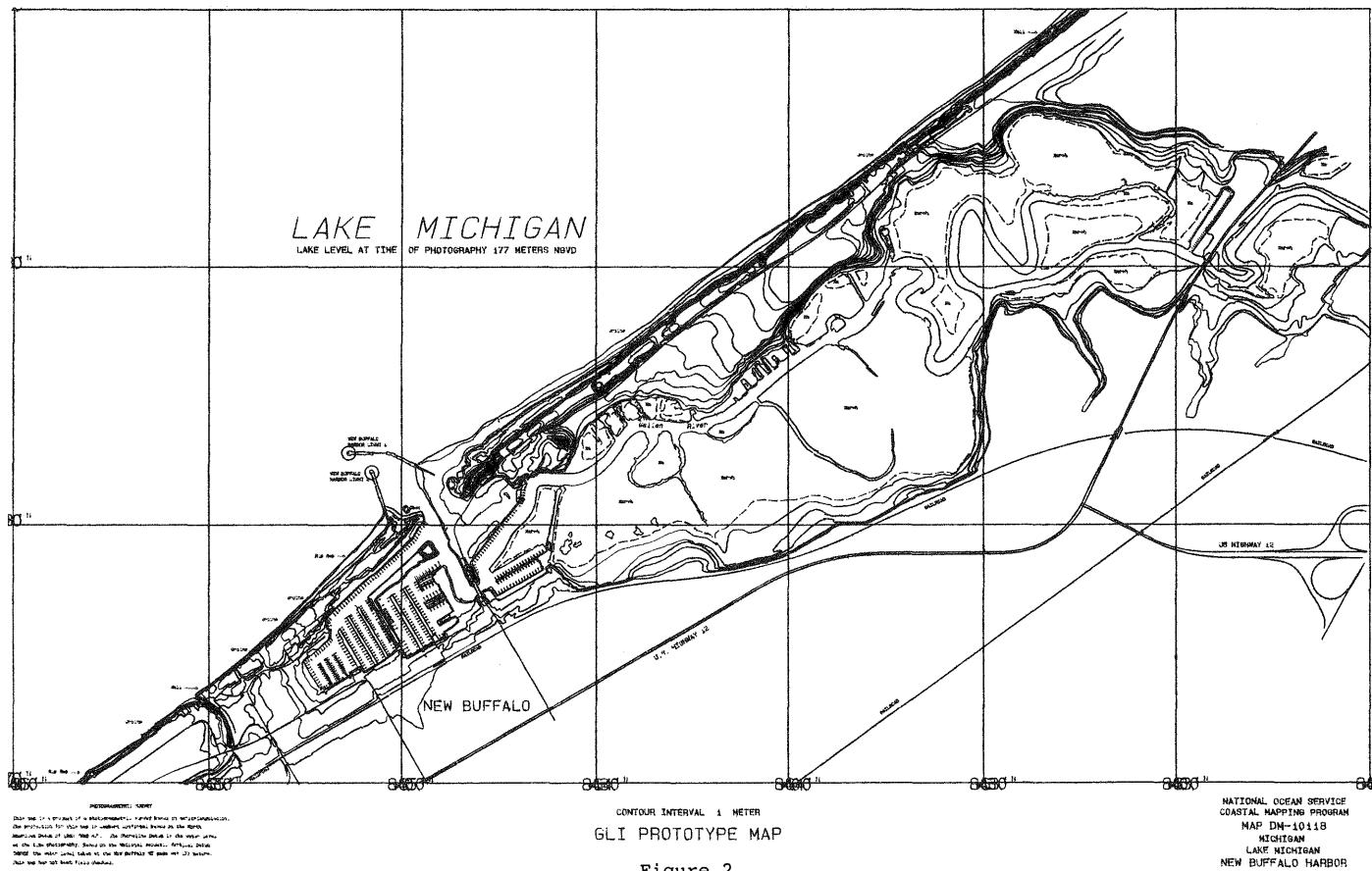


Figure 2

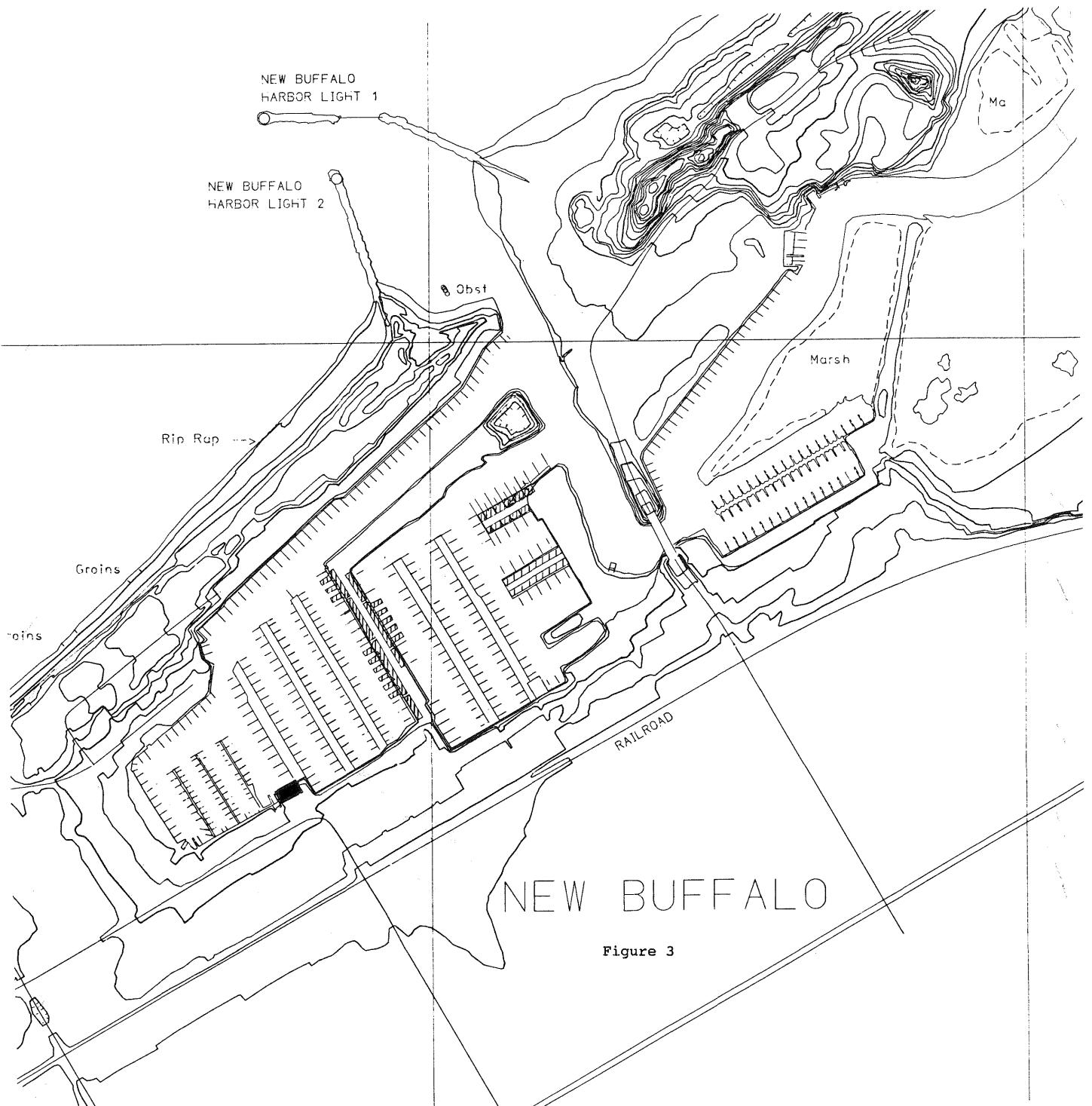


Figure 3

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