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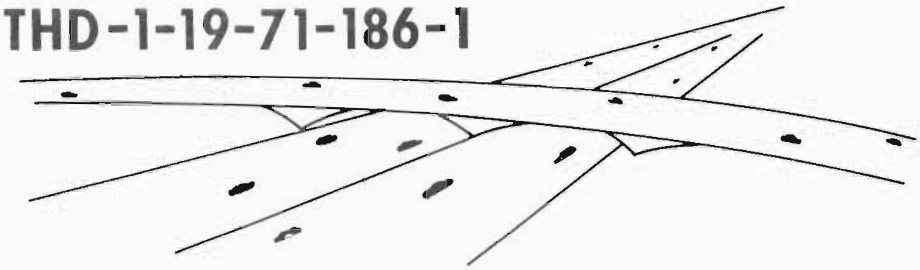

DEPARTMENTAL RESEARCH

Report Number: **186 - 1**

IMPLEMENTATION OF NUMERICAL GROUND IMAGE SYSTEM

TEXAS HIGHWAY DEPARTMENT

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16. Abstract

This report recommends a method of implementing a numerical ground image system which will augment and interface with the Roadway Design System (RDS) developed in a previous research effort by the Texas Highway Department in cooperation with the Federal Highway Administration. Proprietary software packages, a previously developed research system and the scan profile system developed by the Department were evaluated to obtain quantitative and qualitative comparisons.

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IMPLEMENTATION OF NUMERICAL GROUND IMAGE SYSTEM

INTERIM REPORT

by

Larry G. Walker

Research Report 186-1
Implementation of Numerical Ground Image System

Research Study 1-19-71-186

Conducted by
Division of Automation
Texas Highway Department
In cooperation with the
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May 1973

The opinions, findings, and conclusions expressed in this publication are those of the author and not necessarily those of the Federal Highway Administration.

ABSTRACT

This report recommends a method of implementing a numerical ground image system which will augment and interface with the Roadway Design System (RDS) developed in a previous research effort by the Texas Highway Department in co-operation with the Federal Highway Administration. Proprietary software packages, a previously developed research system and the scan profile system developed by the Department were evaluated to obtain quantitative and qualitative comparisons.

Key Words: numerical ground image, Roadway Design, digital terrain model, surface model, contour plot

SUMMARY

The interface of a numerical ground image system (NGI) with the Roadway Design System (RDS) for purposes of automated terrain evaluation is the objective of this study. The original objective was to implement either the NGI System produced on a previous Texas Highway Department sponsored research project or one of the available proprietary packages. During the course of the study, the scan profile system for terrain representation was developed as an alternative solution to the problem.

Benchmark tests were made on two proprietary systems and the scan profile system. For these tests, the ability of the system to produce contour plots was considered adequate to obtain quantitative and qualitative measures of their effectiveness. (The system produced by the research project mentioned above was not tested since it did not have contour plotting capabilities.) The sample terrain selected was contoured by manual methods for comparison with the contours produced by the computer packages. The terrain sample was chosen to test the adequacy of the terrain model and in particular the ability to handle slope discontinuity.

The candidate systems were then compared on the basis of the following factors which are considered to be most important to the success of the numerical ground image implementation: adequacy of the model, handling of discontinuities, data operator skill level, requirement for adjustment of grid and other parameters, availability to other user agencies, compatability with RDS, estimated effort required to complete and test the implementation, and processing efficiency. On the basis of this evaluation and the bench mark tests, it was concluded that the scan profile approach is the most feasible system for the proposed implementation.

IMPLEMENTATION

The overall objective of this study was directed toward the implementation of new procedures either from prior research or from other sources. During the course of the study significant new approaches to the problem were conceived and developed. These new technology approaches are recommended for full implementation in this report. This new methodology is expected to simplify the proposed implementation, result in new simplified data acquisition procedures and possibly generate the requirement for data acquisition equipment modifications to augment the new approaches. The final results of this study will be a complete implementation of new methodology to augment previous research efforts.

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IMPLEMENTATION OF NUMERICAL GROUND IMAGE SYSTEM

INTERIM REPORT

Numerical ground image systems for storing and retrieving terrain data offer advantages in many applications of highway and route location design for which conventional cross-section methods are inadequate. The overall objective of this study is the implementation of a numerical ground image system which will augment and interface with the Roadway Design System (RDS). The latter system was developed in a previous research effort by the Texas Highway Department in cooperation with the Federal Highway Administration.

This implementation was to be approached by first evaluating several available NGI systems and implementation of the most feasible system. The original proposal envisioned evaluation and possible implementation of an experimental numerical ground image system produced by an earlier Texas Highway Department sponsored HPR project. This is referred to as Maxwell's NGI System. The possibility that implementation of this system might not prove feasible was envisioned and the scope of this study also provided for the evaluation of commercially available systems which might be implemented. During the course of the study a new simplified approach to the numerical ground image storage and retrieval was developed by the study staff. This interim report summarizes the evaluations of all of these systems, including the new approach conceived during the study, and gives recommendation for the implementation.

Objectives of the Study

The following paragraphs show the objectives for this study as stated in the original proposal.

> The overall objective proposed for this study is the implementation of a flexible numerical terrain storage retrieval system and the interfacing of

this facility with the TIES Road Design System (now RDS) and its extensions into route location investigation. The desired system must be flexible enough to efficiently store and retrieve numerical terrain data in such a manner that ground elevations at any point are readily available for numerous applications such as point elevations, cross-sections, volume determinations, and three-dimensional presentation. Specific objectives are as follows:

1. Study the NGI System produced under Research Project No. 120.
2. Study the available commercial offerings.
3. Prepare an interim report recommending the implementation of either the previously developed NGI system or one of the commercially available systems.
4. Adapt and install the selected system for use by applications.
5. Develop and demonstrate program modules which will create terrain cross-sections from the numerical ground model along alignments stored in the TIES Road Design System.

Evaluation of Maxwell's NGI System

The extent of the numerical ground image system developed by Maxwell is stated[1] to have been limited by time and resource constraints which limited the extent to which the system could be tested in an operating engineering design environment. Research reports resulting from Maxwell's study indicate that considerable time was devoted to a systems analysis approach to the problem of developing an NGI system, to studies of previously developed systems and to discussions of systems design techniques. The study did develop a system for storing random XYZ data in an NGI master data file. Data is stored by sectors which can be passed through core in a "roller towel" procedure. This makes it possible to retrieve the sector of data that includes any point in question. A sector represents a geographic area. When the proper sector of data is in core the elevation of any given XY point within the sector may be computed.

Storage of data is accomplished by the NGI data subsystem interfaced with a data edit program. Computation of elevations is accomplished by the NGI elevation subsystem which is designed to interface with application programs. The system also includes an NGI test subsystem which provides a means of testing the completeness of the NGI master file data by means of predicting the quality of results produced by the NGI elevation subsystem. The system uses an algorithm for computing elevations based on a cluster of surrounding data points. The system does not develop a global mathematical model in the sense of a set of equations which represent the surface, but the surface is represented through the capability for computing the elevation at any point from the cluster of data points surrounding the data point. For these reasons the density and distribution of data points affects the surface elevations that can be computed and makes the system sensitive to these factors. The test subsystem was developed to study the validity of the model and accuracy of elevations and to eliminate extrapolation type errors. The system requires input data on the total number of sectors, total number of terrain points, and project identification codes. Sector boundaries and orientation are also required.

Considerable evaluation was made in the study of the coordinate system for terrain data points, the grouping system for terrain data points, the type of numerical surface, the type of surface fitting technique, the extent of surface fit and the mode of surface data storage. Maxwell concluded that his optimal system would consist of terrain data grouping by sector stored in a local data coordinate system for each sector. The local coordinate system is related to the real world coordinate system of the project by appropriate translation rotation and scale constants, and data point coordinates are stored in lieu of any type of surface coefficients. The type of surface selected was parabolic, and conventional least squares surface fitting techniques were used to compute surface elevations based on the cluster of nine data points. The roving surface technique is used to select the cluster of nine data points closest to the desired horizontal point. These optimal feature selections were made by a conventional systems analysis approach and evaluated on the basis of accuracy, through-put, data density requirements, weighting and cluster size.

Maxwell recommends further study of the type of surface and acknowledges that the polynomial surface may not be the most general approximation of terrain surfaces. He also recommends additional study of the surface fitting and the clustering techniques and recognizes the need for quantitizing terrain roughness so that the required data density for a specified level of accuracy could be predetermined and eliminate problems of data sensitivity. He also recognized the need for clustering techniques that would better represent the terrain surrounding the unknown point and the need for recognizing and handling any slope discontinuities in the data.

Though admittedly limited in scope, Maxwell's system design was thorough and the resulting modular NGI System represents a sound approach. This system could be adopted for implementation and interface with the RDS System. Such implementation would require extensive familiarization of the project staff with:

1. Data input formats
2. Data distribution and density requirements
3. Use of the test subsystem to evaluate the sensitivity of the system to data density and distribution.

It would also require the:

1. Determination of adequate methods for acquiring the necessary data
2. Development of interface routines in RDS for extracting the necessary surface for preliminary design or roadway design.
3. Extensive modification of the NGI System to incorporate facilities for handling terrain slope discontinuities
4. Extensive testing and proving of Maxwell's algorithms.

The modifications to incorporate facility for handling terrain slope discontinuities in Item 3 above are considered a must for any acceptable NGI System. This is particularly true if the system is to be used for more precise design activities such as interchange design.

Evaluation of Commercially Available NGI Systems

Literature describing a variety of software packages for creating numerical representations of XYZ data was evaluated by the study staff. These included both domestic and foreign proprietary packages and packages which have been developed by educational and governmental agencies. Maxwell gives a good summary of the various approaches that had been used for NGI systems at the time of his study.[1] Most of the commercially available systems apparently used an approach similar to Maxwell's cluster, roving surface, and polynomial surface equation techniques. In most cases it is apparent that these techniques have been greatly refined beyond Maxwell's work. For example, some systems divide a circle into a given number of sectors in an attempt to assure at least one data point in each sector. Others have facility for modifying the cluster area to take advantage of data distribution. Several approaches to weighing the influence of data points were noted and various surface equation approaches were used.

Some of the foreign systems purport to use somewhat different approaches and refer to such things as spline lines and terrain lines for handling discontinuities. It was found to be extremely difficult to obtain definitive information on these packages, however, and it was prohibitive to benchmark any of them. Most of the domestic proprietary packages were created for producing contours of surface data. Many of them evolved from early efforts at representing subsurface seismic data. They have been refined, however, to include sophisticated smoothing and contour plotting capabilities and adjustment techniques for adapting to the data distribution. Most of these systems rely on creating a surface model by computing the elevations of the nodes of a grid. This has the effect of smoothing out sharp slope discontinuities which may be desirable in the analysis of trends for some types of data. It is not at all desirable when representing terrain data which contains many natural sharp discontinuities of slope. Some of the packages have recognized this problem and handled it by allowing the data to include slope discontinuity boundaries. No extrapolation or inclusion of data points across boundaries is allowed. Junkins[2] reports a new method of representing surfaces with a family of locally valid mathematical functions which join together continuously. This approach allows the extraction of contour lines quite easily without smoothing. Junkins further reports a saving in computer time required to produce contours over other NGI systems.

Two commercial contour packages were studied in more detail and their capabilities for producing contours were compared in a benchmark test. One of these systems had a facility for producing roadway cross-sections and the other reported that this could be easily added. It was not considered feasible to attempt to interface them with the RDS System to test the cross-section ability. Comparison of computer time and storage requirements for producing contours was deemed to be adequate for comparing the packages. These benchmark tests and other evaluation considerations will be discussed in later sections.

Either of the two proprietary systems selected for benchmarking could be interfaced with RDS in accordance with the objectives of this study. The requirements for learning the internals of the system would be as great or greater than would be required in the case of Maxwell's System. This may be even more difficult and offer less flexibility because of the proprietary nature of the packages. The problem of adapting adequate data acquisition procedures and expertise in handling the sensitivity of the system to data distribution and density would probably be greater than for Maxwell's System and the interface with RDS would be at least as difficult. The adoption of a proprietary system for this purpose would limit its availability to other users.

Development of the "Scan Profile" NGI Approach

During the course of the study a number of considerations became apparent which prompted consideration of alternate approaches to either Maxwell's or the commercial NGI systems. Some of these factors are as follows:

1. It was determined that considerable effort would be required to modify, adapt and interface with the existing systems.
2. Any of the random XYZ schemes require considerable expertise on the part of the operator doing the data collection.
3. There is also an expertise required in determining proper grid size and sensitivity factors for data distribution.
4. There were problems in handling slope discontinuities and input of data to define these.
5. Preliminary investigation revealed some rather large requirements for core, auxiliary storage and computer processing time.

The "Scan Profile" process was conceived as an alternative specialized solution for interface with RDS. It is a combination data acquisition scheme and simplified approach to storage and retrieval of the terrain data required by RDS. It is particularly adapted to conventional automated data acquisition methods which will require only minor change in operator procedures and degree of expertise required. It provides a straightforward method for identifying and handling slope discontinuities. It is anticipated that the effort required to complete development of this approach for storing and retrieval of terrain data will be approximately equivalent to the effort required for adapting one of the other NGI approaches. Computer core and processing requirements are expected to be lower than those required for the NGI systems. Auxiliary storage will be dependent on the amount of data taken and should compare favorably with other systems.

These preliminary conclusions are based on a limited demonstration of the scan profile concept which was conducted in connection with the benchmarks of the other systems. The benchmarks will be discussed in a later section of this report. The scan line profile approach produces a faceted model of the ground surface. Each facet is bounded by either three or four data points. (Four point facets may represent a curved surface.) The faceted surface model contains all data points. For this reason any degree of accuracy desired can be obtained by taking more data. The faceted model is quite adequate for producing cross-sections for use by RDS. It has also been demonstrated to produce reasonable contours in a direct manner. Smoothing techniques would need to be employed, however, to produce contours aesthetically comparable to those produced by the commercial NGI systems.

Terrain data is captured in the form of parallel scan profiles. The profiles may be irregularly spaced and points along the profiles may be irregularly spaced. The roughness of the terrain determines the density and distribution of data points which in turn determine facet size. The facets in effect make up a quasi-orthogonal grid which varies in size locally to fit the terrain data.

The profiles are taken in an arbitrary coordinate system where the profile lines have a constant Y value. The arbitrary coordinate system may be along or parallel to a flight line or parallel to a given real world coordinate system bearing. The arbitrarily chosen coordinate system must be referenced to the coordinate system being used by RDS.

The scan profiles are analogous to a set of cross-sections along a straight baseline. This is illustrated in Figure 1, but the data includes a very significant set of additional information which identifies significant slope discontinuity boundaries. A close observation of the complete set of profiles in Figure 1 reveals (to the trained observer) an obvious V-bottom ditch which enters on the right side and proceeds diagonally across the surface area shown. The mental process used in arriving at this conclusion seems simple but actually it involves a complex intuitive thought process. To reach the same conclusion by computer logic from the raw data would be almost prohibitive. For this reason the scan profile approach depends upon the data operator to identify significant slope discontinuity boundaries. The outside edges of the profiles are automatic boundaries. The operator needs only to identify the other significant boundaries which in this case were the two edges of the V-bottom ditch. Note that all discontinuities are not identified, but the ones that are identified divide the surface into discreet areas as shown in Figure 2. Within these areas the system uses an algorithm to connect up the remaining points to achieve a transition from profile to profile as illustrated in Figure 3. The scan profile transition algorithm connects points on adjacent profiles on the basis of their relative position between their common discontinuity boundaries.

It follows that the operator needs only to establish enough discontinuity boundaries so that the transition algorithm from profile to profile in any given area will adequately determine the model. When digitizing data from a photogrammetric stereo model it is a simple matter to sketch in the desired discontinuity boundaries and then record the discontinuity points as specially noted data points in the profile. This assures that the faceted model as shown in Figure 4 will always reflect the slope discontinuities which have been identified.

The scan profile approach appears to offer a simplified alternative to conventional NGI methods and contour packages. It is particularly adaptable to generating cross-sections and profiles in any orientation. This approach is also quite compatible to the data acquisition for orthophoto mapping which may be a future consideration. Although this is simply a variation of a number of techniques, no

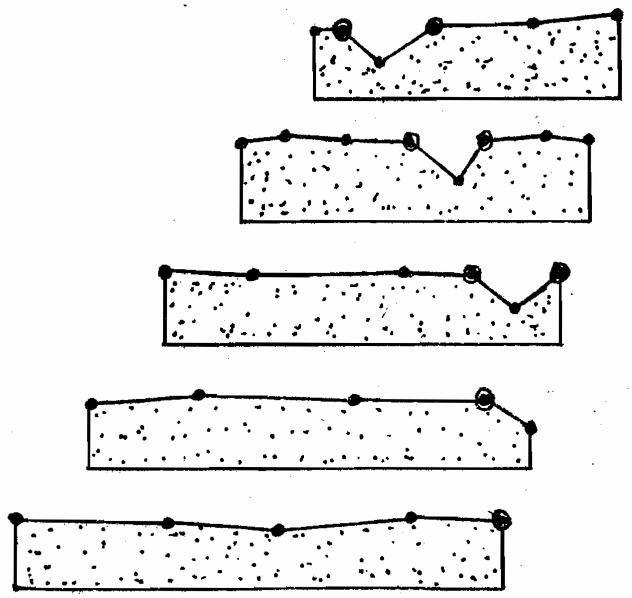


Figure 1. Scan Profiles with Discontinuity Points Noted.

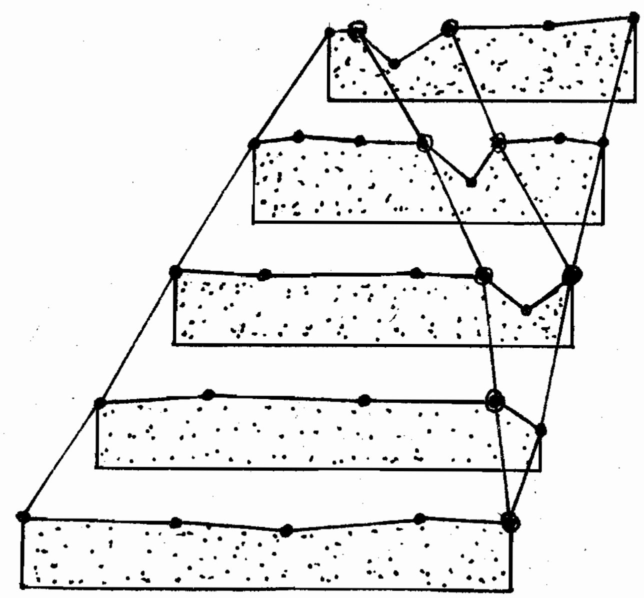


Figure 2. Scan Profiles with Discontinuity Points Connected.

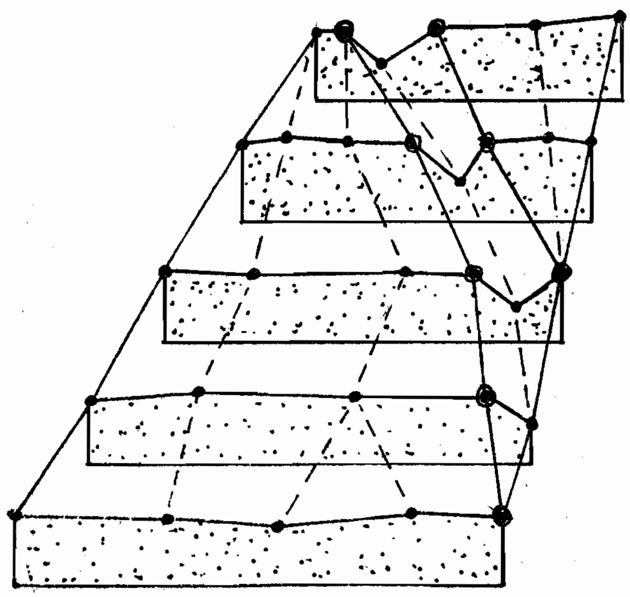


Figure 3. Scan Profile with All Points Connected.

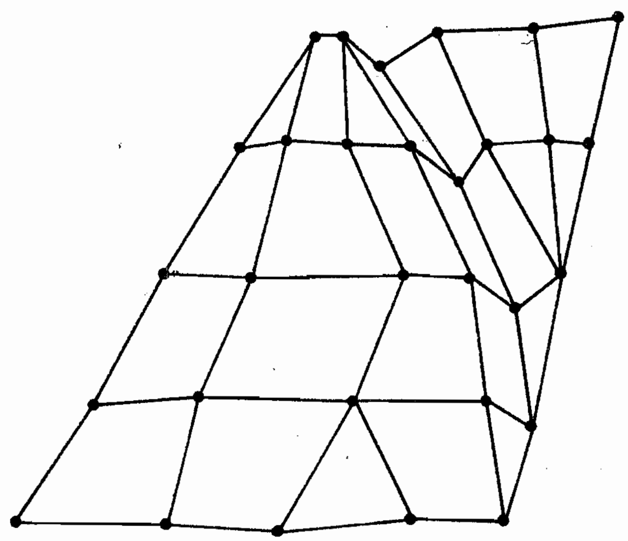


Figure 4. Faceted Surface Model

references to this particular approach were found in the literature studied. A system reported by the Swedish National Road Board[3] indicates similar approaches to data acquisition including slope discontinuity, but surface elevations are then computed in a manner similar to Maxwell's. The scan profile approach is particularly compatible with the RDS System in software and data acquisition techniques. It handles slope discontinuities in a straightforward manner and is not subject to sensitivity to data characteristics.

NGI System Benchmark Tests

Two of the commercially available NGI systems and the scan profile approach were subjected to a specially designed benchmark test. The proprietary systems are referred to as Systems A and B. The purpose of the test was to obtain quantitative and qualitative measures of the effectiveness of the system in handling real world terrain data which included typical slope discontinuities associated with terrain data. The test specifications are given in Table I. A test based on storing data and presenting it in contour fashion was selected because the two commercial systems could provide this without modification and this type of test was considered to be adequate to show the effectiveness of the systems.

The Maxwell NGI System was not included in this test because it did not have the facility for handling discontinuities nor did it have contour plotting capabilities. The effort required to achieve a benchmark test appeared to roughly be equivalent to the effort that would be required to totally implement Maxwell's System. On the other hand it was possible with a very limited effort to achieve a benchmark test using the scan profile approach. Existing RDS routines were modified to accomplish the storage and retrieval of scan profile data. Some indexing and translation steps were bypassed and, of course, this was not efficient use of data storage facilities. It did, however, provide an easy method of obtaining test results. A simple routine for deriving straight line or curved contours from three or four point data sets was available and was adapted for the graphic presentation of contours for the scan profile benchmark test.

Contours of a test area were prepared by manual takeoff from a photogrammetric model. These contours as shown in Figure 5 were used as a control for the test. They constitute an analog representation of the test terrain and naturally reflect some operator bias and manual smoothing. Scan profile data was then

TABLE I. SAMPLE CONTOUR PLOT DATA

Formats are given below for sample contour plot data consisting of approximately 300 cards. This data will generate a plot approximately 7-1/2" x 14-1/2" at a scale of 1"=40'. The desired contour interval is 1.0'. The data points are given as X, Y, Z coordinates and discontinuity lines are defined in terms of line segments with end points (X1, Y1) and (X2, Y2).

In addition to producing a contour plot from this data taking into consideration the discontinuity lines, the following information is desired:

+ Computer time to generate the plot - indicate configuration
+ Core and auxiliary storage requirements
+ Plot time - indicate equipment.

Card Formats

Card Type	Columns	Format	Definition
0	1 - 80	-	Card summarizes following data - read and discard
1	1 - 20	F20.5	Scale
	21 - 40	F20.5	Contour interval
	41 - 79	-	Blank
	80	I1	'1'
2	1 - 20	F20.5	X-coordinate of data point (feet)
	21 - 40	F20.5	Y-coordinate of data point (feet)
	41 - 60	F20.5	Z-coordinate of data point (feet)
	61 - 79	-	Blank
	80	I1	'2'
3	1 - 15	E15.8	X-coordinate of first end point of discontinuity line segment (X1) (feet)
	16 - 30	E15.8	Y-coordinate of first end point of discontinuity line segment (Y1) (feet)
	31 - 45	E15.8	X-coordinate of second end point of discontinuity line segment (X2) (feet)
	46 - 60	E15.8	Y-coordinate of second end point of discontinuity line segment (Y2) (feet)
	61 - 79	-	Blank
	80	I1	'3'

Figure 5. Control Contours Prepared Manually

digitized from the same photogrammetric model and used for each of the three benchmark tests. Examination of the scan profile data used reveals a need for a small amount of additional data to make it more compatible with the manual contours; however, this data is believed to be at least as representative of the terrain as random XYZ points would provide. Figure 6 shows the contours produced by the scan line profile approach superimposed over the control contours. This plot also shows the data points and selected discontinuity boundaries. It was not necessary to select any grid size parameters or data distribution parameters. The plot comparison with the manually prepared contours is good and could be improved by including a small amount of additional data. Smoothing techniques would greatly improve the appearance of this plot but this was not in the scope of the limited effort applied to demonstrating the concept.

Figure 7 shows the first plot produced by proprietary system A superimposed over the control contours. This plot gives a poor representation of the terrain surface. Figure 8 is a second trial using proprietary system A after adjusting parameters to account for the data distribution. This plot was also superimposed over the control contours. The adjustments were made by the vendor and it has been presumed that they involved grid size and an alternate cluster parameter to handle the data distribution produced by scan profile data acquisition methods. The vendor states that the latter adjustment could have been identified without a trial and error approach. He demonstrated routines for preliminary data analysis. This plot does give a good representation of the terrain surface and is aesthetically pleasing. It would be improved by additional data also.

Figure 9 shows the contours produced by proprietary system B superimposed over the control contours. This plot is aesthetically pleasing but is not a good representation of the terrain surface. It is possible that it could have been improved on a second trial as in the case of system A.

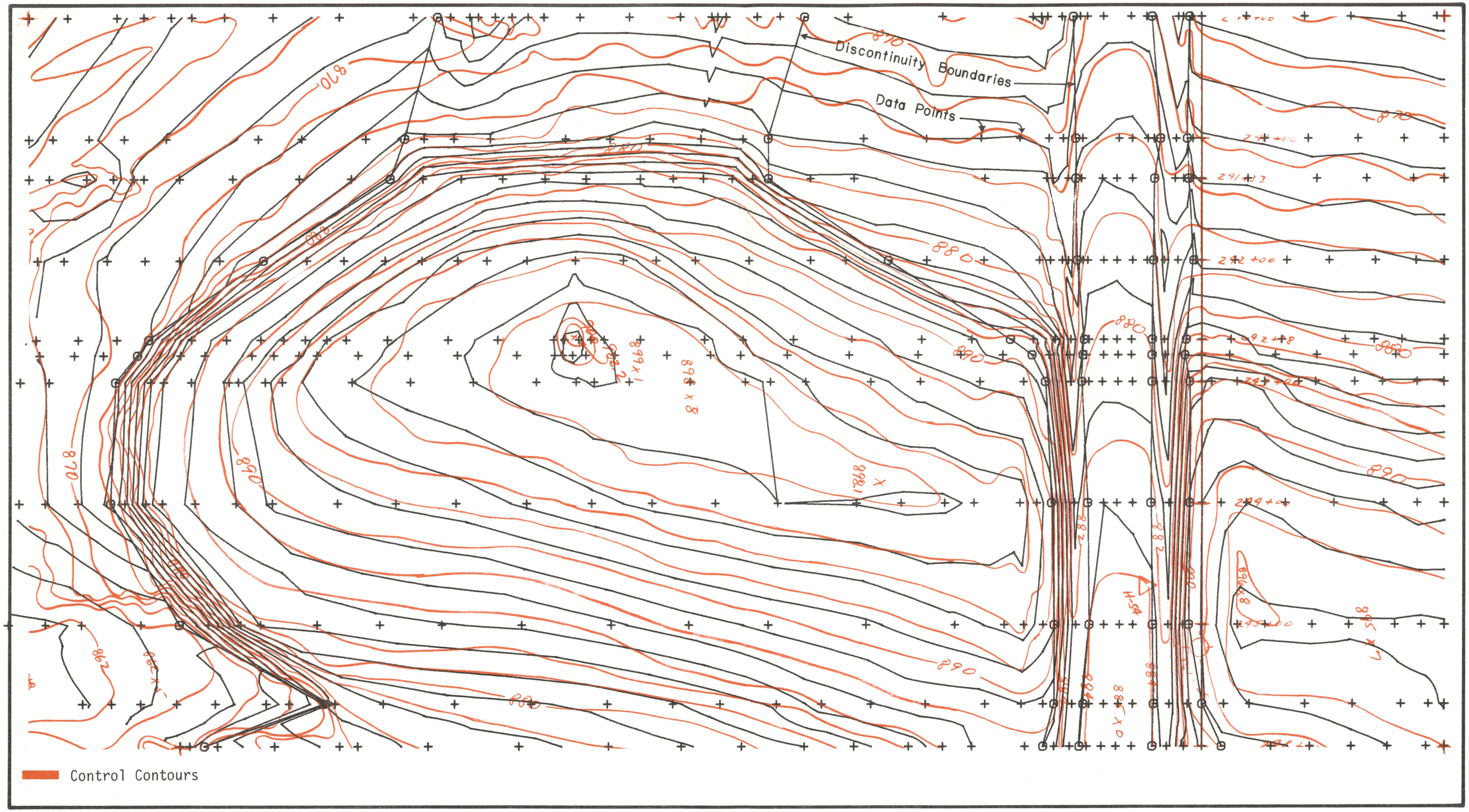


Figure 6. Scan Profile Contours Superimposed on Control

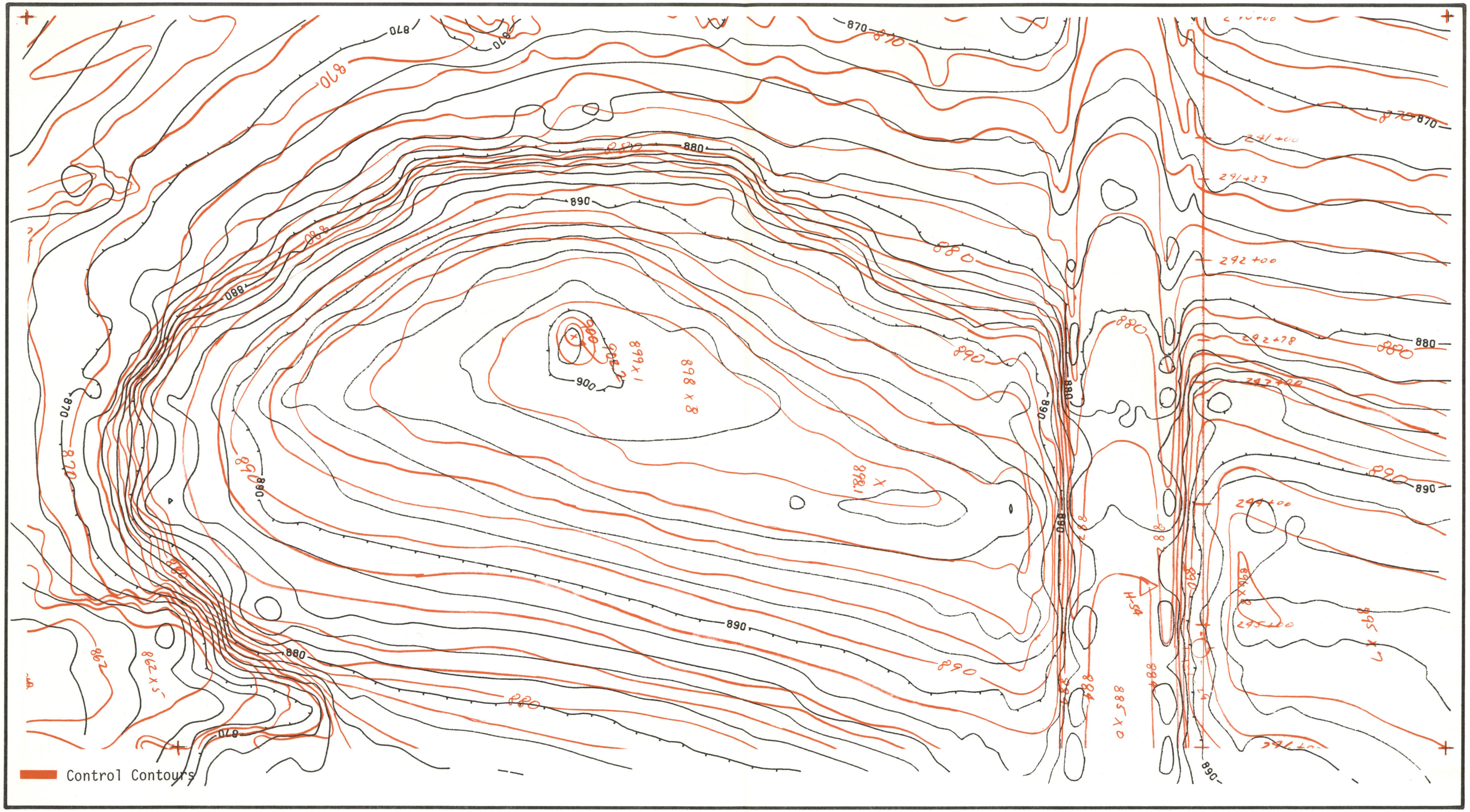


Figure 7. Contours by Proprietary System A, First Trial, Superimposed on Control

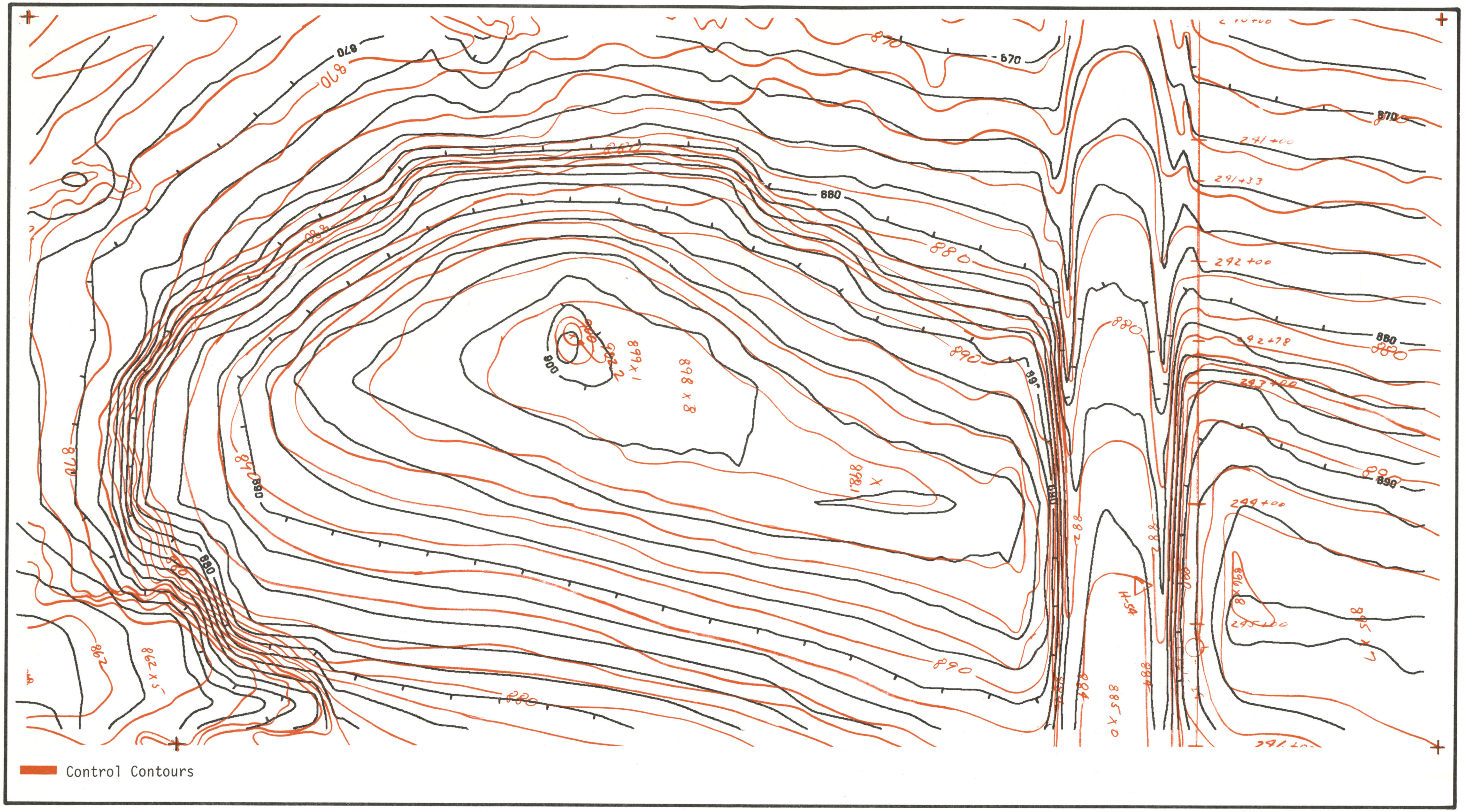
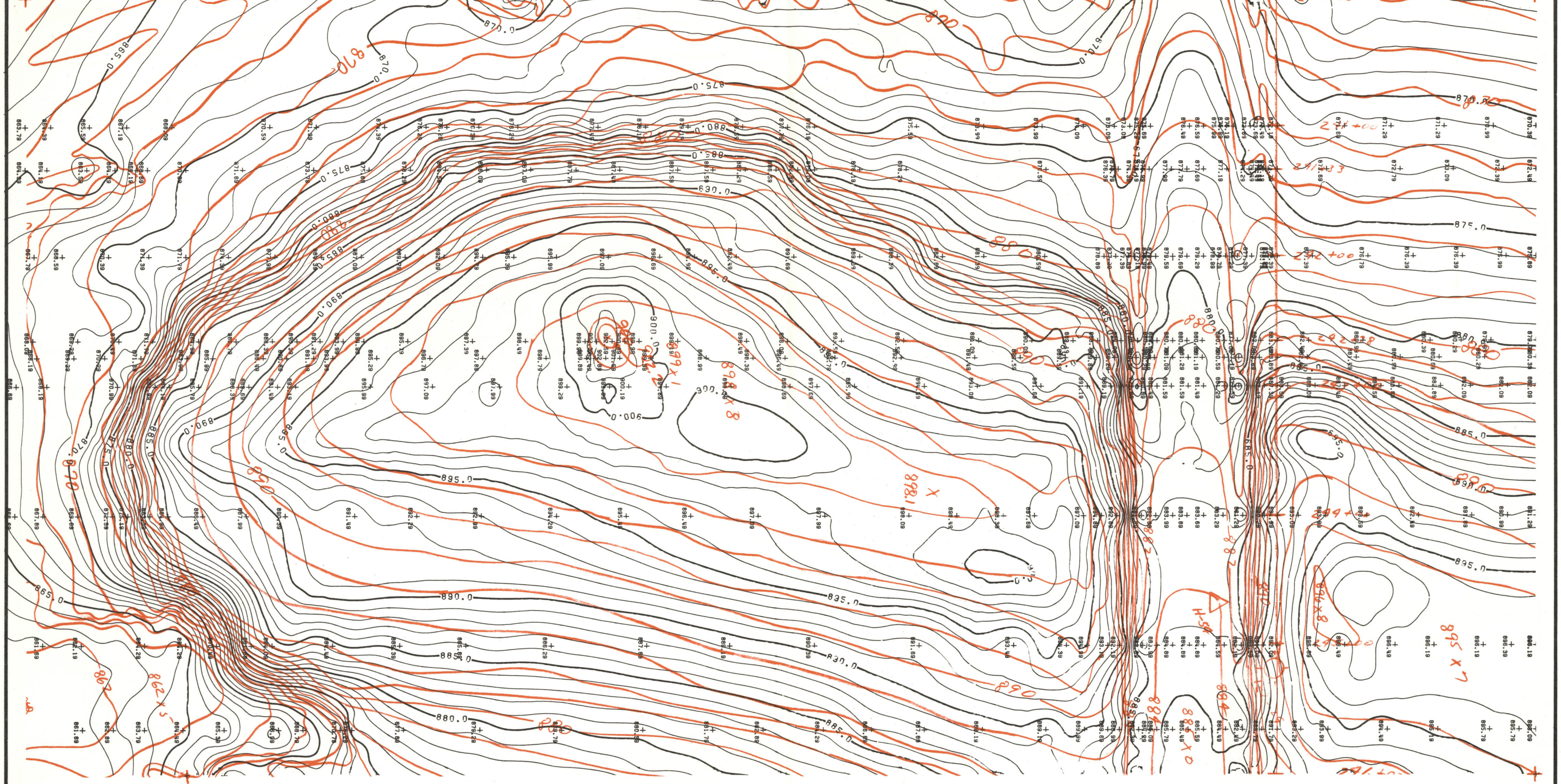


Figure 8. Contours by Proprietary System A, Second Trial, Superimposed on Control



Control Contours

Figure 9. Contours by Proprietary System B Superimposed on Control

Figure 10 is a very significant plot. It shows the contours produced by proprietary system A, second trial, superimposed over the contours produced by the scan profile approach which are shown in red. An excellent correlation between the two systems is exhibited even though the scan profile approach included no smoothing. Both plots were the result of identical data which was taken in one of the first scan profile data acquisition experiments. It is assumed that the improvement that could be expected by inclusion of additional data would have a similar effect with both systems. In both cases their comparison with the control contours was affected by the lack of significant data and the probability that the control contours were affected by operator bias and smoothing. In the opinion of the author, the scan profile demonstration which was the result of very limited development effort provided as good or better representation of the terrain surface.

Table II shows the comparison of computer processing time, core storage requirements and processing units for the three benchmark tests. The times shown are for the complete process of building an NGI data file and generating the contour plot. This chart can only serve to give a general indication of these factors because of the variation in computer equipment and operating systems and in the amount of plotting produced. The scan profile plot and the system A plots were prepared at the specified scale. The scan profile plot includes data points and discontinuity boundaries. The system A plot contains additional annotation and tick marks. The plot for system B was prepared at a larger scale with a smaller contour interval and contains annotated data points.

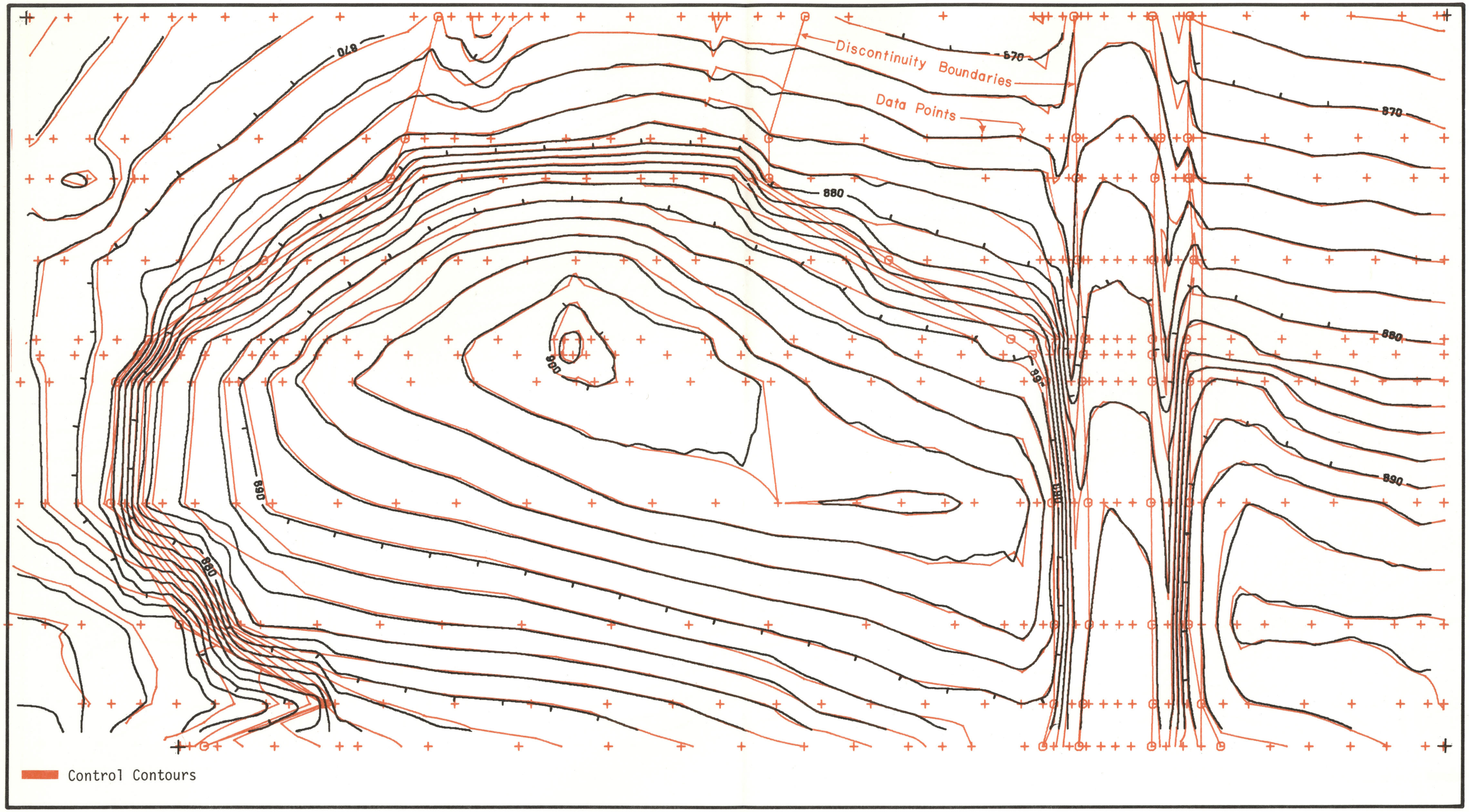


Figure 10. Contours by Proprietary System A, Second Trial, Superimposed on Scan Profile Contours

TABLE II. COMPARISON OF BENCHMARK TESTS

NGI SYSTEM	COMPUTER PROCESSING TIME	CENTRAL PROCESSING UNIT	CORE STORAGE REQUIREMENTS
Scan Profile Method	25.96 Sec.	IBM 370-155	$<$30K bytes
Proprietary System A	240.98 Sec.	Univac 1108	180K bytes
Proprietary System B	1320. Sec.	IBM 370-145 (VS-I)	220K bytes

Summary and Recommendations

A summary of the factors which influenced the following recommendations is given in Table III. In general it should be stated that an NGI interface with RDS could be accomplished with some degree of success with the scan profile approach, one of the proprietary systems or the Maxwell System. Table III compares these NGI systems. In the opinion of the author the order in which they are listed above is the order of their feasibility for interface with RDS. Proprietary Systems A and B were selected for test purposes as being representative of the best of such systems and System A was selected as being the most feasible for interface with RDS. The value judgments in Table III were based on the benchmark test results, examination of literature and software approaches, discussions with vendors and preliminary appraisals of the programming required to implement the various systems. The factors shown are considered to be most important to the success of the NGI system implementation. This evaluation of these factors shows the scan profile approach to be the most feasible system for the proposed implementation. It is also significant that the scan profile system reflects a new technology approach which offers benefits in many areas.

It is recommended that the following steps be taken:

1. Adopt the Scan Profile approach.
2. Develop the RDS/NGI routines as illustrated in Figure 11.
   A. Process Cross-Section Request*
   B. Access NGI*
   C. Create NGI File
   D. Create Cross-Section

*These routines are essentially complete. They would be the same for either approach.

These recommendations can be completed within the allotted time and funds for this project. It is believed that the scan profile approach will prove to be a significant contribution to the field of terrain surface representation.

TABLE III. FACTORS INFLUENCING RECOMMENDATIONS

FACTORS	SCAN PROFILE SYSTEM	PROPRIETARY SYSTEM A	MAXWELL'S SYSTEM
Adequacy of Model	Good	Good	Not tested - Not expected to compare
Handling of Discontinuities	Good	Good to fair - Needs better data entry method	None
Data Operator Skill Level	Slightly more than for conventional cross-sections	Considerably more than for conventional cross-sections	Considerably more than for conventional cross-sections
Requirement for Adjustment of Grid & Other Parameters	None	Necessary	Necessary
Availability to other user agencies	Yes	Proprietary	Yes
Compatability with RDS	Good	Fair	Good
Estimated effort required to complete & test implementation (man months)	Six	Eight (Purchase cost must also be considered)	Ten
Processing Efficiency	Good	Fair	Not tested - expected to be less than System B

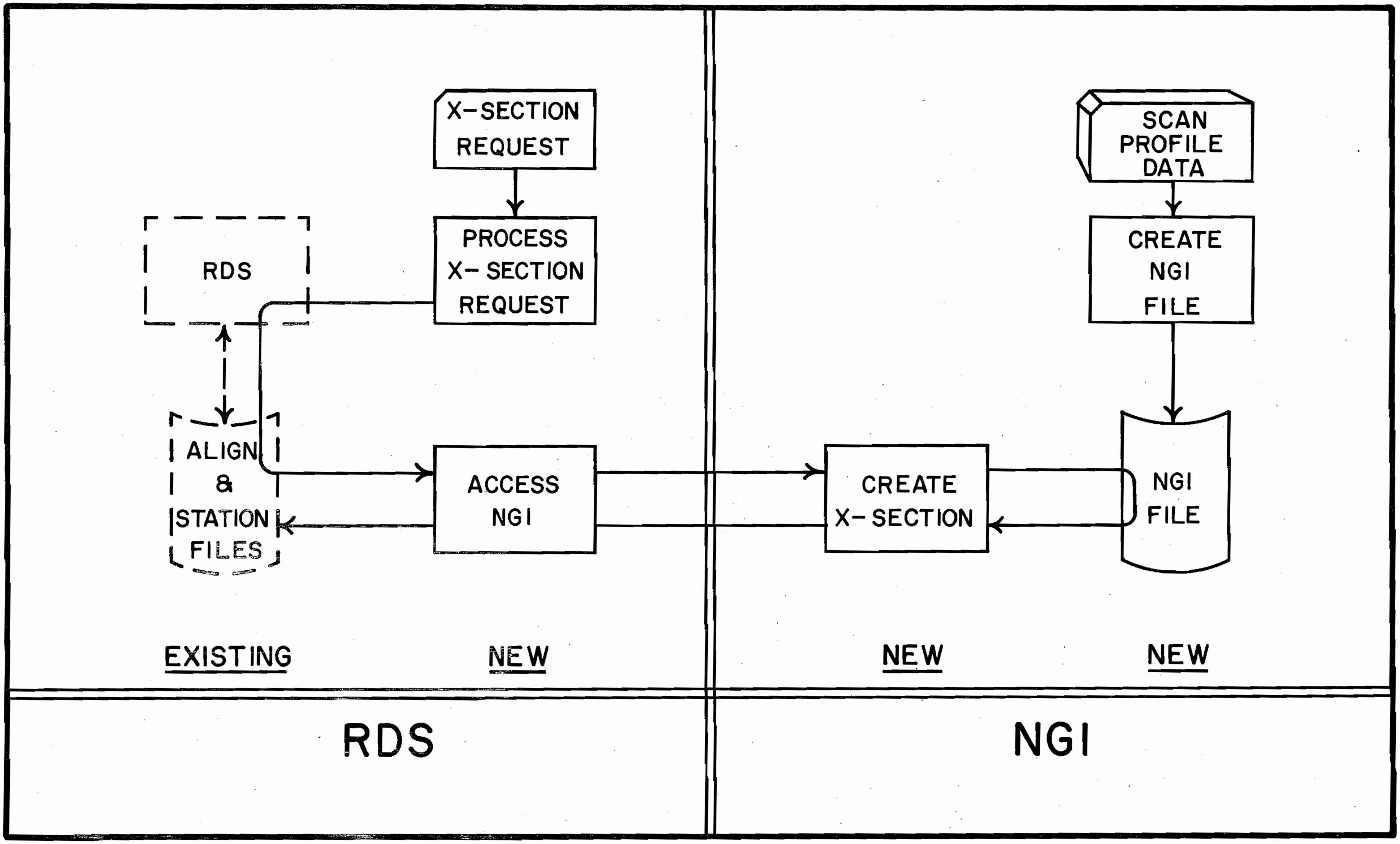


Figure 11. Schematic of Proposed RDS/NGI Interface

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