A COMPARISON OF VARIOUS ORE RESERVE ESTIMATES AT THE BUCKHORN MINE, EUREKA COUNTY, NEVADA

By

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Abstract

An abundance of computerized exploration drillhole and production blasthole data from Cominco Resources' Buckhorn Mine in Nevada provides the opportunity for a comprehensive study to evaluate various grade estimation techniques. The Buckhorn ore-body is a bulk mineable, volcanic hosted, epithermal gold-silver deposit that formed in a Miocene hot springs system.

Forty separate block models, estimated from exploration drillhole data, were compared with 12 block models derived from blasthole data. The effect of choosing a smaller mining size block over the larger block size that might be dictated by drillhole spacing was examined in some cases. Some block models and datasets had geological constraints imposed on them while others did not. For each of four major block model configurations various polygonal based, inverse distance and geostatistical estimates were calculated and compared to each other and to known production data. During the course of this study, many of the common statistical and geostatistical techniques for analysis of data were employed and in some cases, the methods themselves were questioned.

Results showed that estimating small, mining size blocks is important regardless of the grade interpolation method used because the best of these block models, although less accurate predictors of actual grade at any given location, tended to reflect the overall true grade distribution of the ore blocks

which were eventually mined. Because all ore estimates are calculated from nearest exploration composites, some of the small block size models can be seen as fairly accurate, geometrically correct approximations (one possible realization) of the true, unknown shape of the orebody.

It was found that, in addition to separating oxide from sulfide exploration composites, the imposition of a second type of geological boundary, an ore zone outline within which ore was likely to occur and outside of which there was little basis for predicting the existence of recoverable reserves, measurably improved the estimates of tonnage and grade.

And finally, the method of calculating conditional probability proposed by G.F. Raymond (Raymond 1979, 1982, and 1984), and as further refined here, was found to be the most accurate, stable, and generally useful of the various methods used to generate block models and estimates of ore reserves at the Buckhorn Mine.

Table of Contents

List of Tables

List of Figures

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And special thanks to my wife, Susan, and my kids, Jaime and Christopher, whose patience with late nights and absences to converse with the likes of IBM, VAX, Calcomp, and other sub-sentient predictors of reality, although stretched at times, held to the end. Susan's encouragement to finish this thing, when at times I didn't want to, is now particularly appreciated.

1. INTRODUCTION

The Buckhorn Mine is a small, low grade epithermal gold deposit hosted by altered Tertiary volcanic rocks. It is located in Eureka County, Nevada approximately 60 miles southwest of the town of Elko (Fig. 1). The mine is a joint venture of Cominco Resources International Ltd. (76%) and Equinox Resources (24%). Bar Resources retains a 20% net proceeds interest. Gold and silver mineralization is disseminated along NNW trending faults and fractures with ore grades encountered in a near surface oxide zone and extending downward into sulfide ore at depth. Only the oxide ore is mined in the open pit operation. Gold and silver are extracted using heap leach technology. Published minable reserves are 3.1 million tons of ore containing 0.04 oz./ton gold and 0.6 oz/ton silver at a 0.02 oz./ton gold cutoff grade (Munroe et al., 1988).

Although there has been sporadic mining activity on the property since the early 1900's, the current open pit operation was started up in February of 1984. Initially, ore reserves were calculated by an outside consulting company using a 20' block model with kriged block grades and an open pit was designed using this model. In 1985, reserves were recalculated by Cominco Ltd. using inverse distance cubed interpolation, lognormal kriging, and ordinary kriging and the open pit was redesigned using the inverse distance model because estimates using this method most

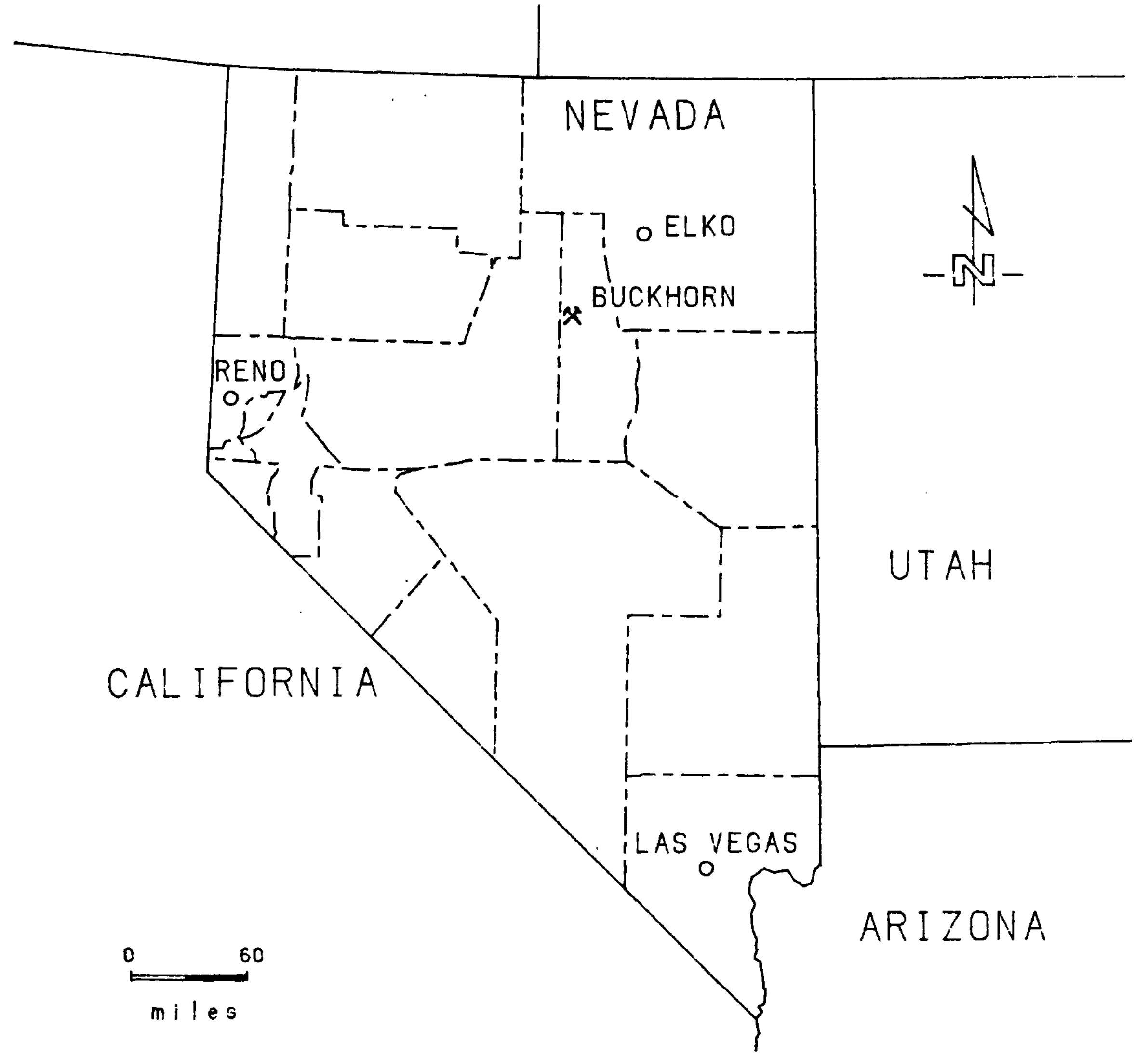


Fig. 1. Location Map.

closely resembled mined tonnage and grade figures available for the first year's production. Although blasthole data was available after the first few months of operation, no attempt was made to compare estimates from exploration drilling to blasthole results. The blasthole data is the only data on which production can be reported from the mine because no other reliable measure of head grade is available. Ore is dumped from stockpiled material into the crusher and samples are taken sporadically every 2 or 3 hours from the conveyors. There is no good way of documenting where in the main pit ore is being sampled from and, in some cases, whether the ore is coming from the main pit, a low grade stockpile, an ore stockpile or from other small pits which have been mined on the property.

The current study was designed to answer a number of questions, not the least of which was why there appeared to be better estimates of tonnage and grade by the inverse distance cubed method than by kriging. Other topics to be investigated include:

1) <u>Effect of Estimation Block Size:</u> It is commonly accepted by geostatisticians that regardless of the block size used, kriging will generate reserve figures which are correct on average and that the best block size for estimation purposes is one that is close to the original exploration drillhole spacing, and furthermore, that we are fooling ourselves if any attempt to estimate grades for very small size mining blocks is made. This is true if one is interested in predicting the grade of an individual block, but intuitively, it can be surmised that for mine planning purposes and the estimation of global reserves, a different philosophy must be adopted. For example, if only one block was estimated (the whole deposit), any estimate (including kriging) should give an average block grade which is equal to the average of all of the samples used to calculate the grade, and that grade will probably be below cutoff (i.e. 0 tons of ore). If the deposit is divided up into 9 equal size blocks, there may result one block in the middle whose grade is slightly above the mining cutoff, and 8 at below cutoff grade. If this analogy is

continued down to a mining scale, it is more important to estimate to the mine design block size (20' x 20' x 20' at Buckhorn) than to a 50' x 50' x 20' block size (Buckhorn drillholes are spaced on a fairly regular 50' exploration grid), because in mining no one is impressed by a "correct on average" estimate unless that estimate is correct on average above a chosen mining cutoff grade. For any 50' block that is estimated at below cutoff there is some reasonable probability that at least one 20' block contained within the larger block would have been estimated to have a grade above cutoff. Although the grade of each of the smaller mining blocks may not have been accurately predicted, a better overall picture of the true distribution of the block grades and ore reserves expected at the mining scale has been obtained.

To see what difference in global tonnage and grade there might be, 2 block models were generated, one with 20' x 20' x 20' blocks, and one with 60' x 60' x 20' blocks. It was expected that ore reserves based on the 60' block would be lower than for the 20' block size.

2) Effect of Ore Zone Outlines: The importance of constraining the interpolation to within geological boundaries has been amply demonstrated by numerous practitioners of geostatistics over the years (e.g. David, 1988). In this study, only exploration drillholes within the oxide zone were used because it was obvious that the sulfide ore would not be mined, and that sulfide mineralization was more erratic and showed evidence of belonging to a different statistical population of samples. Similarly, only oxide zone blastholes were used for

comparison. However, as will be seen, there is a second type of geological boundary in the Buckhorn data and in many other datasets that the author has encountered. This is the rocktype "ore". It is felt by the author that if an intuitively or quantitatively derived boundary can be defined which encircles mineralized areas, that this in itself is an important geological boundary which, if taken into account, minimizes numerous errors of population mixing which result in unwarranted extrapolation and/or "smoothing" of ore grades. To test this idea rigorously, 2 further block models were generated which took the original 20' and 60' block models and imposed this new geological boundary on them. For estimates on these 2 block models, only exploration composites within this "ore zone" outline were used to generate ore reserve figures. These were later compared to production estimates based on blasthole information within the same outline.

3) <u>Accuracy of Various Polygonal and Inverse Distance Estimates:</u> We are often told that, in most cases, polygonal estimates are dangerous and that inverse distance methods will range from an estimate which resembles kriging with a variogram showing pure nugget effect, through to an estimate which most closely resembles a polygonal estimate when the power of distance is high enough (Journel and Huijbregts, 1978). Somewhere in between (we don't know where beforehand), there may be a power of inverse distance that would resemble the kriged estimate--especially if anisotropies in the variogram are taken into account and sample spacing is on a regular grid. At Buckhorn, the inverse distance cubed interpolation method was chosen (no anisotropies were modelled), so it was decided to try polygonal

estimates and various powers of inverse distance from power zero (straight average) to power ten in order to see if any of these other estimates would perform better than the inverse distance cubed method. In particular, the behaviour of the inverse distance cubed interpolator that was used for the 20' block model of the original mine design was monitored to see if it would work equally well on all of the other 3 block models, and to compare this method to kriged estimates.

4) Effectiveness of Conditional Probability Estimates: During the period 1979 to 1985, most geostatistical studies at Cominco were performed by G.F. Raymond. Pivotal to his philosophy of practical geostatistics is the method of calculation of conditional probabilities using relative variograms and ordinary kriging which he has developed over the past 12 years (Raymond 1979, 1982, 1984). Early attempts indicated that prospects for using kriged estimates as an accurate block estimator at Buckhorn were grim. Consequently, it seemed reasonable to attempt Raymond's approach of "conditional probability".

5) Comparison With Blasthole Data: The last and most important question to be addressed was not only how well the various ore reserve estimates performed against each other, but how well they compared with the reserves calculated from actual production blasthole data. For each of the 4 exploration block models, a parallel block model using 20' or 60' blocks with and without the previously mentioned ore zone outline was constructed which contained block estimates based on blasthole data on each bench and within the outlines. Great care was taken to ensure

that partial block percentages were calculated on the edges of the outlines, and that these "block partials" were used when reporting tonnages derived either from exploration drilling or blasthole estimates so that the total tonnages estimated from either set of samples would be exactly the same, and would lie completely within the various outlines imposed on the block models.

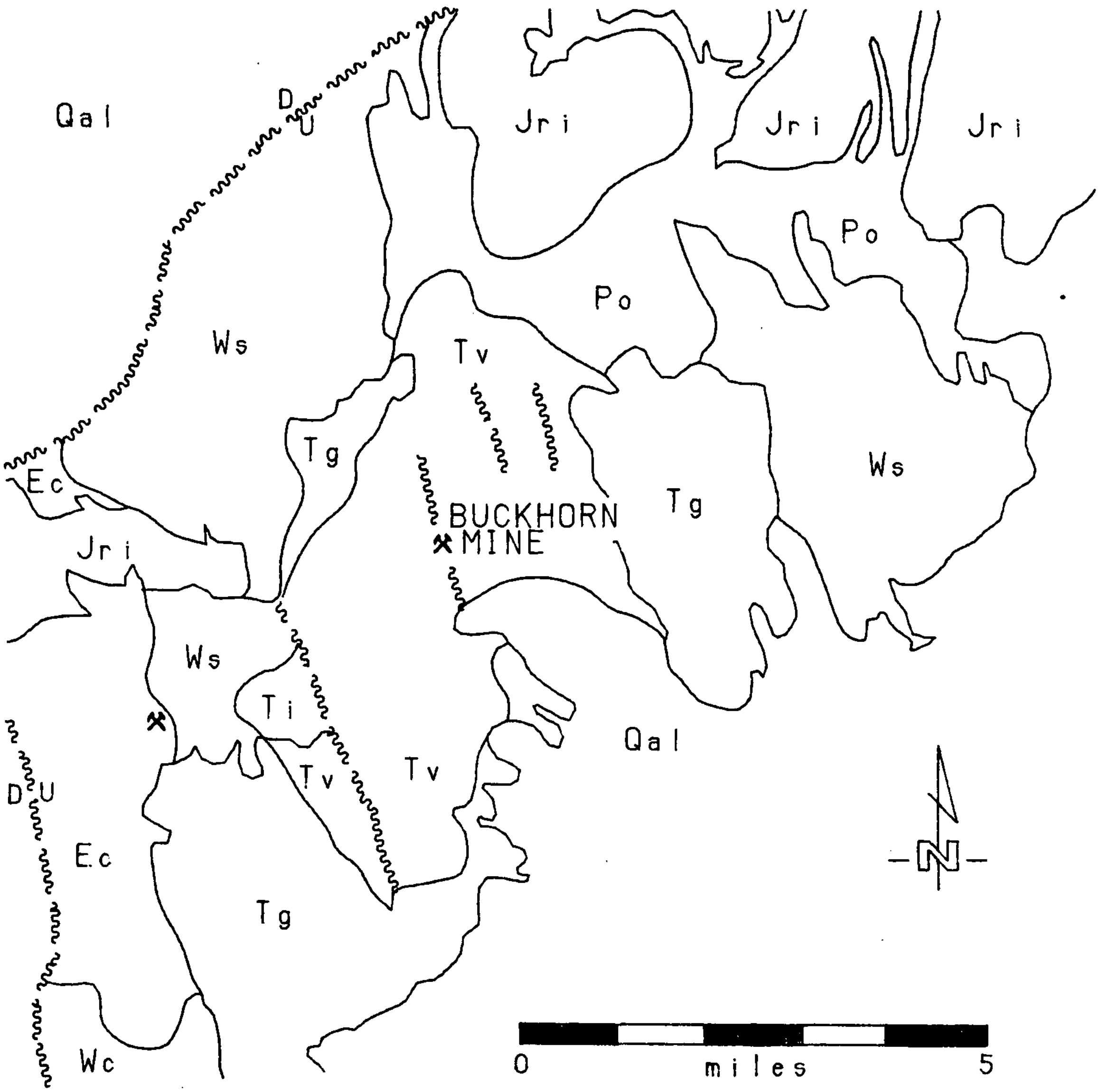
For each model, simple statistical parameters were calculated, distributions were modelled and examined by use of histograms and probability graphs, separate variograms were calculated, back estimation techniques were employed, and each of 10 separate reserve calculations were compared to the best available block estimates that could be derived from the blasthole data.

It is important to note that this work is devoted mainly to determining the best possible ore reserve estimate. The distinction is made between providing the best estimate of the grade of an individual block and the related, but separate problem of predicting the distribution and average grade of all blocks within and above grade cutoffs. The best possible calculation of ore reserves, which will be used by the mining company to determine the economic potential of the deposit prior to a production decision, is the goal of this study. In the case of the Buckhorn Mine, this calculation would result in four crucial numbers -- tons of ore, grade of ore, tons of waste, and the cutoff grade that is used in the calculation.

2. GEOLOGY OF THE BUCKHORN DEPOSIT

The gold and silver at Buckhorn is hosted by altered Tertiary volcanic flows with mineralization localized along high angle normal fault systems. The deposit is similar to the many other volcanic hosted precious metal deposits which have been formed in near surface hot spring environments in the Basin and Range province of the southwestern United States.

Regionally, the Tertiary volcanic and sedimentary rocks unconformably overly Paleozoic sedimentary and volcanic units which are broadly represented by two assemblages referred to as the autochthonous eastern carbonate assemblage and the allochthonous western siliceous and volcanic assemblage. Locally, the two assemblages are juxtaposed along the Roberts Mountains thrust fault, which surfaces a few miles to the west of the Buckhorn and Cortez areas. Generally, eastern assemblage rocks of the lower plate are exposed to the west whereas the western assemblage of the upper plate shows up to the east of the thrust fault surface trace and siliceous and volcanic units of the western facies outcrop to the north, east and west of the Buckhorn mine area (Fig. 2). A third suite, referred to as the Paleozoic overlap assemblage, is represented locally by the Brock Canyon formation and is made up largely of coarse clastic rocks which were derived from the post-thrusting erosion of both the eastern carbonate and the western siliceous rocks. To the north



Qal ALLUVIUM	Jri JURASSIC INTRUSIVE
Ti TERTIARY INTRUSIVE	Po PALEOZOIC OVERLAP
Tv TERTIARY VOLCANICS	Ws WESTERN SILICEOUS
Tg TERTIARY GRAVELS	Ec EASTERN CARBONATE

Fig. 2. Regional Geology Map of an area encompassing the Buckhorn mine (after Munroe, Godlewski, and Plahuta, 1988).

of the Buckhorn deposit, Jurassic quartz monzonite stocks intrude the Paleozoic units.

Tertiary rock types include a 750 foot thickness of basal alluvial fan deposits, which are overlain by up to 350 feet of Miocene basaltic andesite that hosts the Buckhorn mineralization. In places the basalts are overlain by younger sediments which include relatively coarse clastic material similar to the earlier Tertiary fan deposits, some pelites, and siliceous hot spring sinter deposits containing fossil reeds.

On the mine property, and more specifically, around the main North Buckhorn Pit study area (Fig. 3), the dominant rocktype is basaltic andesite, but there are also some of the younger Miocene sediments exposed in the area of the open pit, and a breccia unit just to the northeast.

In areas of mineralization, the volcanics have been extensively argillically altered. The alteration zone extends for about 3,000 feet along the strike of a major N10°W high angle fault and ranges from 100 feet to 1,000 feet in width. The clay alteration extends to a depth of about 200 feet. The upper two thirds of the altered volume has been oxidized whereas the lower one third is a reduced sulfide zone. Both the oxide and the sulfide zones contain gold and silver. Laterally, kaolinite close to the fault gives way to montmorillinite and the transition from one clay to the other appears to define the limits of the ore body on either side of the structure (Plahuta, 1986).

As evidenced by sinters, argillic alteration, and the presence of explosion breccias in the vicinity of the mine, the

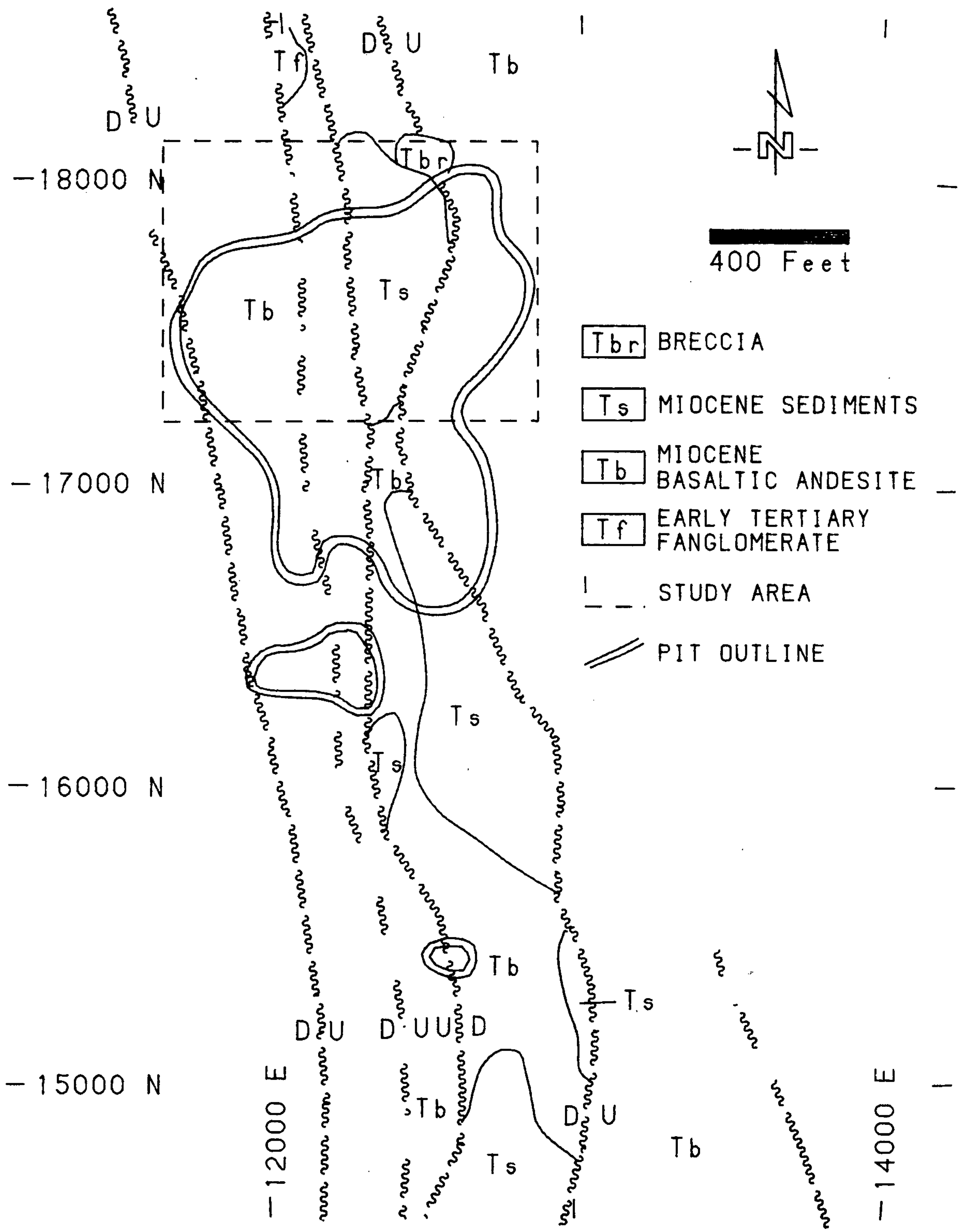


Fig. 3. Geological map of the Buckhorn Mine (after Munroe, Godlewski and Plahuta, 1988).

mineralization has been deposited in a near surface hot spring environment. The high angle faults and fracturing in the area provided conduits for hot hydrothermal fluids and prepared the basaltic andesite for alteration and stockwork mineralization. The occurrence of explosion breccias indicates that sporadic breaching of a sealed system relieved pressure buildup, initiated hydraulic fracturing and lowered boiling horizons which would in turn cause gold and silver to deposit from the cooled fluids and to deposit into the porous, fractured host rocks.

3. AVAILABLE DATA AND BLOCK MODELS

3.1 EXPLORATION DATA

Exploration drillholes were drilled approximately on a regular 50' x 50' grid. The majority of the data comes from rotary drill cuttings which were sampled every 10' from the collar and fire assayed for both gold and silver. Although silver grades were available from exploration drillholes, there are no silver assays from blastholes, and therefore estimates of silver grades could not be compared to blasthole data and were ignored in this study. The only geological information available was the location of the oxide/sulfide boundary in feet from the collar of the hole.

The rotary drillholes are vertical, but there are a few inclined diamond drillholes that were included because these and a few other close spaced rotary holes provided the only information on lag distances of less than 50' for calculating horizontal variograms. There were various campaigns of rotary drilling on the property, all in clusters, which defined various areas in the open pit, drilled in different years and assayed by different labs. The inclined holes, and the different series of rotary holes, might therefore constitute different supports. There was no adequate method of comparing either the reliability of the diamond drillhole assays against the rotary drillholes, or indeed the various different series of rotary drillholes against each other. All samples were accepted if they were within the oxide zone and fell within 100' of the rectangular study area shown on Figure 3.

Raw 10' drillhole samples were composited to 20' lengths such that each weighted composite fell within a 20' mining bench starting at elevation 6900' with it's center vertically in the middle of the bench. Composites of less than 5' were discarded. Bench plans showing the exploration composites can be found in Appendix A.

Altogether there were 3,670 exploration composites generated, of which 2,432 fell within the rectangular study area where production data from the main North Buckhorn pit was available for comparison.

3.2 BLASTHOLE DATA

The blastholes (shown on the bench plans in Appendix A) are spaced approximately 12 - 14' apart. Blasthole cuttings for the upper 20' are sampled from the ring of cuttings at the collar and fire assayed for gold only. Although there appears to be a fairly constant silver to gold ratio (about 15:1), the recovery of silver from the heap leaching process is low (< 40%). Therefore any silver recovered is considered a bonus and silver values are not used for the open pit design, or to determine mine cutoffs or daily production ore limits.

There are a total of 8,752 blasthole assays available that represent production data to the end of July, 1986. The outline of the perimeter of the individual blasts was used to determine the mined out area within which ore reserves would be calculated. All blastholes are in the oxide zone; the sulfide mineralization was not encountered until later in 1986.

3.3 BLOCK MODELS

3.3.1 Introduction

To save on computer time and costs, only 2 benches (6860 and 6840) were modelled. The 2 benches represent a well sampled area both for exploration and blasthole data in that there is adequate sampling within the mined area on both benches and on the 2 benches immediately above and below. The volume contained within the mining outlines on the 6840 and 6860 benches, together represent a total of 1.155 million tons of ore and waste material. This was considered sufficient to generate a reliable estimate of production against which exploration ore reserve estimates could be compared.

3.3.2 Four Foot Block Models

One of the aims of this study is to compare estimates of actual production tons and grade with exploration ore reserve estimates generated from both 20' and 60' block models within fixed boundaries. To do this in a consistent manner so that polygonal estimates could be compared to estimates on both 20' and 60' block sizes such that all three calculations reported the same overall tonnage, a 4' x 4' x 20' block model was generated on the 2 benches. This block size was chosen for two principal reasons:

1) Representative polygonal estimates could be calculated to very small blocks which could be recombined in groups that would closely resemble traditional hand drawn polygonal boundaries. Because the average sample blasthole spacing is at least 12', there are, on average, at least 9 closest neighbour 4' blocks.

2) The 4' block size divides evenly into the 20' and 60' block sizes and the 20' blocks divide evenly into the 60' blocks. Because the origins of the 3 block models are exactly the same, 25 original 4' blocks exactly represent each 20' block, 225 4' blocks fit into a 60' block, and 9 20' blocks are contained in a 60' block.

Because different outlines (mined limits, ore zone boundaries) are imposed on the various block models, the 4' model was used to determine which very small blocks were within a boundary and which were outside. Then, the number of valid 4' blocks inside the larger blocks were used to calculate fractional block percentages (block partials) within particular boundaries. In this way, exactly the same tonnage was represented by each of the larger block size models and, for example, a large 60' block whose grade is later estimated, might be weighted by as little as 1/225 of its volume when calculating total reserves because 224/225 of the block is outside the area to be estimated.
Normal methods of accepting or rejecting blocks tend to throw out a block if it's center is outside of a boundary. Figure 4 shows

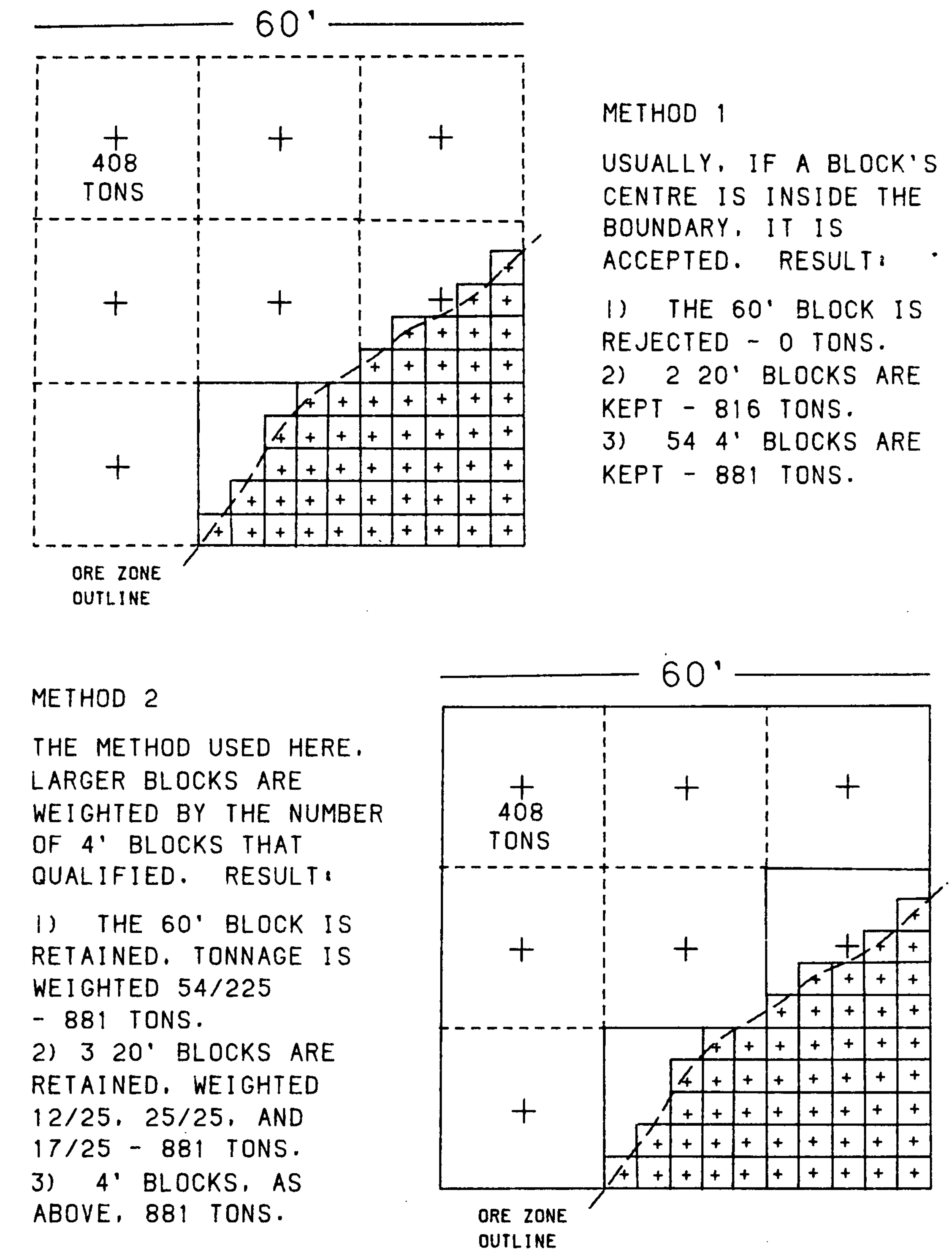


Fig. 4. Two methods of accepting or rejecting blocks within an outline. Method 2. is used in this work.

the difference in results between this method and the one employed for this study.

3.3.3 Twenty Foot Block Models

Two 20' block models were generated. The first represents the actual block size and outline used in initial production planning. Each block represents 408 tons of material if 100% of the block falls inside the mined limits. All blocks along the mined limits were checked to see if any selected 4' blocks were contained within it, and, based on the number of these small blocks within the outline, a percentage fraction was generated along with the block location which could later be used to calculate actual tonnage within the outline. For this model, percentages were multiples of 4% because there are a maximum of 25 4' blocks exactly contained in a 20' block.

The second 20' block model is a subset of the first. A conservative ore zone outline (shown on bench plans, Appendix A) which generally contained only exploration composites that graded better than 0.01 opt. was digitized (see Chapter 4. for rationale). Again, block partials were calculated for this subset of 20' blocks from the 4' model to estimate tonnages straddling the boundary. Simultaneously, second exploration and blasthole data files were created which contained only drillhole composites or blastholes which were completely inside the ore zone outline (even if outside the mined limits). These files are used later to study statistics and generate variograms, and to generate various polygonal, inverse distance, and kriged estimates for this block model.

3.3.4 Sixty Foot Block Models

The 60' block models were generated in exactly the same way as the 20' block models. The first 60' model contained blocks which were completely or partly inside the mine limits on the 6840 and 6860 benches and block partial percentages were stored. The second was a subset which contained 60' blocks which represented those large blocks or partial blocks which were contained inside the selected ore zone boundary.

Although the 60' blocks are slightly larger than the 50' exploration drillhole spacing, this block size was chosen because it approximates the spacing of the drillholes and also fits the 4' and 20' block models. All three models share the same origin and therefore the smaller blocks fit inside the 60' blocks.

3.4 SUMMARY OF BLOCK MODELS AND DATASETS

The net result is 6 block models and 4 separate datasets. These are summarized in Table I. In order to refer to the various datasets and block models, short names have been assigned which may be used elsewhere in the text and figures.

Table I

Summary of Block Models and Datasets

	Short Name	#Blocks or Composites	Within Mine Limits ?	Within Ore Zone Outline?	Bench
Block Models					
4x4'	4FOOT	70,775	*yes*	*no*	6840-6860
	4FOOTG	46,331	*yes*	*yes*	6840-6860
20x20'	BUCK	2,999	*yes*	*no*	6840-6860
	BUCKG	2,089	*yes*	*yes*	6840-6860
60x60'	BUCK60	386	*yes*	*no*	6840-6860
	BUCK60G	305	*yes*	*yes*	6840-6860
Exploration Composites					
	BEX	2,432	*no*	*no*	6600-6900
	BEXG	1,036	*no*	*yes*	6780-6880
Blasthole Samples					
	BBH	8,752	*yes*	*no*	6780-6880
	BBHG	6,315	*yes*	*yes*	6780-6880

4. STATISTICS

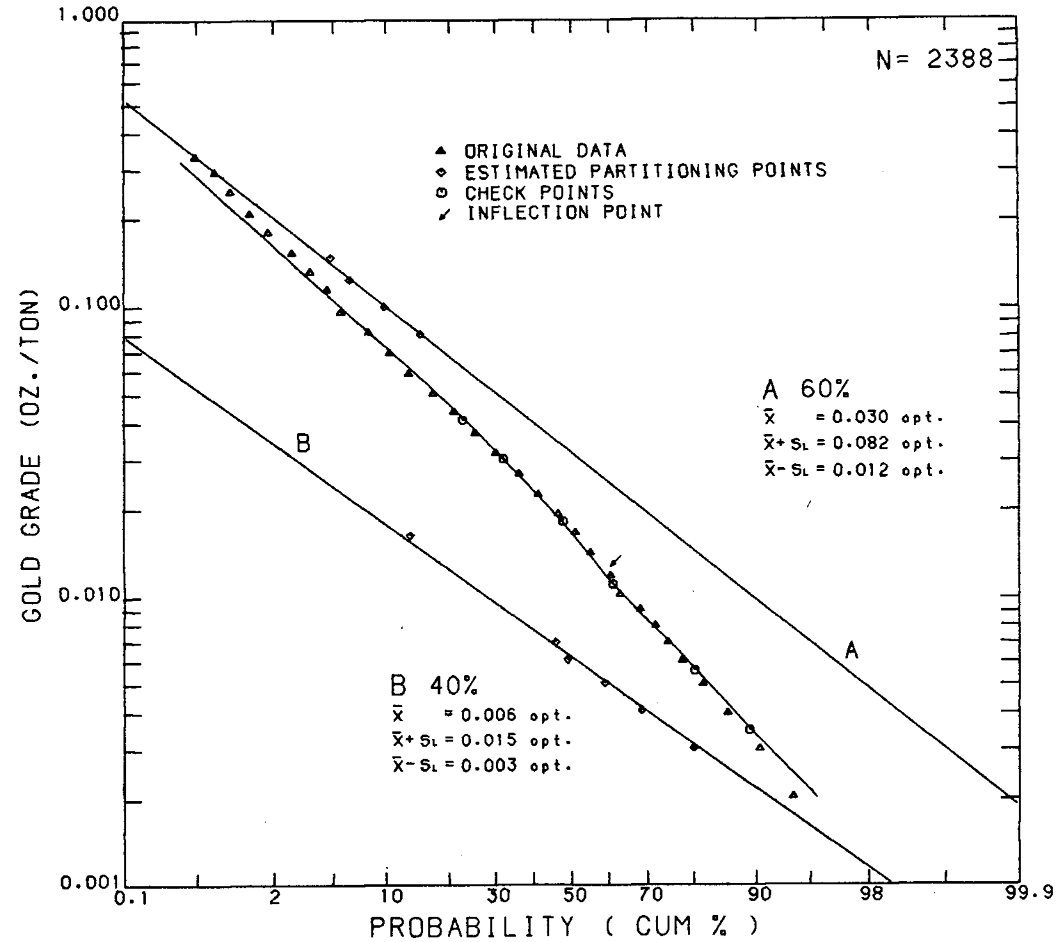
In any ore reserve study, a statistical evaluation of the data is considered important. One of the most important results that can be obtained is the confirmation of the normal or lognormal nature of the sample data. Very few people rigorously test their results in any way -- usually a histogram or probability graph is drawn, and a best fit curve or straight line is used (depending on which type of graph was chosen) to point out that "it's close enough" and that's the last we hear about it. Alternatively, various newer and much more complex kriging methods are employed to offset the deleterious effect of having non-perfect data distributions (examples are multigaussian, indicator and probability kriging). Because of their complexity, these methods are often difficult to "sell" to management in a mining company. One further objective of this study will be to show that much simpler estimation methods can be used (probably over 90% of the time) if a determined effort is made to understand the nature of the results from a classical statistical study.

The author has studied numerous geochemical, geophysical, drillhole, and remote sensing datasets over the past 5 or 6 years and has found, almost without exception, that non-lognormal appearing datasets can be explained by inappropriate mixing of data from separate populations. Where classical statistical parameters such as mean and variance are reported for these mixed datasets, they are nearly meaningless. What is needed is a way of splitting up these separate, (usually) lognormal populations (David, 1988), and a way of testing whether the resulting partitioned populations have any basis in fact.

One such method has been documented and demonstrated (Sinclair, 1976), and will be used here. In the case of this study, use of the conditional probability estimate (which will be described later) is critically dependent on the assumption that the data is lognormally distributed.

The 2,388 non-zero exploration 20' composites from the original (BEX) dataset were used to construct a probability graph (Fig. 5). At first glance, a best fit straight line can be drawn through the points on the curve which would seem to adequately indicate a lognormal distribution. However, if a ruler is placed between the first and the last or second last point, it can be seen that every single point on the plot is above the straight line, and that they seem to define a gently curving line of points. Examination of the histogram below shows that the distribution of the samples does not define a "bell" shaped curve. The question is, can 2 or more populations be defined which, when added in the proper proportions, add up to create a cumulative probability which resembles the one shown for all of the 20' exploration composites?

Using Sinclair's method, two straight line populations were modelled which show that if 2 lognormal populations (A and B, Fig. 5) are added together in the proportion A=60% and B=40%, the original data points can be approximated (check points, Fig. 5).



LOWER LIMIT	%	
0.000	6.2	******
0.001	0.0	
0.001	3.0	***
0.002	4.5	*****
0.003	3.7	****
0.004	4.5	****
0.005	9.0	*********
0.008	8.3	********
0.011	7.5	*******
0.015	8.9	*********
0.020	10.7	***********
0.028	10.5	**********
0.039	8.1	********
0.054	6.0	******
0.075	4.3	****
0.104	1.8	**
0.143	1.4	*
0.198	0.8	* BEX DATA

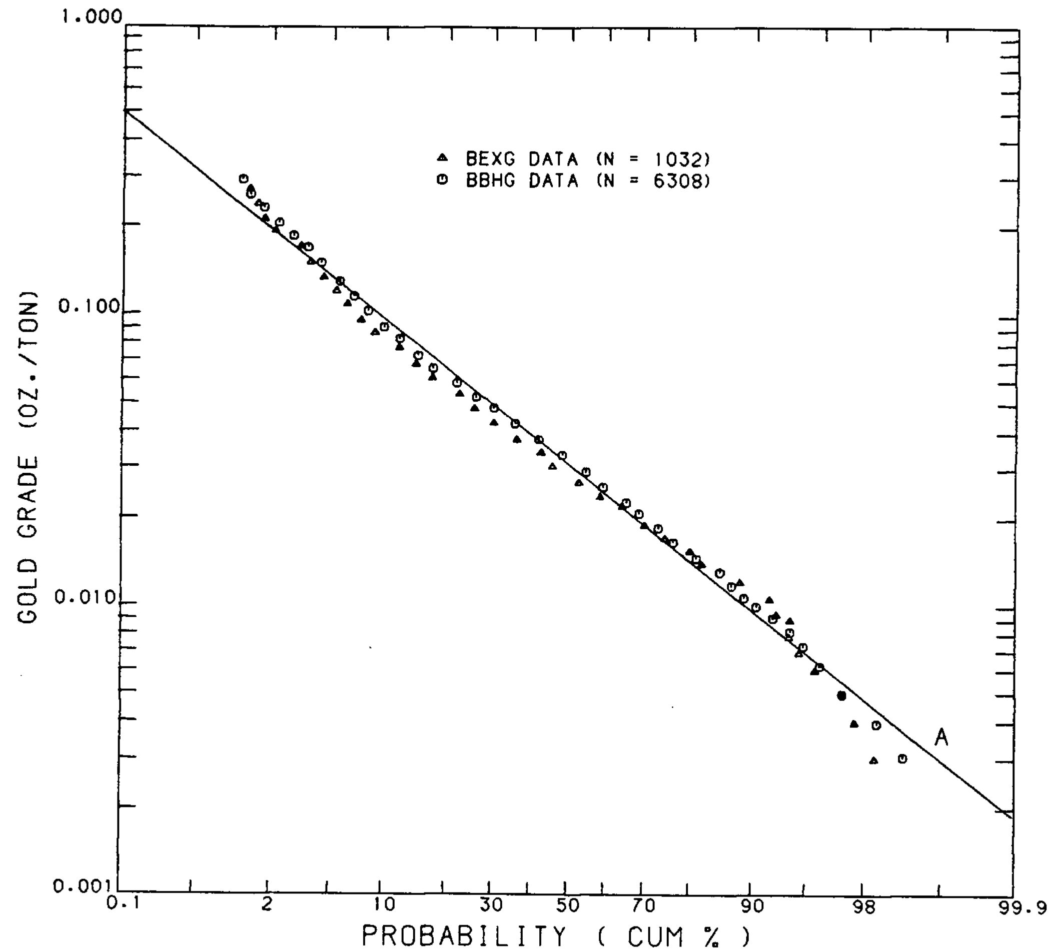
LOWER LIMIT	%	
0.000	0.0	
0.001	2.9	***
0.002	3.1	***
0.003	2.6	***
0.004	2.4	**
0.005	3.8	****
0.007	6.4	******
0.010	8.4	********
0.014	9.5	*********
0.019	12.1	************
0.026	12.4	************
0.036	10.7	***********
0.049	8.1	********
0.066	5.4	*****
0.091	3.3	***
0.124	1.9	**
0.169	1.2	*
0.230	0.6	* BBH DATA

Fig. 5. Partitioned log probability plot of 20' exploration composites. The histogram below shows a large number of low grade samples which cause the original curve to depart from a perfect lognormal distribution.

By studying the resulting lognormal populations, as straight lines on a probability graph, one can define a range of grades from approximately 0.005 opt. to 0.035 opt. for which there is some probability that a sample is drawn from one or the other population. Also, it can be seen that 90% of the members of population A (approximately 1,300 samples) should be above 0.010 opt., whereas only 28% of population B should be above 0.010 opt. (approximately 265) samples. It was this 0.01 grade cutoff that was selected to define the ore outlines that were used to construct the second set of 3 "ore zone" block models examined in this study.

A conservative boundary was drawn on every bench for which there was a mining outline (blasthole data). The ore zone boundary is considered conservative because it lies closer to the "greater than 0.01 opt. exploration composites" than to the nearest composite which grades less than 0.01 opt. The line essentially encloses zones which are bounded by 0.01 opt. gold exploration composites. According to the probability graph, if the outlined zone truly represents the modelled population "A" in Figure 5, then it should also include a number of values (10%) which are less than 0.01 opt.

Two separate datasets were created, one which represents exploration data within the outline (BEXG dataset), and one which represents the blasthole data within the same zone (BBHG dataset). The resulting data were then plotted on a log probability graph (Fig. 6) along with the higher modelled population "A". Within each of the new datasets there are values below 0.01 (8% for the exploration composites and 9% for the



LOWER LIMIT	%	
0.003	0.5	*
0.004	1.4	*
0.005	1.8	**
0.007	0.5	*
0.008	5.3	*****
0.011	7.3	*******
0.014	7.2	*******
0.017	12.5	*************
0.022	11.8	************
0.028	10.3	**********
0.035	10.9	***********
0.045	7.9	********
0.056	6.1	******
0.071	5.9	******
0.090	2.4	**
0.113	1.7	**
0.143	1.5	*
0.180	0.9	*
0.228	0.5	* BEXG DATA

LOWER LIMIT	%	
0.003	0.8	*
0.004	2.1	**
0.006	1.1	*
0.007	3.0	***
0.009	5.7	******
0.012	6.3	******
0.015	7.8	********
0.019	10.2	**********
0.024	10.2	**********
0.030	11.2	***********
0.038	11.0	***********
0.048	9.0	*********
0.061	6.0	******
0.077	4.6	*****
0.097	3.2	***
0.122	2.1	**
0.154	1.6	**
0.195	0.9	*
0.245	0.6	* BBHG DATA

Fig. 6. Log probability plot of blasthole data compared to partitioned exploration data. The straight line is the modelled population A from Figure 5. Both sets of data represented above are drawn from within the ore outline interpreted from the graph in Fig. 5.

blastholes) which compare favourably with the expected 10% from the model population "A". The blasthole data with 6,308 samples is accurately represented by the straight line model. The exploration data shows smoothing that was apparent only subtly in the raw data -- namely a slight underestimation of the percentage of composites expected at higher grades and a slight overestimation of the percentage of composites at lower grades. This is consistent with the expected result when using the weighted averaging process which originally created the composites, and it is accentuated by the fact that there are fewer samples in the exploration dataset (only 1,032 composites).

Both the exploration and the blasthole plotted points show a slight tendency to "rise" to higher grades between the 2nd and 5th percentiles in the graph. For the blastholes this probably indicates that there are a few areas of unexpectedly high grades, but for the exploration data it is almost certainly due to a smaller number of irregular drillholes which were closer than 50' apart (not on the grid pattern) and which were almost exclusively collared in higher grade ore areas. This gives a slightly higher than expected number of samples in the high grade categories. Generally however, the modelling seems to have accurately predicted the existence of these discreet zones of higher grades. Notice also that whether the model is to be believed or not, the exploration and blasthole grade distributions in this outline are nearly identical which indicates that there is little or no bias between the 2 types of samples. The reason for only generating the BEXG and BBHG datasets on benches where there was blasthole data was so that the existence of any sampling bias could be

Table II

Simple Statistics of the Exploration and Blasthole Data

Data	n	Arith. Mean	Arith. Variance	Relative Variance	Log_{10} Mean	Log_{10} Variance
BEX	2432	0.031	0.00224	2.3	-1.82	0.311
BEXG	1036	0.043	0.00276	1.5	-1.55	0.162
BBH	8752	0.037	0.00310	2.2	-1.71	0.288
BBHG	6315	0.047	0.00380	1.7	-1.51	0.162

checked in this way. A chart summarizes the simple statistics of the four datasets (Table II). Relative variances were calculated because, in order to use Raymond's conditional probability method, relative variograms are used. The population relative variance should be a guide in choosing the sill value in a relative variogram in the same way that the variance should be an indicator for actual variograms. These simple statistics will be analyzed further in the section on variography (Section 5.4.1).

There is another method of modelling lognormal populations (e.g. Raymond, 1982) which is integral to the conditional probability approach to ore reserve estimation; this is, to add a constant to individual grades to create a 3-parameter lognormal model. Figure 7 shows that a constant of 0.005 opt. added to the original set of arithmetic gold grades produces a series of points which approach a straight line lognormal model. This value should be used later to compute conditional probability for the 2 "non-ore outline" block models (BUCK and BUCK60) because,

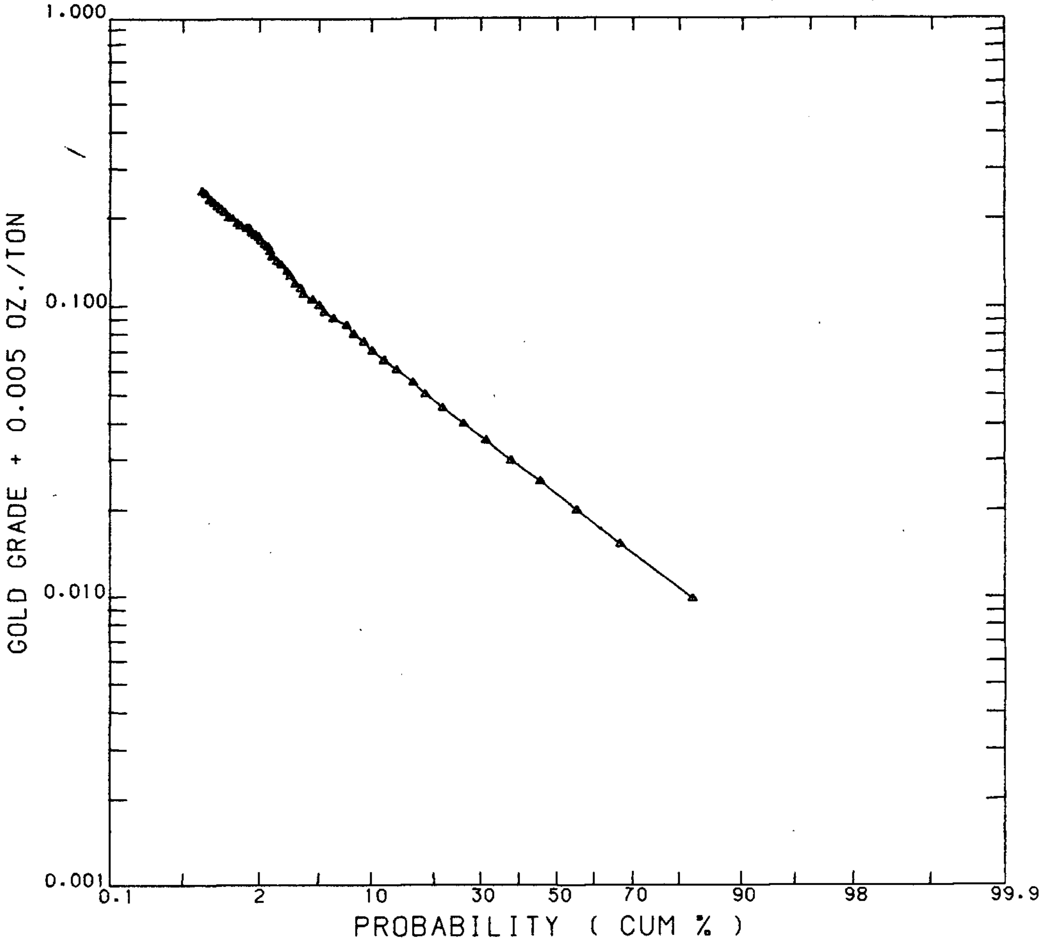


Fig. 7. Log probability plot shows the effect of adding a constant of 0.005 opt. to the original data to create a 3-parameter lognormal distribution.

according to Raymond (1982, 1984), it is the only way to ensure that kriging variances are related to a log transformed kriged grade.

However it should be mentioned here, and it will be amplified on further in later sections, that the 3-parameter lognormal concept is one which the author has difficulty with. Conceptually, a distribution can be modelled by assigning a frequency to every single value in that dataset and, regardless of what constant one adds to each discreet value, it doesn't change the frequency with which that value occurs. The fact that it appears to generate a straighter line when plotted on a log probability graph doesn't change the fact that one really hasn't altered the distribution of the raw arithmetic data.

Modelling the 3-parameter lognormal distribution with a positive constant does have an effect however. What happens is that the relative and lognormal population variances are decreased. The lognormal mean is shifted up and the best fit line through the distribution flattens out and becomes less steep (the steeper the line, the greater the variance). Effectively, this procedure crudely models the linear portion of the line on the log probability plot which represents the upper population. The closer the original distribution is to lognormal, the better the chance that the 3-parameter approximation will come close to the truth. The attempt however can never totally succeed in modelling the higher mean and lower variance of the upper, high grade portion of the data because, although the effect of the lower grade population is minimized (mainly by bringing the values into the same order of magnitude as the high grades), this population is still represented in the calculation of lognormal mean and variance. The effect will be that the predicted mean is low and the predicted variance is high for the upper population of grades.

The advantage of using Sinclair's method to accurately partition the data is that both the upper and lower populations are modelled correctly, and more importantly, further studies of the partitioned log probability plot provide percentages which represent the actual numbers of samples which can be expected from either modelled population within a grade range, as was shown earlier. These values can be used to separate the different populations if it can be shown that they are located in discreet zones as they are for the Buckhorn study.

However, use of the 3-parameter lognormal distribution is better than not doing anything at all. The effect of this modelled distribution on kriging variances will be discussed in later chapters.

5. ORE RESERVE CALCULATIONS

5.1 INTRODUCTION

For each of the 20' and 60' block models, gold reserves were calculated using 10 different methods -- 2 polygonal, 6 inverse distance based calculations, ordinary kriging and conditional probability. This resulted in 40 separate exploration ore reserve calculations which could then be compared to the kriged blasthole results for each of the 4 block models.

Undiluted reserves were calculated separately on each of the 2 benches studied (6840 and 6860) and a total reserve for the 2 benches combined was also calculated. The block partial percentages which were stored for each block for every model were used to produce volume weighted grade estimates and total tonnages. This meant that each of the reserve calculations on any block model produced identical total tonnages at a 0.0 cutoff grade. This greatly facilitated the comparison of different methods of reserve calculation within each model. Also, any 4', 20', or 60' model for which reserves were calculated (regardless of whether exploration or blasthole data was used) and which shared the same outline constraints, all produced the same total tonnage. This meant that the 20' block vs. 60' block reserve calculations yield identical total tonnages within the outline and therefore the different block size models can be compared directly with each other.

5.2 POLYGONAL ESTIMATES

In place of traditional hand drawn polygonal outlines, a computer generated 4' block model was employed. The grade assigned to any 4' block is the grade of the composite or blasthole on the same bench nearest to the center of the small block. Four such estimates were made -- two for exploration data (one within the mined limits and one which represented a subset inside the ore zone outline), and two comparable estimates using blasthole data.

Reserve reports were generated for each of the models (Appendix C). The blasthole polygonal estimates in fact represent the tonnage and grade that would have been reported at the mine in their production statistics. Because the exploration data was not interpolated using the various other methods down to the 4' block models, the polygonal estimate was not used for direct comparisons with other methods. Instead, the 4' blocks were recombined into the 20' and 60' block models and grades were volume weighted to produce what will be referred to as the <u>polygon weighted</u> grade estimate (see Fig. 8 for a graphical explanation of the polygon weighted method).

5.3 INVERSE DISTANCE

Six inverse distance reserve estimates were calculated for all 20' and 60' block models. These were inverse distance to the

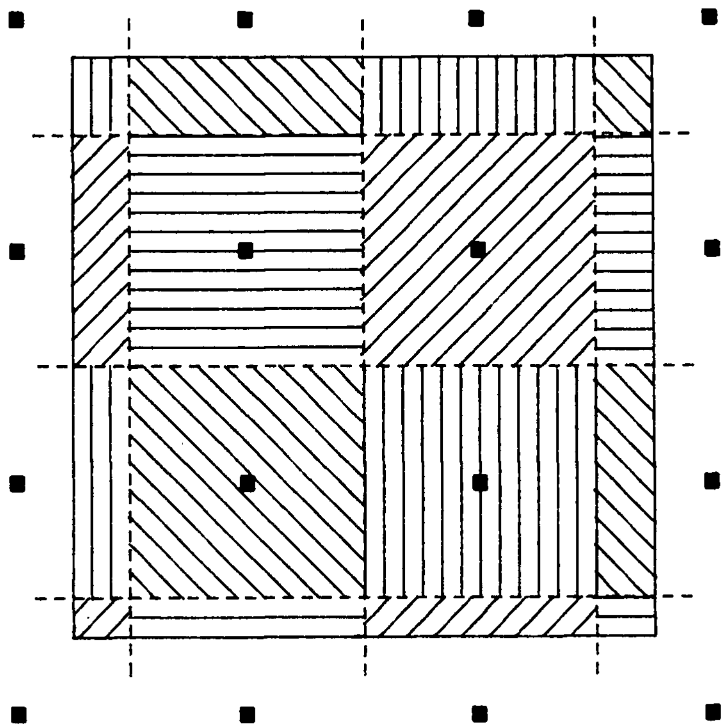


Fig. 8. Graphical explanation of the polygon weighted method of calculating block grades. The small solid boxes show the location of drillholes, whereas shaded areas represent the sub-volumes within a large block which will assume the grade of the nearest drillhole.

zero (ID0), inverse distance (ID1), inverse distance squared (ID2), inverse distance cubed (ID3), inverse distance to the fifth power (ID5), and inverse distance to the tenth (ID10). All of these empirical models have been used in practice and are included here because of the uncertainty of knowing which inverse distance approach to use in a practical study.

ID0 represents the straight average of all of the qualifying drillhole composites whereas each of the other estimates is distance weighted to some power. It was expected that ID10 would be a high enough power to be comparable to a polygonal estimate, the difference being that drillholes on the bench above and below

Table III

Parameters Used to Generate Inverse Distance Weighted Block Model Estimates from Exploration Composites.

Composite length	20'
Anisotropy	*none*
Minimum number of samples accepted	5
Maximum number of samples accepted	12
Maximum search radius	150'
Rectangular search radius	150' x 150' x 30'
Power of distance	0, 1, 2, 3, 5 & 10

would have some small weight assigned to them (the composites vertically above and below the nearest composite to the block center would probably be ranked second and third in the weighting).

The search parameters used are shown in Table III. These were chosen because they are exactly the same values that were initially used to generate the 20' inverse distance cubed block model that was used for open pit design and mine planning at Buckhorn. Therefore, the ID3 estimate calculated for the 20' block model which wasn't constrained by the ore zone outline (BUCK block model), is identical to the one used at the mine and can be scrutinized carefully relative to all other estimates that could have been generated. No attempt was made to weight inverse distance estimates differently relative to any preferred direction.

The ID3 estimate that was used for mine planning can be thought of as the geologist's "gut feel" best estimate before the mine went into production. As will be seen, this may be because this particular calculation performed well when estimating block grades in every cutoff category. This fact seemed to be apparent before this study was initiated and it serves to remind us that the geologists feelings about the accuracy or usefulness of a grade estimate should not be ignored -- any calculation should look reasonable regardless of the advanced methods which may be used to generate an ore reserve estimate. However, without attempting to analyze the results at this point, it should be pointed out that the ID3 estimate doesn't produce the best prediction of tonnage -- the performance of the grade estimate is easier to get a feeling for than the estimate of tonnage. In fact, of the inverse distance methods, it turns out that inverse distance to the fifth comes closer to predicting the blasthole kriged tonnage at each grade cutoff for the BUCK block model.

5.4 KRIGING

5.4.1 Variogram Analysis

The approach taken in this study was to study exploration data as if it was the only data available because the general aim was to make the best reserve calculation possible before production started, and then compare the estimates with the known blasthole results. Therefore, all variograms were calculated and modelled from exploration composites and the parameters derived were used to krige the exploration data before any attempt was made to determine a better variogram derived from the blasthole data.

Three basic types of variogram were calculated for each of the two exploration datasets (BEX and BEXG) in the four principal compass directions starting at 0° (north) and incrementing by 45°. The search window was 30° on each side of the direction being calculated, and for lags greater than 20', the composites on the bench above and below were used in the calculation. For the vertical variogram, the lag distance was 20' with a 5° window -- essentially a down hole variogram on the vertical drillholes. Actual, lognormal and relative variograms were calculated with 40' lag increments in the horizontal directions which included weighted distance calculations to determine the average lag for plotting and modelling the results.

All three types of variogram show consistent results (Appendix D contains a listing of all of the calculated variogram values), but because conditional probability estimates as defined later rely on the relative variogram, the relative variogram was modelled.

The three types of variogram for both datasets all indicated similar anisotropy patterns. The N-S direction has a lower variogram value at the first lag than does the E-W direction and $\gamma(1)$ in the NW-SE direction is lower than for NE-SW. With one exception (the lognormal variogram on the BEX exploration dataset), the NW-SE direction showed the lowest variogram value at the first significant lag. The major structural trend determined from geological mapping on the property is thought to be N10°W (Plahuta 1986); therefore the modelled anisotropies are consistent with expectations. The vertical variogram was used to define the nugget effect. The models that were used for each of the exploration datasets are shown in Figures 9 and 10. Notice that, although the variograms are shown only to lag distances of 150', all variograms (actual, lognormal and relative) reached constant sill values in all horizontal directions.

The final variograms were calculated only to 150' because, after assuming that the constant sill values demonstrated stationarity (David, 1977), all subsequent variograms were simultaneously calculated in all directions as variogram clouds with 4' lags. This resulted in five, large arrays (38 lags X 1024 gamma values x 5 directions) held in core on Cominco's IBM mainframe computer. All final variograms were only calculated to 150' to cut down on costs of computing. Blasthole variograms (Figs. 11 and 12) with smaller lag distances and more data confirmed that lags beyond this distance need not be calculated.

It should also be noted that, although close spaced samples which included angled diamond drillholes initially were retained in the hope that they would be useful in showing structure at lags of less than 50', the resulting variogram values were thought to be unreliable. In general the average grade of these sample pairs was about 0.015 opt. greater than the average grade of pairs at longer lag distances. As might be expected, only the relative variograms consistently showed gamma values at the first lag which were lower than at the second lag. These

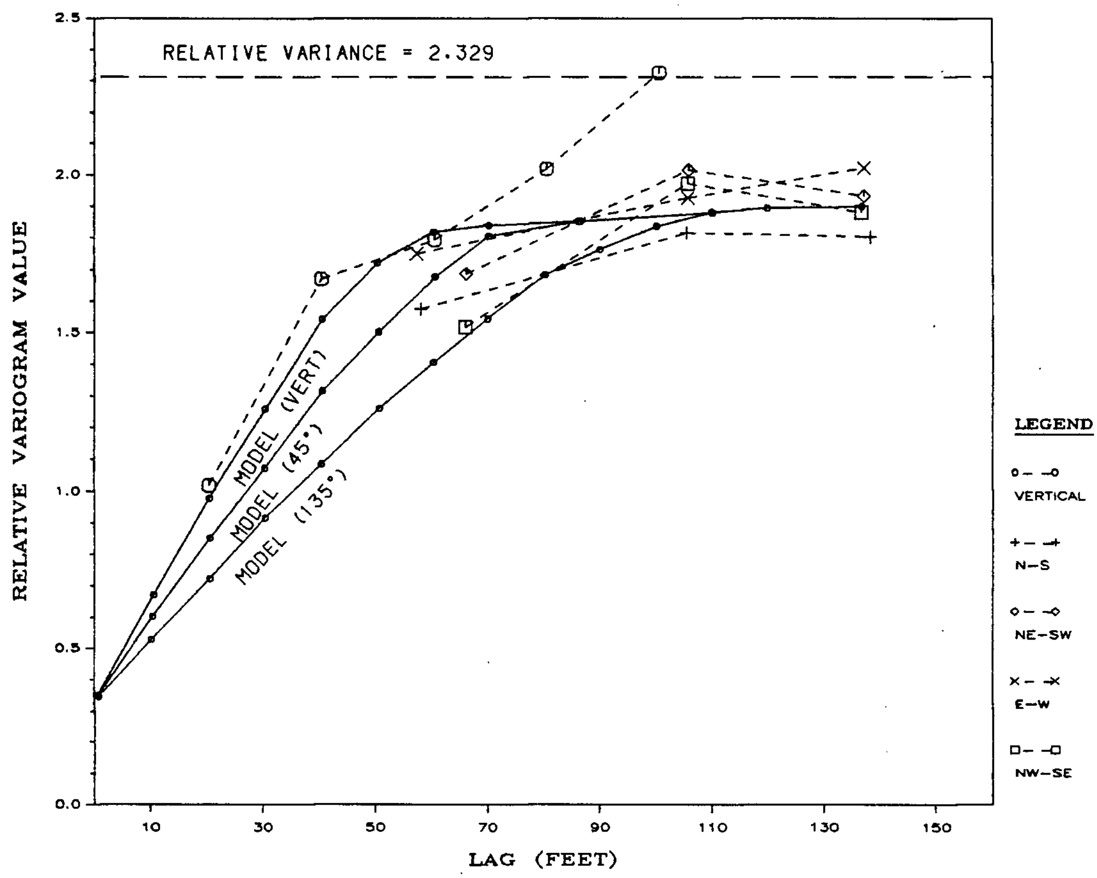


Fig. 9. Modelled relative variogram of the BEX data.

values were initially noted and plotted on early versions of the variograms, but were not used in modelling because they were considered too unreliable and inconsistent between the various types of variograms.

5.4.2 Some Observations on Variogram Modelling

Having defined the variograms which will be used later in this study, a slight digression into the nature of variograms is

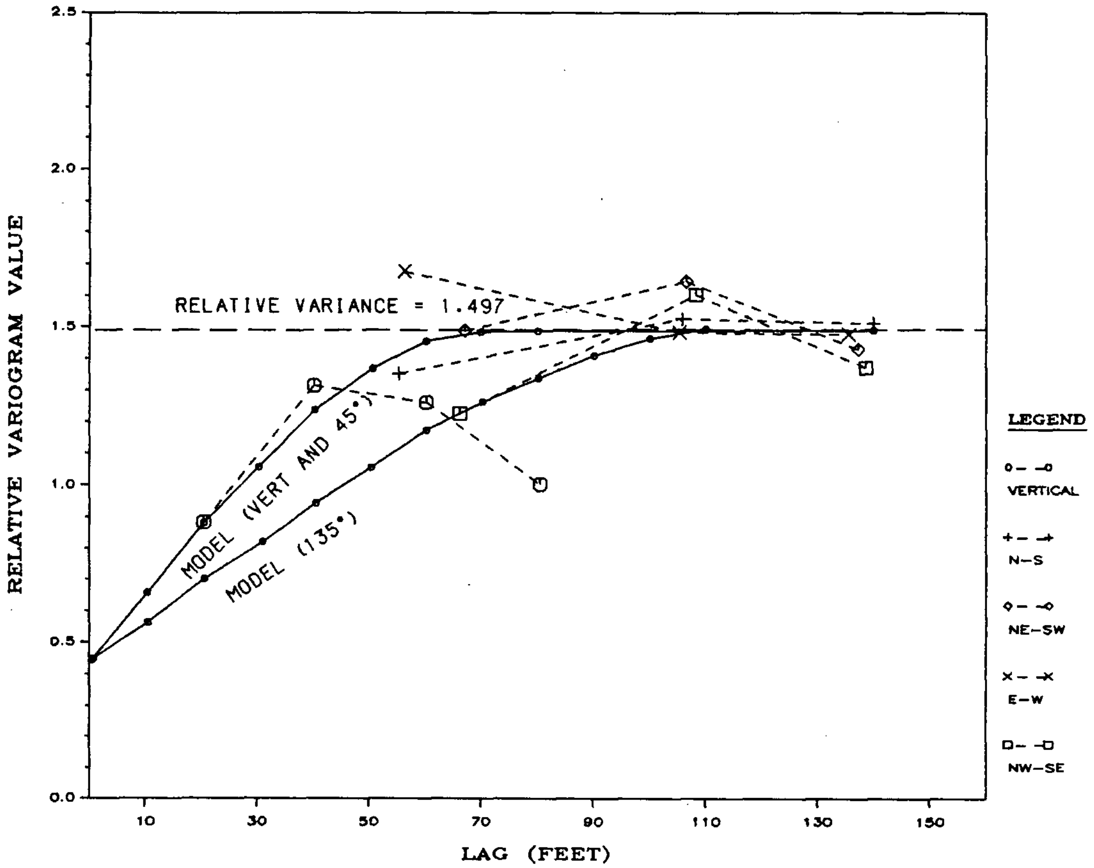


Fig. 10. Modelled relative variogram of the BEXG data.

undertaken. Although this particular section of the thesis might have been one of the shortest were it not for the following discussion, the study of variograms actually consumed over 50% of the time spent on the entire project because of the belief on the part of the author that repeated, sophisticated attempts at variogram modelling would a) provide better variograms which would b) provide better kriged estimates. Complex colour coded variogram clouds were drawn on a high resolution graphics monitor, and attempts were made to develop better variograms based on median squared pair differences and other percentiles, or a "different" relative variogram which was calculated as one half the mean squared pair differences divided by their mean pair value, etc. These variograms didn't provide any new, or more useful information than was already apparent from the actual, lognormal and relative variograms. After returning to basics and modelling the best relative variograms available, and proceeding to krige the data in the most reasonable fashion (including prerequisite back analyses), and then continuing on to conditional probability and final comparison of the results, in a final act of desperation a simple experiment was performed. The final relative variogram was rotated such that the major axis of anisotropy was 90° away, and one of the 20' block models (BUCKG) was re-kriged. Then the two kriged estimates were compared.

Both models calculate similar kriged estimates and kriging variances and produce nearly identical ore reserve estimates in every grade range category. The experiment tends to support David's statement that the variogram is robust and that "the effects of misinterpreting *C* and *a*, are not very important" (David, 1977).

However, there are slight differences in the results from the two different variograms (Table IV). The estimates using the rotated variogram predict a total of 6,500 more tons above the 0.020 cutoff at a slightly lower grade than the original variogram (0.041 opt. vs. 0.042 opt.), and it predicts about 4,600 tons less above the 0.050 cutoff at the same grade as the other estimate. Even more interesting was the fact that when the difference between the 2 estimates is greater than 0.010 opt. (arbitrarily chosen to differentiate between similar and

Table IV

Ore Reserves Predicted by Using the "Rotated" Variogram Compared to Kriged Exploration Estimate and "Actual" for the BUCKG Model.

BLOCK MODEL: BUCKG 20' BLOCKS - WITHIN ORE ZONE OUTLINE

METHOD: BHKRIGE BLASTHOLE KRIGED - "ACTUAL"

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
TOTAL	0.000	756122.25	0.040	30336.14	28070.44	0.007	184.60
TOTAL	0.010	728051.81	0.041	30151.54	124929.62	0.016	2012.15
TOTAL	0.020	603122.19	0.047	28139.39	276722.06	0.027	7487.60
TOTAL	0.035	326400.12	0.063	20651.79	143338.62	0.042	5952.25
TOTAL	0.050	183061.50	0.080	14699.55	183061.50	0.080	14699.55

BLOCK MODEL: BUCKG 20' BLOCKS - WITHIN ORE ZONE OUTLINE

METHOD: "GOOD" EXPLORATION "GOOD" KRIGED ESTIMATE

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
TOTAL	0.000	756122.25	0.039	29523.88	408.00	0.009	3.73
TOTAL	0.010	755714.25	0.039	29520.15	86186.00	0.017	1500.25
TOTAL	0.020	669528.25	0.042	28019.90	350814.87	0.028	9654.29
TOTAL	0.035	318713.37	0.058	18365.61	182996.25	0.041	7531.16
TOTAL	0.050	135717.12	0.080	10834.45	135717.12	0.080	10834.45

BLOCK MODEL: BUCKG 20' BLOCKS - WITHIN ORE ZONE OUTLINE

METHOD: "ROTATED" EXPLORATION "ROTATED" KRIGED ESTIMATE

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
TOTAL	0.000	756122.25	0.039	29212.79	0.00	0.000	0.00
TOTAL	0.010	756122.25	0.039	29212.79	80163.87	0.017	1390.62
TOTAL	0.020	675958.37	0.041	27822.17	358860.69	0.027	9746.67
TOTAL	0.035	317097.69	0.057	18075.50	185966.44	0.041	7628.64
TOTAL	0.050	131131.25	0.080	10446.85	131131.25	0.080	10446.85

dissimilar estimates), the estimate from the rotated variogram tends to be closer to the actual block grade determined from blasthole kriging significantly more often (204 estimates vs. 137), and the average error of the estimate is 7% lower than for the variogram that is actually used in this study. Block grades using the rotated variogram are also more likely to be close to the true grade in the highest category above 0.050 opt. by almost a two to one margin. But still, the fact remains that the originally modelled variogram did a slightly better job of predicting higher total reserves in the highest and most profitable grade ranges and there was no good reason to model the anisotropy in any other direction than that indicated by geology.

Perhaps, even though the anisotropy is slight, the 45° direction is actually the true anisotropy that should have showed up on the variograms. As was mentioned above, many variograms were examined, and in the course of studying the results, the following conclusion was reached: when data is lognormally distributed the variogram calculated from all sample pairs is more likely to be a measure of the continuity of grades <u>between</u> structures than a measure of the magnitude and direction of discontinuities <u>within</u> structures.

The variograms used here are biased toward showing anisotropies which relate to areas of highest grade differentials. This includes the relative variogram which has been calculated as $\gamma(h) \ / \ m(h)^2$ (David, 1977) where $m(h)$ is fairly constant at Buckhorn. These areas of highest grade differential occur at boundaries where gold grades increase rapidly from low background values. Within the smaller high grade structures, although there is some potential for achieving high grade differences amongst samples separated by a given distance, there are fewer pairs. Therefore, the subtle directional trends that might show up within the high grade areas where sampled values are similar, will be "drowned out" by the numerous pairs which are detecting high grade/low grade boundaries.

In other words, using Buckhorn as an example, the modelled variogram does not indicate in any way that where a block is evaluated in a high grade area where all samples are similar in grade, that the error estimate should be lower. Instead what it shows is that where there is a transition from very high to very low values, on average, it is better to weight the estimate relative to a 135° anisotropy and to assume a high kriging variance. Unfortunately, the same assumptions are applied indiscriminately to the calculation of every kriged grade in the deposit. The variogram tends to pick up the edges of structures and does not show the lower variance amongst samples within either the low grade areas or the high grade areas.

More complex forms of kriging, like indicator and probability kriging, take account of this observation by assuming that different grade ranges might best be kept separate and be modelled by different variograms but these methods have the inherent drawback of not having an associated kriging variance and creating numerous separate estimates for a block using indicators only instead of actual grades.

To propose a different solution to this problem, what if 3 or 4 actual or relative variograms were modelled? By examining a variogram cloud, determine 3 intervals of absolute differences between samples that would (say) represent squared differences for about 50% of all pairs in lag windows past the assumed range, then 70% of the squared differences, then 90%, and finally 100%. Thus regardless of the lag being calculated, if the squared difference exceeds the 50th percentile squared differences, but not the 70th percentile threshold, then that pair would be used in the calculation of each of the three highest variograms. When kriging, the maximum squared difference between any two of the samples selected to estimate a block would determine which one of the 3 or 4 variograms to use. This method might have the advantage of calculating an accurate kriged error estimate which takes into account the fact that the samples used in kriging (regardless of their actual grade) either were relatively the same grades, or conversely, varied tremendously. Also separate structures (anisotropies) might actually show up for each of the variograms. This seems to be the case at Buckhorn. Appendix E contains a listing of variogram values that were generated in approximately the same way as discussed above and the various variograms show that the major axes of anisotropy vary between 0° and 45° except for the one variogram which has been computed from all of the values in the composited data.

Although kriging using the rotated variogram at Buckhorn showed a result that might not occur often elsewhere, and although there is always the possibility that both variograms are wrong, there may be some merit in the idea that variograms, especially those derived from lognormally distributed data, represent structures relating to the areas where the highest grade differentials exist. Essentially, instead of grouping the data on the basis of grade ranges, the idea presented above would make the divisions on the basis of the variability ranges of the data used to calculate the kriged estimate. If the 10 or 12 values used to krige the block grade were all similar, one can be sure that the grade estimate will be better than if the grades varied over a wide range of values. It shouldn't matter if actual or relative variograms are used to represent these structures.

In addition to those discussed above, the variogram study produced some further observations:

1) Variogram clouds, although proving not to be too useful for actual modelling, were most useful in determining the lag windows which were used. These graphs showed the density of pairs at different distances, and resulted in the final selection of only 3 lag windows in every horizontal direction. In particular, the clustering of numerous pairs at approximately 110' in the 45° and 135° directions showed up nicely. Because of the 30° search window, the pairs at this distance represented samples that were separated by 50' in one direction and 100' in the other.

Also shown clearly on the variogram clouds were the mistakes that could be made by choosing incorrect or smaller lag windows for the sake of creating more points on the variogram curve. In some cases, because there were fewer samples in a small lag window, the variogram would become almost rhythmically spiky and in other cases, where a significant distance was dissected by short lag windows, an apparently nested variogram structure might show up.

2) The premise that the variogram sill should equal the variance (or relative variance) of the composited data was examined (i.e. David, 1988). Where only one population of assays (inside the ore outline) was modelled, the variogram sill and the population relative variance coincided (Fig. 10). Where there was a mix of samples in the original dataset, the sill was significantly lower than might be predicted by the relative variance (Fig. 9). This phenomenon was noted in actual, lognormal and relative variograms. In fact it may make sense to use this observation as a test for inappropriate mixing of sample populations. The discrepancy between the variogram sill and the population variance in the latter case might be explained by the fact that samples closest to each other tend to be from the same population generally (not always, but generally) and therefore, even though there is some mixing which will increase the variogram values calculated, the average variance amongst sample pairs is not as high as the sample set's overall variance. On the other hand, if a single population can be defined, the theoretical expectation that the variogram sill should equal the population variance is fulfilled.

Although all of the above observations may be on shaky ground because they are based only on the results from one deposit, and although there is not enough time to test all of these ideas out exhaustively in the present study, the results

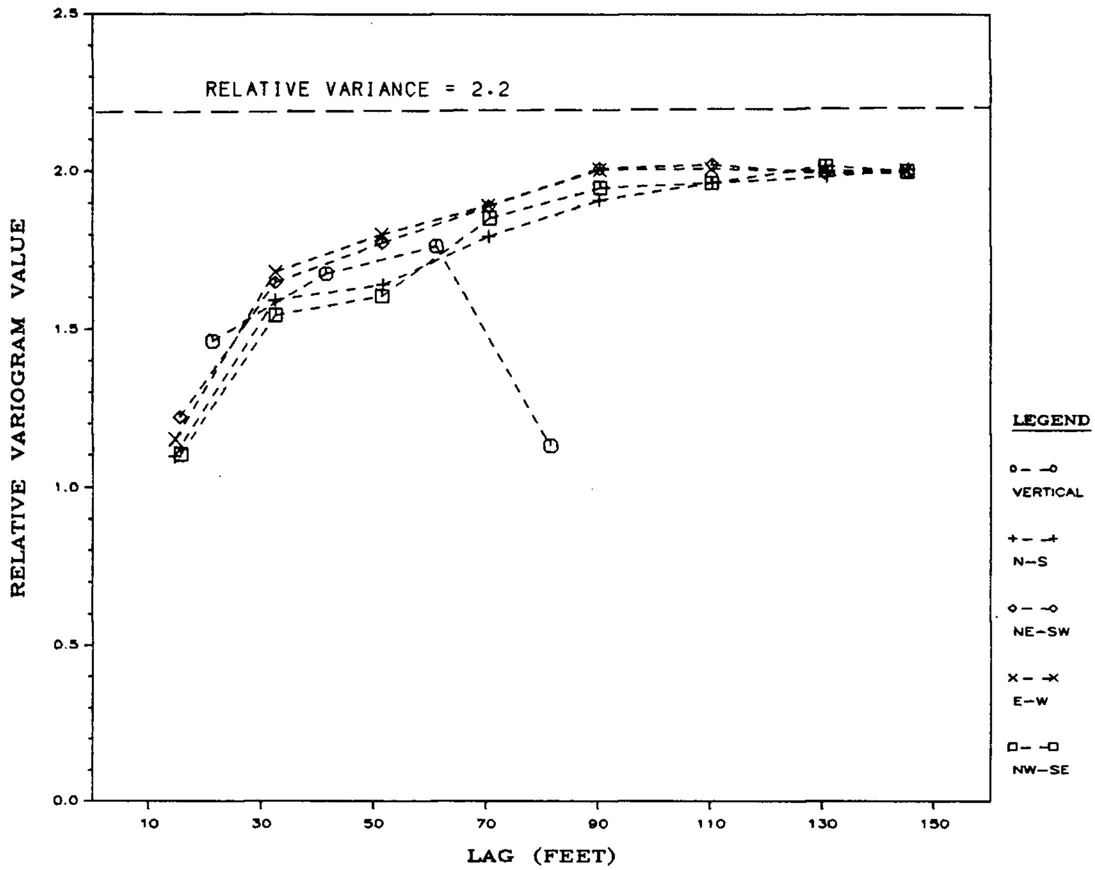


Fig. 11. Experimental relative variogram from the BBH data.

seemed to be consistent in the context of the Buckhorn study, and it was felt that these points should be mentioned.

It is also worth noting that the blasthole data was eventually modelled and showed a very slight anisotropy in the 135° and N-S directions with the N-S direction showing lower variogram values at longer lag distances, while the 135° direction showed the lowest values of $\gamma(h)$ at distances up to 50'. There may be nested structures, but not at any distance that could have been inferred from the exploration variograms.

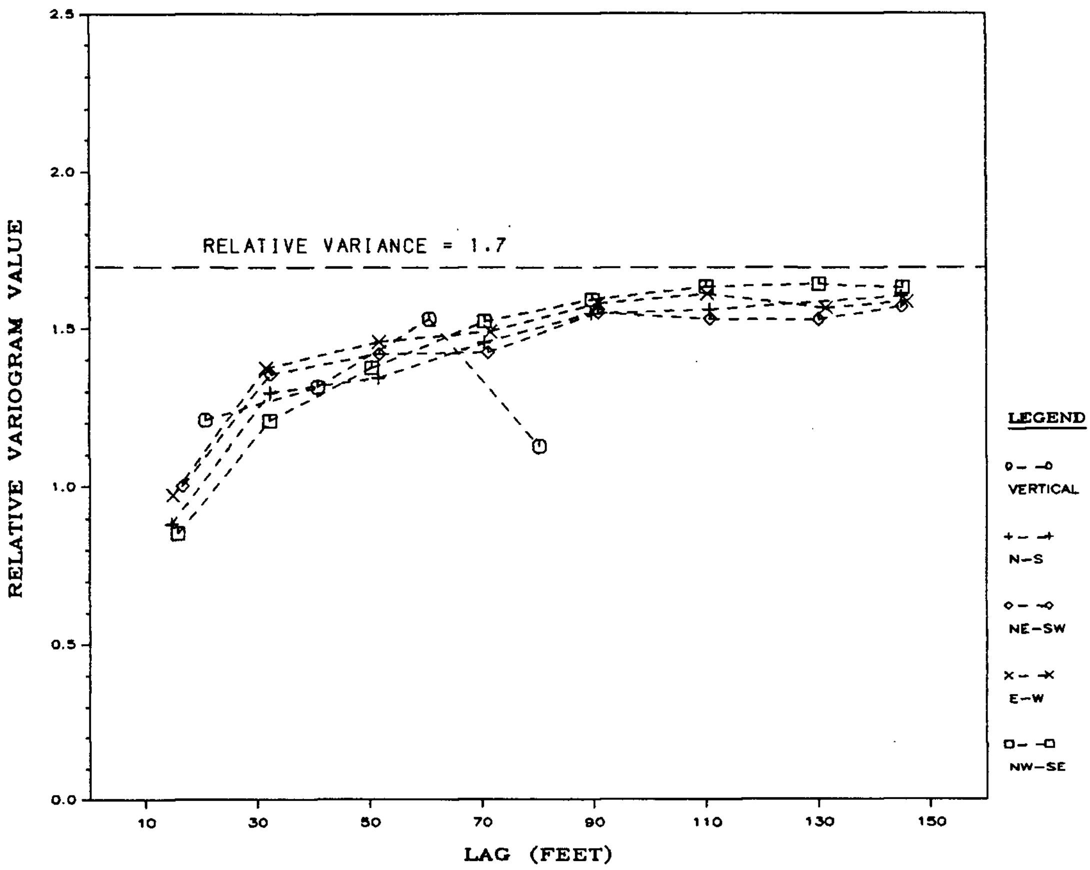


Fig. 12. Experimental relative variogram from the BBHG data.

Generally however, the blasthole calculations indicate essentially isotropic variograms (Figs. 11 and 12).

Finally, before leaving the subject of variograms, the effect of the 3-parameter lognormal distribution calculation should be mentioned. In order to create a relative kriging variance which would be consistent with the calculation of conditional probabilities calculated from a 3-parameter lognormal distribution, the value at each lag is calculated as γ / (*mean grade + constant*)^2. To make sure that kriged grades would not be affected by different constants applied to the relative variogram models, four separate kriged estimates for the BUCK 20' model using the BEX dataset were generated, one with no constant, and three with constants of 0.002, 0.005 and 0.050. The resulting kriged estimates were compared and all four were virtually identical. The relative shapes of the different variograms is all that is important -- the only difference is that each estimate now produces different relative kriging variances. In order to make the relative shapes the same, only C_0 and C were recalculated for the BEX data variogram using the different constants. Ranges and anisotropies were modelled identically.

The fact that the kriged grades would be the same was not an unexpected result. Kriging with either an actual or relative variogram produces an averaged value which is derived from the raw arithmetic data. When arithmetic data has a constant added to every value, the new mean minus the constant will equal the original mean and the arithmetic variance will be identical. Only the relative variance changes and this change is also reflected in the kriging variances which are calculated during kriging with a relative variogram that has the constant added into the denominator.

5.4.3 Kriging and Back Analysis

There is little to say about the method that was used to krige the data. Once the parameters were defined (Table V), the data was used to calculate kriged point samples at locations where composites were removed and the actual versus predicted grades were compared both in grade ranges and across various

Table V

Parameters Used for Kriging Exploration Data

Composite length		20'
Minimum number of samples accepted		5
Maximum number of samples accepted		12
Maximum search radius		150'
Rectangular search radius		150' x 150' x 30'
Relative variogram BEX	C_0, C	0.26 1.15
$(\gamma / (m + 0.005)^2)$		
	a (135°)	120'
	a (45°)	90'
	a (vert)	72'
Relative variogram BEXG	C_0, C	0.45 1.05
(γ / m^2)		
	a (135°)	120'
	a (45°)	70'
	a (vert)	70'
Maximum kriging variance		*n/a*

kriging variance ranges. Because relative variograms produce relative kriging variances which are influenced only by the geometry of the samples used (discussed later in the section on conditional probability), and because higher grade samples tended to be in the middle of the various imposed outlines, kriged estimates in the back analysis did not suffer significantly when kriging variances were higher near the edges of the outlines. Also to ensure that the proportional effect was indeed accounted for by using the relative variogram, relative kriging variances were plotted against kriged grades and showed comparable relative kriging variances across all grade ranges.

The variogram models were deemed acceptable and the 20' composites were then used to calculate kriged block grades.

6. CONDITIONAL PROBABILITY

6.1 THEORY

6.1.1 Introduction

The following description is the method proposed and used by G.F. Raymond (Raymond 1979, 1982, 1984). There is some disagreement as to whether the method should be called by the name conditional probability or changed to avoid conflict with other meanings of the term but traditional usage in the literature by Raymond is used here. That is, its use is continued here with the understanding that it refers strictly to the method referred to by Raymond and all references to conditional probability are used in this context.

6.1.2 The Conditional Distribution

Kriged block grades have an advantage over other estimates in that there is a simultaneously calculated measure of the error (kriging variance). Although grades estimated by kriging have the further theoretical property of being correct on average (a property known as conditional unbias), the estimates tend to smooth the true picture (David, 1977). If an operation were to mine to cutoff boundaries established from kriged estimates from exploration grades, the predicted grade and tonnage should be recovered, but in practice, there is usually better information available (geological information, visual estimates, blasthole data, etc.) upon which production decisions can be made. In general, this better selectivity can lead to mining a higher grade of ore than predicted by ordinary kriging from exploration samples. The method of calculating conditional probabilities attempts to predict the effect that the more abundant information will have on the final grade estimate, and on the distribution of ore blocks within the orebody. The method depends on an assumption of normal data distribution.

When one talks about kriged grade, the predicted, or expected average grade ($\bar{x}$) of a block is being referred to. Kriging variance (σ^2) is the magnitude of an expected squared deviation from the predicted mean grade for the block (a prediction of the error associated with the estimate). In other words, although it is nearly certain that the grade won't be exactly as predicted, there is an expectation (based on the knowledge of the properties of the normal distribution) that if the data is normally distributed, 67% of all true grades will be between $\bar{x} \pm \sigma$ (where σ is the square root of the kriging variance and can be thought of as a standard error). This means that some percentage of the blocks with kriged grades above cutoff will, in fact, be waste and others with predicted grades below cutoff will actually be ore (Fig. 13). If the distribution of actual grades for a particular expected kriged grade is normal as shown in Figure 13, both a tonnage above cutoff and the average grade of the ore fraction of the blocks can be calculated, based on the knowledge of the properties of the normal curve. This

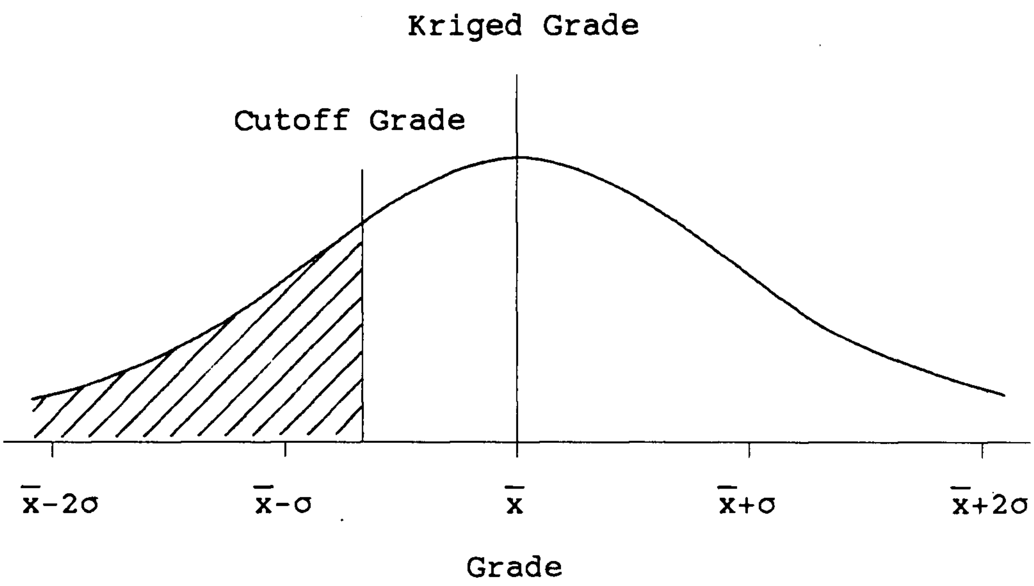


Fig. 13. The conditional distribution. Given a kriged block grade ($\bar{x}$) and kriging variance (σ^2), the actual block grades will be normally distributed about the mean. A certain percentage of blocks whose kriged grade is above cutoff will eventually turn out to be waste (shaded area under the curve).

average grade will be higher than the kriged grade because waste tons have now been eliminated. Notice that although it is possible to predict how many blocks are <u>expected</u> to be ore or waste, it is not possible to predict <u>which</u> ones will be ore. The predicted distribution of sample or block grades given estimated block grades, is called the conditional distribution. The mean value of the distribution (the exploration kriged estimate) is the conditional expectation, and the conditional variance is a measure of expected dispersion of actual grades about this mean.

As an example of the use of the conditional distribution, suppose there are 3 stockpiles representing waste, low grade, and

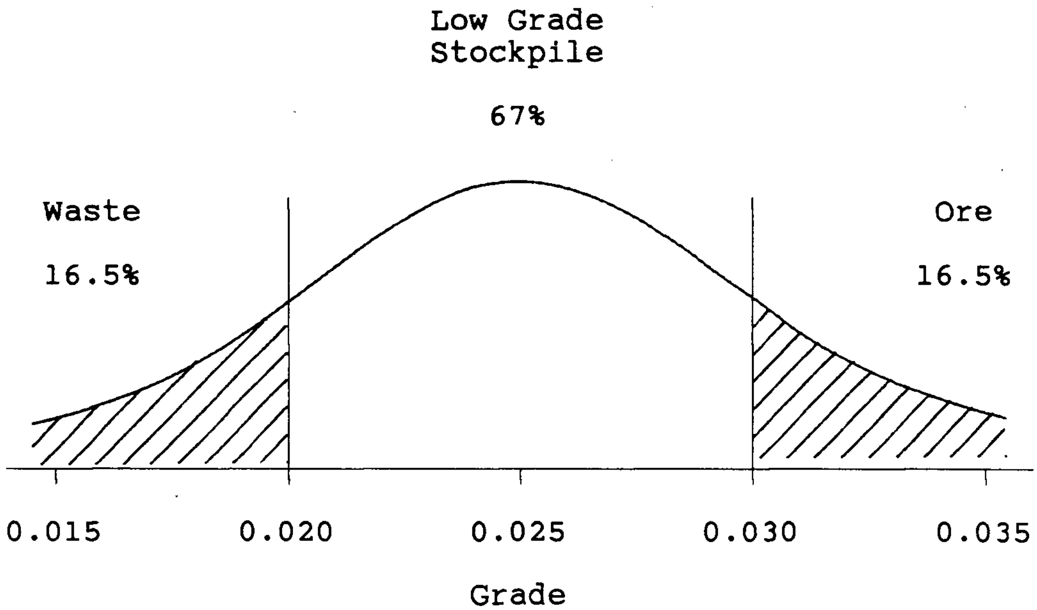


Fig. 14. Expectations of ore and waste derived from normally distributed block grades. If the kriged block grade is 0.025 and kriging variance is 0.000025, (σ = 0.005), 16.5% of the true block grades will be waste and 16.5% will actually be ore grade.

mill grade, with cutoffs at 0.020 and 0.030 opt. gold. If all blocks with a kriged grade of 0.025 opt. have a constant kriging variance of 0.000025 oz/ton^2 (σ = 0.005 opt.), then based on the normal distribution, there is an expectation that 16.5% of all blocks with kriged grade of 0.025 opt. should actually go to the waste stockpile and 16.5% should go to the ore stockpile (Fig. 14), although even with these errors, the average grade of the low grade stockpile would remain 0.025 opt.

Conditional probability uses exploration data and block estimates based on that data to estimate tonnages and grades which eventually will be mined. The calculation is refined by subtracting the kriging variance of production block estimates from exploration block kriging variances according to the "smoothing relationship" (David, 1977). The remaining conditional variance will approximate the uncertainty in the kriged block estimates using exploration data (an amount of error which can't be eliminated even when the deposit is mined). The resulting conditional distribution can be used to predict new probable tonnage and grade figures for the mine.

In the preceding discussion there were at least two assumptions made. First, the conditional distribution is known and assumed to be normally distributed -- this can be verified statistically with real data. The second assumption is that kriging variances of both the exploration and blasthole kriged grades are known (i.e. blasthole kriging variance could be calculated in advance of having the production data available). In practice, the problem is more complex.

6.1.3 Distribution of Sample Grades and Block Grades

In many grade estimation problems, the sample grades follow a lognormal distribution and, for practical purposes, this results in a corresponding lognormal distribution of actual block grades about the estimated grades (Journel and Huijbregts, 1978). Like the normal distribution, the characteristics of the lognormal distribution are also well known. Unfortunately grade distributions are rarely perfectly lognormal. If a lognormal distribution is plotted on log probability paper, a straight line

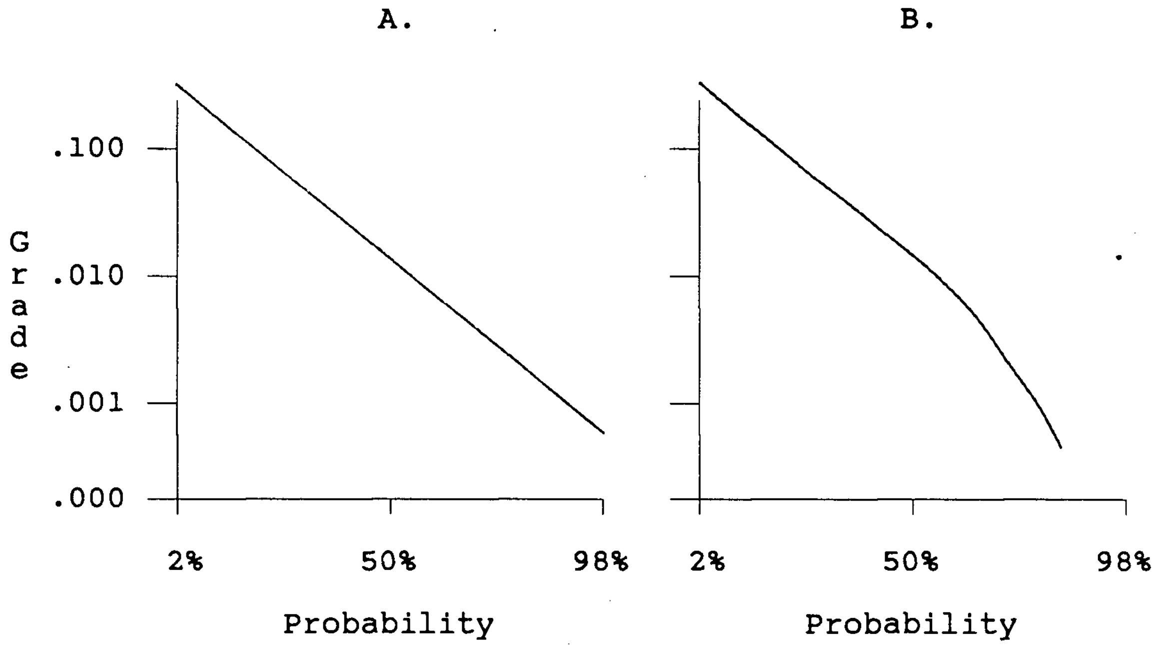


Fig. 15. Probability plots of perfect (A) and imperfect lognormal distributions (B). The curved portion of curve B is due to a larger than expected number of low grade samples.

can be expected (Fig. 15a). However in reality, the log transformed grades of real exploration data rarely plot as a straight line, but due in part to an abundance of low grade material around the orebody, the plotted distribution is non-linear as in Figure 15b.

For simplicity, the example shown in Figure 16 illustrates the problem for the case of a normal distribution of mineralized composites which have numerous low grade samples included in the study of the histograms. If these composites are used to estimate the blocks, conditional probability will not predict the correct distribution of actual block grades. If the erroneous

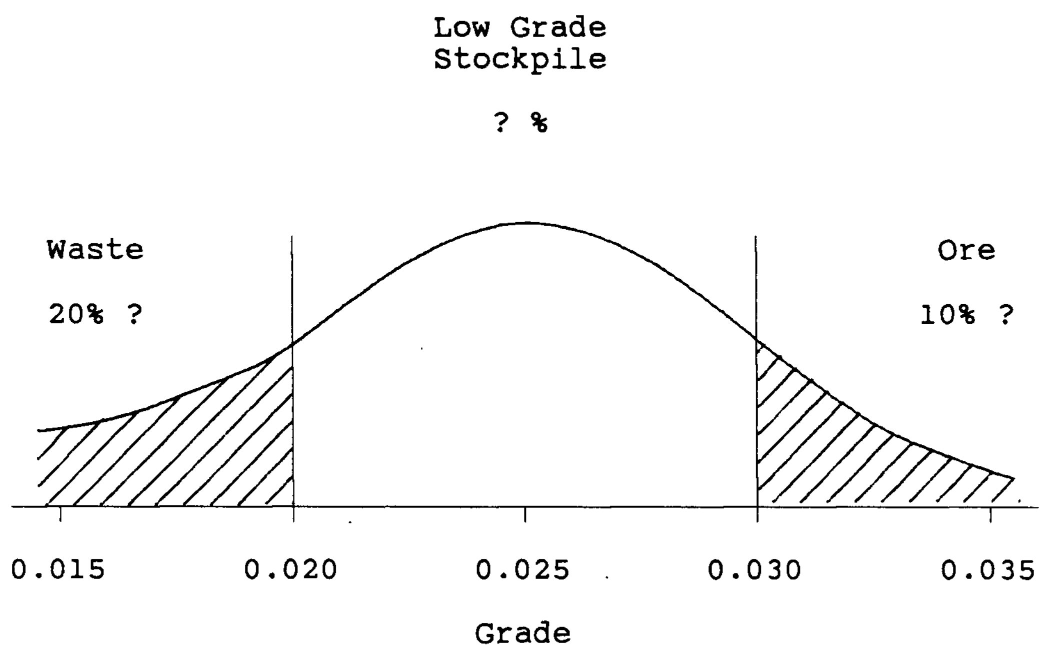


Fig. 16. The effect of estimating ore and waste percentages from imperfect normal distributions. The number of miscalculated blocks will no longer be predictable.

assumption is made that the distribution of actual blocks is normal, there will be a serious error in predicting the percentage of material above cutoff as well as in the determination of average grade of this material. Based on the same figures as in the previous example, (kriged grade = 0.025 opt. and $\sigma^2 = 0.000025$ oz/ton^2), 16.5% of the blocks are still predicted to be waste when in fact maybe 20% or more will be less than 0.02 opt. and similarly, less than 16.5% will really be ore grade. The log transformed grades in the BEX dataset at Buckhorn show a similar imperfect pattern (Fig. 5).

In order to calculate conditional probabilities, a way must be found to work with populations of a known distribution with predictable attributes (i.e. normal or lognormal). This doesn't present a problem with the BEXG dataset which is a lognormal subset of the complete data, but in order to calculate conditional probability for block models whose grades were interpolated from the BEX or BBH datasets, something will have to be done to correct for their imperfect distribution.

Raymond (1982) shows that many grade distributions can be made nearly lognormal by the addition of an experimentally derived constant to the raw grades before log transforming. The original distribution of samples is neither normal nor lognormal. However, the distribution of *ln(grade + constant)* approximates an acceptable lognormal distribution that can be used for modelling ore reserves.

As discussed earlier, a constant of 0.005 appears to straighten out the log probability plots of gold distributions for the BEX dataset. In calculating conditional probability, 0.005 opt. was added to the grades before log transforming. For the BEXG dataset, no constant was necessary.

6.1.4 Constant Kriging Variance

Because of the nature of the kriging equations, kriging variance is a function of both the geometry of the samples around the block to be estimated, and their grades. With lognormal data, one of the major problems that has to be faced is what's known as the proportional effect -- as grade increases, kriging variance (or the error of the estimate) increases. Although an attempt could be made to model this increase for various sample geometries and grade ranges, it would be simpler if a way could be found to obtain kriging variances that changed only due to changes in the pattern of the samples around the block to be estimated. Thus if there was, for instance, a square drilling pattern, a reasonably constant kriging variance could be expected. This can be done by use of relative variograms.

Because it has been observed that kriging variance tends to increase proportionally with grade squared, the variogram values at every lag distance can be divided by the square of the mean grade of all of the samples used to calculate the value. When the relative variogram is used to estimate blocks which are kriged from drillholes on a square or rectangular grid around the block, kriging variances will be fairly constant. In effect relative kriging variances will change only if the geometry or spacing of the samples around the block to be estimated is changed.

6.1.5 Combining 3-Parameter Lognormal Distributions with Relative Variograms

If the grades can be assumed to be 3-parameter lognormal, then kriging variance will have to be calculated in such a way as to predict the variance of the 3-parameter lognormal distribution. To do this, the relative variogram is calculated as $\gamma(h) / (m(h) + constant)^2$. The constant is the same one that is added to grades to produce the 3-parameter lognormal distribution, whereas *m* is the average of all samples used to calculate $\gamma(h)$ at h. The relative kriging variance will now correspond to the same altered distribution as the grades.

At Buckhorn, it is possible to assume constant relative kriging variances where exploration grid drilling is regularly arranged relative to blocks being estimated, and these relative variograms can be used in conjunction with a 3-parameter lognormal model of the sample data.

6.1.6 Determining the Constant Relative Blasthole Kriging Variance

Use of the relative variogram will theoretically provide the constant kriging variance without regard to grade of the samples, dependent only on the combination of block size to be estimated from blasthole kriging, and the blasthole pattern or spacing. If there is no blasthole data available, reasonable grades could be substituted at the anticipated blasthole locations, and a small subset of the theoretical pattern could be kriged. The resulting relative kriging variance could be used in the conditional probability calculation. The assumption will have to be made that the exploration and blasthole variograms are the same and the same constant (and therefore the same variogram) is used to model identical 3-parameter lognormal distributions. Alternatively, if actual blasthole data is available for a few of the benches (as at Buckhorn), the real blasthole data can be kriged.

Because all estimates in this study are based on exploration results only, kriged estimates from the exploration derived variograms were calculated from the available blasthole data at

Buckhorn. These block grades were plotted and relative kriging variances were contoured. By visual examination of the best sampled areas, and comparisons with histograms of kriging variances, only two constant relative kriging variances were necessary, one for each of the 20' block models and the other for the 60' block models. These are shown later in Table VI along with other parameters used in calculating conditional probability.

Once the constant blasthole kriging variance is calculated, exploration block models are examined to see if there is a maximum relative kriging variance. Usually any block with a higher relative kriging variance than the maximum will be ignored in subsequent calculations because the kriged grade would be considered too unreliable. This parameter was considered unnecessary at Buckhorn because the sample density was adequate in all locations and back estimation showed that kriged grades did not suffer significantly in any kriging variance range.

6.2 CALCULATION OF CONDITIONAL PROBABILITY

For each block in the mine model, the following information is now available:

1) The exploration kriged estimate.
2) The associated exploration kriging variance.
3) A maximum allowable exploration kriging variance.

4) The constant relative kriging variance from production kriging of blastholes.

5) A knowledge of the expected shape of the error distribution and, if necessary, the constant required for the 3-parameter lognormal distribution.

Other parameters that are required for the calculation include the specific gravity so that ore fractions (probabilities) can be converted to tonnage, an arbitrary minimum value to consider for ore (to prevent meaningless calculations in areas of waste), and finally the significant cutoff grades must be specified.

Therefore, assuming a block model has been prepared which contains kriged grade and relative kriging variance, only the following input parameters are needed to run the computer program which will calculate the conditional probabilities:

1) Cutoff grade.

2) Constant to add to grades for the 3-parameter lognormal distribution.

3) Minimum exploration kriged value for inclusion in the calculation.

4) Maximum acceptable exploration kriging variance.

5) Constant relative kriging variance of production estimates.

6) Specific gravity of ore.

Then for each block:

1) Check if the block is below minimum exploration kriged grade, or if kriging variance is above the maximum allowable -- ignore the block calculation if either condition is true.

2) Assume conditional expectation is kriged grade plus the constant.

3) Assume conditional variance is the exploration relative kriging variance minus the constant blasthole kriging variance. Multiply by $(kriged\ grade + constant)^2$ to obtain arithmetic variance.

4) Transform the conditional distribution to a log-normal model and calculate the percentage of material that is likely to be above the log transformed cutoff and then calculate the expected logarithmic grade of the ore fraction of the block.

5) Transform the predicted grade back to an arithmetic value and subtract the constant.

6) Multiply ore fraction times the block tonnage to obtain tonnage above cutoff for the block.

After calculating conditional probability for each block, the last step is to tally up the tonnages and determine the new grade to obtain final global estimates for the deposit. The parameters used for the Buckhorn conditional probability runs are summarized in Table VI. The calculation was performed on each of the 20' and 60' block models at 4 cutoff grades (0.01, 0.02, 0.035 and 0.05 opt. gold), a total of 16 runs. Ore reserves to

Table VI

Parameters Used to Calculate Conditional Probability

Block size	20' x 20' x 20' or 60' x 60' x 20'			
	BUCK	BUCK60		
Blasthole kriging variance	0.080	0.040		
Constant added to grades	0.005	0.005		
	BUCKG	BUCK60G		
Blasthole kriging variance	0.080	0.040		
Constant added to grades	*n/a*	*n/a*		
Cutoff grades	0.010	0.020	0.035	0.050
Minimum value to consider for ore	0.005			
Specific Gravity	1.634			

compare with the other types of estimates were calculated by assuming that total ounces on a bench were the same as total ounces predicted by kriging. For each of the other reserve reports, reserves were calculated within cutoff ranges and then cumulatively above cutoff grades. For conditional probability, total reserve above a cutoff grade is the result of the calculation. To calculate grades within cutoff ranges, it was necessary to work backwards -- tons and grade above 0.05 opt. were subtracted from tons and grade above 0.035 opt. by converting to metal (ounces of gold). This procedure was repeated until the calculation of metal in the 0.0 to 0.01 range was reached. For this grade range, total ounces (and tons) above

0.01 opt. were subtracted from total ounces above 0.0 predicted by the corresponding kriged block model. In this way it was possible to generate reserve reports that were identical in form to the other reports and which could therefore be compared with them.

6.2.1 Example Calculation of Conditional Probability

To illustrate the calculation of conditional probability, the following example is calculated using a kriged block grade of 0.030 opt. with a relative block kriging variance of 0.28. Assume the constant blasthole kriging variance has been calculated as 0.080, a constant of 0.005 is added to create a 3-parameter lognormal distribution and specific gravity is 1.634. The conditional probability calculation will be calculated for a 0.035 cutoff grade.

The conditional expectation ($\bar{x}$) will be the kriged grade + the 0.005 constant. Before working with the lognormal distribution, the 0.005 constant must also be added to the cutoff grade (x_c):

$$\bar{x} = 0.030 + 0.005$$
$$= 0.035$$
$$x_c = 0.035 + 0.005$$
$$= 0.040$$

The conditional variance (σ^2) is the exploration relative block kriging variance minus the blasthole constant relative block kriging variance. Arithmetic (as opposed to relative) kriging variance is calculated as follows:

$$\sigma^2 = (\ 0.28 - 0.08\ ) \times (\ 0.030 + 0.005\ )^2$$
$$= 0.000245$$

The logarithmic mean ($\bar{x}_{ln}$) and logarithmic variance (σ^2_{ln}) can now be calculated using standard equations:

$$\sigma^2_{ln} = ln \left(1 + \frac{\sigma^2}{\bar{x}^2} \right) \qquad [1]$$

$$= ln \left(1 + \frac{0.000245}{(0.035)^2} \right)$$

$$= ln\ (1.2)$$

$$= 0.18232$$

$$\bar{x}_{ln} = ln\ (\bar{x}) - \frac{\sigma^2_{ln}}{2} \qquad [2]$$

$$= ln\ (0.035) - \frac{0.18232}{2}$$

$$= -3.44357$$

Above a given cutoff grade (x_c), the ore fraction, or probability (T) and the grade above cutoff (G) are calculated as follows:

$$T = 1 - F\left(\frac{1}{\sigma_{ln}} \, ln \, \frac{x_c}{\bar{x}} + \frac{\sigma_{ln}}{2} \right) \qquad [3]$$

$$G = \frac{\bar{x}}{T} \left[1 - F\left(\frac{1}{\sigma_{ln}} \, ln \, \frac{x_c}{\bar{x}} - \frac{\sigma_{ln}}{2} \right) \right] \qquad [4]$$

where $F(z)$ can be read from standard tables showing the cumulative normal distribution (i.e. David, 1977, page 9). The program used for the actual calculations uses an approximation formula. Using values calculated previously, and substituting into equations [3] and [4] above:

$$T = 1 - F\left(\frac{1}{\sqrt{0.18232}} \, ln \, \frac{0.040}{0.035} + \frac{\sqrt{0.18232}}{2} \right)$$

$$= 1 - F\,(0.526)$$

Interpolating $F(0.526)$ from the table, gives ore fraction (T) equal to 0.299.

$$G = \frac{0.035}{0.299} \left[1 - F\left(\frac{1}{\sqrt{0.18232}} \, ln \, \frac{0.040}{0.035} - \frac{\sqrt{0.18232}}{2} \right) \right]$$

$$= 0.1169 \, [\, 1 - F\,(0.099)\,]$$

Again using a standard table $F(0.099)$ can be interpolated. The resulting grade above cutoff (G) is 0.0538. The constant which was originally added to the kriged grade must now be subtracted to yield a grade of 0.049 opt. Assuming block size for this example is 20' x 20' x 20', and knowing that specific gravity is 1.634, the tonnage of the whole block can be calculated:

$$\text{Total Block Tons} = 20 \times 20 \times 20 \times 1.634 \times \frac{62.42796}{2000}$$

$$= 408.03 \text{ Tons}$$

$$\text{Ore Tons} = \text{Total Block Tons} \times T$$

$$= 408.03 \times .299$$

$$= 122.16 \text{ Tons}$$

Therefore, when tallying up reserves above a 0.035 opt. cutoff, the 20' block will contribute 122 Tons at a grade of 0.049 opt. gold.

Although it is unlikely that this specific block will yield exactly 122 tons of ore, the result can be re-stated. Since we are dealing with constant relative variances, in general it can be said that approximately 30% of all blocks which had an initial kriged grade of 0.030 opt., will in fact be found to be above the 0.035 cutoff and the grade of these ore blocks will average 0.049 opt. gold.

6.3 DISCUSSION

In Raymond's method of dealing with conditional probability, he uses point kriging on the centers of a grid for kriging exploration grades and for determining constant relative kriging variances of blastholes. He says that size of the chosen grid will not affect any estimate except to improve local precision, and the assumption is that mining will be to contours around kriged blasthole point estimates (Raymond, pers. comm.). This is a practical approach which he has tested over the years, but it draws criticism from those who would argue that the point estimates don't represent block grades.

In the approach used here, block grades are kriged, and furthermore, comparisons are made to blasthole kriged block grades where the block size is exactly the same as estimated from exploration data. In other words, when 60' blocks are kriged from exploration data, the mining method is assumed to be selective to 60'. The constant relative kriging variance is computed for the 60' blocks, and conditional probability is calculated for the large block size using a 12' to 14' theoretical blasthole spacing. This alleviates any problem of deciding which is the best block dispersion to superimpose on a kriged mean. There is no need to apply the affine correction methods described by some authors (i.e. David, 1977, 1988; Giroux and Sinclair, 1986). The kriging variance of the block is theoretically the required dispersion minus the kriging variance of a similar size block which will be kriged using blasthole data according to the "smoothing relationship" (David, 1988).

Another assumption stated by Raymond, and supported by Sinclair (pers. comm.) is that the distribution of errors is assumed to be lognormal, and that this is the weakest of the assumptions made when dealing with this method of conditional probability. It is the author's conviction that this assumption is neither necessary, nor is it used in any way when calculating conditional probability as described earlier. The only assumptions made in this regard are that the distribution of kriged blasthole grades is lognormal, that the exploration kriged estimate is conditionally unbiased (i.e. kriged grade = conditional expectation), and that exploration kriging variances minus blasthole kriging variances reflects the expected block dispersion (conditional variance).

The only questionable assumption that Raymond makes, is that the normalized shape of the 3-parameter lognormal distribution will be replicated in every grade range (i.e. that the conditional distribution is 3-parameter lognormal regardless of kriged grade). In the case of the BEX dataset at Buckhorn, a 3-parameter distribution was modelled exactly as laid out by Raymond in his various papers. In the case of the BEXG dataset there was no need to add a constant and therefore, theoretically, the latter calculation would lead to results which render any doubts about the 3-parameter distribution irrelevant. What about the two models (BUCK and BUCK60) which used the assumption?

It is obvious that in the case of this study, the subselected BEXG and BBHG datasets represent the upper portions of the BEX and BBH datasets respectively. They indicate near perfect lognormal distributions. This means that the distribution of actual block grades given predicted grades, in all 4 block models, in any area that could potentially be ore (> 0.020 opt. gold), is lognormal. The shape of a histogram of the predicted grades will also be lognormal and will not look like the histogram of the raw BEX dataset composites (that was modelled as 3-parameter lognormal) in any of the 4 block models.

Therefore, in reality, the problem is not the distribution of the 20' exploration composites in the BEX data, or the corresponding kriged block grades -- in higher grade areas they are both actually lognormal, instead the problem will be kriging variances. By using a variogram which is calculated from all of the available data without regard to mixing of different populations, the anisotropies were about the same and the ranges were similar, but predicted kriging variances will be higher than they should be. The conditional distribution of low grade areas is lognormal but an incorrect variogram model is being applied and therefore kriging variances in these areas are calculated incorrectly. Since, in the case of the Buckhorn deposit, nearly 100% of the lower grade population is below the lowest grade of ore that is of interest (0.02 opt. gold), there is no real problem. In the high grade areas, the 3-parameter approximation, although never perfect, is a much better predictor of relative kriging variance than if the constant hadn't been used. But when conditional probability is modelled from this variogram, the conditional distributions will still be wider (and therefore less precise) than they should be. When grade estimation is performed for a block where kriging used samples from both populations, there's going to be trouble, regardless of the modelled frequency distribution or variogram used.

A greater amount of effort should go into choosing a variogram which will minimize kriging variance in the obvious areas of interest -- i.e. in areas of higher grade ore. As will be shown in the next chapter the effort will be repaid with a better global ore reserve estimate.

In order to support the basic methodology and assumptions used in Raymond's approach to conditional probability, the following summary is offered with corresponding quotes or references, mainly from Michel David's most recent text-book on geostatistical ore reserve estimation (David, 1988):

1) Ordinary kriging is used to define the conditional distribution. "Ordinary kriging ... is still the tool to use in most circumstances" (David, 1988, page 112).

2) The relative variogram can be calculated as $\gamma(h)/m(h)^2$ (ibid., page 43). The relative variogram is the "favoured alternative" to the logarithmic variogram when dealing with proportional effect (ibid., page 42). It is the best variogram to use with ordinary kriging (ibid., page 127). The relative variance times the kriged grade squared will yield the arithmetic variance (ibid., page 99). The relative variogram should reach a sill value which is equal to the population relative variance (ibid., page 47). The theoretical expectation that the use of the relative variogram will yield constant relative kriging variances can be checked experimentally

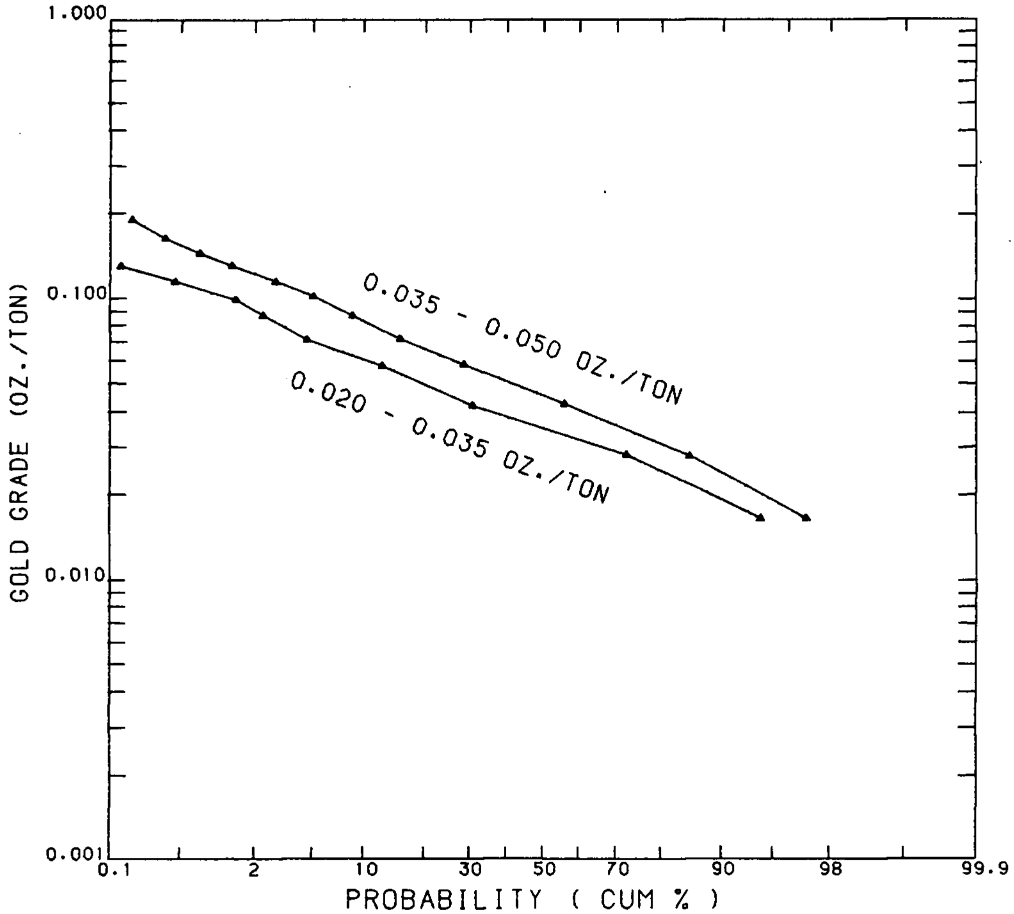


Fig. 17. Cumulative probability plot of the grades of actual (blasthole kriged) blocks given exploration kriged block grades within 2 grade ranges where there were a significant number of blocks. The plot shows that actual block grades are lognormally distributed about the mean (kriged grade).

using back estimation techniques. This expectation was checked at Buckhorn using both back estimation and contour maps of exploration and blasthole relative kriging variances and proves to be true.

3) The lognormal case is most common in mining applications (David, 1988, page 123). "On the basis of experience", estimated blocks will follow a lognormal distribution with a smaller

variance (ibid., page 74). Figure 17 shows that within the two grade ranges where there are the most samples estimated (0.020-0.035 opt. and 0.035 - 0.050 opt.), the distribution of actual kriged blasthole block grades is also approximately lognormal at Buckhorn (as predicted by Journel and Huijbregts, 1978).

4) In the non-normal case, kriging is the best approximation to the conditional expectation (David, 1977, page 255 and page 309). In the author's opinion, the weak assumption, the one which may have the greatest effect on the conditional probability estimate is this assumption that the ordinary kriged estimate, using logarithmic data, will be conditionally unbiased. Figure 18 shows a comparison of kriged blasthole block grades (variable 1) within ranges of exploration kriged estimates (variable 2). The results show acceptable comparisons within the important grade ranges (0.020 - 0.065 opt.) where 90% of the estimated ore blocks are contained, but overall, there is not a perfect correspondence between expected and actual average grades. However, the assumption that the kriged estimate actually is conditionally unbiased is the same one that is made by the many geostatisticians who work with ordinary kriging and relative variograms.

5) The last assumption is also traditionally well accepted by geostatisticians. That is the "smoothing relationship" described by David (1988, page 74):

$$VAR(Z^{*}) = VAR(Z) - \sigma_K^2$$

"This relationship has been checked experimentally very well".

```
COMPARE ACTUAL VS. EXPLORATION KRIGED BLOCK GRADES

        NORTH     EAST     ELEV  ! REG. VARIANCE  !   RANGES    MIN.   1ST INC  NO.INC1  2ND INC
MIN.      0.0      0.0      0.0  ! CONST    0.000 ! VARIABLE 1  0.000   1.000        2    1.500
MAX.  99999.0  99999.0  99999.0  ! POWER    2.000 ! VARIABLE 2  0.000   1.000        2    1.500

VARIABLE       ELEMENT  MULTIPLIER           DESCRIPTOR                      FILENAME FILETYPE
1 DEPENDENT     AU      100.0000  BBNG KRIGED BLOCK GRADES - "ACTUAL"       ACTUAL2G KRIGE
2 INDEPENDENT   AU      100.0000  BEXG EXPLORATION KRIGED BLOCK GRADES      BEXGKRIG KRIGE
  LOCATION                        20' BLOCK MODEL WITIN OUTLINE             BUCKG    GRID

VAR 1                                      < <  VAR 2    MIDPOINTS  > >                     ROW
MIDPT  0.92  1.74  2.75  4.11  5.59  7.06  8.71 10.34 11.61 13.27 14.83 16.47 17.81 18.92  0.00  TOTAL
 0.62     0    21    60    16     3     0     1     0     2     1     0     0     0     0     0    104
 1.60     0    76   217    60    11     4     3     3     2     3     1     0     0     0     0    380
 2.70     0   122   409   148    32    14    12     7     6     3     1     0     0     0     0    754
 4.16     0    21   174   129    28    12    12     2     0     0     0     0     0     0     0    378
 5.71     0     4    81    68    35     5     6     0     1     0     0     0     0     0     0    200
 7.16     0     1    25    34    16    12     8     0     1     1     0     0     0     0     0     98
 8.69     0     2     7    18    11     6     3     6     2     2     1     0     0     0     0     58
10.10     1     0    11    12    18     1     2     5     1     1     0     1     1     0     0     54
11.62     0     1     3     8     4     1     2     1     1     4     2     0     1     2     0     30
13.02     0     0     1     3     3     1     0     0     0     0     0     2     1     1     0     13
14.66     0     0     0     2     1     2     1     1     0     0     0     0     0     0     0      7
16.65     0     0     0     1     0     0     0     0     0     1     0     2     0     0     0      4
17.84     0     0     0     0     0     0     0     0     0     1     1     0     0     0     0      3
19.18     0     0     1     1     1     0     0     0     0     0     0     0     1     0     0      4
 0.00     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0      0
 0.00     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0      0
24.19     0     0     0     0     1     0     0     0     0     0     0     0     0     0     0      1
 0.00     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0      0
 0.00     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0      0
27.88     0     0     0     0     0     0     0     1     0     0     0     0     0     0     0      1
TOTAL     1   248   989   500   164    58    50    26    16    17     6     5     4     3     0   2089

VARIABLE 2
MEAN   0.92  1.74 |2.75  4.11  5.59| 7.06  8.71 10.34 11.61 13.27 14.83 16.47 17.81 18.92  0.00 |3.826|
                  |                |                                                            |     |
VARIABLE 1        |                |                                                            |     |
MEAN  10.06  2.41 |3.12  4.32  5.84| 5.66  5.37  7.30  4.50  7.53  9.01 13.93 13.45 12.32  0.00 |3.848|
SD.    0.00  1.36  1.89  2.64  3.51  3.12  2.99  5.58  3.55  5.31  5.51  2.60  3.51  0.59  0.00  2.290
VARIA  0.00  1.84  3.57  6.97 12.29  9.71  8.91 31.11 12.59 28.23 30.40  6.75 12.29  0.34  0.00  5.865
REG V 0.000 0.316 0.367 0.374 0.360 0.303 0.309 0.583 0.622 0.498 0.374 0.035 0.068 0.002 0.000  0.363

ABSOLUTE DIFFERENCE VARIABLES(1-2)

MEAN   9.14  0.99  1.29  1.90  2.65  2.91  3.94  4.88  7.11  6.67  7.00  3.05  5.00  6.60  0.00  1.791
RT MS  9.14  1.52  1.89  2.62  3.52  3.51  4.48  6.33  7.98  7.87  8.19  3.80  5.61  6.62  0.00  2.451
MN SQ 83.63  2.30  3.56  6.86 12.42 12.29 20.10 40.04 63.61 61.91 67.08 14.43 31.44 43.80  0.00  7.352
REGMS99.891 0.819 0.473 0.404 0.403 0.247 0.263 0.376 0.469 0.350 0.298 0.052 0.098 0.122 0.000  0.523

CUMULATIVES ABOVE LOWER LIMIT

VARIABLE 1
LOLIM  0.00  1.00  2.00  3.50  5.00  6.50  8.00  9.50 11.00 12.50 14.00 15.50 17.00 18.50 20.00
NO.    2089  1985  1605   851   473   273   175   117    63    33    20    13     9     6     2
MEAN  3.848 4.017 4.589 6.268 7.955 9.59910.96412.09113.79715.78017.57419.14620.25621.46326.033

VARIABLE 2

LOLIM  0.00  1.00  2.00  3.50  5.00  6.50  8.00  9.50 11.00 12.50 14.00 15.50 17.00 18.50 20.00
NO.    2089  2088  1840   851   351   187   129    79    53    37    20    14     9     5     2
MEAN  3.826 3.827 4.108 5.691 7.94810.01411.34213.00714.31315.48117.36218.44719.54620.93623.963
1GIV2 3.848 3.845 4.038 5.109 6.241 6.592 7.012 8.054 8.42110.11712.32013.73713.63013.77515.958

TOTAL VARIABLE 1 !  MEAN     3.848 ! SD       2.810 ! VARIA     7.898 ! V/(M+C**P)   0.533
TOTAL VARIABLE 2 !  MEAN     3.826 ! SD       2.428 ! VARIA     5.893 ! V/(M+C**P)   0.403
```

Fig. 18. Computer printout of the comparison between actual grades (variable 1) and kriged estimates (variable 2) within estimated grade ranges. 90% of all ore grade kriged estimates fall in columns 3,4 and 5. The comparison shows that kriged estimates are conditionally unbiased in these 3 ranges (maximum difference is approximately 0.004 opt.). However, in other columns, the correspondence is not as good. All data has been multiplied by 100. The same program was used in back estimation and to analyze some of the other "actual vs. predicted" comparisons.

In addition to the above, David also provides support for the assumption that a pre-defined contour based on a cutoff grade can be useful for defining potential ore (David, 1988, page 200), that samples in a dataset should not include obviously barren samples (ibid., page 37), and that variograms which are computed across boundaries with high grade variations (as discussed earlier in the section on variograms) "gives no indication about the continuity inside the mineralized zone" (ibid., page 37). Finally, along the lines of computing a variogram within a pre-defined boundary (ibid., page 105):

".... the extension variance should be derived from the variogram of the grade of samples in selection units above the cut-off. When the selection units are points, we can simply compute the variogram of the grade of samples above the cut-off. Actually, we do not expect that the structural characteristics of the variogram (magnitude of nugget effect, ranges, anisotropy) will change dramatically with the cut-off. The main changes will most probably affect the sill of the variogram".

The only point made in this thesis that differs from this analysis, is that the anisotropies might also change, depending on the geometry of the deposit, and the distribution of ore grades within the orebody.

The itemization of all of these points has been performed mainly to illustrate that conditional probability, as implemented in this study, uses assumptions which are commonly made by most geostatisticians when they employ a relative variogram and ordinary kriging to estimate ore reserves. The method developed by Raymond is an elegant derivation of minable reserves using common, everyday assumptions. Although not used here, even the use of point kriging from exploration estimates should be acceptable if the assumption is made that mining will be to contoured point estimates derived from blasthole data on the same grid -- there is no change of support.

7. COMPARISON OF CALCULATED ORE RESERVES

7.1 INTRODUCTION

Various methods were used to compare the block models and ore reserves. Scattergrams of predicted versus actual block grades were produced (Appendix F). Individual reserve reports (Appendix C) were examined to compare predicted grades and tonnages within ranges and total tonnage and grade above cutoffs, and bench maps of the resulting predicted block grades (Appendix B) were compared with each other. The vast amount of data gave a good idea of what the results were, but methods of distilling the data into a smaller amount of space were required in order to explain the patterns.

These methods and the broad conclusions that can be drawn from them are detailed below. Later, each of the individual questions raised in Chapter 1 are re-examined separately.

7.2 METAL GRAPHS

Four graphs were constructed (Figs. 19, 20, 21 and 22), one for each block model, to show the total amount of metal (ounces of gold), for both benches, that was above each of the significant mine cutoffs. The greater than 0.050 opt. cutoff is

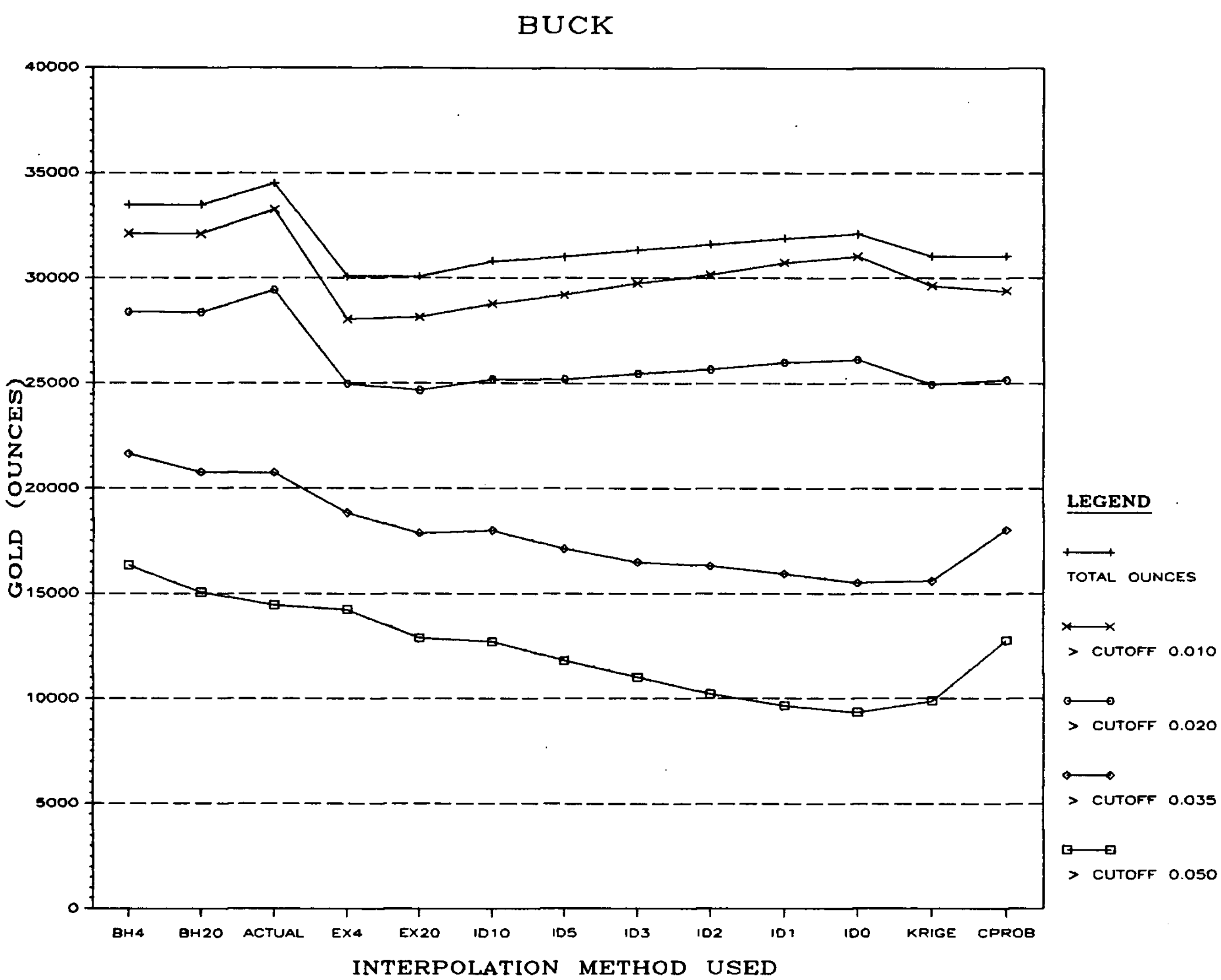


Fig. 19. Metal graph for the BUCK block model.

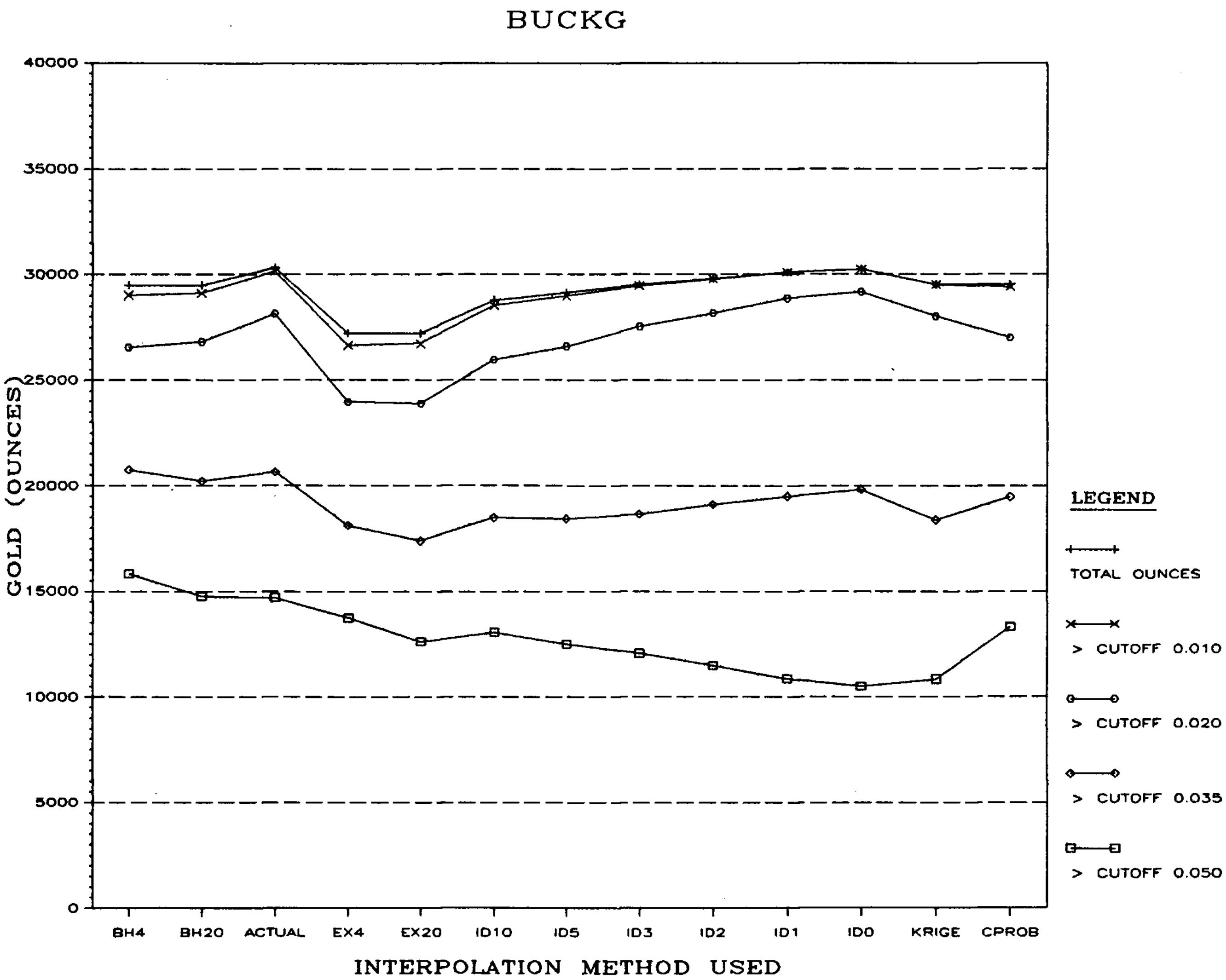


Fig. 20. Metal graph for the BUCKG block model.

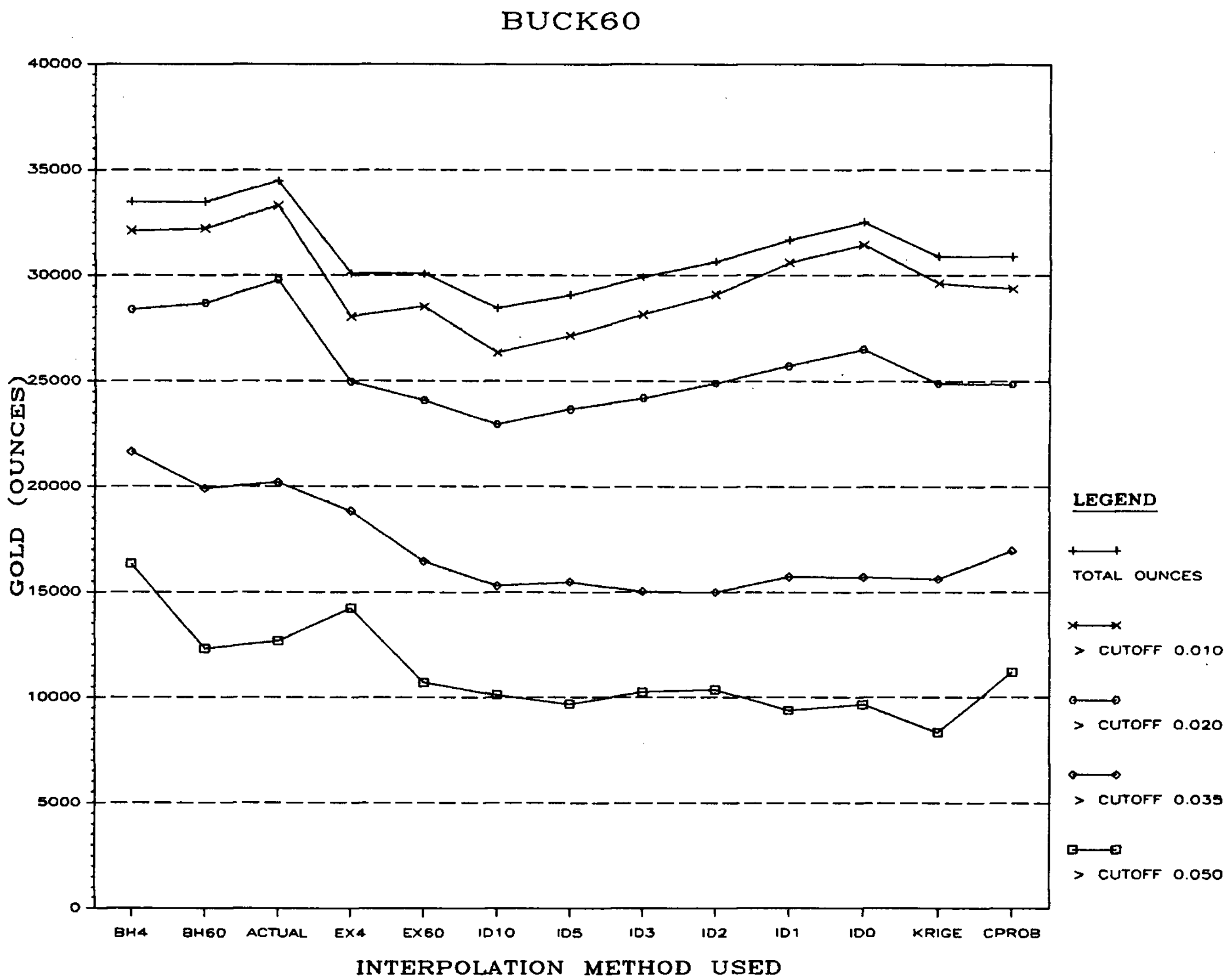


Fig. 21. Metal graph for the BUCK60 block model.

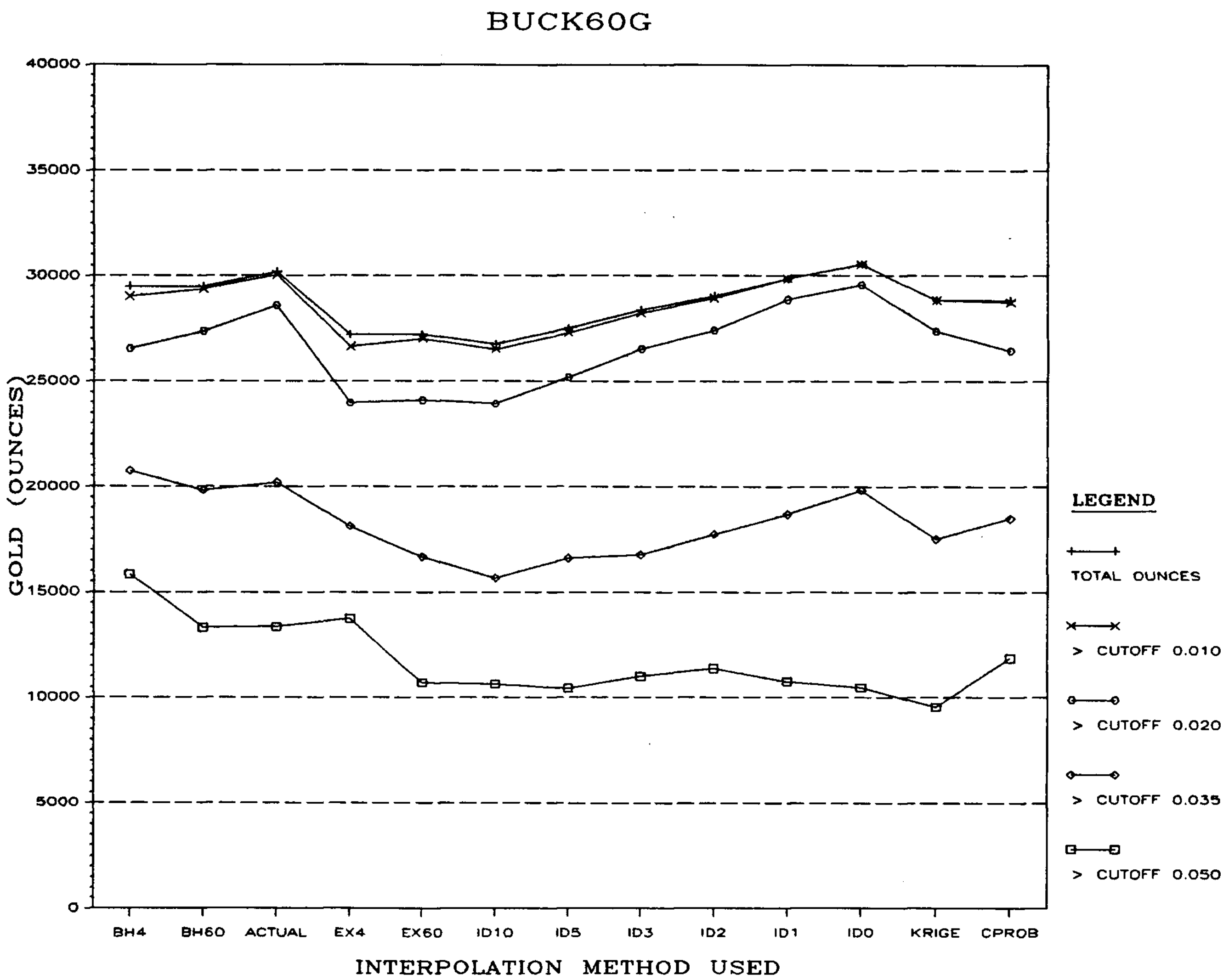


Fig. 22. Metal graph for the BUCK60G block model.

not actually monitored at the mine but the other categories are significant. They represent waste (< 0.010 opt.), lean ore (0.010 to 0.020 opt.), low grade (0.020 to 0.035 opt.) and ore (> 0.035 opt. gold).

Each of the exploration estimates is shown with 3 blasthole estimates, where BH4 is the 4' polygonal estimate, either BH20 or BH60 is the polygon weighted 20' or 60' block estimate depending on the model's block size, while results from blasthole kriging are referred to as "actual". Similarly, EX4 and EX20 or EX60, are the polygonal and polygon weighted estimates from exploration data. The meanings of the rest of the abbreviations on the graphs should be self-evident. Comparing between 20' and 60' models shows, as would be expected, that the 4' polygonal estimate based on either the exploration or the blasthole data is identical for both models. Straight polygonal estimates are obviously insensitive to block size.

The 60' block models are very sensitive to the chosen method of predicting ore reserves above lower grade cutoffs, and less sensitive to method at higher cutoffs compared to the 20' block models. For example, in both 60' models, total amount of metal above 0.050 opt. is similar across all averaging methods (polygon weighted, inverse distance and ordinary kriging).

Notice also, that ordinary kriging invariably produces one of the lowest (and least accurate) estimates above 0.05 opt., and also tends to be lowest in the over 0.035 opt. category for 20' block models. On the other hand, conditional probability, which directly uses <u>both</u> kriged grade <u>and</u> kriging variance, and which cannot be calculated from any of the other methods, is consistently either the best estimate or is one of the 2 or 3 closest approximations of the actual metal above any of the cutoffs shown. This is especially true for the BUCKG and BUCK60G block models where interpolation was confined to the ore zone outline. More important, whichever of the other estimates is close varies with the specified cutoff. For instance, referring to the BUCKG graph (Fig. 20), conditional probability shows excellent agreement with actual estimates on every curve. Generally above 0.0, 0.01 and 0.02, kriging, ID0, ID1, ID2 and ID3 are also good estimators. Above 0.035, the three closest estimates are the straight average (ID0), followed by conditional probability and ID1, and over 0.05 opt., the only estimate that even comes close is ID10.

Still referring to the graphs, any estimate for the geologically constrained block models (Figs. 20 and 22), has a chance of predicting the correct ore reserves above a given cutoff, while for the other two unconstrained models, no method predicts the correct ore reserves above any cutoff range. This is because all of the extra ounces reported from blastholes in these block models come from areas of low results from exploration drilling. No ore reserve method, no matter how smart, can predict metal where there was absolutely no indication of ore from exploration drilling. These extra ounces represent "new" ore that was found when the deposit was mined.

Conditional probability comes close to providing not only the best estimate of the grade distribution of the ore, it also produces very similar estimates between the different models. It appears to be the safest, and most stable all-round estimate of ore reserves regardless of what data is used, or for which block model it is calculated. No other method comes close to providing similar (or correct) answers for all four block models.

Assuming that the most valid comparisons will be provided from the BUCKG and BUCK60G models (which show excellent agreement between conditional probability and the kriged blasthole data), these two models also show that kriging does generate "a correct on average" estimate. Kriging provides a fairly accurate estimate of total ounces in the deposit. However, it does not show a correct on average estimate of contained ounces above any significant cutoff grade. What it does provide is a good, unbiased distribution of block grades and good estimates of kriging variance, which in turn allow for excellent results from conditional probability.

Notice also that in each of the four graphs, if the trend of the inverse distance calculations is examined, there is some grade at which the trend of the line tends to flatten, and for the 20' models the trend of the curve then reverses itself. The ID0 calculation always predicts the most total ounces in the deposit and usually the lowest number of ounces above 0.05 opt., while inverse distance to the tenth (ID10) behaves in exactly the opposite manner. For the 60' models, the lines become flat at either 0.035 or 0.05 opt. cutoffs.

Finally, although there are other patterns that might be found, there is one important observation that can be made here. The BUCKG block model is apparently a good approximation of the ore reserve picture within the imposed outline. The actual production figures (tons and grade) at the mine are based on straight polygonal estimates derived from the daily blasthole data. The mine was designed on 20' blocks and monthly grade reconciliation (predicted vs. actual) is a comparison of the polygonal production estimate from blastholes with original 20' bench plots of the grade predicted from the exploration drilling (using an inverse distance cubed calculation). An examination of the BUCKG metal graph (Fig. 20), shows that on average, the polygonal (BH4) and polygon weighted (BH20) estimates are similar, and that these estimates agree well with the conditional probability estimate (no exploration method predicts the higher amount of low grade tons shown by blasthole kriging). These estimates would not have been close to the predicted reserves if the pit was designed using 60' blocks (compare BH4 and BH60 on Fig. 22). This seems to show that either by luck, accident, or design, the production statistics at the mine using straight polygonal boundaries, will reconcile to the predicted ore reserves about as well as if they had tried to combine the raw data into 20' blocks before comparing. On a monthly basis, either method will adequately reflect predicted production in every grade range, and for grade reconciliation (subtracting production from reserves) either method will also work. Kriged blasthole grades, which should reflect the "best estimate", were not used at the mine. All indications are that more gold would have been recovered if mining was done to kriged blasthole outlines.

In summary, the graphs show the strengths and weaknesses of the various methods quite well. Overall, conditional probability seems to be the best estimator regardless of block model or what raw data was used -- at least compared to each of the other methods shown. However, in most cases, it is not sufficient to make comparisons on "metal above cutoff". If more tons have to be mined to recover the gold, the economics of the planned operation can be drastically affected. A comparison of tons and grade within grade ranges is also necessary.

7.3 ORE RESERVE CHARTS

Many of the same conclusions can be drawn from the ore reserve charts (Tables VII, VIII, IX and X). These, however, show a number of things in addition. The charts essentially distill all of the reserve reports (Appendix C) into four pages. Instead of showing cumulative reserves above a grade cutoff however, these tables show the predicted amount of ore (tons, grade, and ounces of gold) within the grade ranges. In addition, a percentage error has been calculated (compared to actual), and a rank from best to worst estimate has been assigned. The various estimates are then printed, in order of rank assigned, but on either side of the actual reserve figure depending on whether the given method underestimated or overestimated the tonnage, grade, or ounces, as the case may be. Because the conditional probability method attempts to predict the reserves from production blasthole kriging based on an error estimate derived from exploration kriging, and because blasthole kriging in general should provide the best estimate of mined tons and

TABLE VII

COMPARISON OF BLASTHOLE INDICATED RESERVES WITHIN GRADE CATEGORIES VS. RESERVES CALCULATED BY EACH EXPLORATION METHOD FOR BUCK BLOCK MODEL (20 FOOT BLOCKS, NO ORE OUTLINE).

Legend: METHOD / TONS (X 1000) / % ERROR / RANK

TONNAGE

CUT-OFF		METHOD	TONS (X 1000)	% ERROR	RANK
0.000	UNDERESTIMATED	ID0	161.9	0.359	7
		ID1	179.6	0.289	5
		ID2	228.2	0.096	3
		KRIGE	228.7	0.094	2
	ACTUAL	BHK	252.5	0.000	0
	OVERESTIMATED	ID3	262.7	0.041	1
		ID5	315.8	0.251	4
		CPROB	325.7	0.290	6
		ID10	375.3	0.487	8
		EX20	407.3	0.613	9
		EX4	450.3	0.784	10
0.010	UNDERESTIMATED	EX4	215.6	0.141	4
		EX20	239.1	0.048	2
		ID10	249.3	0.007	1
	ACTUAL	BHK	251.1	0.000	0
	OVERESTIMATED	ID5	275.9	0.099	3
		CPROB	287.0	0.143	5
		ID3	294.6	0.173	6
		ID2	304.7	0.214	7
		KRIGE	316.0	0.258	8
		ID1	322.9	0.286	9
		ID0	326.9	0.302	10
0.020	UNDERESTIMATED	EX4	232.1	0.278	10
		EX20	254.4	0.209	8
		CPROB	267.8	0.167	6
		ID10	270.6	0.158	5
		ID5	302.5	0.059	2
	ACTUAL	BHK	321.5	0.000	0
	OVERESTIMATED	ID3	335.1	0.042	1
		ID2	349.8	0.088	3
		KRIGE	350.5	0.090	4
		ID1	376.6	0.172	7
		ID0	395.2	0.229	9
0.035	UNDERESTIMATED	EX4	110.6	0.264	10
		EX20	119.8	0.203	9
		CPROB	126.5	0.158	8
		ID10	126.8	0.156	7
		ID5	129.4	0.139	6
		ID3	132.4	0.119	5
		KRIGE	139.2	0.073	4
		ID2	147.9	0.016	3
		ID0	148.4	0.012	2
	ACTUAL	BHK	150.3	0.000	0
	OVERESTIMATED	ID1	151.7	0.010	1
0.050	UNDERESTIMATED	KRIGE	120.7	0.329	10
		ID0	122.7	0.317	9
		ID1	124.2	0.309	8
		ID2	124.4	0.308	7
		ID3	130.3	0.275	6
		ID5	131.5	0.268	5
		ID10	133.2	0.259	4
		EX20	134.5	0.252	3
		EX4	146.5	0.185	2
		CPROB	148.0	0.176	1
	ACTUAL	BHK	179.7	0.000	0

GRADE

CUT-OFF		METHOD	GRADE (OPT.)	% ERROR	RANK
0.000	UNDERESTIMATED	EX4	0.004	0.200	1
	ACTUAL	BHK	0.005	0.000	0
	OVERESTIMATED	EX20	0.005	0.000	0
		ID10	0.005	0.000	0
		CPROB	0.005	0.000	0
		ID5	0.006	0.200	1
		ID3	0.006	0.200	1
		ID2	0.006	0.200	1
		ID1	0.006	0.200	1
		KRIGE	0.006	0.200	1
		ID0	0.007	0.400	2
0.010	UNDERESTIMATED	EX4	0.014	0.067	1
		ID10	0.014	0.067	1
	ACTUAL	BHK	0.015	0.000	0
	OVERESTIMATED	EX20	0.015	0.000	0
		ID5	0.015	0.000	0
		ID3	0.015	0.000	0
		ID2	0.015	0.000	0
		ID1	0.015	0.000	0
		ID0	0.015	0.000	0
		KRIGE	0.015	0.000	0
		CPROB	0.015	0.000	0
0.020	UNDERESTIMATED	EX4	0.026	0.037	1
	ACTUAL	BHK	0.027	0.000	0
	OVERESTIMATED	EX20	0.027	0.000	0
		ID10	0.027	0.000	0
		ID5	0.027	0.000	0
		ID3	0.027	0.000	0
		ID2	0.027	0.000	0
		ID1	0.027	0.000	0
		ID0	0.027	0.000	0
		KRIGE	0.027	0.000	0
		CPROB	0.027	0.000	0
0.035	UNDERESTIMATED	ID5	0.041	0.024	1
		ID3	0.041	0.024	1
		ID2	0.041	0.024	1
		ID1	0.041	0.024	1
		KRIGE	0.041	0.024	1
	ACTUAL	BHK	0.042	0.000	0
	OVERESTIMATED	EX4	0.042	0.000	0
		EX20	0.042	0.000	0
		ID10	0.042	0.000	0
		ID0	0.042	0.000	0
		CPROB	0.042	0.000	0
0.050	UNDERESTIMATED	ID0	0.076	0.050	2
		ID1	0.078	0.025	1
	ACTUAL	BHK	0.080	0.000	0
	OVERESTIMATED	ID2	0.082	0.025	1
		KRIGE	0.082	0.025	1
		ID3	0.084	0.050	2
		CPROB	0.086	0.075	3
		ID5	0.090	0.125	4
		ID10	0.095	0.188	5
		EX20	0.096	0.200	6
		EX4	0.097	0.213	7

OUNCES

CUT-OFF		METHOD	OUNCES	% ERROR	RANK
0.000	UNDERESTIMATED	ID0	1066	0.143	3
		ID1	1154	0.073	1
	ACTUAL	BHK	1245	0.000	0
	OVERESTIMATED	KRIGE	1396	0.121	2
		ID2	1445	0.161	4
		ID3	1576	0.266	5
		CPROB	1654	0.329	6
		ID5	1803	0.449	7
		EX20	1934	0.554	8
		EX4	2023	0.626	9
		ID10	2032	0.633	10
0.010	UNDERESTIMATED	EX4	3088	0.193	7
		EX20	3468	0.094	3
		ID10	3589	0.062	2
	ACTUAL	BHK	3826	0.000	0
	OVERESTIMATED	ID5	4002	0.046	1
		CPROB	4234	0.107	4
		ID3	4302	0.124	5
		ID2	4494	0.175	6
		KRIGE	4713	0.232	8
		ID1	4757	0.243	9
		ID0	4912	0.284	10
0.020	UNDERESTIMATED	EX4	6132	0.294	9
		EX20	6785	0.219	7
		CPROB	7141	0.178	6
		ID10	7193	0.172	5
		ID5	8067	0.071	2
	ACTUAL	BHK	8685	0.000	0
	OVERESTIMATED	ID3	8973	0.033	1
		ID2	9353	0.077	3
		KRIGE	9354	0.077	3
		ID1	10046	0.157	4
		ID0	10620	0.223	8
0.035	UNDERESTIMATED	EX4	4595	0.271	10
		EX20	4997	0.208	9
		CPROB	5266	0.165	8
		ID10	5284	0.162	7
		ID5	5332	0.154	6
		ID3	5477	0.132	5
		KRIGE	5704	0.096	4
		ID2	6097	0.033	3
		ID0	6165	0.022	2
		ID1	6274	0.005	1
	ACTUAL	BHK	6306	0.000	0
0.050	UNDERESTIMATED	ID0	9334	0.354	10
		ID1	9658	0.331	9
		KRIGE	9880	0.316	8
		ID2	10207	0.293	7
		ID3	11004	0.238	6
		ID5	11798	0.183	5
		ID10	12710	0.120	4
		CPROB	12751	0.117	3
		EX20	12886	0.108	2
		EX4	14236	0.015	1
	ACTUAL	BHK	14446	0.000	0

T A B L E   V I I I

COMPARISON OF BLASTHOLE INDICATED RESERVES WITHIN GRADE CATEGORIES VS.
RESERVES CALCULATED BY EACH EXPLORATION METHOD FOR BUCKG BLOCK MODEL
(20 FOOT BLOCKS, WITHIN ORE OUTLINE).

TONNAGE

CUT-OFF					.......UNDERESTIMATED...							ACTUAL	...OVERESTIMATED......								
0.000	METHOD				ID1	ID0	KRIGE	ID2	ID3	CPROB	ID5	BHK	ID10	EX20	EX4						
	TONS (X 1000)				0.0	0.0	0.4	2.9	7.8	14.8	19.9	28.1	39.4	73.6	101.9						
	% ERROR				1.000	1.000	0.985	0.898	0.720	0.474	0.290	0.000	0.403	1.623	2.631						
	RANK				7	7	6	5	4	3	1	0	2	8	9						
0.010	METHOD						ID0	ID1	KRIGE	ID2	ID3	BHK	ID5	CPROB	ID10	EX4	EX20				
	TONS (X 1000)						60.4	69.2	86.2	95.9	118.7	124.9	150.4	152.8	169.8	186.4	193.1				
	% ERROR						0.516	0.446	0.310	0.233	0.050	0.000	0.204	0.223	0.359	0.492	0.546				
	RANK						9	7	5	4	1	0	2	3	6	8	10				
0.020	METHOD									EX4	EX20	BHK	CPROB	ID10	ID5	ID3	ID2	ID0	ID1	KRIGE	
	TONS (X 1000)									221.8	243.9	276.7	279.2	280.6	301.7	324.7	328.9	335.7	338.2	350.8	
	% ERROR									0.199	0.118	0.000	0.009	0.014	0.090	0.173	0.189	0.213	0.222	0.268	
	RANK									7	4	0	1	2	3	5	6	8	9	10	
0.035	METHOD								EX4	EX20	ID10	BHK	ID5	CPROB	ID3	KRIGE	ID2	ID1	ID0		
	TONS (X 1000)								105.5	114.1	129.7	143.3	143.9	147.9	159.9	183.0	186.6	210.1	224.1		
	% ERROR								0.264	0.204	0.095	0.000	0.004	0.032	0.116	0.277	0.302	0.465	0.563		
	RANK								6	5	3	0	1	2	4	7	8	9	10		
0.050	METHOD	EX20	KRIGE	ID0	ID10	ID1	ID5	EX4	ID2	ID3	CPROB	BHK									
	TONS (X 1000)	131.3	135.7	135.9	136.6	138.7	140.2	140.5	141.9	145.0	161.5	183.1									
	% ERROR	0.283	0.259	0.258	0.254	0.243	0.234	0.232	0.225	0.208	0.118	0.000									
	RANK	10	9	8	7	6	5	4	3	2	1	0									

GRADE

CUT-OFF					.......UNDERESTIMATED...							ACTUAL	...OVERESTIMATED......								
0.000	METHOD								ID1	ID0	EX4	BHK	EX20	ID10	ID5	ID3	ID2	CPROB	KRIGE		
	GRADE (OPT.)								0.000	0.000	0.006	0.007	0.007	0.007	0.007	0.007	0.008	0.008	0.009		
	% ERROR								1.000	1.000	0.143	0.000	0.000	0.000	0.000	0.000	0.143	0.143	0.286		
	RANK								3	3	1	0	0	0	0	0	1	1	2		
0.010	METHOD								EX4	EX20	ID10	BHK	ID5	ID3	CPROB	ID2	KRIGE	ID1	ID0		
	GRADE (OPT.)								0.014	0.015	0.015	0.016	0.016	0.016	0.016	0.017	0.017	0.018	0.018		
	% ERROR								0.125	0.062	0.062	0.000	0.000	0.000	0.000	0.063	0.063	0.125	0.125		
	RANK								2	1	1	0	0	0	0	1	1	2	2		
0.020	METHOD										EX4	BHK	EX20	ID10	ID5	ID3	CPROB	ID2	ID1	ID0	KRIGE
	GRADE (OPT.)										0.026	0.027	0.027	0.027	0.027	0.027	0.027	0.028	0.028	0.028	0.028
	% ERROR										0.037	0.000	0.000	0.000	0.000	0.000	0.000	0.037	0.037	0.037	0.037
	RANK										1	0	0	0	0	0	0	1	1	1	1
0.035	METHOD							ID5	ID3	ID2	ID1	KRIGE	BHK	EX4	EX20	ID10	ID0	CPROB				
	GRADE (OPT.)							0.041	0.041	0.041	0.041	0.041	0.042	0.042	0.042	0.042	0.042	0.042				
	% ERROR							0.024	0.024	0.024	0.024	0.024	0.000	0.000	0.000	0.000	0.000	0.000				
	RANK							1	1	1	1	1	0	0	0	0	0	0				
0.050	METHOD									ID0	ID1	BHK	KRIGE	ID2	CPROB	ID3	ID5	EX20	ID10	EX4	
	GRADE (OPT.)									0.077	0.078	0.080	0.080	0.081	0.082	0.083	0.089	0.096	0.096	0.098	
	% ERROR									0.037	0.025	0.000	0.000	0.012	0.025	0.038	0.113	0.200	0.200	0.225	
	RANK									3	2	0	0	1	2	3	4	5	5	6	

OUNCES

CUT-OFF					.......UNDERESTIMATED...							ACTUAL	...OVERESTIMATED......								
0.000	METHOD				ID1	ID0	KRIGE	ID2	ID3	CPROB	ID5	BHK	ID10	EX20	EX4						
	OUNCES				0	0	4	23	59	125	146	185	262	480	561						
	% ERROR				1.000	1.000	0.980	0.875	0.682	0.323	0.207	0.000	0.420	1.602	2.041						
	RANK				7	7	6	5	4	2	1	0	3	8	9						
0.010	METHOD						ID0	ID1	KRIGE	ID2	ID3	BHK	ID5	CPROB	ID10	EX4	EX20				
	OUNCES						1072	1219	1500	1632	1949	2012	2386	2406	2580	2672	2837				
	% ERROR						0.467	0.394	0.254	0.189	0.032	0.000	0.186	0.196	0.282	0.328	0.410				
	RANK						10	8	5	3	1	0	2	4	6	7	9				
0.020	METHOD								EX4	EX20	ID10	BHK	CPROB	ID5	ID3	ID2	ID0	ID1	KRIGE		
	OUNCES								5848	6500	7472	7488	7535	8174	8882	9050	9371	9386	9654		
	% ERROR								0.219	0.132	0.002	0.000	0.006	0.092	0.186	0.209	0.251	0.254	0.289		
	RANK								7	4	1	0	2	3	5	6	8	9	10		
0.035	METHOD							EX4	EX20	ID10	ID5	BHK	CPROB	ID3	KRIGE	ID2	ID1	ID0			
	OUNCES							4394	4771	5414	5931	5952	6146	6572	7531	7634	8630	9309			
	% ERROR							0.262	0.198	0.090	0.004	0.000	0.033	0.104	0.265	0.283	0.450	0.564			
	RANK							6	5	3	1	0	2	4	7	8	9	10			
0.050	METHOD	ID0	KRIGE	ID1	ID2	ID3	ID5	EX20	ID10	CPROB	EX4	BHK									
	OUNCES	10486	10834	10853	11473	12069	12494	12615	13063	13312	13732	14700									
	% ERROR	0.287	0.263	0.262	0.219	0.179	0.150	0.142	0.111	0.094	0.066	0.000									
	RANK	10	9	8	7	6	5	4	3	2	1	0									

TABLE IX

COMPARISON OF BLASTHOLE INDICATED RESERVES WITHIN GRADE CATEGORIES VS. RESERVES CALCULATED BY EACH EXPLORATION METHOD FOR BUCK60 BLOCK MODEL (60 FOOT BLOCKS, NO ORE OUTLINE).

TONNAGE (METHOD – TONS (X 1000) – % ERROR – RANK)

CUT-OFF		METHOD	TONS (X 1000)	% ERROR	RANK
0.000	UNDERESTIMATED	ID0	156.1	0.299	5
0.000	UNDERESTIMATED	ID1	169.7	0.238	4
0.000	UNDERESTIMATED	KRIGE	202.0	0.093	2
0.000	ACTUAL	BHK	222.7	0.000	0
0.000	OVERESTIMATED	ID2	243.3	0.092	1
0.000	OVERESTIMATED	CPROB	275.1	0.235	3
0.000	OVERESTIMATED	ID3	294.5	0.322	6
0.000	OVERESTIMATED	EX60	309.5	0.390	7
0.000	OVERESTIMATED	ID5	343.1	0.540	8
0.000	OVERESTIMATED	ID10	395.8	0.777	9
0.000	OVERESTIMATED	EX4	450.3	1.022	10
0.010	UNDERESTIMATED	EX4	215.6	0.072	3
0.010	ACTUAL	BHK	232.5	0.000	0
0.010	OVERESTIMATED	ID10	234.3	0.008	1
0.010	OVERESTIMATED	ID5	245.7	0.057	2
0.010	OVERESTIMATED	ID3	272.4	0.172	4
0.010	OVERESTIMATED	ID2	294.4	0.267	5
0.010	OVERESTIMATED	EX60	302.3	0.300	6
0.010	OVERESTIMATED	CPROB	307.2	0.322	7
0.010	OVERESTIMATED	KRIGE	321.5	0.383	8
0.010	OVERESTIMATED	ID0	332.2	0.429	9
0.010	OVERESTIMATED	ID1	338.6	0.456	10
0.020	UNDERESTIMATED	EX4	232.1	0.347	10
0.020	UNDERESTIMATED	EX60	285.2	0.198	9
0.020	UNDERESTIMATED	ID10	292.6	0.177	8
0.020	UNDERESTIMATED	CPROB	295.8	0.168	7
0.020	UNDERESTIMATED	ID5	315.7	0.112	5
0.020	UNDERESTIMATED	ID3	345.9	0.027	2
0.020	ACTUAL	BHK	355.4	0.000	0
0.020	OVERESTIMATED	KRIGE	357.5	0.006	1
0.020	OVERESTIMATED	ID2	368.1	0.036	3
0.020	OVERESTIMATED	ID1	372.8	0.049	4
0.020	OVERESTIMATED	ID0	399.3	0.123	6
0.035	UNDERESTIMATED	EX4	110.6	0.382	10
0.035	UNDERESTIMATED	ID2	113.5	0.365	9
0.035	UNDERESTIMATED	ID3	114.9	0.357	8
0.035	UNDERESTIMATED	ID10	122.7	0.314	7
0.035	UNDERESTIMATED	EX60	136.0	0.240	6
0.035	UNDERESTIMATED	CPROB	138.6	0.225	5
0.035	UNDERESTIMATED	ID5	140.9	0.212	4
0.035	UNDERESTIMATED	ID0	142.9	0.201	3
0.035	UNDERESTIMATED	ID1	151.8	0.152	2
0.035	UNDERESTIMATED	KRIGE	173.8	0.028	1
0.035	ACTUAL	BHK	178.9	0.000	0
0.050	UNDERESTIMATED	KRIGE	100.3	0.394	9
0.050	UNDERESTIMATED	ID10	109.7	0.337	8
0.050	UNDERESTIMATED	ID5	109.7	0.337	8
0.050	UNDERESTIMATED	EX60	122.1	0.263	7
0.050	UNDERESTIMATED	ID1	122.2	0.262	6
0.050	UNDERESTIMATED	ID0	124.6	0.248	5
0.050	UNDERESTIMATED	ID3	127.4	0.231	4
0.050	UNDERESTIMATED	ID2	135.7	0.181	3
0.050	UNDERESTIMATED	CPROB	138.3	0.165	2
0.050	UNDERESTIMATED	EX4	146.5	0.115	1
0.050	ACTUAL	BHK	165.6	0.000	0

GRADE (METHOD – GRADE (OPT.) – % ERROR – RANK)

CUT-OFF		METHOD	GRADE (OPT.)	% ERROR	RANK
0.000	UNDERESTIMATED	EX4	0.004	0.200	1
0.000	ACTUAL	BHK	0.005	0.000	0
0.000	OVERESTIMATED	EX60	0.005	0.000	0
0.000	OVERESTIMATED	ID10	0.005	0.000	0
0.000	OVERESTIMATED	ID5	0.006	0.200	1
0.000	OVERESTIMATED	ID3	0.006	0.200	1
0.000	OVERESTIMATED	ID2	0.006	0.200	1
0.000	OVERESTIMATED	ID1	0.006	0.200	1
0.000	OVERESTIMATED	KRIGE	0.006	0.200	1
0.000	OVERESTIMATED	CPROB	0.006	0.200	1
0.000	OVERESTIMATED	ID0	0.007	0.400	2
0.010	UNDERESTIMATED	EX4	0.014	0.067	1
0.010	UNDERESTIMATED	ID5	0.014	0.067	1
0.010	UNDERESTIMATED	ID3	0.014	0.067	1
0.010	UNDERESTIMATED	ID2	0.014	0.067	1
0.010	UNDERESTIMATED	ID1	0.014	0.067	1
0.010	ACTUAL	BHK	0.015	0.000	0
0.010	OVERESTIMATED	EX60	0.015	0.000	0
0.010	OVERESTIMATED	ID10	0.015	0.000	0
0.010	OVERESTIMATED	ID0	0.015	0.000	0
0.010	OVERESTIMATED	KRIGE	0.015	0.000	0
0.010	OVERESTIMATED	CPROB	0.015	0.000	0
0.020	UNDERESTIMATED	EX4	0.026	0.037	1
0.020	UNDERESTIMATED	ID10	0.026	0.037	1
0.020	UNDERESTIMATED	ID5	0.026	0.037	1
0.020	UNDERESTIMATED	KRIGE	0.026	0.037	1
0.020	ACTUAL	BHK	0.027	0.000	0
0.020	OVERESTIMATED	EX60	0.027	0.000	0
0.020	OVERESTIMATED	ID3	0.027	0.000	0
0.020	OVERESTIMATED	ID2	0.027	0.000	0
0.020	OVERESTIMATED	ID1	0.027	0.000	0
0.020	OVERESTIMATED	ID0	0.027	0.000	0
0.020	OVERESTIMATED	CPROB	0.027	0.000	0
0.035	UNDERESTIMATED	ID5	0.041	0.024	1
0.035	UNDERESTIMATED	ID2	0.041	0.024	1
0.035	ACTUAL	BHK	0.042	0.000	0
0.035	OVERESTIMATED	EX4	0.042	0.000	0
0.035	OVERESTIMATED	EX60	0.042	0.000	0
0.035	OVERESTIMATED	ID10	0.042	0.000	0
0.035	OVERESTIMATED	ID3	0.042	0.000	0
0.035	OVERESTIMATED	ID1	0.042	0.000	0
0.035	OVERESTIMATED	ID0	0.042	0.000	0
0.035	OVERESTIMATED	KRIGE	0.042	0.000	0
0.035	OVERESTIMATED	CPROB	0.042	0.000	0
0.050	UNDERESTIMATED	ID2	0.076	0.013	1
0.050	ACTUAL	BHK	0.077	0.000	0
0.050	OVERESTIMATED	ID1	0.077	0.000	0
0.050	OVERESTIMATED	ID0	0.078	0.013	1
0.050	OVERESTIMATED	ID3	0.080	0.039	2
0.050	OVERESTIMATED	CPROB	0.081	0.052	3
0.050	OVERESTIMATED	KRIGE	0.083	0.078	4
0.050	OVERESTIMATED	EX60	0.088	0.143	5
0.050	OVERESTIMATED	ID5	0.088	0.143	5
0.050	OVERESTIMATED	ID10	0.092	0.195	6
0.050	OVERESTIMATED	EX4	0.097	0.260	7

OUNCES (METHOD – OUNCES – % ERROR – RANK)

CUT-OFF		METHOD	OUNCES	% ERROR	RANK
0.000	UNDERESTIMATED	ID0	1066	0.078	2
0.000	UNDERESTIMATED	ID1	1076	0.069	1
0.000	ACTUAL	BHK	1156	0.000	0
0.000	OVERESTIMATED	KRIGE	1269	0.098	3
0.000	OVERESTIMATED	CPROB	1518	0.313	4
0.000	OVERESTIMATED	EX60	1545	0.336	5
0.000	OVERESTIMATED	ID2	1571	0.359	6
0.000	OVERESTIMATED	ID3	1795	0.553	7
0.000	OVERESTIMATED	ID5	1923	0.664	8
0.000	OVERESTIMATED	EX4	2023	0.750	9
0.000	OVERESTIMATED	ID10	2091	0.809	10
0.010	UNDERESTIMATED	EX4	3088	0.118	3
0.010	UNDERESTIMATED	ID10	3403	0.028	2
0.010	UNDERESTIMATED	ID5	3487	0.004	1
0.010	ACTUAL	BHK	3501	0.000	0
0.010	OVERESTIMATED	ID3	3937	0.125	4
0.010	OVERESTIMATED	ID2	4191	0.197	5
0.010	OVERESTIMATED	EX60	4442	0.269	6
0.010	OVERESTIMATED	CPROB	4546	0.299	7
0.010	OVERESTIMATED	KRIGE	4749	0.356	8
0.010	OVERESTIMATED	ID1	4906	0.401	9
0.010	OVERESTIMATED	ID0	4944	0.412	10
0.020	UNDERESTIMATED	EX4	6132	0.362	10
0.020	UNDERESTIMATED	EX60	7642	0.204	9
0.020	UNDERESTIMATED	ID10	7677	0.201	8
0.020	UNDERESTIMATED	CPROB	7883	0.179	7
0.020	UNDERESTIMATED	ID5	8182	0.148	6
0.020	UNDERESTIMATED	ID3	9169	0.046	4
0.020	UNDERESTIMATED	KRIGE	9273	0.035	2
0.020	ACTUAL	BHK	9607	0.000	0
0.020	OVERESTIMATED	ID2	9902	0.031	1
0.020	OVERESTIMATED	ID1	9973	0.038	3
0.020	OVERESTIMATED	ID0	10789	0.123	5
0.035	UNDERESTIMATED	EX4	4595	0.388	10
0.035	UNDERESTIMATED	ID2	4626	0.384	9
0.035	UNDERESTIMATED	ID3	4776	0.364	8
0.035	UNDERESTIMATED	ID10	5172	0.312	7
0.035	UNDERESTIMATED	EX60	5728	0.238	6
0.035	UNDERESTIMATED	CPROB	5768	0.232	5
0.035	UNDERESTIMATED	ID5	5793	0.229	4
0.035	UNDERESTIMATED	ID0	6053	0.194	3
0.035	UNDERESTIMATED	ID1	6355	0.154	2
0.035	UNDERESTIMATED	KRIGE	7286	0.030	1
0.035	ACTUAL	BHK	7513	0.000	0
0.050	UNDERESTIMATED	KRIGE	8327	0.343	10
0.050	UNDERESTIMATED	ID1	9372	0.261	9
0.050	UNDERESTIMATED	ID0	9664	0.238	8
0.050	UNDERESTIMATED	ID5	9680	0.237	7
0.050	UNDERESTIMATED	ID10	10106	0.203	6
0.050	UNDERESTIMATED	ID3	10243	0.192	5
0.050	UNDERESTIMATED	ID2	10363	0.183	4
0.050	UNDERESTIMATED	EX60	10717	0.155	3
0.050	UNDERESTIMATED	CPROB	11188	0.118	1
0.050	ACTUAL	BHK	12683	0.000	0
0.050	OVERESTIMATED	EX4	14236	0.122	2

TABLE X

COMPARISON OF BLASTHOLE INDICATED RESERVES WITHIN GRADE CATEGORIES VS. RESERVES CALCULATED BY EACH EXPLORATION METHOD FOR BUCK60G BLOCK MODEL (60 FOOT BLOCKS, WITHIN ORE OUTLINE).

TONNAGE

CUT-OFF	.......UNDERESTIMATED...										ACTUAL	...OVERESTIMATED......									
0.000						ID1	ID0	KRIGE	ID2	CPROB	BHK	ID3	EX60	ID5	ID10	EX4						— METHOD
						0.0	0.0	0.0	8.5	10.1	21.2	21.8	25.0	31.2	38.3	101.9						— TONS (X 1000)
						1.000	1.000	1.000	0.601	0.522	0.000	0.028	0.178	0.467	0.805	3.800						— % ERROR
						7	7	7	5	4	0	1	2	3	6	8						— RANK
0.010								ID0	ID1	KRIGE	BHK	ID2	ID3	ID5	CPROB	ID10	EX4	EX60				
								54.9	58.5	87.2	88.6	92.1	101.8	129.9	145.3	167.3	186.4	191.4				
								0.381	0.340	0.016	0.000	0.040	0.149	0.466	0.640	0.889	1.104	1.160				
								5	4	1	0	2	3	6	7	8	9	10				
0.020								EX4	EX60	CPROB	BHK	ID10	ID5	ID0	ID2	KRIGE	ID3	ID1				
								221.8	276.6	293.6	308.8	311.8	323.6	346.2	350.0	357.0	357.1	365.1				
								0.282	0.104	0.049	0.000	0.010	0.048	0.121	0.133	0.156	0.156	0.182				
								10	4	3	0	1	2	5	6	7	8	9				
0.035				EX4	ID10	ID3	EX60	ID5	ID2	CPROB	BHK	ID1	KRIGE	ID0								
				105.5	119.9	138.9	142.4	150.2	158.0	159.8	162.2	192.5	193.0	222.5								
				0.350	0.261	0.143	0.122	0.074	0.026	0.015	0.000	0.187	0.189	0.372								
				9	8	5	4	3	2	1	0	6	7	10								
0.050	ID10	KRIGE	EX60	ID5	ID0	ID3	ID1	EX4	CPROB	ID2	BHK											
	118.7	119.0	120.7	121.3	132.5	136.4	140.1	140.5	147.2	147.6	175.3											
	0.323	0.321	0.312	0.308	0.244	0.222	0.201	0.198	0.160	0.158	0.000											
	10	9	8	7	6	5	4	3	2	1	0											

GRADE

CUT-OFF	.......UNDERESTIMATED...										ACTUAL	...OVERESTIMATED......									
0.000						ID1	ID0	KRIGE	EX4	ID10	BHK	ID5	EX60	ID3	ID2	CPROB						— METHOD
						0.000	0.000	0.000	0.006	0.006	0.007	0.007	0.008	0.008	0.009	0.009						— GRADE (OPT.)
						1.000	1.000	1.000	0.143	0.143	0.000	0.000	0.143	0.143	0.286	0.286						— % ERROR
						3	3	3	1	1	0	0	1	1	2	2						— RANK
0.010									EX4	EX60	BHK	ID10	ID5	CPROB	ID3	ID2	ID1	ID0	KRIGE			
									0.014	0.015	0.016	0.016	0.016	0.016	0.017	0.017	0.017	0.017	0.017			
									0.125	0.062	0.000	0.000	0.000	0.000	0.063	0.063	0.063	0.063	0.063			
									2	1	0	0	0	0	1	1	1	1	1			
0.020								EX4	ID10	ID5	BHK	EX60	ID3	CPROB	ID2	ID1	ID0	KRIGE				
								0.026	0.026	0.026	0.027	0.027	0.027	0.027	0.028	0.028	0.028	0.028				
								0.037	0.037	0.037	0.000	0.000	0.000	0.000	0.037	0.037	0.037	0.037				
								1	1	1	0	0	0	0	1	1	1	1				
0.035					ID2	ID5	ID3	ID1	KRIGE	CPROB	BHK	EX4	EX60	ID10	ID0							
					0.040	0.041	0.041	0.041	0.041	0.041	0.042	0.042	0.042	0.042	0.042							
					0.048	0.024	0.024	0.024	0.024	0.024	0.000	0.000	0.000	0.000	0.000							
					2	1	1	1	1	1	0	0	0	0	0							
0.050											BHK	ID2	ID1	ID0	KRIGE	ID3	CPROB	ID5	EX60	ID10	EX4	
											0.076	0.077	0.077	0.079	0.080	0.081	0.081	0.086	0.089	0.090	0.098	
											0.000	0.013	0.013	0.039	0.053	0.066	0.066	0.132	0.171	0.184	0.289	
											0	1	1	2	3	4	4	5	6	7	8	

OUNCES

CUT-OFF	.......UNDERESTIMATED...										ACTUAL	...OVERESTIMATED......									
0.000						ID1	ID0	KRIGE	ID2	CPROB	BHK	ID3	EX60	ID5	ID10	EX4						— METHOD
						0	0	0	78	89	142	166	197	219	232	561						— OUNCES
						1.000	1.000	1.000	0.451	0.373	0.000	0.175	0.389	0.547	0.642	2.964						— % ERROR
						7	7	7	4	2	0	1	3	5	6	8						— RANK
0.010									ID0	ID1	BHK	KRIGE	ID2	ID3	ID5	CPROB	ID10	EX4	EX60			
									959	988	1434	1483	1532	1683	2124	2307	2601	2672	2918			
									0.331	0.311	0.000	0.034	0.068	0.174	0.481	0.609	0.814	0.863	1.035			
									5	4	0	1	2	3	6	7	8	9	10			
0.020							EX4	EX60	CPROB	ID10	BHK	ID5	ID2	ID0	ID3	KRIGE	ID1					
							5848	7434	7959	8256	8396	8574	9680	9758	9772	9858	10190					
							0.304	0.115	0.052	0.017	0.000	0.021	0.153	0.162	0.164	0.174	0.214					
							10	4	3	1	0	2	5	6	7	8	9					
0.035				EX4	ID10	ID3	EX60	ID5	ID2	CPROB	BHK	ID1	KRIGE	ID0								
				4394	5028	5761	5955	6163	6354	6624	6859	7929	7955	9353								
				0.359	0.267	0.160	0.132	0.101	0.074	0.034	0.000	0.156	0.160	0.364								
				9	8	7	4	3	2	1	0	5	6	10								
0.050		KRIGE	ID5	ID0	ID10	EX60	ID1	ID3	ID2	CPROB	BHK	EX4										
		9541	10434	10466	10636	10702	10752	11000	11375	11857	13352	13732										
		0.285	0.219	0.216	0.203	0.198	0.195	0.176	0.148	0.112	0.000	0.028										
		10	9	8	7	6	5	4	3	2	0	1										

grade, blasthole kriged estimates are what is referred to as "actual" in the charts.

The best way of evaluating how well a method works is to select one that does a good job of predicting in a particular grade range, and then to follow just that one method through the other grade ranges. Usually it is best to start with the total ounces portion of the chart (since that's the most important item that should be predicted correctly), and then after checking how well the method behaves in other grade ranges, look to tonnage and grade portions of the table to see if the pattern is consistent there.

As an example, refer to Table VIII where the exploration polygonal estimate (EX4) is the best estimate of total ounces over a cutoff of 0.050 with only a 6.6% error in the estimate. Conditional probability is second with a 9.4% error. Looking back up the ounces portion of the chart, EX4 as an estimate loses its appeal abruptly. Its rank drops to 6th, 7th, 7th, and 9th, and the average percent error goes from 26.2%, to 21.9%, 32.8% and then finally to 204%. Why does EX4 do so well in predicting total ounces over 0.05 opt.? Looking back to grades and tonnages, the answer is obvious. EX4 makes the worst estimate of grade, overestimating by 22.5% and it also makes a bad estimate on tonnage. Together, this combination of tonnage and overestimated grade manage to come out reasonably close in the prediction of actual ounces above the 0.050 opt. cutoff. The chart suggests that the exploration polygonal estimate should not become the method of choice. Conditional probability on the other hand, ranked second in the initial comparison, then 2nd in most other ranges with errors of 9.4%, 10.4%, 0.6%, 19.6% and then 32.3% (the high errors in the lowest category are due to the fact that there are actually very few ounces of gold -- predicting even 50 ounces more or less in the lowest grade range gives a 27% error). Careful examination of the chart shows that no other method consistently outperforms conditional probability in any of the comparisons (tons, grade, or ounces), and that there is no way of predicting which method(s) will do better in any given grade range.

Overall, these charts show the full detail of all ore reserves calculated for this study and they can be referred to quickly for that detail as further comparisons are made.

7.4 SUMMARY CHART AND RANKING OF RESULTS

The last chart (Table XI) summarizes the information in such a way that conclusions can be drawn about which methods are best and how they rank relative to each other within a model, as well as across models. For each method, and for every model, the tabulations contain the average error made in all of the grade categories for tons, grade and ounces, and then the average of the ranks that were assigned from the ore reserve charts. The lowest grade range wasn't used because, as was seen earlier, large percentage errors occurred here in some of the models which were due only to the small amount of metal actually contained in the waste category. The final score is derived by adding the 3 average ranks. This may not be a perfect way to rank the methods

TABLE XI
SUMMARY COMPARISON OF ORE RESERVE METHODS

BUCK BLOCK MODEL

AVERAGE % ERROR	EX4	EX20	ID10	ID5	ID3	ID2	ID1	ID0	KRIG	CPROB
TONS -	21.7	17.8	14.5	14.1	15.2	15.6	19.4	21.5	18.8	16.1
GRADE -	7.9	5.0	6.4	3.7	1.8	1.2	1.2	1.3	1.2	1.9
OUNCES -	19.3	15.7	12.9	11.4	13.2	14.5	18.4	22.1	18.0	14.2
AVERAGE RANK	**EX4**	**EX20**	**ID10**	**ID5**	**ID3**	**ID2**	**ID1**	**ID0**	**KRIG**	**CPROB**
TONS -	6.50	5.50	4.25	4.00	4.50	5.00	6.25	7.50	6.50	5.00
GRADE -	2.25	1.50	1.50	1.25	0.75	0.50	0.50	0.50	0.50	0.75
OUNCES -	6.75	5.25	4.50	3.50	4.25	4.75	5.75	7.50	5.75	5.25
TOTAL RANK	15.50	12.25	10.25	8.75	9.50	10.25	12.50	15.50	12.75	11.00
FINAL RANK	9	6	3	1	2	3	7	9	8	5

BUCKG BLOCK MODEL

AVERAGE % ERROR	EX4	EX20	ID10	ID5	ID3	ID2	ID1	ID0	KRIG	CPROB
TONS -	29.7	28.8	18.1	13.3	13.7	23.7	34.4	38.8	27.8	9.5
GRADE -	9.7	6.6	6.6	3.4	1.5	3.4	5.3	5.0	3.1	0.6
OUNCES -	21.9	22.1	12.2	10.8	12.5	22.5	34.0	39.2	26.8	8.2
AVERAGE RANK	**EX4**	**EX20**	**ID10**	**ID5**	**ID3**	**ID2**	**ID1**	**ID0**	**KRIG**	**CPROB**
TONS -	6.25	7.25	4.50	2.75	3.00	5.25	7.75	8.75	7.75	1.75
GRADE -	2.25	1.50	1.50	1.25	1.00	1.00	1.50	1.50	0.75	0.50
OUNCES -	5.25	5.50	3.25	2.75	4.00	6.00	8.50	9.50	7.75	2.50
TOTAL RANK	13.75	14.25	9.25	6.75	8.00	12.25	17.75	19.75	16.25	4.75
FINAL RANK	6	7	4	2	3	5	9	10	8	1

BUCK60 BLOCK MODEL

AVERAGE % ERROR	EX4	EX60	ID10	ID5	ID3	ID2	ID1	ID0	KRIG	CPROB
TONS -	22.9	25.0	10.9	18.0	19.7	21.2	23.0	25.0	20.3	22.0
GRADE -	9.1	3.6	5.8	6.8	2.6	2.6	1.7	0.3	2.9	1.3
OUNCES -	24.8	21.6	18.6	15.4	18.2	19.9	21.4	24.2	19.1	20.7
AVERAGE RANK	**EX4**	**EX60**	**ID10**	**ID5**	**ID3**	**ID2**	**ID1**	**ID0**	**KRIG**	**CPROB**
TONS -	6.00	7.00	6.00	4.75	4.50	5.00	5.50	5.75	4.75	5.25
GRADE -	2.25	1.25	1.75	2.00	0.75	0.75	0.25	0.25	1.25	0.75
OUNCES -	6.25	6.00	5.75	4.50	5.25	4.75	5.75	6.50	5.25	5.00
TOTAL RANK	14.50	14.25	13.50	11.25	10.50	10.50	11.50	12.50	11.25	11.00
FINAL RANK	10	9	8	4	1	1	6	7	4	3

BUCK60G BLOCK MODEL

AVERAGE % ERROR	EX4	EX60	ID10	ID5	ID3	ID2	ID1	ID0	KRIG	CPROB
TONS -	48.3	42.5	37.0	22.4	16.8	8.9	22.7	28.0	17.1	21.6
GRADE -	11.3	5.8	5.5	4.8	3.8	4.0	3.4	3.5	4.4	2.2
OUNCES -	38.9	37.0	32.5	20.6	16.8	11.1	21.9	26.8	16.3	20.2
AVERAGE RANK	**EX4**	**EX60**	**ID10**	**ID5**	**ID3**	**ID2**	**ID1**	**ID0**	**KRIG**	**CPROB**
TONS -	7.75	6.50	6.75	4.50	5.25	2.75	5.75	6.50	6.00	3.25
GRADE -	2.75	1.75	2.00	1.75	1.50	1.25	1.00	1.00	1.50	1.25
OUNCES -	7.25	6.00	6.00	5.00	5.25	3.00	5.75	7.25	6.25	3.25
TOTAL RANK	17.75	14.25	14.75	11.25	12.00	7.00	12.50	14.75	13.75	7.75
FINAL RANK	10	7	8	3	4	1	5	8	6	2

because much of the detail is obliterated, but it adequately simplifies the process of deciding which are the best 2 or 3 methods, and then the full detail charts (Tables VII, VIII, IX and X) and the metal graphs (Figs. 19, 20, 21 and 22) can be referred to when assessing the reliability of the ranking shown.

Table XI shows that the best block models to use are the BUCKG and BUCK60G, using only 20' composites that fall inside of the ore zone outline, and that the best method for calculating reserves is conditional probability. This calculation ranks first or second in these two models, with only ID2 showing similar results in the case of the BUCK60G model. Closer examination reveals that both ID2 and conditional probability perform well in the latter model; while their final total ranks are similar and less than 8.0, no other method's final rank is less than 11.0. On average, for the 20' block model (BUCKG), conditional probability makes errors of 9.5%, 0.6%, and 8.2% on tons, grade and ounces respectively, and for the 60' model (BUCK60G), 21.69%, 2.2%, and 20.2%. Furthermore, conditional probability ranks consistently well in all four block models, and a search for nearest competitors shows that there can be no way of predicting beforehand which one will be best. Looking at the four block models, the methods that come close, or even that seem to outperform conditional probability can be any of the inverse distance methods -- ID2 does well for the 60' models, and ID5 seems to perform well for the 20' models.

Notice also that for the 20' block models, one of the lowest overall percent errors in grade estimate attained by any method was ID3 on the BUCK block model. This is the original inverse distance cubed, 20' block model with no ore zone outline that is used at the mine. The original "gut feel" that this method provided the best reserve estimate (given the BUCK block model) was an excellent guess at the time.

Lastly, notice again that kriging, by itself, nearly always provided one of the worst ore reserve estimates at Buckhorn. Kriging alone, without taking kriging variance into account (i.e. ignoring that measure of error that is supposed to be kriging's greatest strength) is just another distance weighted averaging technique whose performance relative to any other estimator cannot be evaluated in advance of having the production data available.

7.5 EXAMINATION OF SCATTERGRAMS AND BENCH PLANS

Although both bench maps and scattergrams showing the results have been dutifully reproduced herein (Appendix B and F, respectively), they really offer very little information from which useful conclusions can be drawn. When one is interested in comparing ore reserve estimates, scatter plots in particular, are not the best method of comparing the data (actual vs. predicted). In fact they can be completely deceiving, often lulling one into a false sense of security. Many people point to the scattergram which shows the least amount of scatter and, solely on that basis, use this plot to justify their choice of one method over another. This reasoning however, is flawed in that there are two things that are visually discernable on a scattergram which are independent of each other. One is the amount of scattering (a crude visual appraisal of errors associated with an estimate), and the other is the average "goodness of fit" which is an evaluation of how close the scatter can be modelled by the 45° line which passes from the origin (0,0) through intersections of equal grade on the graph. The only plots that can be compared meaningfully to each other are those which show identical scattering (hard to measure), in which case the graph that shows the least amount of deviation from the 45° slope is best, or else two scatters drawn from the same block model that show identical slopes can be compared to see which provides the least amount of error associated with the estimation of the block grades, in which case the method providing the least scatter is the one to choose. In fact, taken to the extreme, if the only measurement of importance was the visual amount of scatter, the best estimate would be one where the predicted grade was constant (any constant) since then a plot of actual versus predicted grades would appear to show zero "scattering".

What scattergrams do show is the differences in the conditional distributions for every method. Any horizontal line on the scattergrams shown in Appendix F is representative of the conditional distribution at that expected grade, for that particular estimator -- for any given predicted grade there is a scatter of actual grades around it. For any grade estimate that indicates that the block is waste, there is some percentage of blocks that are actually ore. If one could see every individual point on the scatter, it would be possible to determine the percentage of blocks that are underestimated at that grade. Were any of these distributions to be numerically modelled, they might do as good a job as kriging did in the calculation of conditional probabilities at Buckhorn. But this is only because there is a square drilling pattern. Also, none of the other methods provide any way of calculating a conditional distribution without the presence of a vast amount of production data. Kriging, of course, can provide this estimate of conditional expectations before production starts and, especially when drilling is either on an irregular grid, or when drillholes are clustered, kriging has numerous other advantages that do in fact make it "the best linear unbiased" estimate.

The scattergrams in Appendix F, therefore don't show anything surprising. Sixty foot block models show less scatter than 20' block models because the predicted grades are more smoothed than for 20' blocks and therefore estimated grades for 60' blocks can't reach the same extremes as the estimates to 20' blocks. For the same reason, polygonal and ID10 estimates show more scatter than ID1 and ID0. The kriged estimates at Buckhorn tend to be similar to the ID2 or ID1 estimates and therefore also show less scattering than other methods. The ID0 estimate appears to show the least scatter. On the other hand, the slopes of the various best fit lines vary. ID10 and polygonal estimates come closer to 45° slopes but show more scatter than kriged and ID1 estimates, while the kriged and ID1 estimates seriously depart from the 45° line in the higher grade ranges.

The bench plans are a little better, but again they provide only a crude visual estimate of which method is the best one to use. All methods show their highest grades in the same places since every estimate was derived from the same 10 or 12 nearest exploration composites. All methods missed some areas of higher grade and all methods failed to predict some low grade areas for the same reasons -- the nearest composites failed to show lows or highs in those areas because of the large drillhole spacing. Therefore the only thing that can be compared in a very imprecise way is the general shape (width, length and orientation) of those larger areas where blasthole data confirmed the presence of ore.

This is not to say that maps and scattergrams are useless, but visual methods are not precise and therefore are inappropriate for making the types of detailed comparisons of ore reserve estimates based on exploration drilling which are made here. Scattergrams, in particular, should not be used to justify choice of a method on the basis of a lesser amount of scatter alone. Both maps and scatter plots should be produced to give the analyst pictures which he can keep in mind throughout the study to help visualize possible outcomes and assess results for indications of gross error.

Figure 18 (chapter 6) shows a more comprehensive type of comparison that can be used for either back analysis, or for evaluating the different estimates versus "actual". The ore reserve charts shown earlier (Tables VII, VIII, IX and X) also provide a better comparison of reserve estimates because they show the overall distribution of block grades, which in turn provides a different perspective than the simple block-by-block visual comparison afforded by the scatter plots. These charts also show visually, and quantitatively, which methods are under or over estimating in the important ore grade ranges. For global ore reserve estimates, the most important thing is to predict the right distribution of block grades above any cutoff grade within the designed open pit. These numbers provide the basis of economic calculations which are used to evaluate the deposit. This general idea is supported by David (1977) when he says:

> "which small blocks in the large one are really ore and which are really waste is totally irrelevant for monthly planning, less to say for quarterly or yearly planning as long as their percentages of occurrence can be predicted."

7.6 SIXTY FOOT VS. TWENTY FOOT ESTIMATES

As suspected, the reserves tabulated from the 60' block models were lower than from the 20' block models. This would be acceptable if the mining method was only capable of a 60' block selectivity, but this is not the case at Buckhorn. Although any individual 20' block cannot be expected to be exactly correct, the distribution of block grades for a mining method that has a 20' selectivity is correct and this results in higher ore reserves being predicted.

Not only is the grade distribution correct, but the location of the blocks is correct on average. In other words, if one 60' block is calculated as waste, but one of the nine contained 20' blocks is predicted as ore, generally, the exact prediction that the small block is actually ore may be incorrect, but there is probably a valid expectation that another close by block that was predicted to be waste may be ore. In effect, the 20' block model becomes one realization of the possible actual geometry of the orebody that will be mined, with the further benefit of having the ore blocks in generally the right location around exploration ore intercepts. This will result in an open pit design that is more accurate than one designed on a 60' block model which is representative of the exploration drill spacing.

An examination of the scatter plots (Appendix F) does show that on a block by block basis, 60' estimates have less scatter when comparing actual versus predicted grades, but this also is expected. However, it should not be taken to mean that the 60' block models should be used.

7.7 CONSTRAINED VS. UNCONSTRAINED ESTIMATES

The comparisons and ranking shown earlier in sections 7.2, 7.3, and 7.4 demonstrated that those estimates that were constrained by the ore zone outline predicted better (and higher) ore reserves than did the other two estimates. Although the unconstrained estimates predicted a couple of thousand more ounces of gold above a zero cutoff, in all cases they were unable to predict any more ounces above the very low 0.01 opt. cutoff and in the higher grade ore categories, every unconstrained method of ore reserve calculation produced significantly less ounces of gold than the corresponding constrained estimate. This is simply one manifestation of "smearing" of grades that has been noted by almost anyone who has ever calculated ore reserves.

There was no rock type change or change in alteration pattern that could be imposed on the block model to constrain the ore reserve estimate, but as was stated in the introduction, there is a measurable and identifiable geological contact that can be drawn. As with all changes in rock type, it is based on differences in the chemical make-up of the host rocks in that there is a greater amount of gold than normally would be expected in the composition of the altered volcanics. This is a numerically defined contact between ore zone and waste rock. Not all of the material inside the ore zone is ore as defined by an economically derived cutoff grade, but all potential ore occurs within this outline and all grades within the outline are related in that they belong to a definite population of grades which range from near zero to very high, but which form a single, viable lognormal distribution. All of the theory which goes into producing a conditional distribution of grades relies upon assumptions of gaussian distribution of the data, and imposition of the ore zone outline provided a set of values which fulfilled this requirement.

7.8 USING CONDITIONAL PROBABILITY ESTIMATES

Having come to the conclusion that the conditional probability estimate of global reserves is best, the question is how to use the estimates that are produced? Of the four block models, the best one to use at Buckhorn is the BUCKG 20' block model which was constrained by the ore zone outline. The following are the steps that the author would use now, with near perfect hindsight, to redesign the open pit, calculate global ore reserves, and then to do daily and monthly reconciliation at the mine:

1) Krige the exploration 20' composites using the subset BEXG data and the BUCKG block model (try out the idea of using 3 or 4 variograms which reflect various maximum pair differences).

2) Calculate global geologic reserves using conditional probability.

3) Produce inverse distance weighted estimates with increasing powers and choose the one which comes closest in grade, tonnage and metal above the mine design cutoff grades to the conditional probability estimate. In this case, it would be either the ID5 or ID3 estimate. Both predict very close to the same tonnage and grade as conditional probability at both the 0.020 opt., and the 0.035 opt. cutoffs. The open pit design used 0.035 as the mine design cutoff, but valued any block over 0.020 into the economic calculations which decide whether or not a block would be mined. Just like conditional simulation, these inverse distance block models will come close to being one possible geometrically correct realization of the possible shape of the orebody given the exploration

data. Journel and Huijbregts (1978) support the idea that one of the traditional estimators (polygonal, ID1 or ID2) will be similar to a "best" estimate. "Depending on the nugget effect (i.e., the degree of spatial correlation), one or the other of the three standard estimators is close enough to the kriging optimum, but only a structural analysis, i.e., a geostatistical approach, can tell which is the closest".

4) Assuming that this is true, design the open pit using both the ID5 and ID3 block models (perhaps the ID4 model should also be calculated in this case) with appropriate economic input data (price of gold, cost to mine ore, cost to mine waste, etc.).

5) Calculate reserves using each method within the respective open pit outlines.

6) Calculate reserves within each pit using the conditional probability block values for ore fractions and grade above cutoff, and choose the pit design generated by the inverse distance method whose calculated reserves most closely matches the reserves predicted by conditional probability. Report these as minable ore reserves. After this comparison has been made, all of the inverse distance models should be discarded because it is unlikely that any block model will give perfect predictions of individual block grades at any exact location. There is no need to adjust for mining dilution in the reserve estimate

because, although there will be dilution, there will not be any reliable measure of this parameter later, and the true effect of mining dilution will probably be to "lower" the percentage of gold recovery reported from the leach pads.

7) On a day-to-day basis, reconcile the daily production estimate within the total blast outline (not individual blocks) to the conditional probability estimate. The blast outlines at Buckhorn generally contain about 10-15,000 tons of material. This should provide large enough volumes to provide excellent reconciliation. Any ore that is found outside of the original exploration ore zone outline should be treated as "new" ore and should not be subtracted from exploration reserves (instead it should be cumulatively added to initial ore reserves for the mine, and then subtracted to report remaining reserves).

8) Produce monthly production reports. These would show four major groups of headings instead of just two. They would be: 1) predicted tons and grade; 2) actual tons and grade; 3) cumulative error (the difference to date between predicted and actual); and 4) new ore, not predicted from exploration drilling.

Had these steps been followed before production started in 1984, the author believes that the results would have been excellent, and that the economic calculations performed for the feasibility study would also have been more accurate.

8. CONCLUSIONS

All of the initial questions asked before this study started have been adequately answered. It is important to choose a block size which relates to mining selectivity and not to exploration drill spacing. Ore zone outlines, as constructed here, should be imposed on the data and on the block models if at all possible, and this alone will alleviate the need for modelling other distributions like the less accurate 3-parameter lognormal approximation or using more complex estimation methods like multigaussian kriging. Some of the various polygonal or inverse distance ore block calculations will be fairly accurate -- the best one may provide a workable "realization" of the unknown true shape and grade distribution of the orebody. However, without calculating a conditional probability estimate, there is no way of knowing beforehand which of these estimates will be nearest to "actual".

The inverse distance cubed model (ID3) used at the mine was definitely better than the kriged grade estimate when compared to what was actually mined, but other methods including inverse distance to the fifth power (ID5) outperformed ID3 for the original block model, while conditional probability and ID5 both gave better, or much better, estimates when an ore zone outline was applied to the same size block model.

Careful application of conditional probability as practiced by G.F. Raymond and modified in this study, is an extremely robust, accurate, and useful way of calculating ore reserves, and indeed these calculations should be used at all stages of calculating global ore reserves, in mine design, and for reporting daily and monthly production figures at Buckhorn. By applying all of the refinements discussed, excellent agreement with blastholes was attained with conditional probability.

And finally, although kriged block values were not the best in themselves, application of the full power of geostatistical techniques, which provides both a very necessary unbiased linear estimate and an equally important measure of the error associated with the estimate, provides the best combination of tools to estimate mining block grades and tonnages, as well as global ore reserves.

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APPENDIX A

BENCH MAPS OF RAW DATA AND OUTLINES

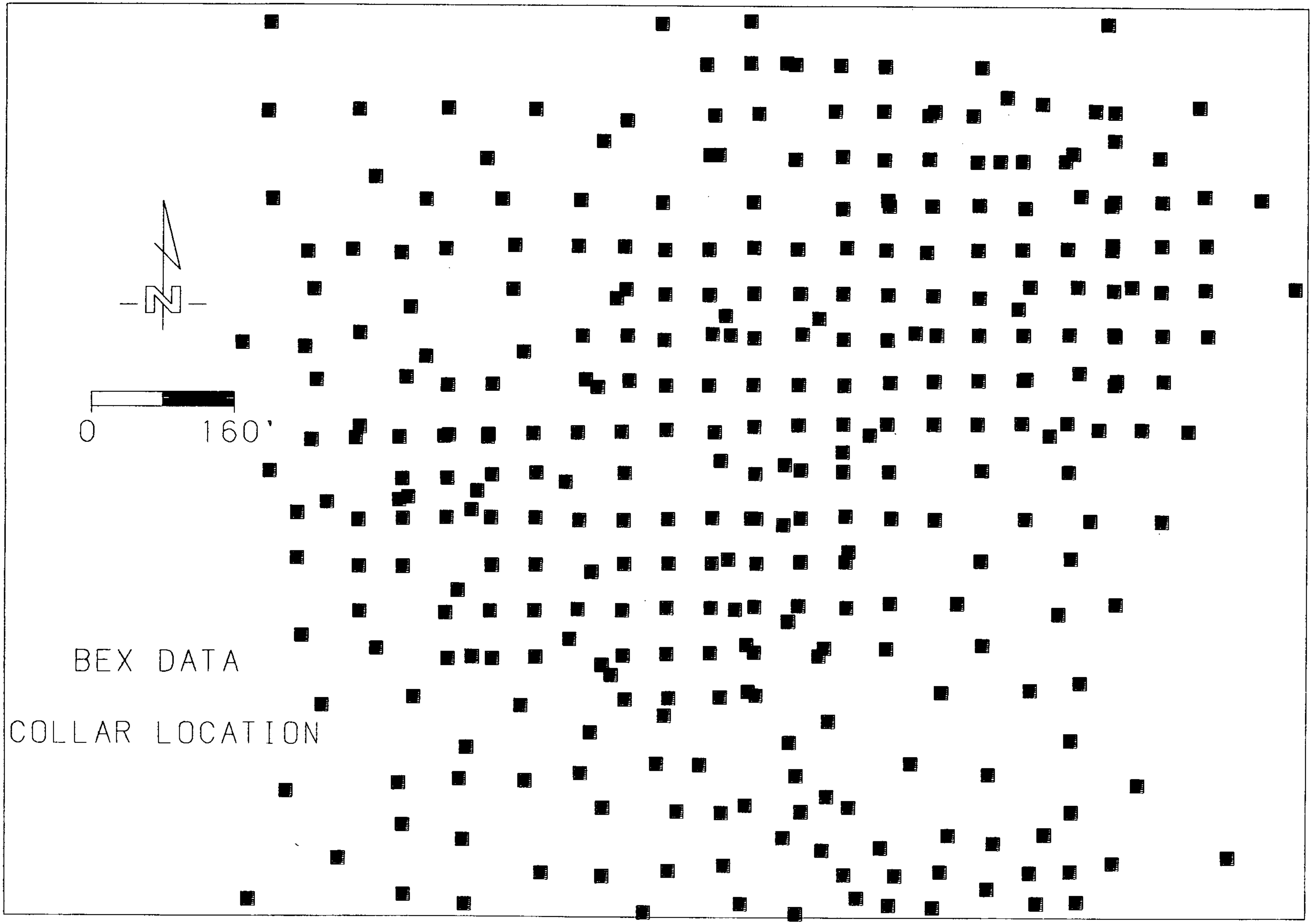
LEGEND:

	Grade (opt.)
+	0.000 - 0.010
□	0.010 - 0.020
⊞	0.020 - 0.035
▨	0.035 - 0.050
■	> 0,050

Outlines

——— Mined Limits

– – – "Ore Zone" Outline
(derived from statistical study)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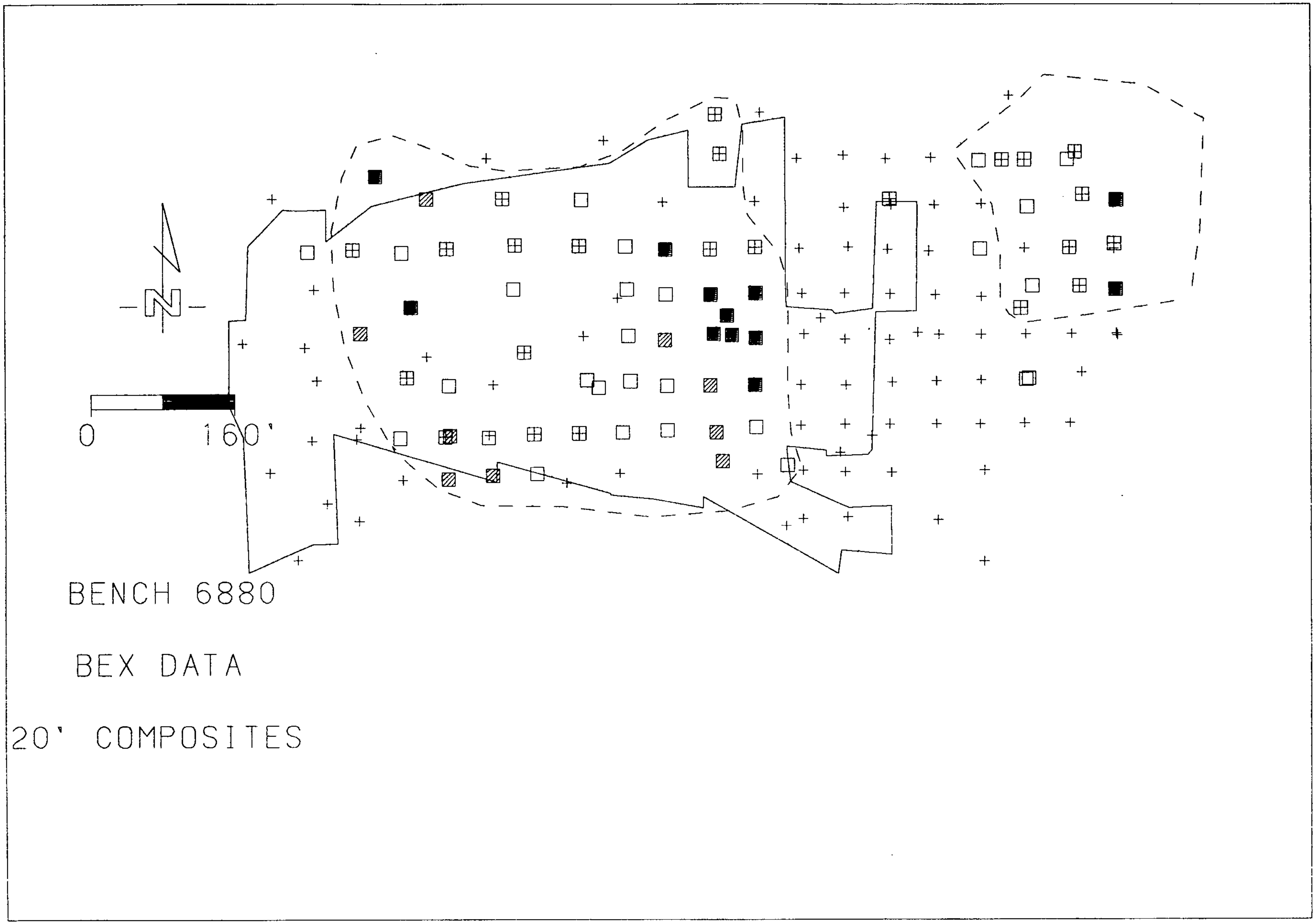
160'
BEX DATA
COLLAR LOCATION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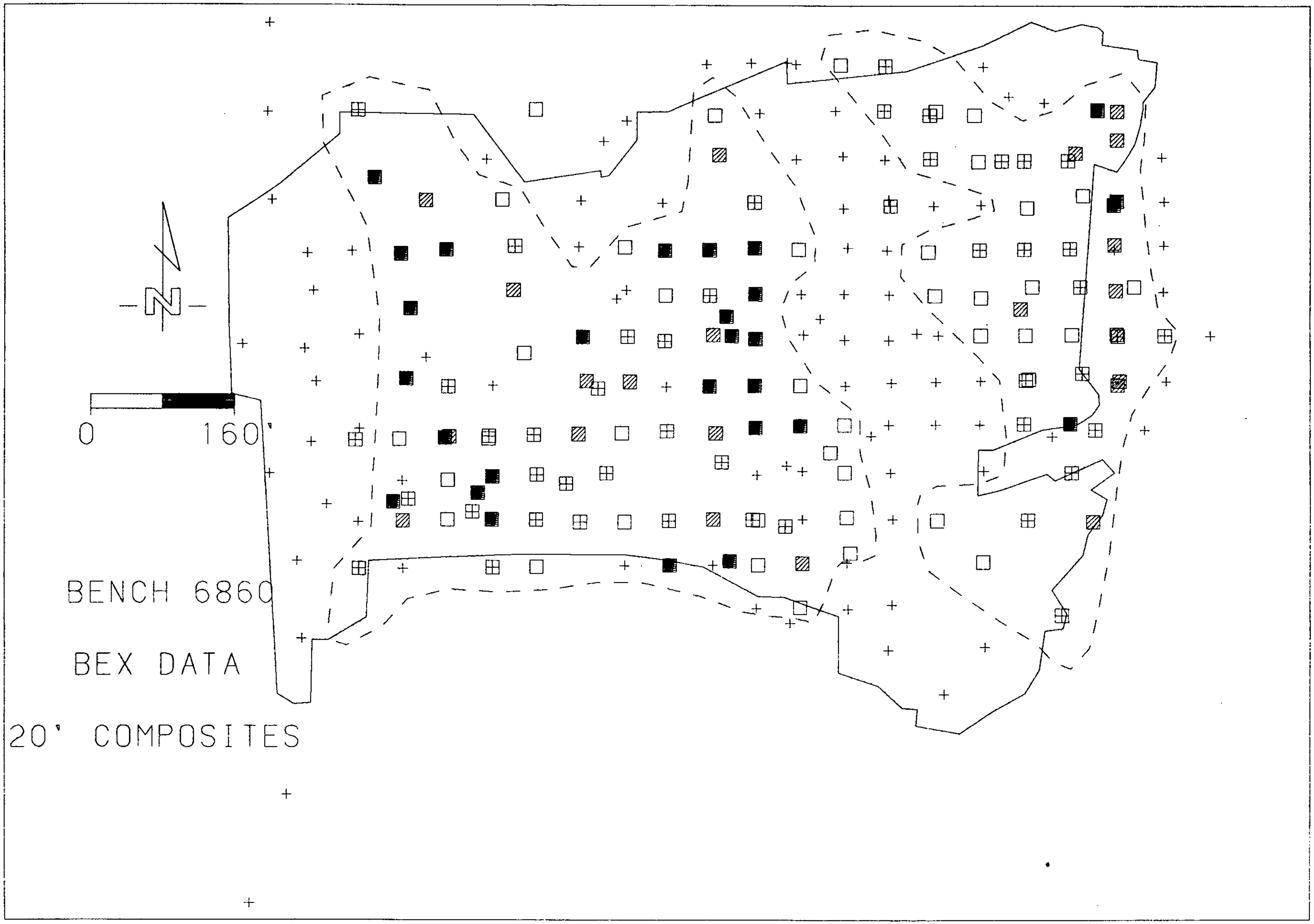
BENCH 6880
BEX DATA
20' COMPOSITES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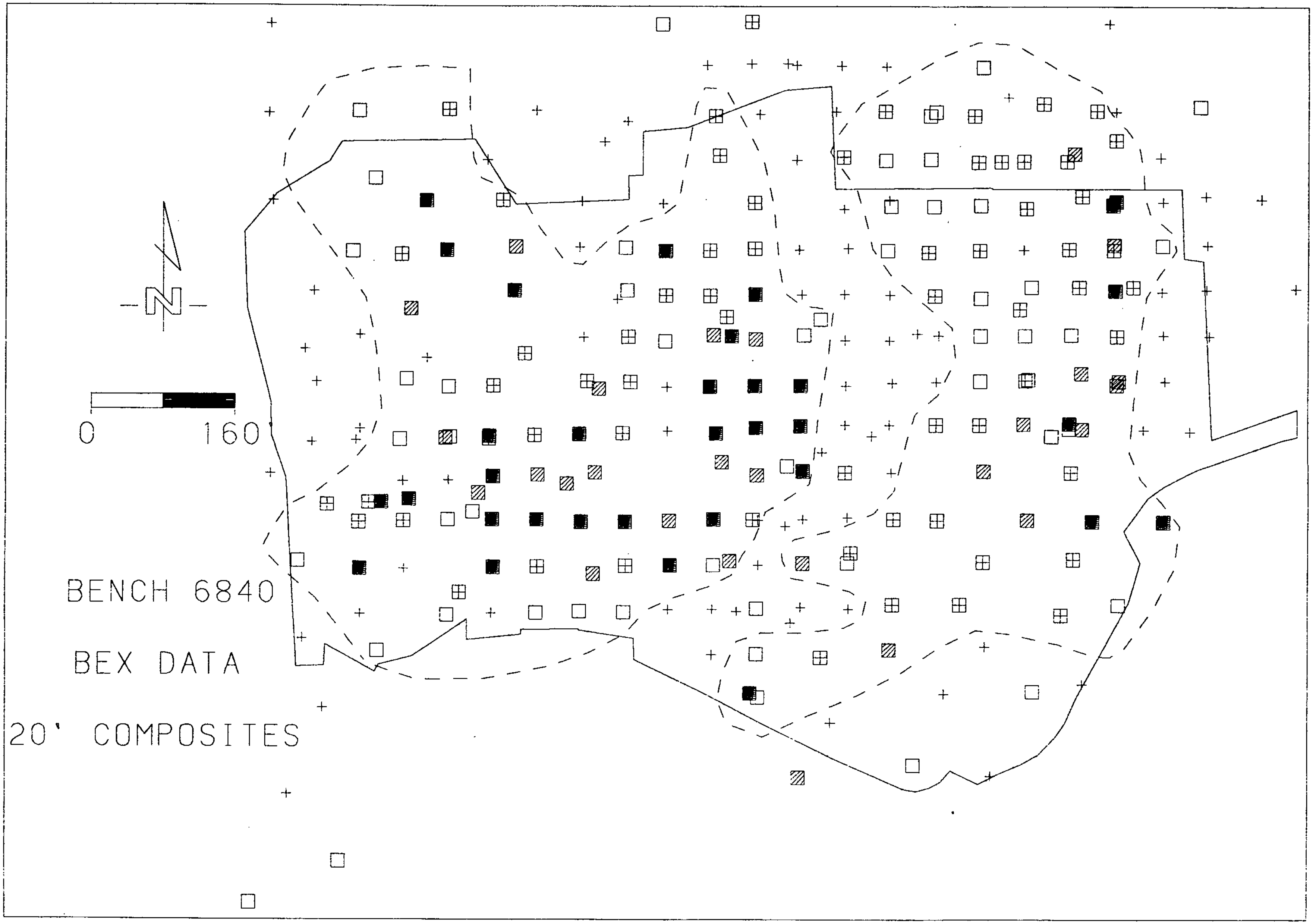
160'
BENCH 6860
BEX DATA
20' COMPOSITES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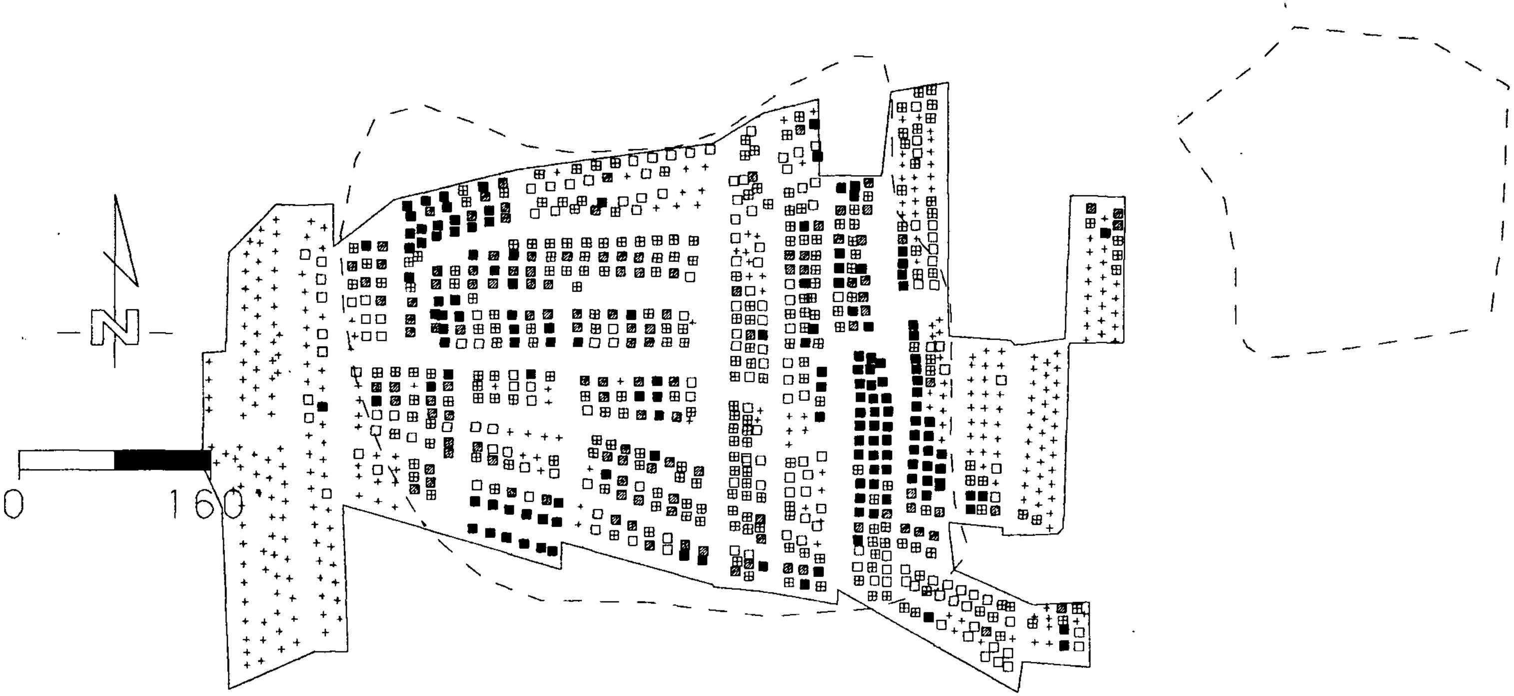
160
BENCH 6840
BEX DATA
20' COMPOSITES

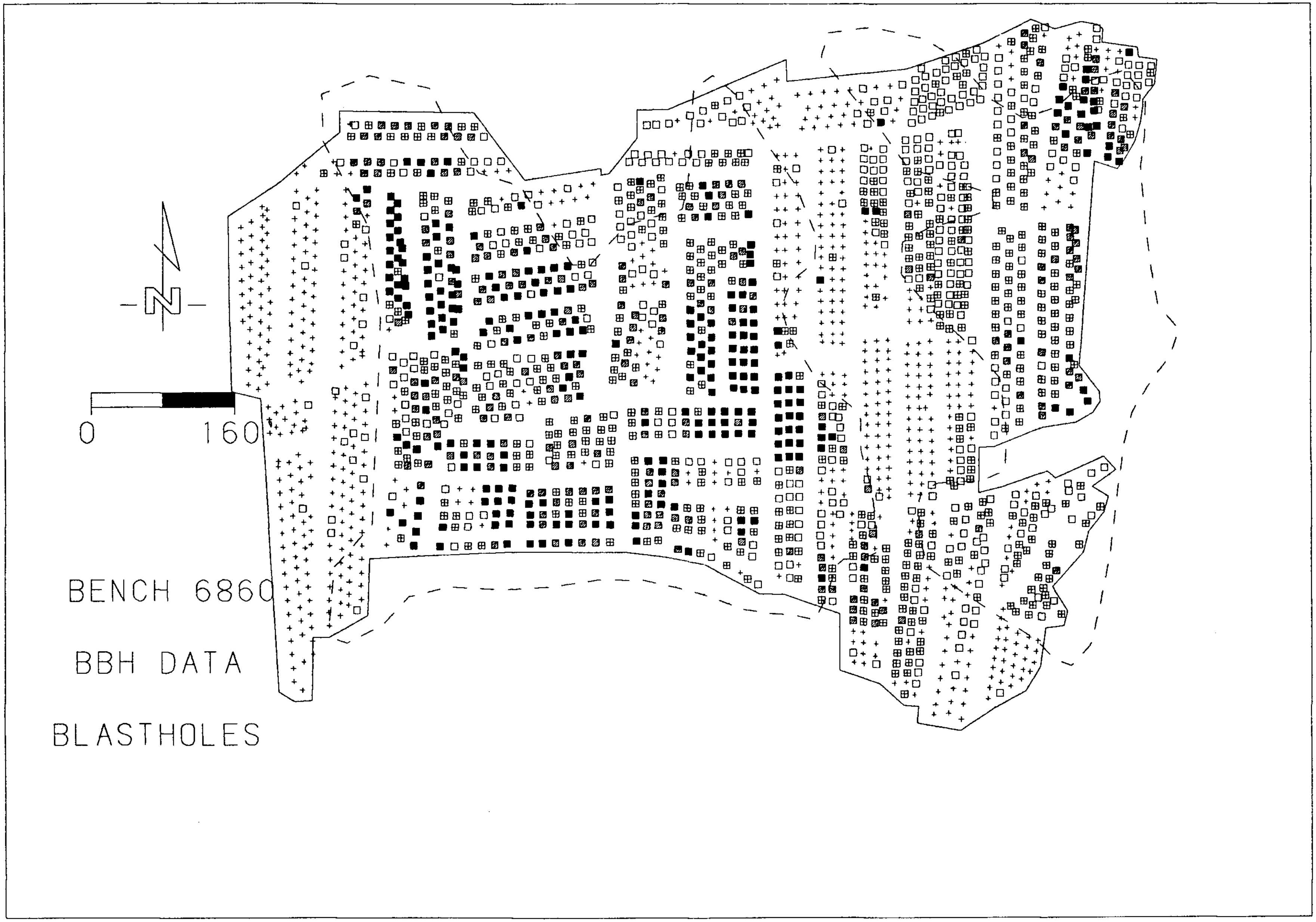

0
160'
BENCH 6820
BEX DATA
20' COMPOSITES



BENCH 6880

BBH DATA

BLASTHOLES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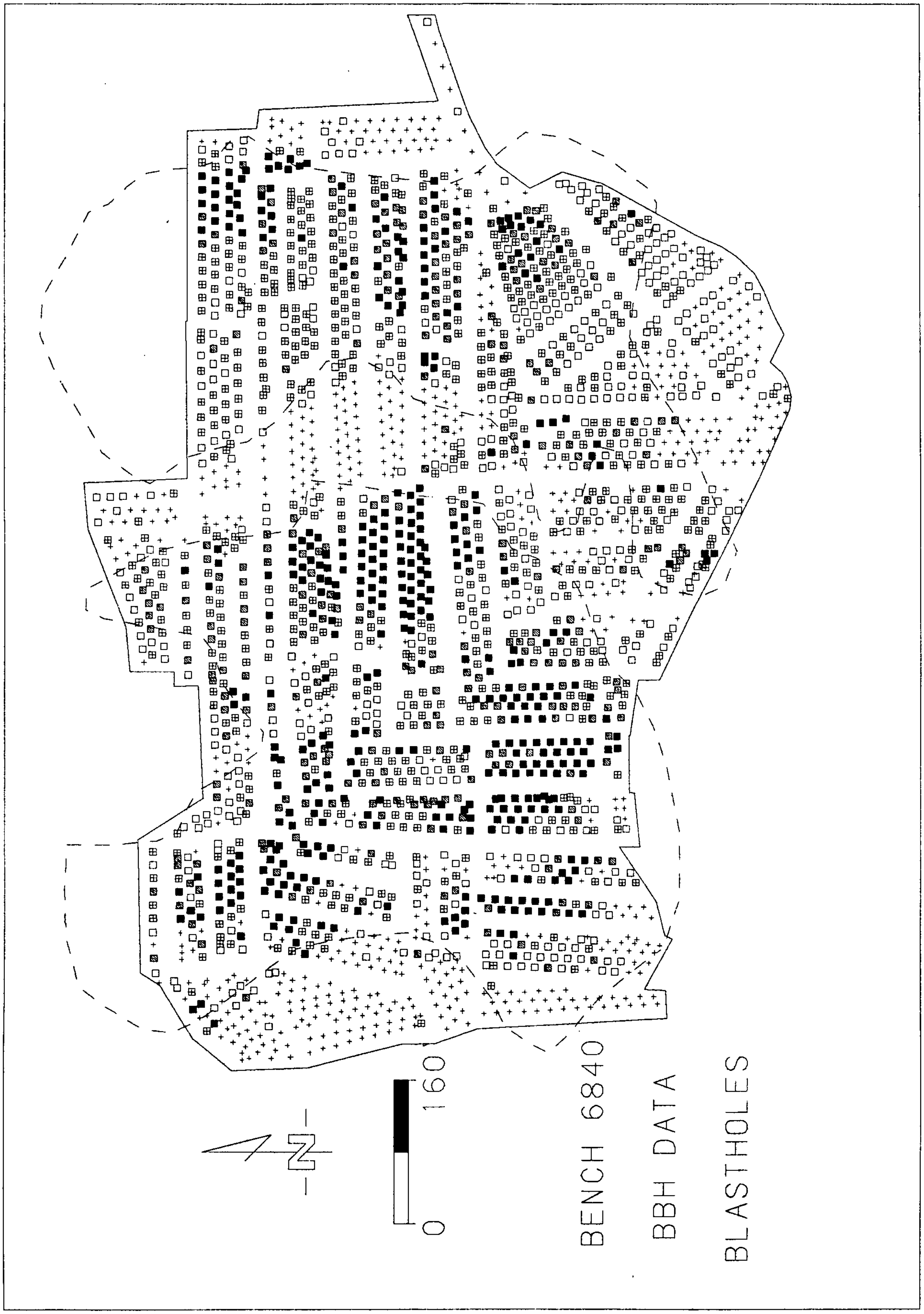
160
BENCH 6860
BBH DATA
BLASTHOLES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160
BENCH 6840
BBH DATA
BLASTHOLES


N
0
160'
BENCH 6820
BBH DATA
BLASTHOLES

APPENDIX B

BENCH MAPS OF RESULTS
(6840' and 6860')

The following bench plans are sorted first by block model, then by bench and finally by method. For any block model, 2 sets of 13 plates, starting with the blasthole polygon weighted estimate and ending at exploration conditional probability, all show results on the same bench so that the different methods easily be compared with each other and to "actual" blasthole results. 4' polygonal estimates are not shown.

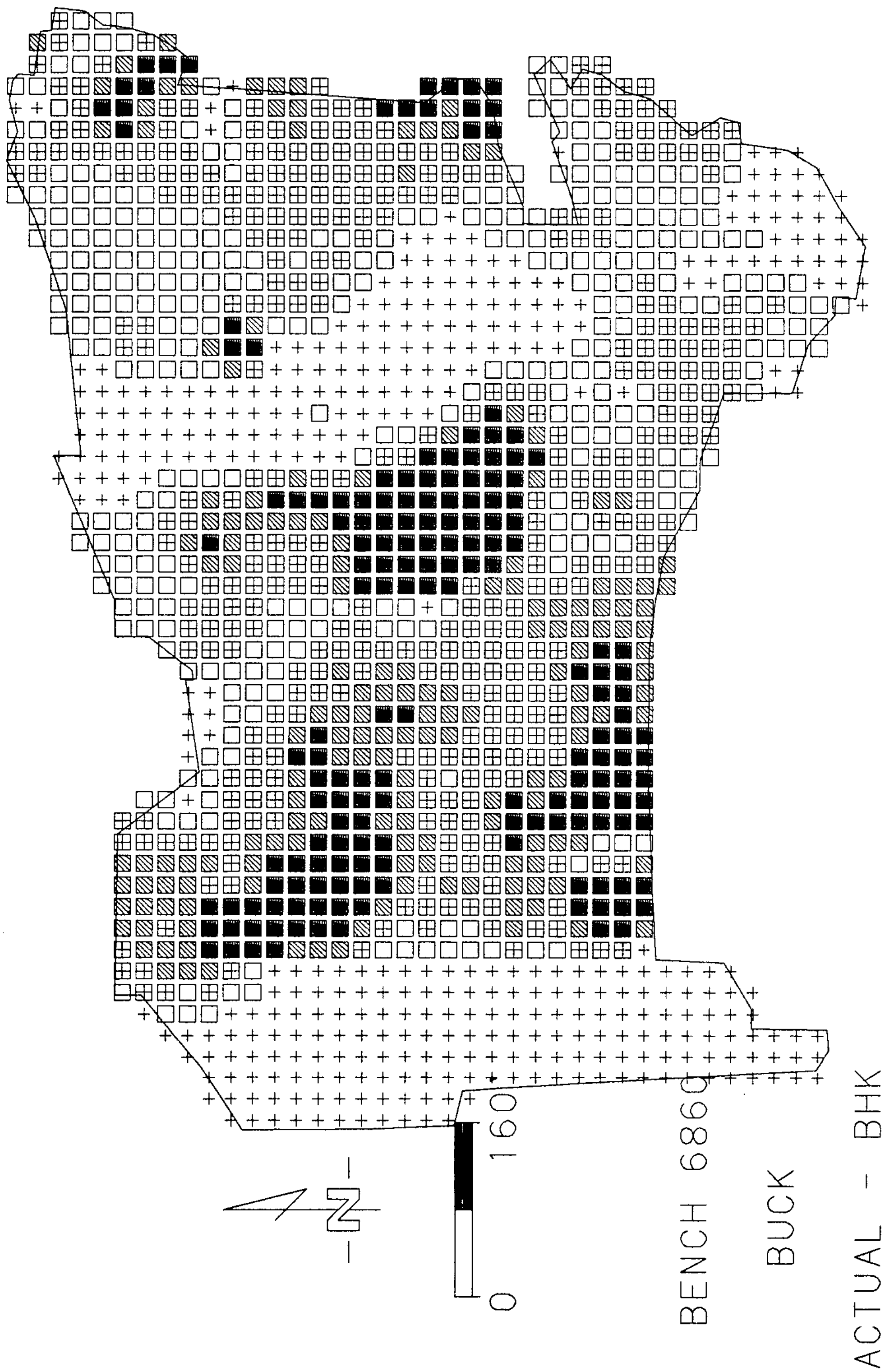
In the case of the conditional probability plots, the cutoff grade is indicated and contours refer to the probability of ore blocks above the cutoff within the contour. Contours are at 40, 60, and 80% probabilities and are plotted on top of "actual" blasthole kriged results for a given block model.

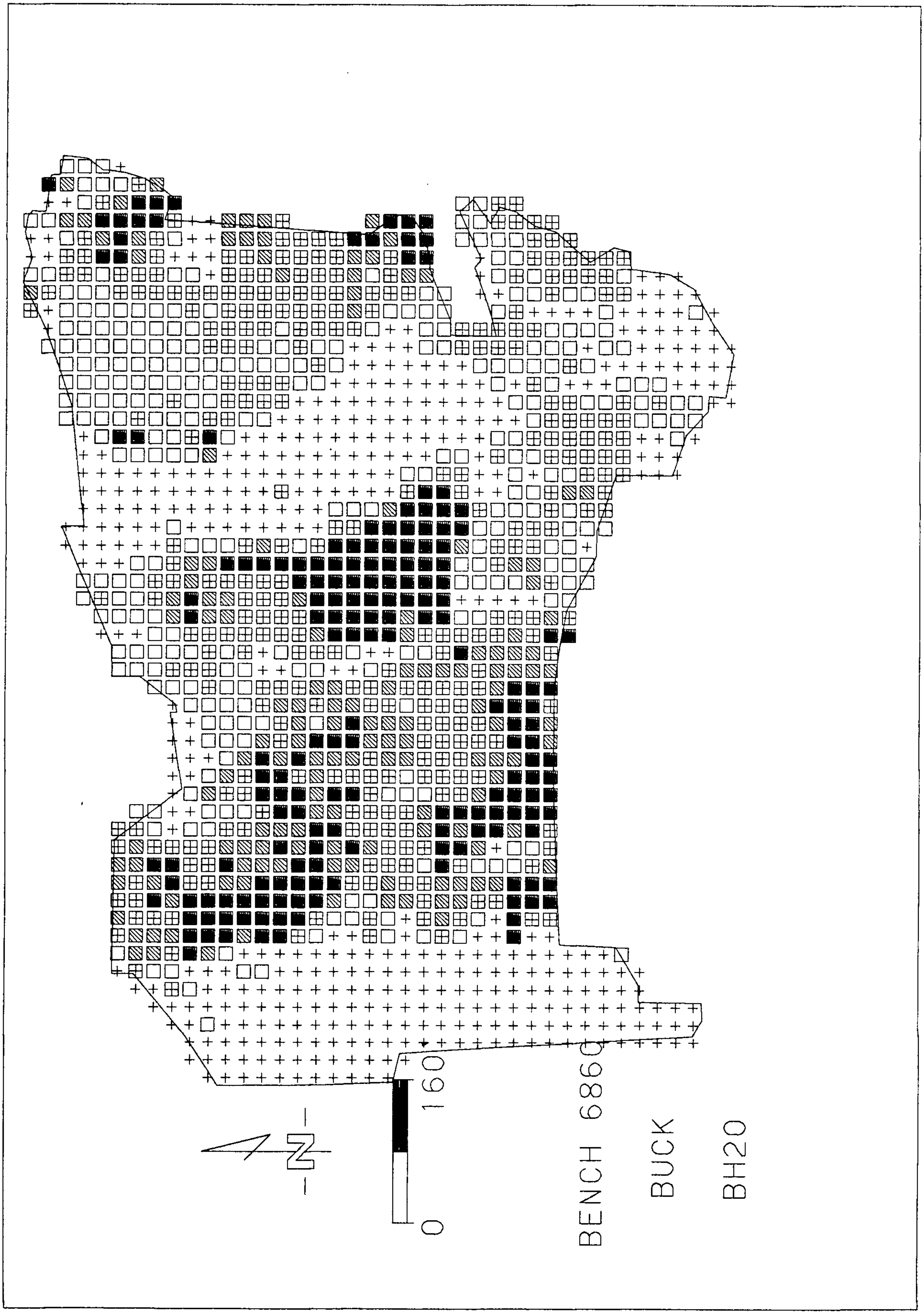
LEGEND:

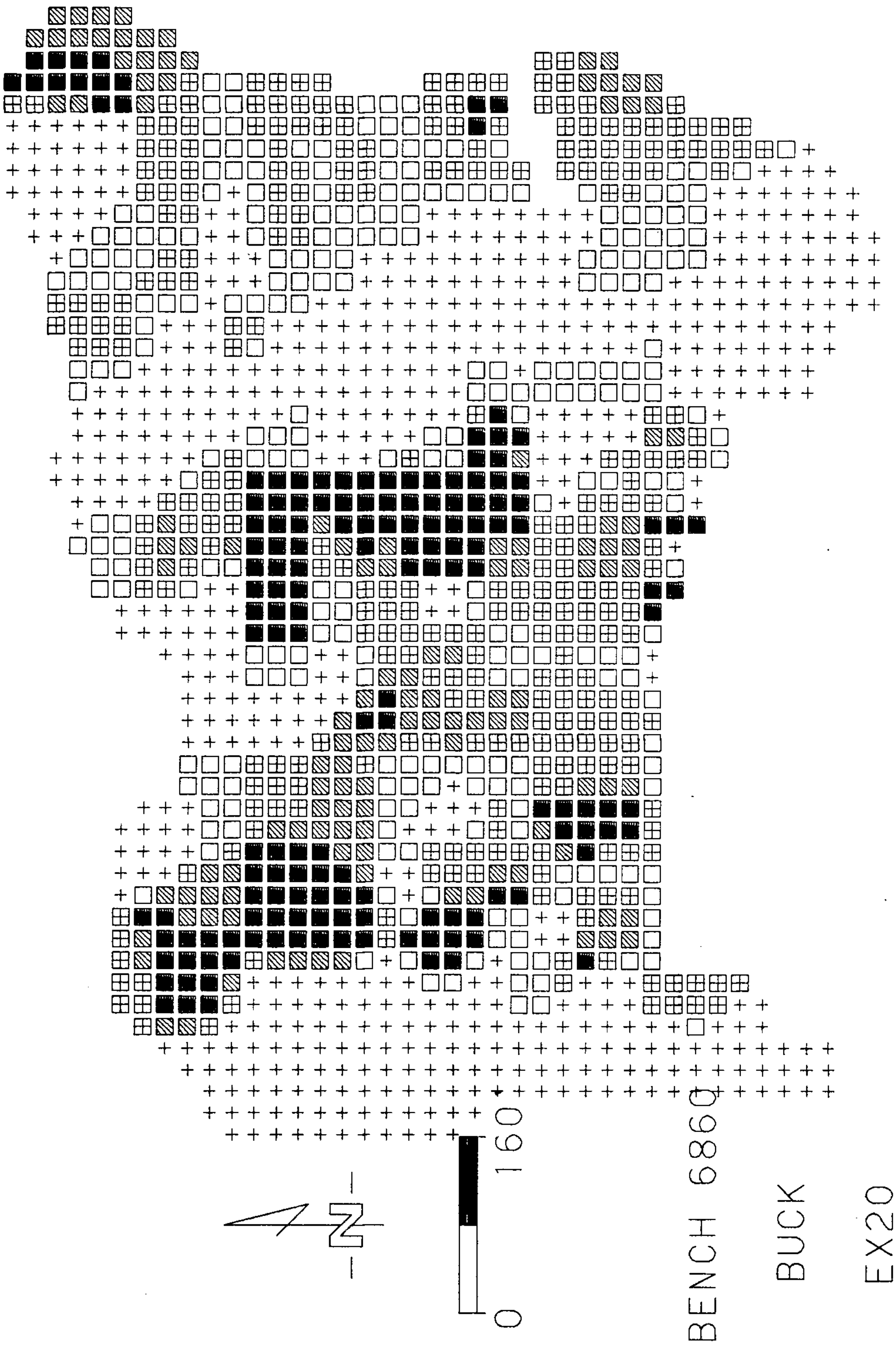
	Grade (opt.)
+	0.000 - 0.010
□	0.010 - 0.020
⊞	0.020 - 0.035
▨	0.035 - 0.050
■	> 0,050

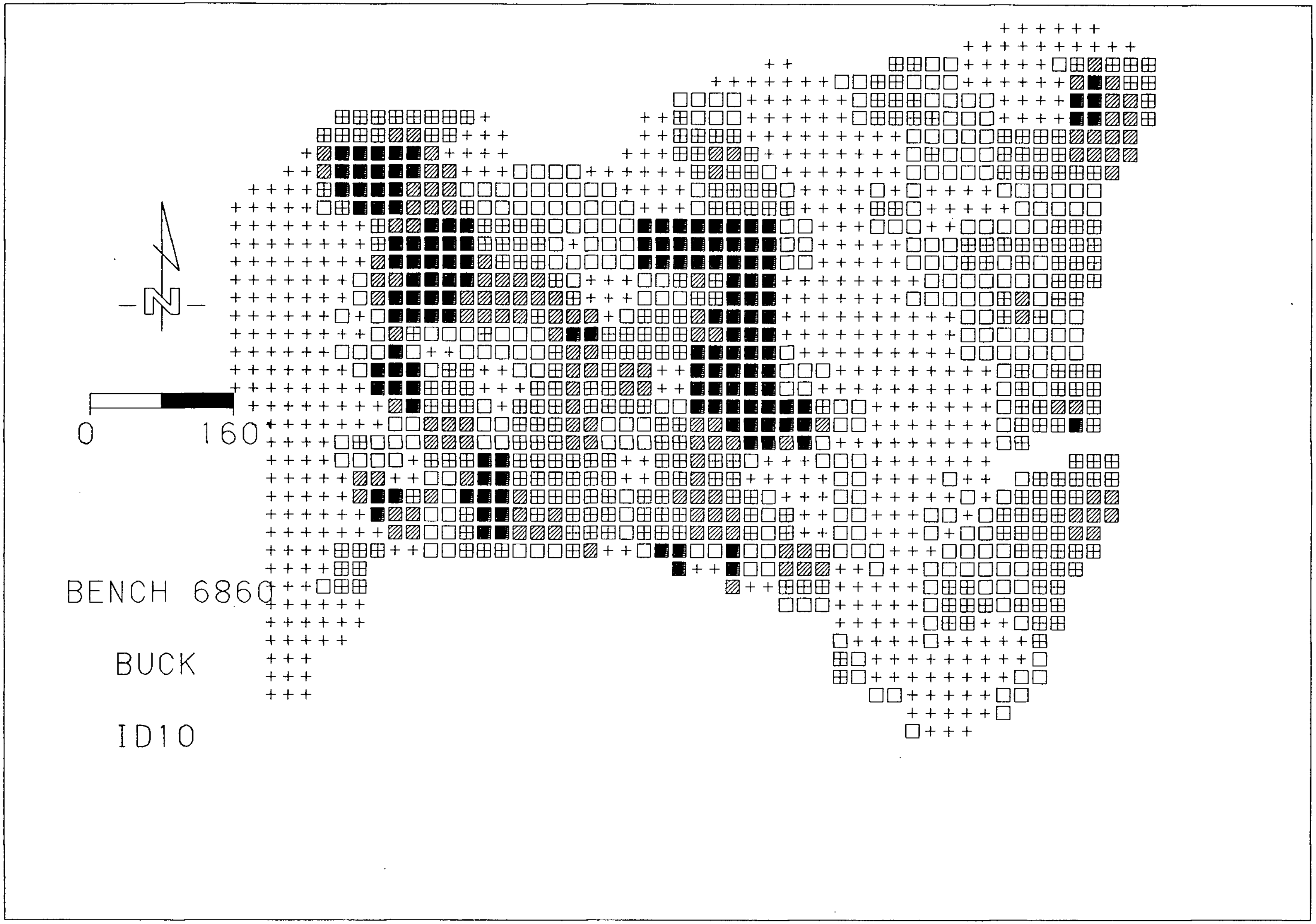
	Block Models
BUCK	20' Blocks, no outline.
BUCKG	20' Blocks, with "ore zone" outline.
BUCK60	60' Blocks, no outline.
BUCK60G	60' Blocks, with "ore zone" outline.

	Method
BHK	Blasthole Kriging.
BH20 or BH60	Blasthole Polygon Weighted (20' & 60')
EX20 or EX60	Exploration Polygon Weighted (20' & 60')
ID10 ID5 ID3 ID2 ID1 ID0	Inverse Distance to the indicated power.
KRIG	Exploration Kriging.
CPROB	Conditional Probability.

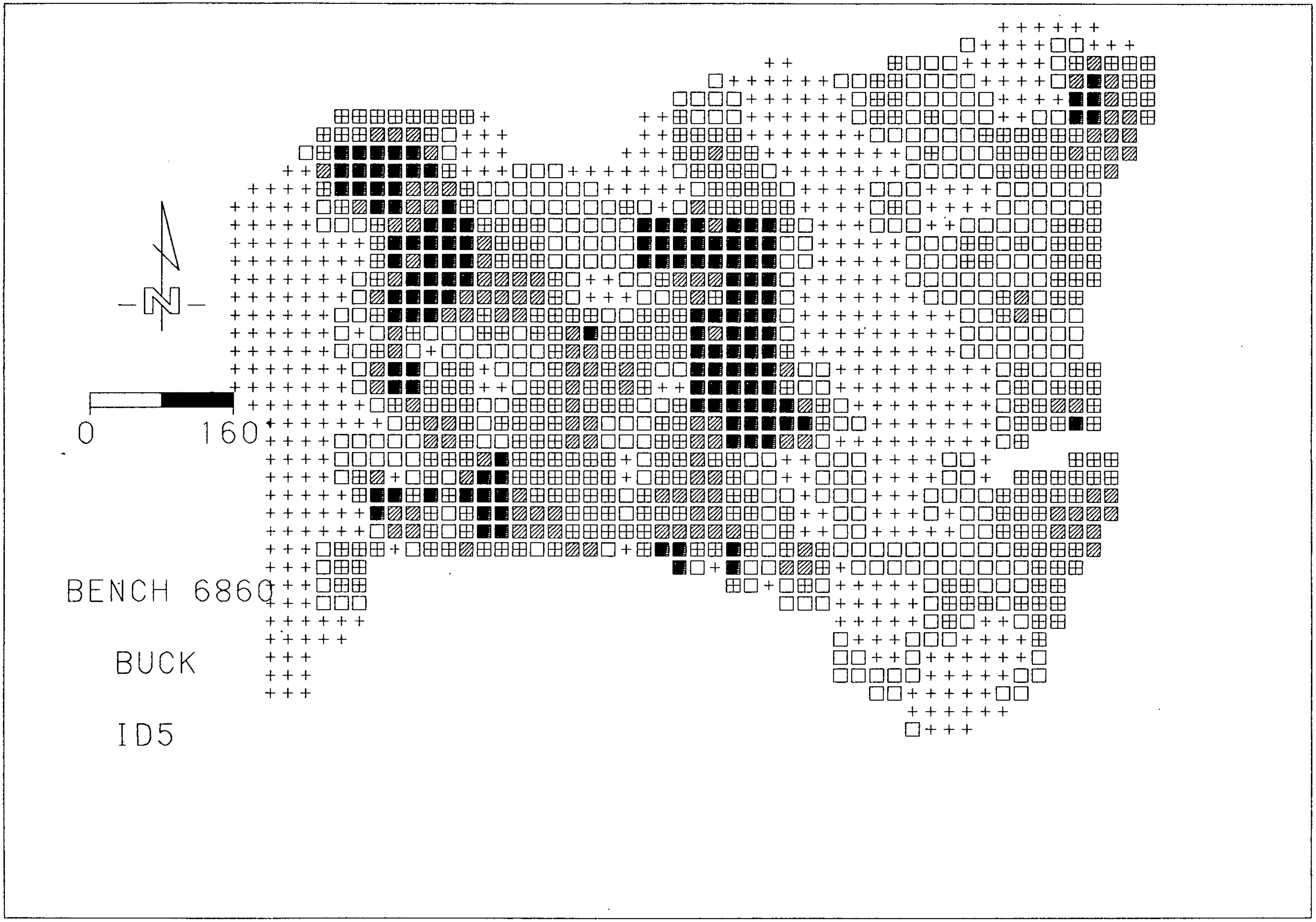

BENCH 6860
BUCK
ACTUAL - BHK
0
160
N


0
160
N
BENCH 6860
BUCK
BH20


0
160
BENCH 6860
BUCK
EX20



124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160
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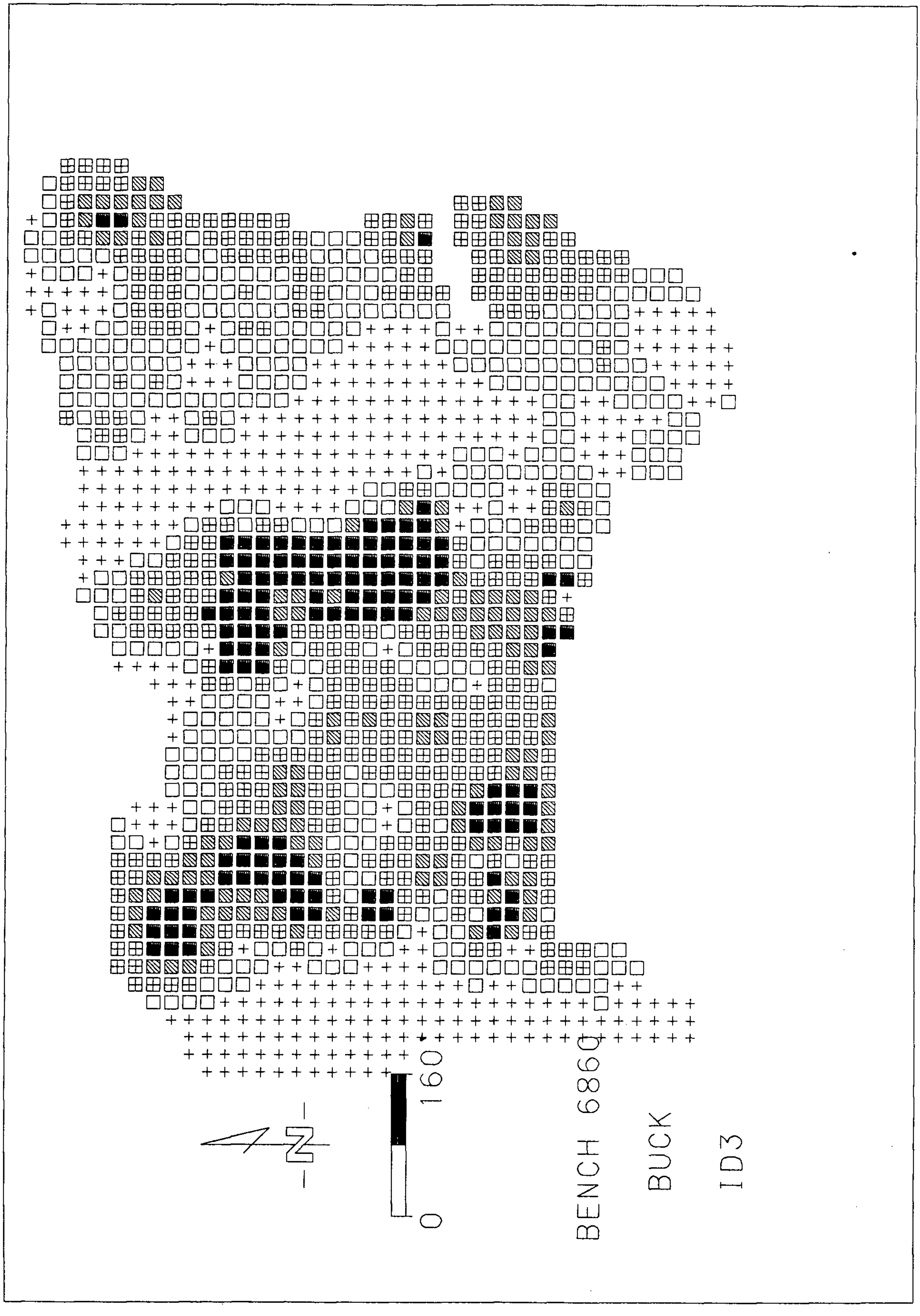
BUCK
ID5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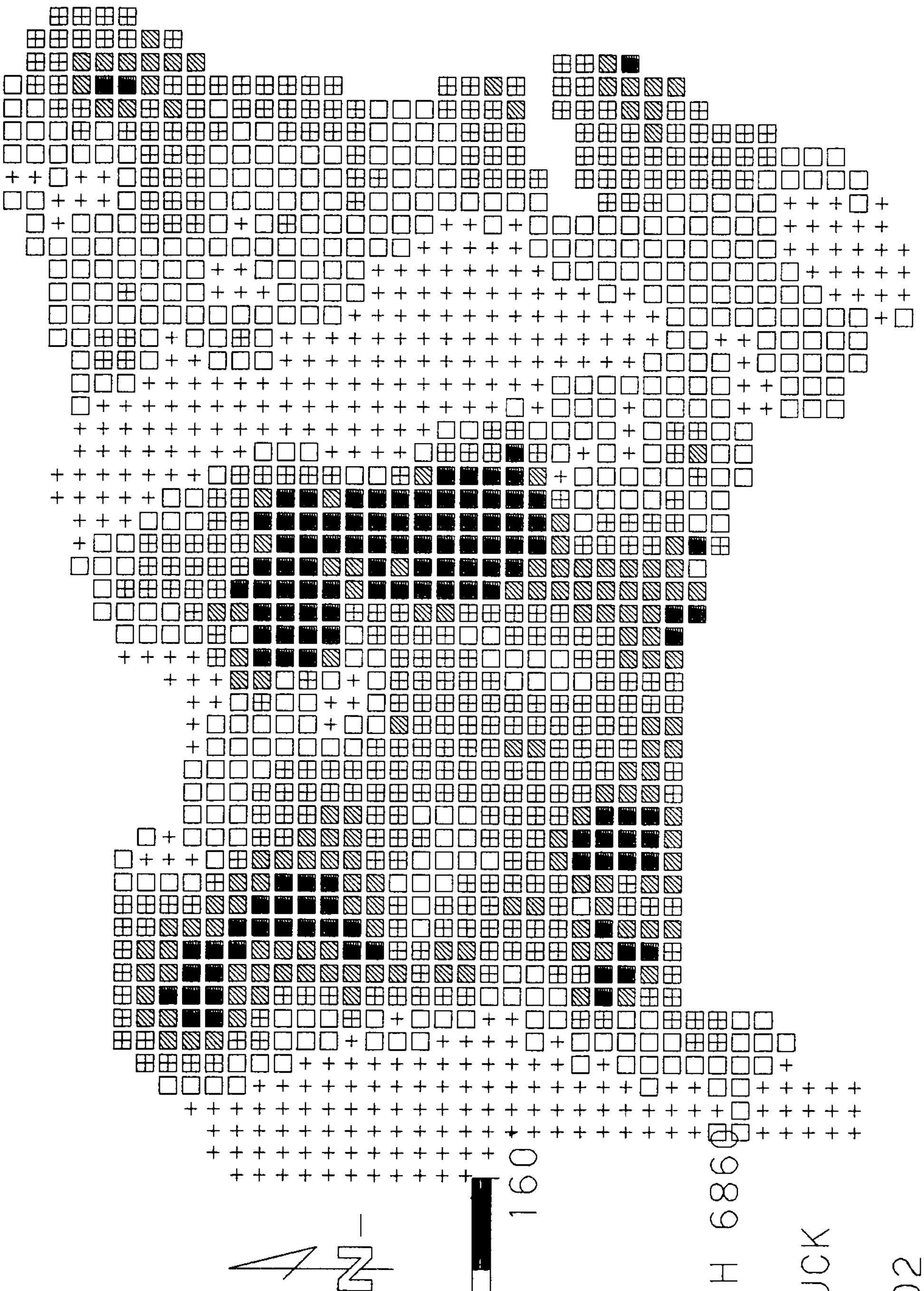
BUCK
ID3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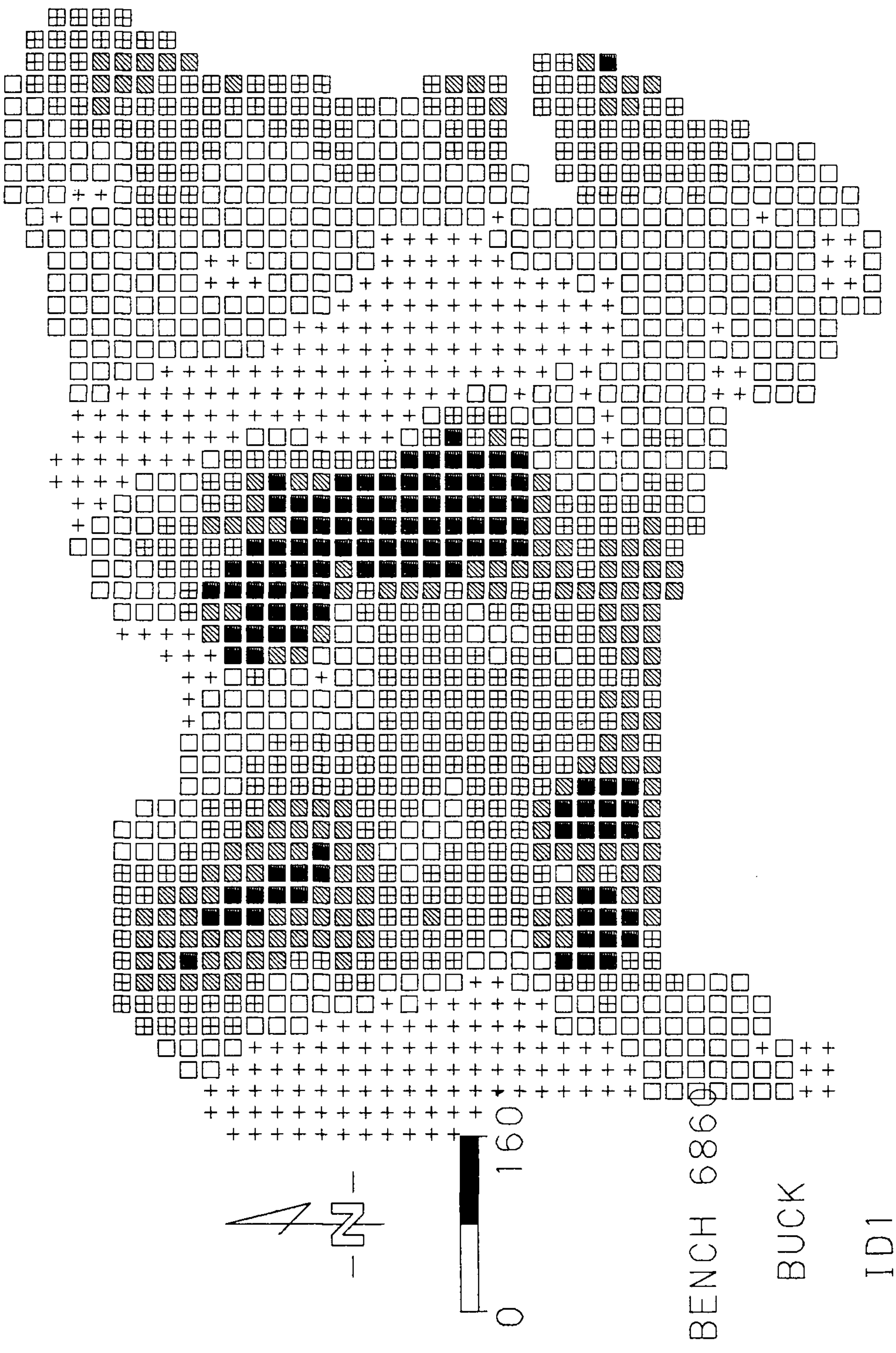
BENCH 6860
BUCK
ID2



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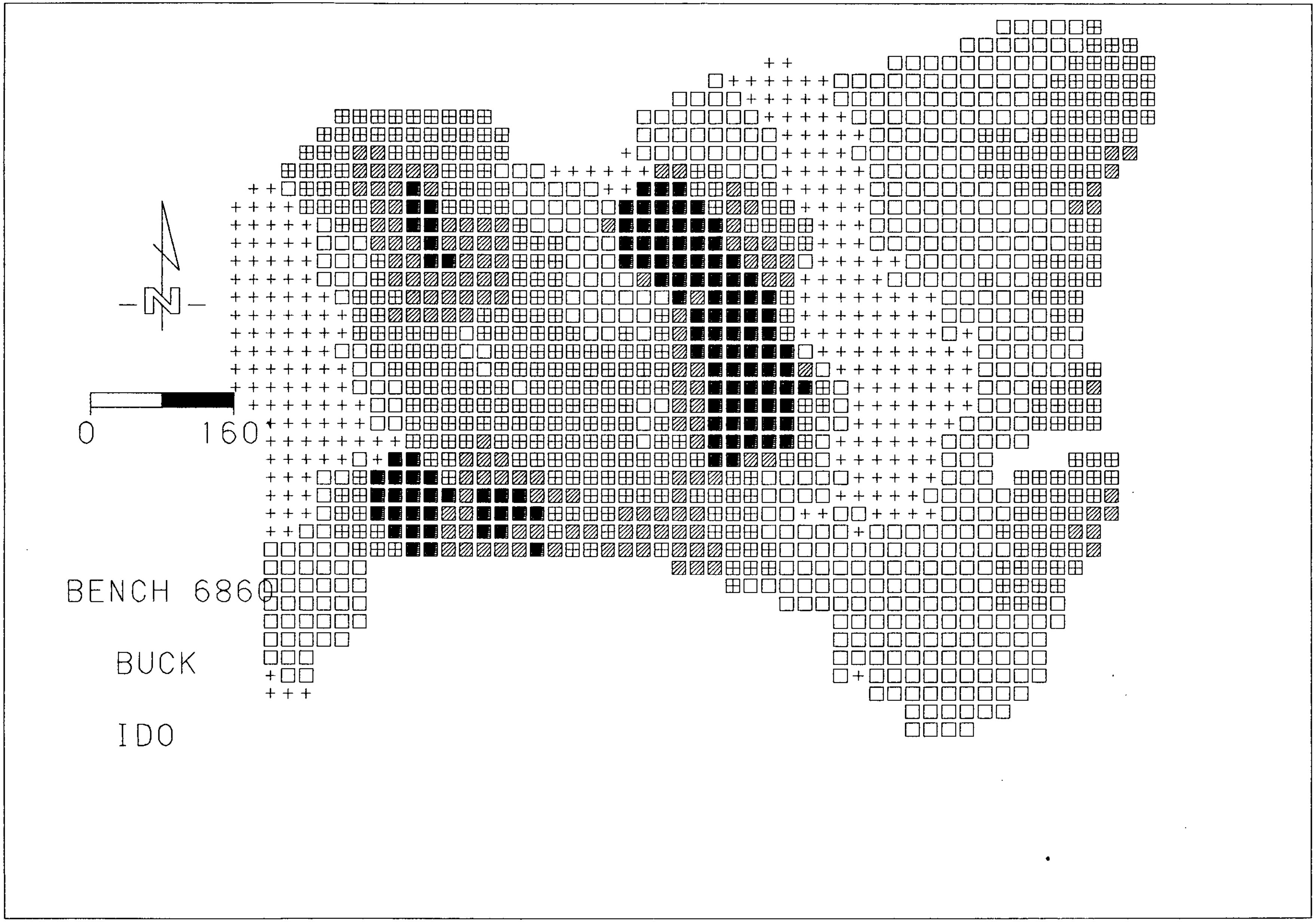
0
BENCH 6860
BUCK
ID1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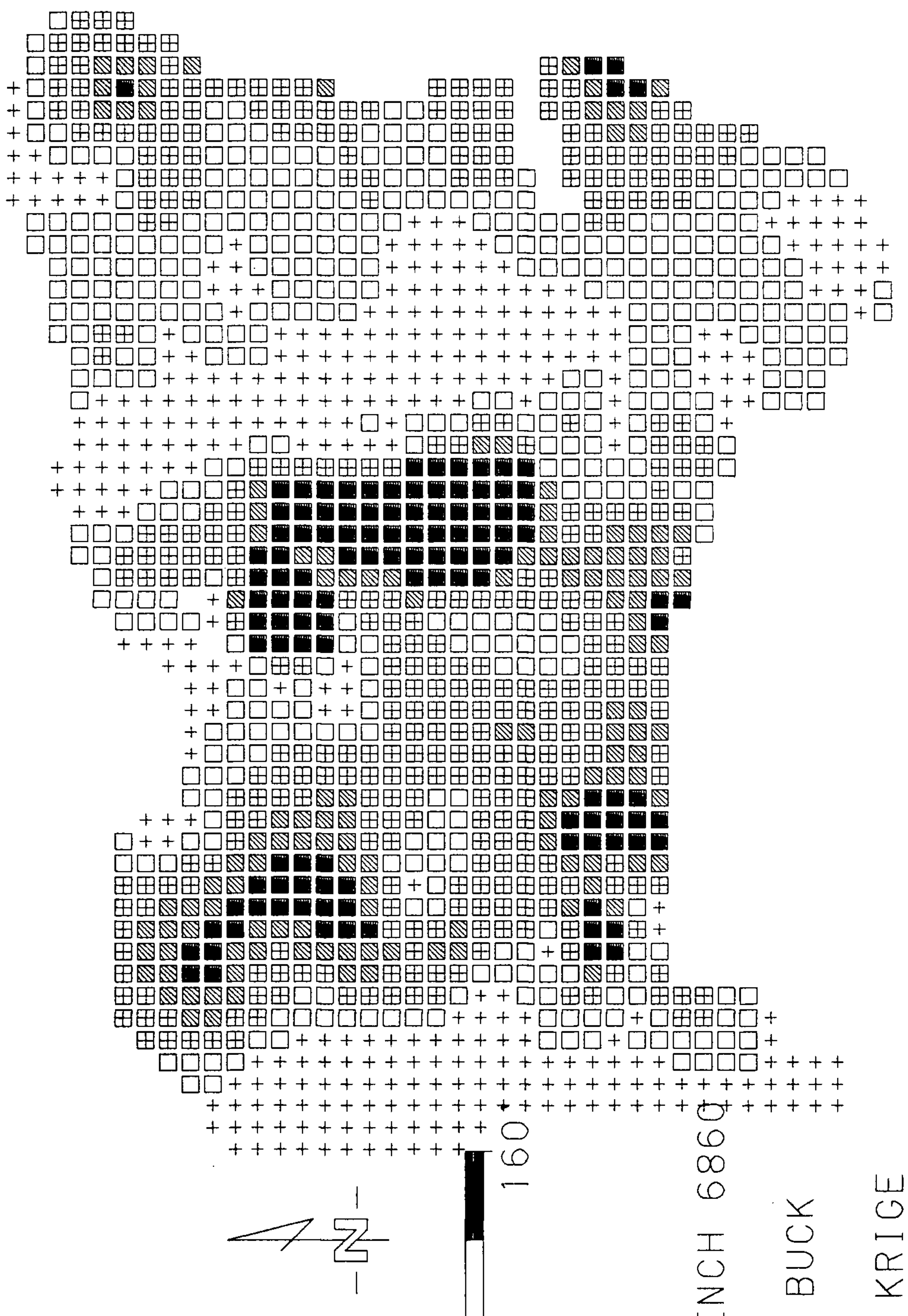
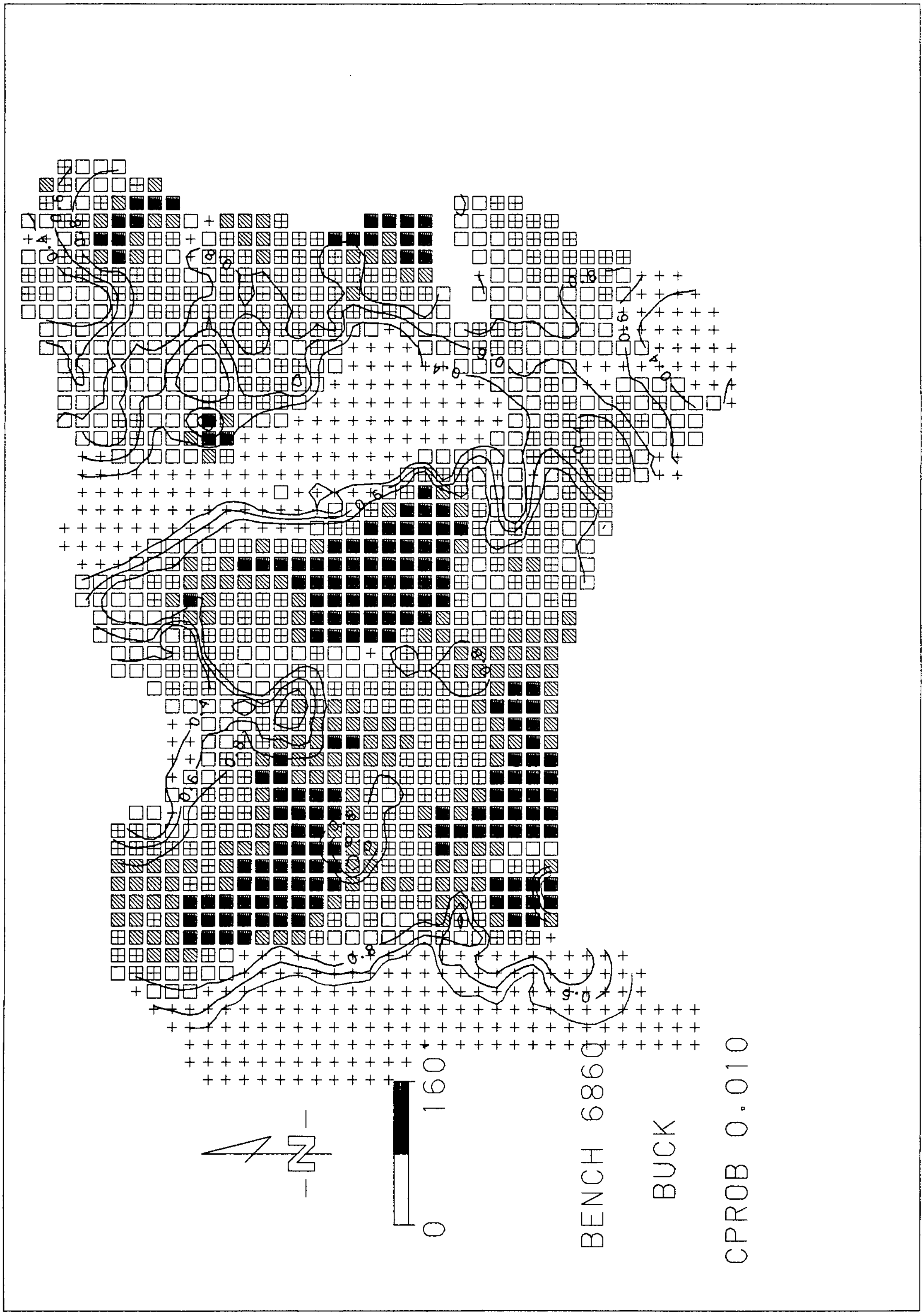
0
160
BENCH 6860
BUCK
IDO


0
160
BENCH 6860
BUCK
KRIGE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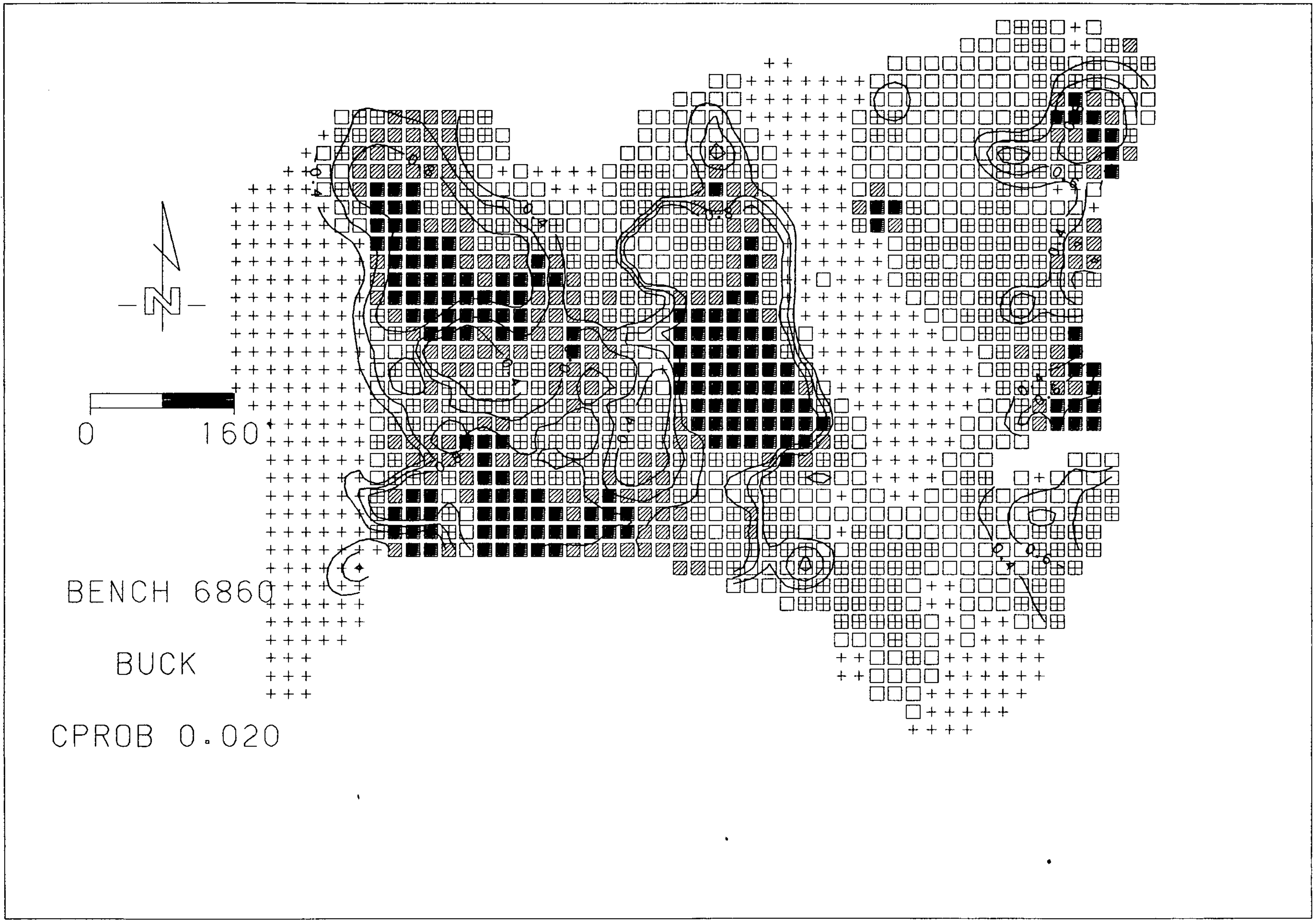
160
BENCH 6860
BUCK
CPROB 0.010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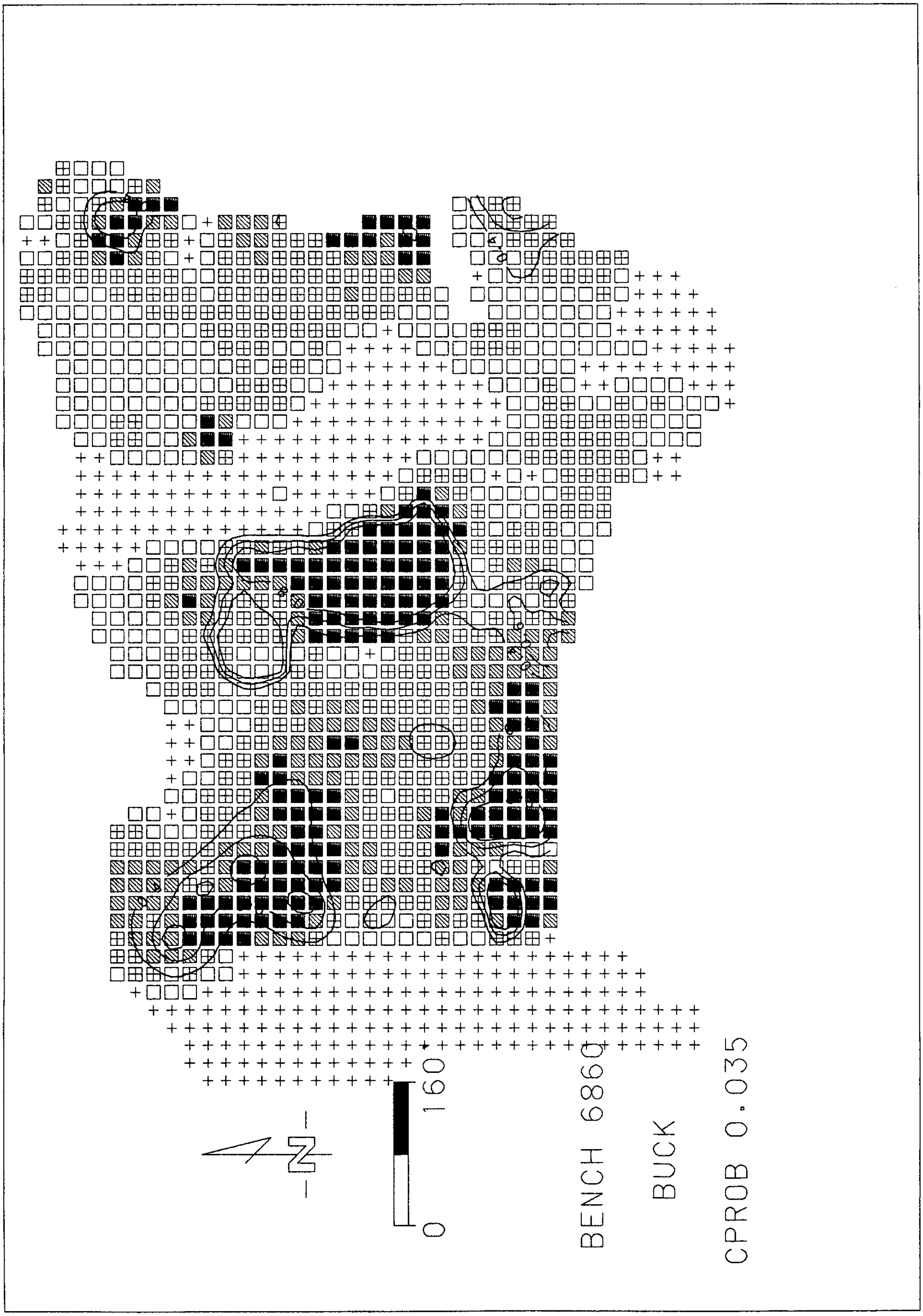
BUCK
CPROB 0.020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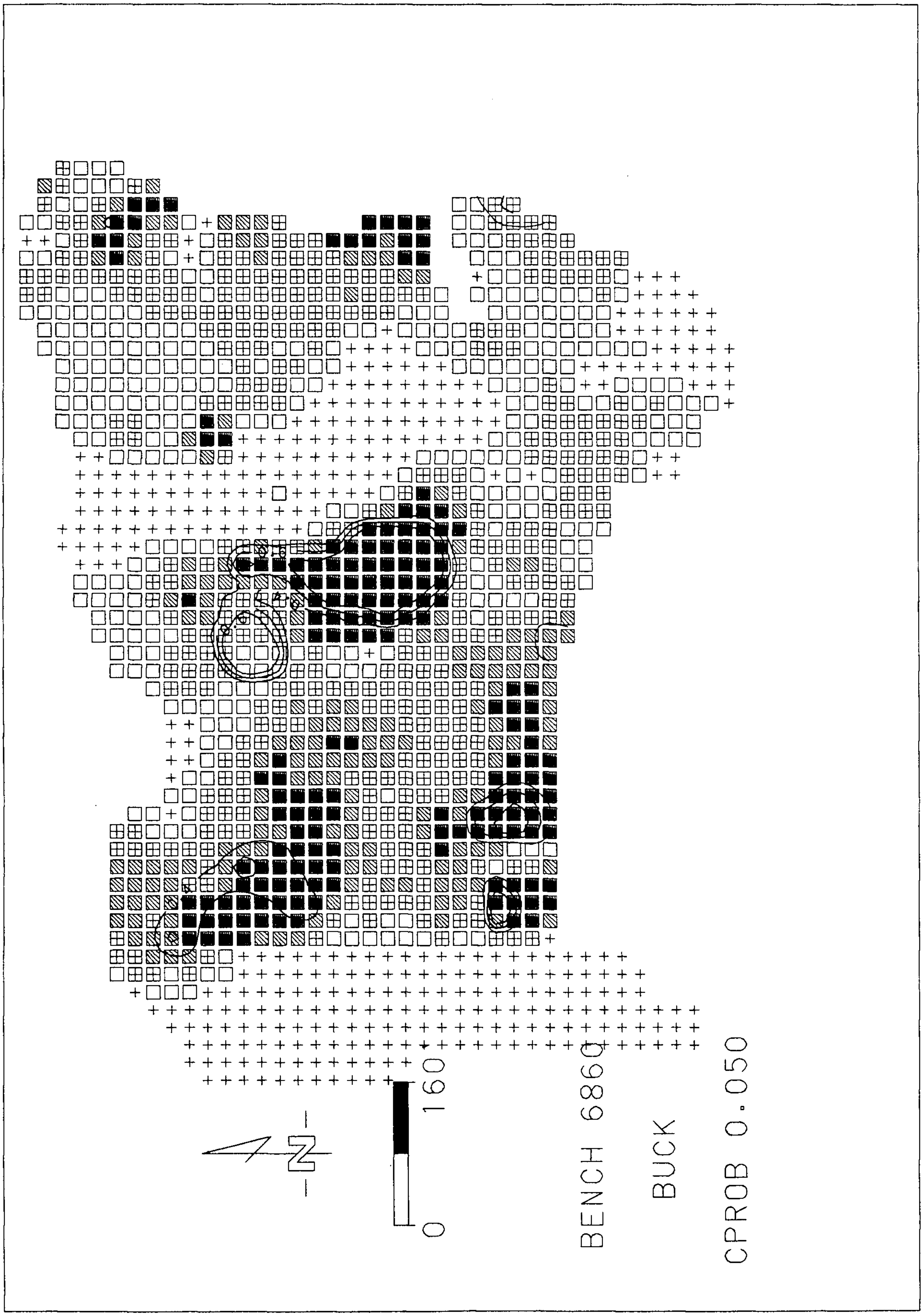
BUCK
CPROB 0.035



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0
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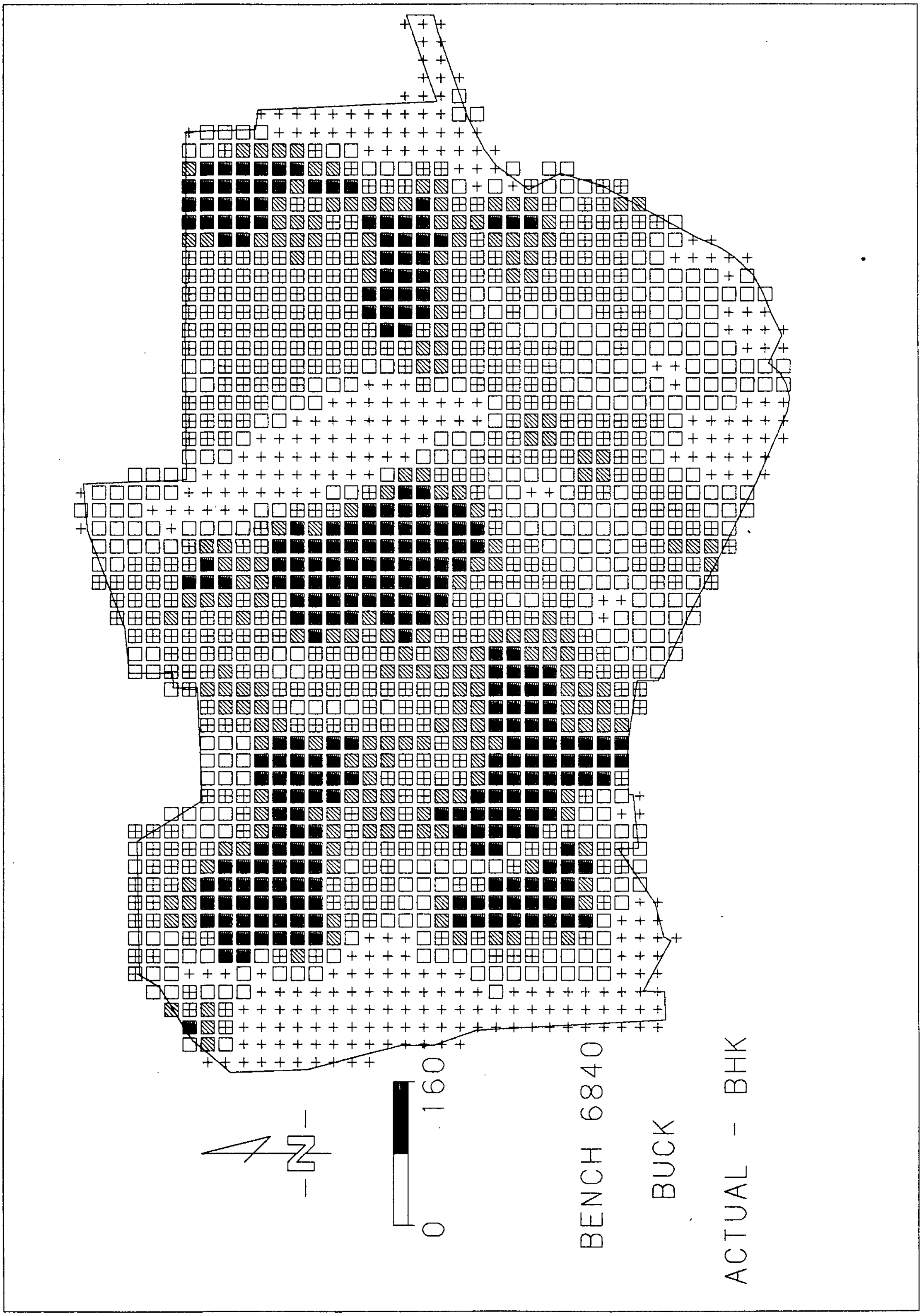
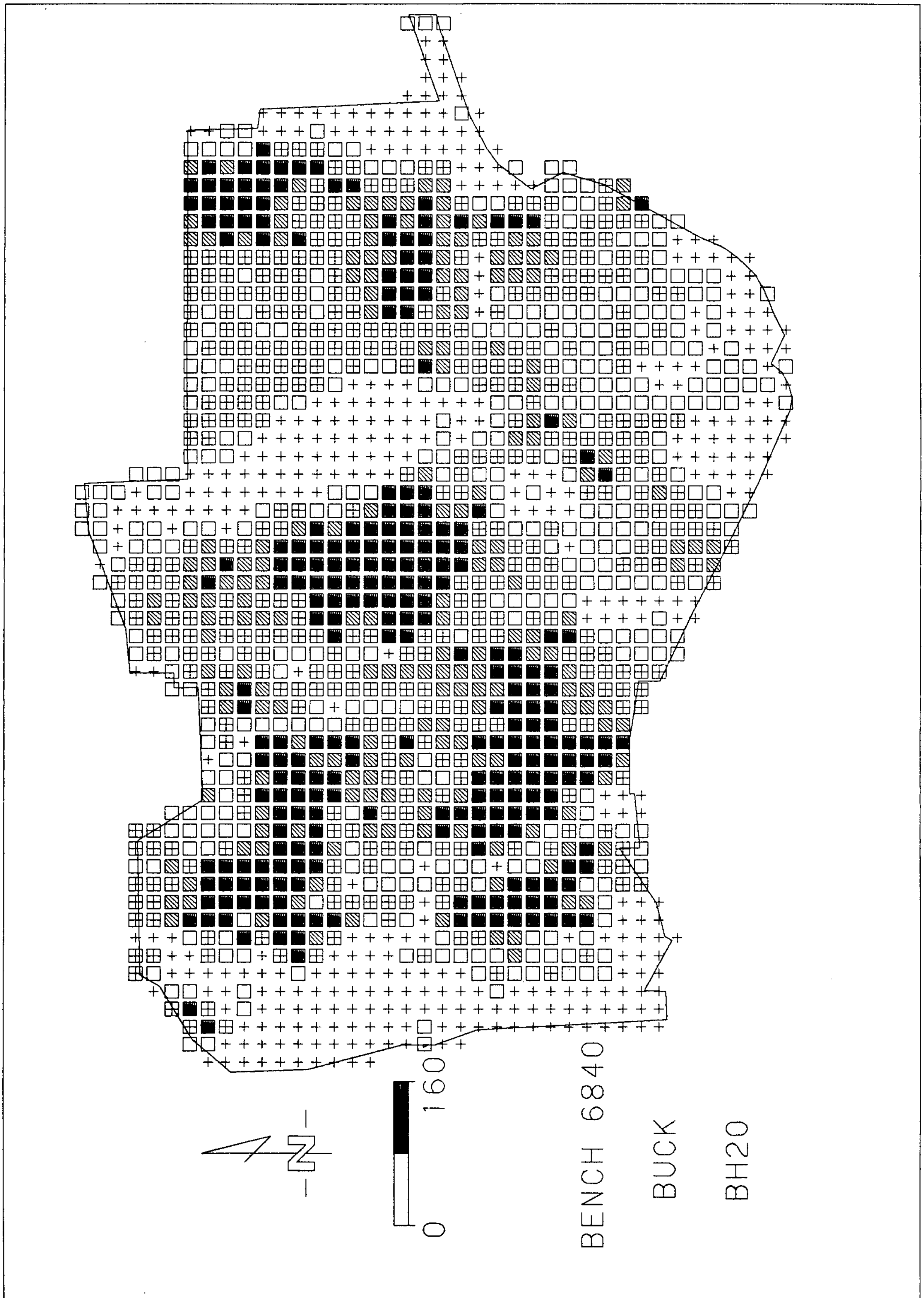
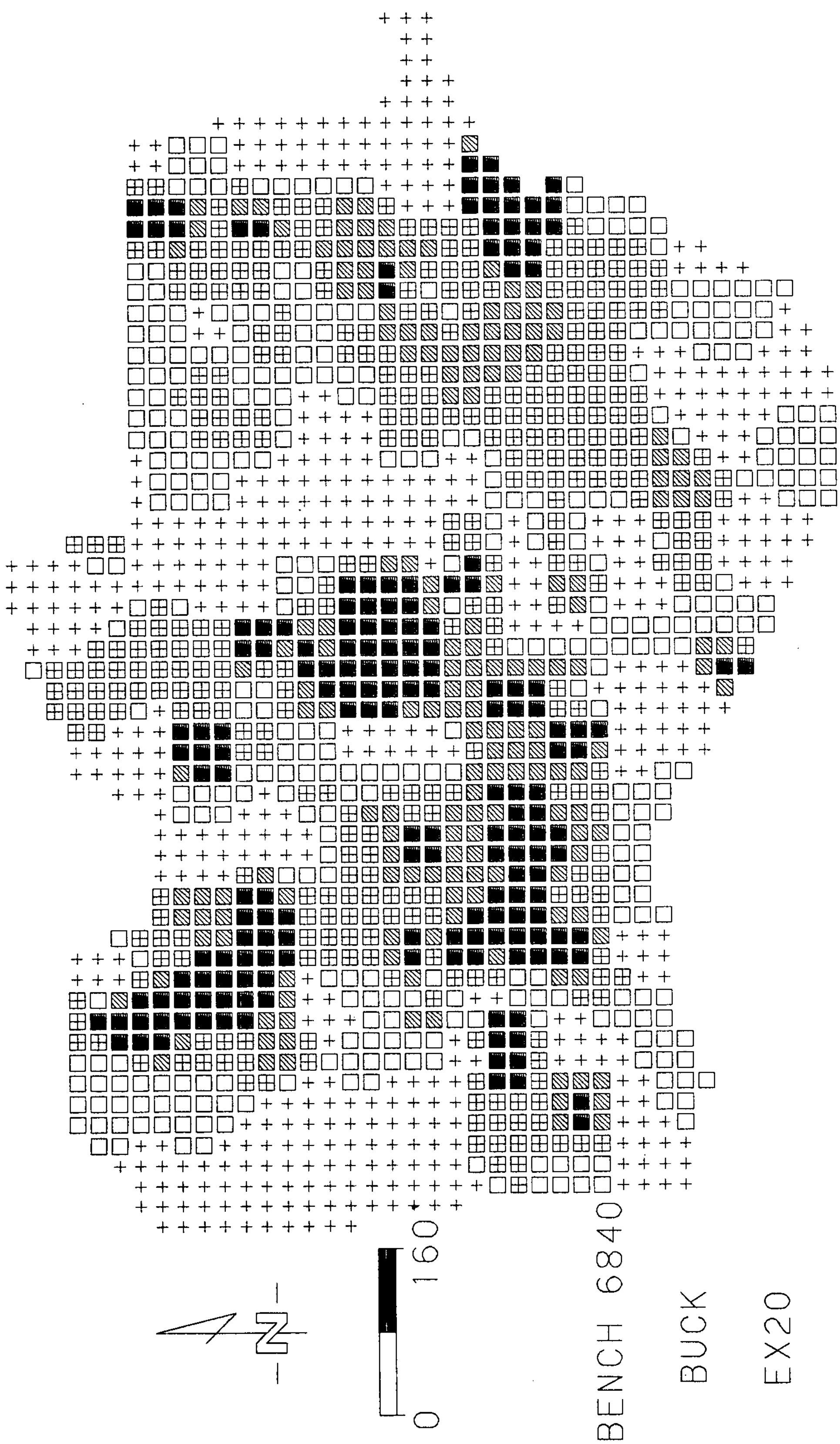
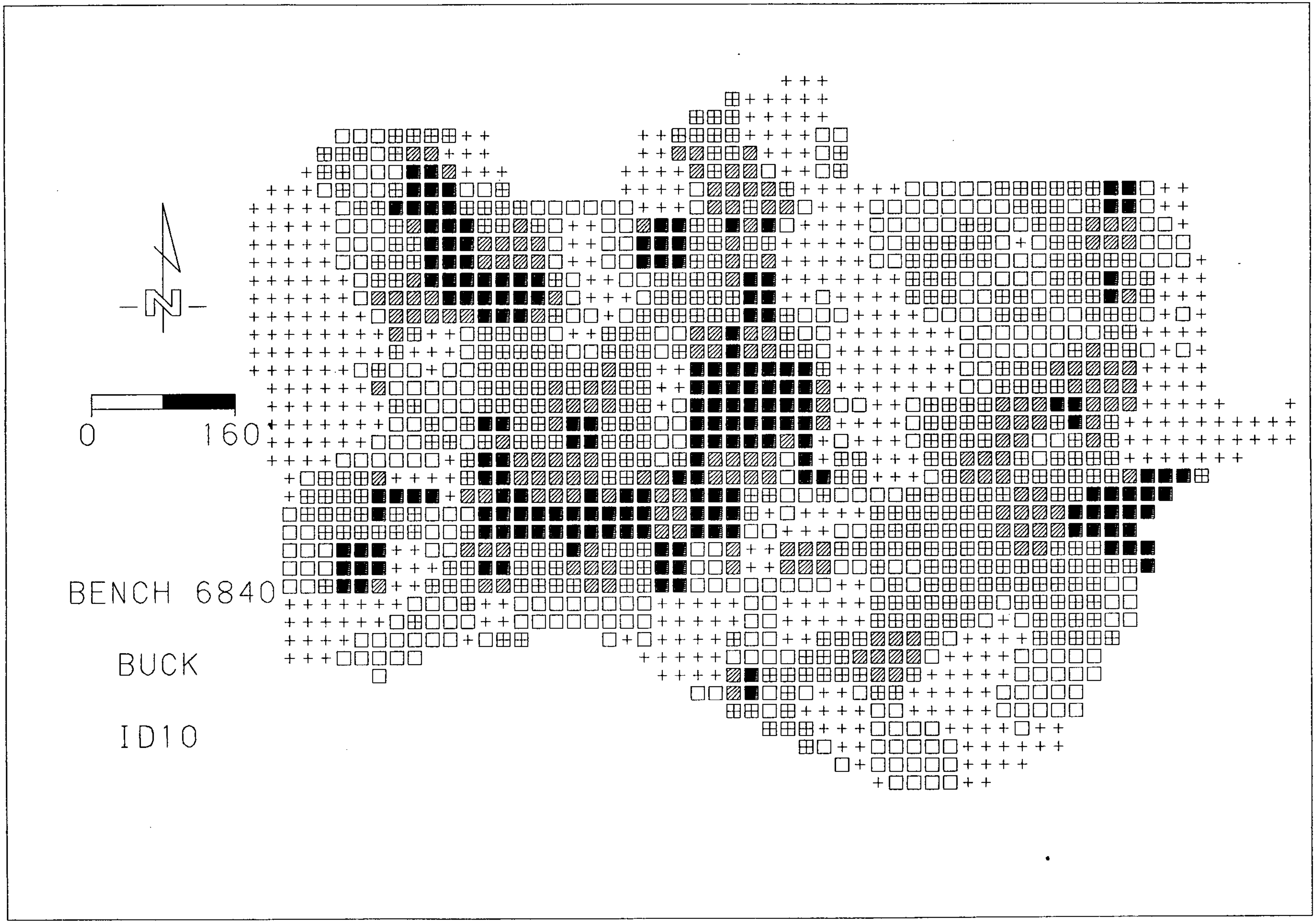
BUCK
CPROB 0.050


0
160
N
BENCH 6840
BUCK
ACTUAL - BHK


0
160
BENCH 6840
BUCK
BH20



N
0
160
BENCH 6840
BUCK
EX20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BUCK
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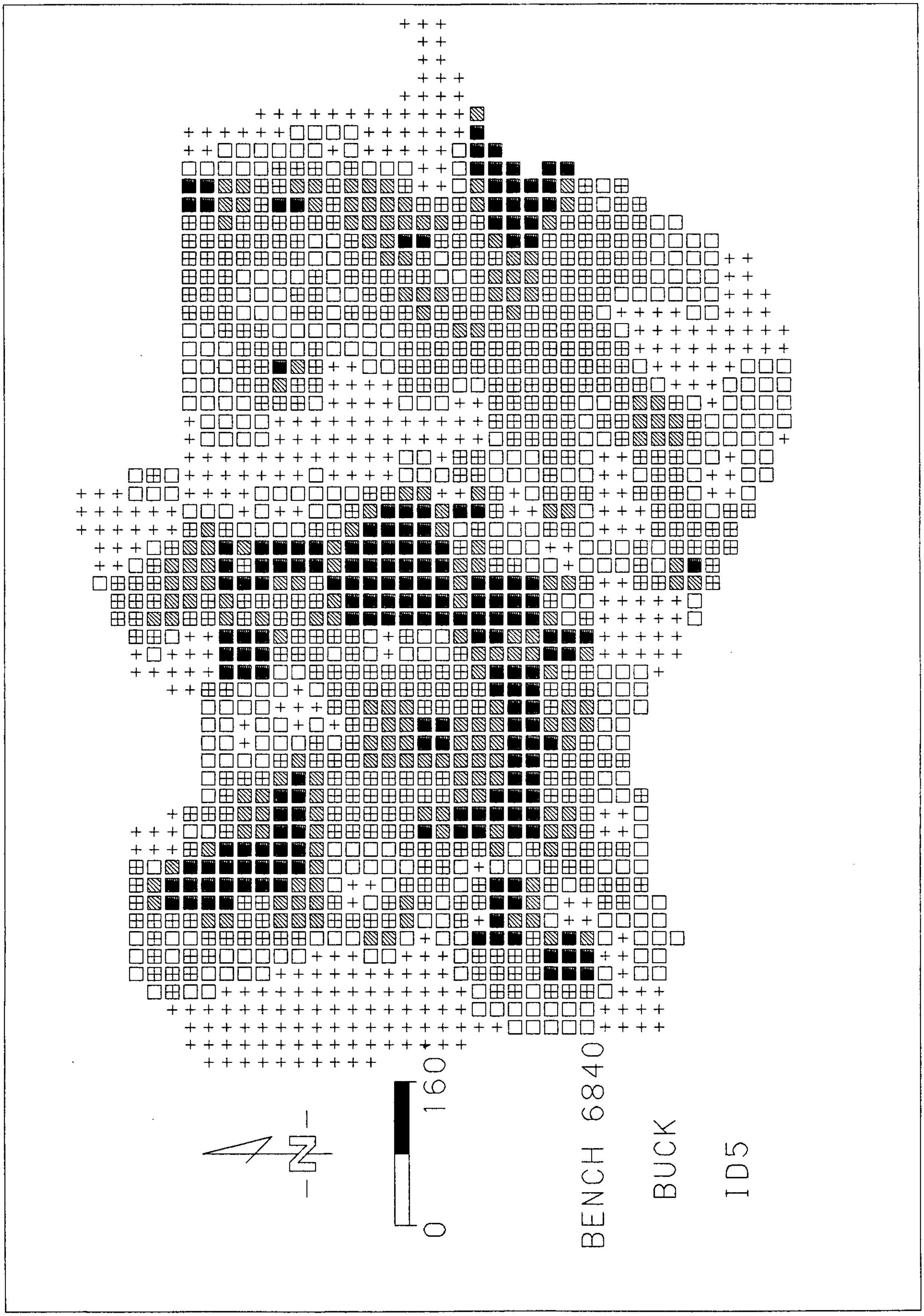
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BUCK
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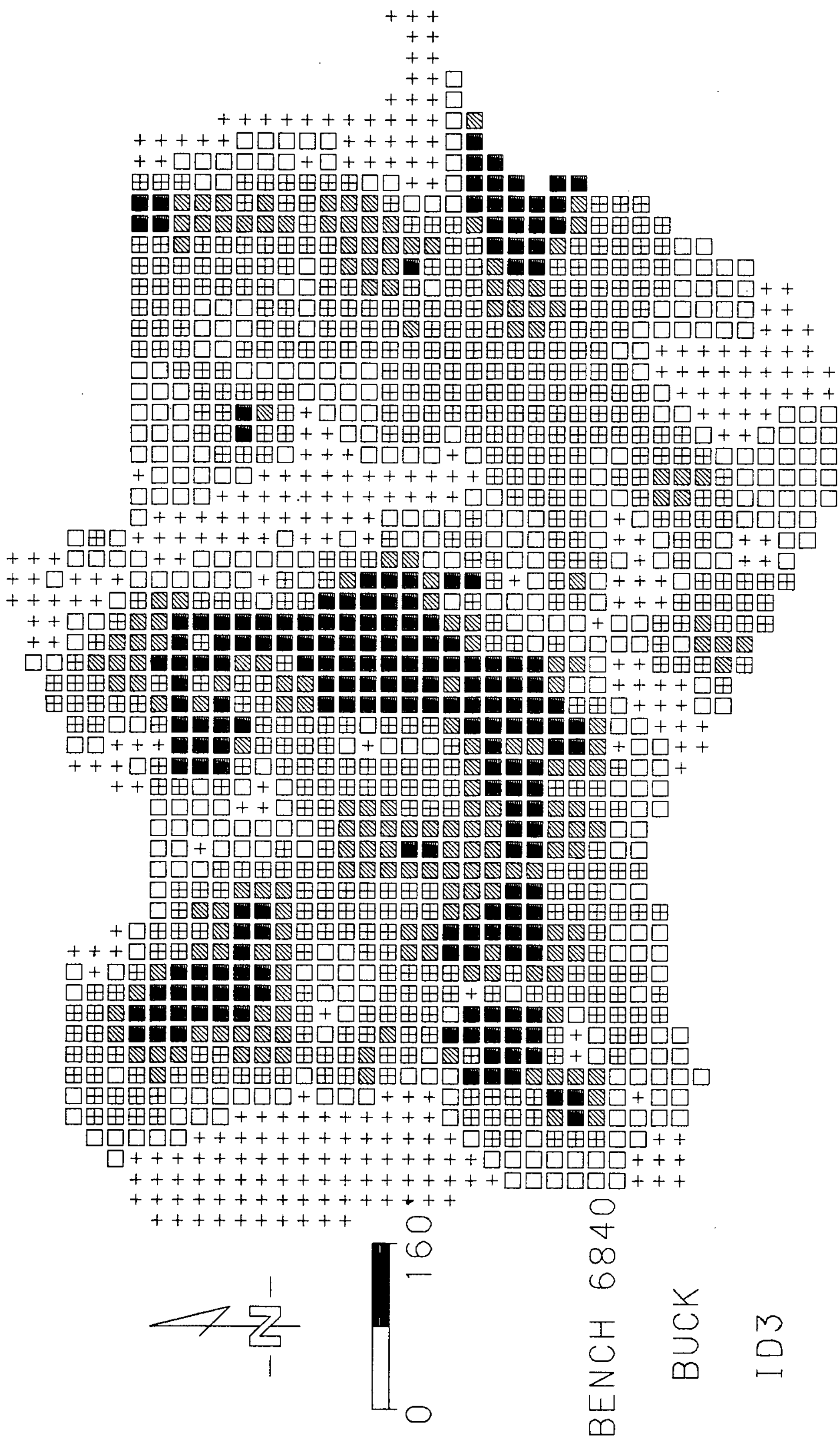
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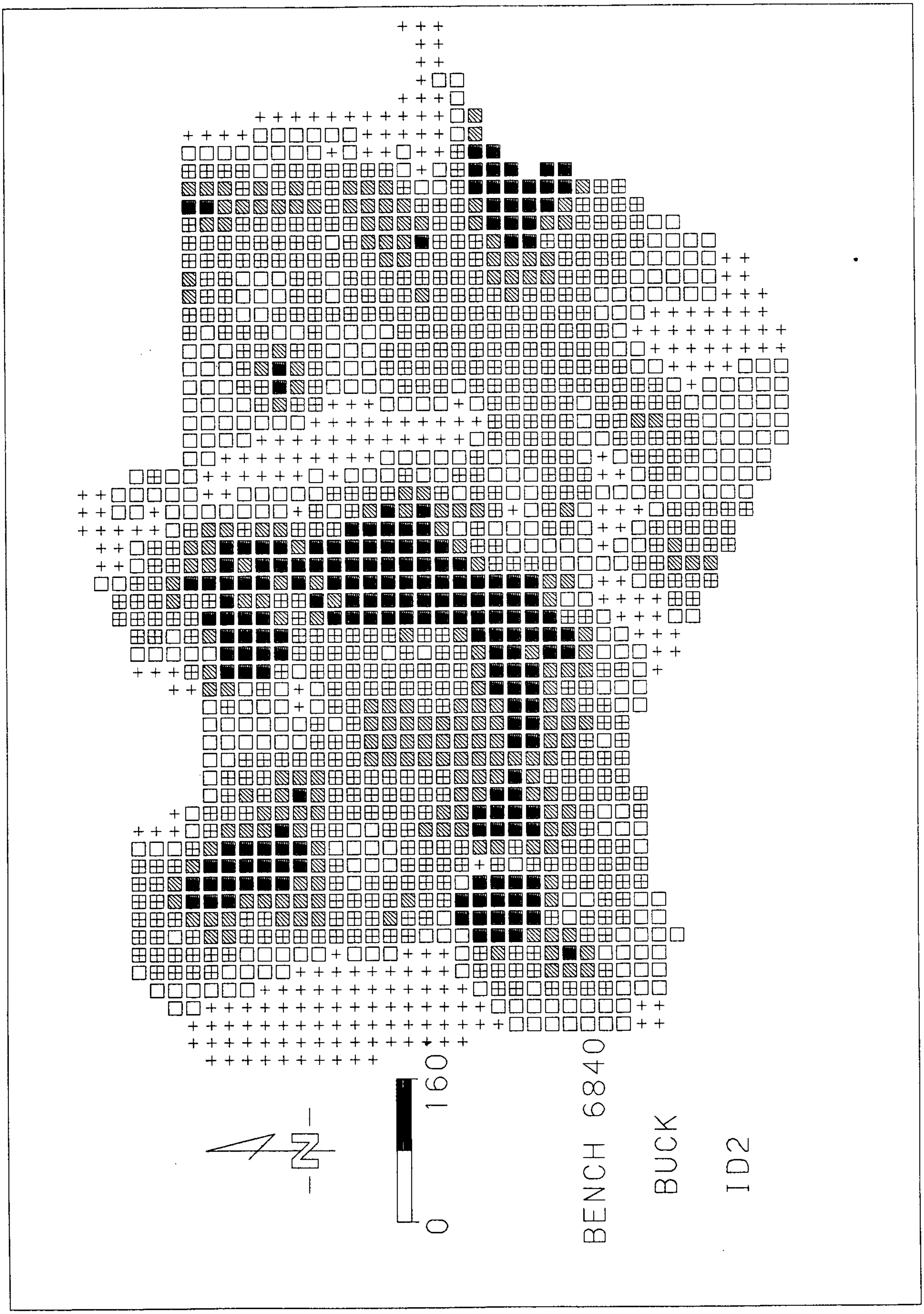
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BUCK
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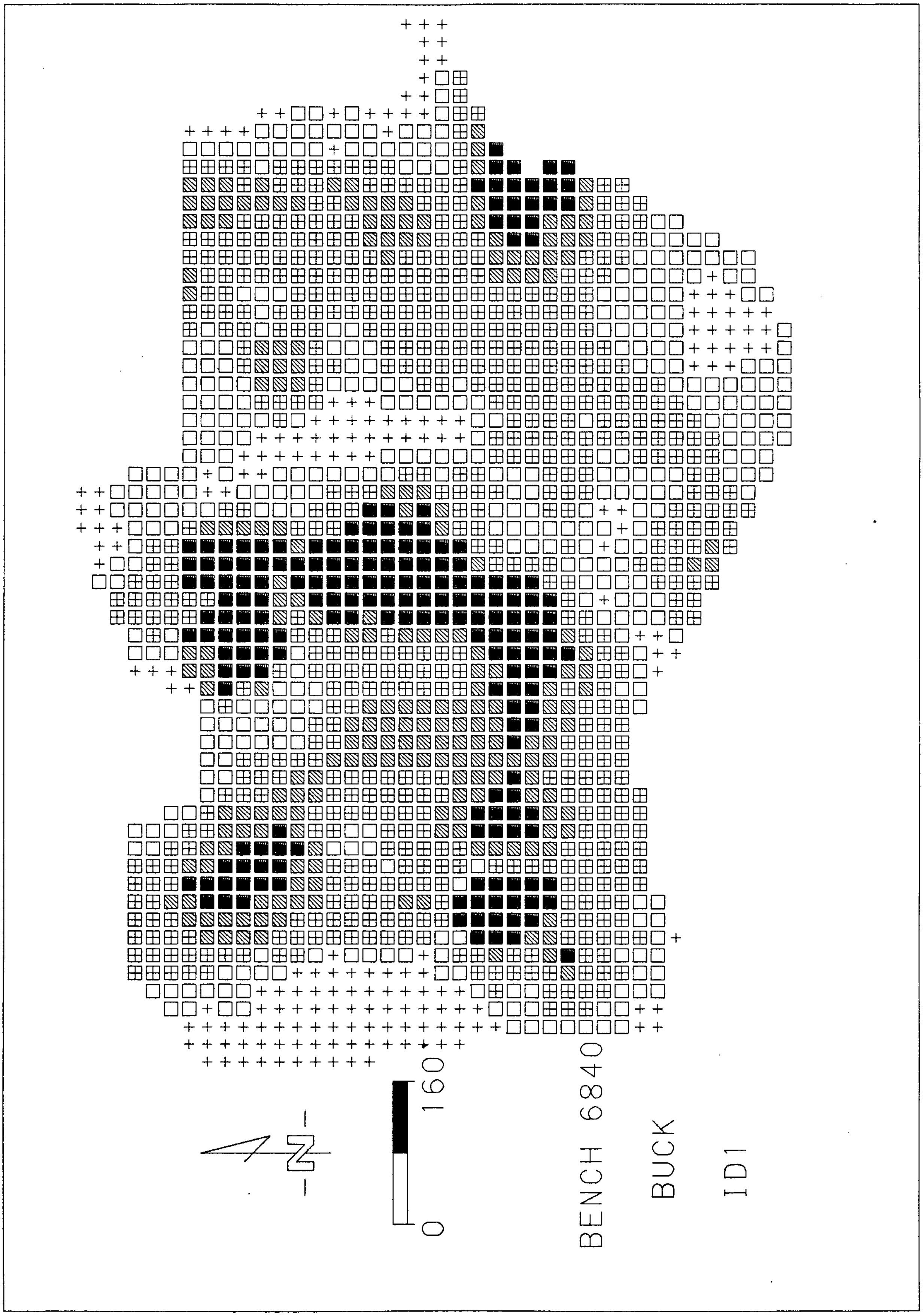

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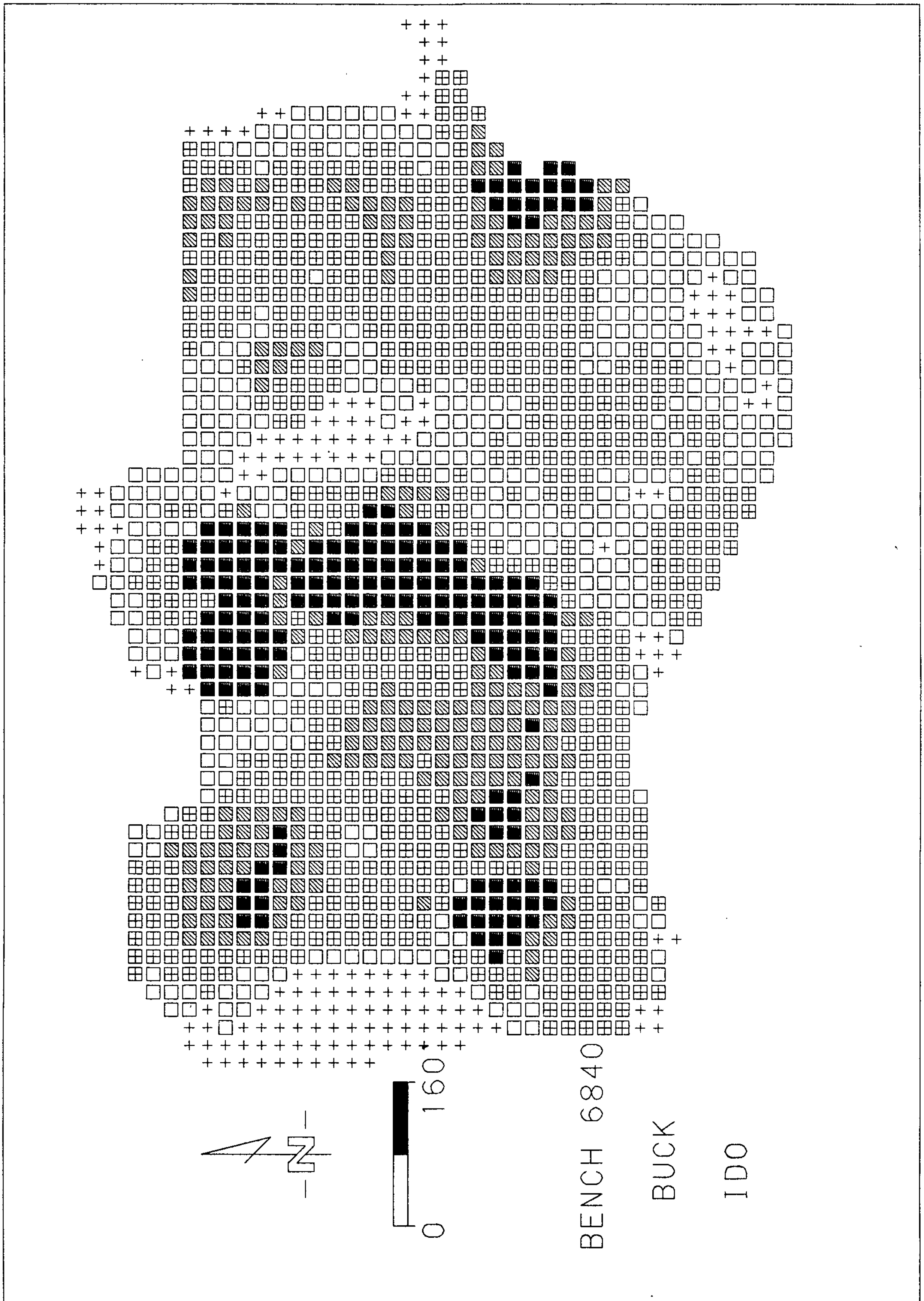
BUCK
ID1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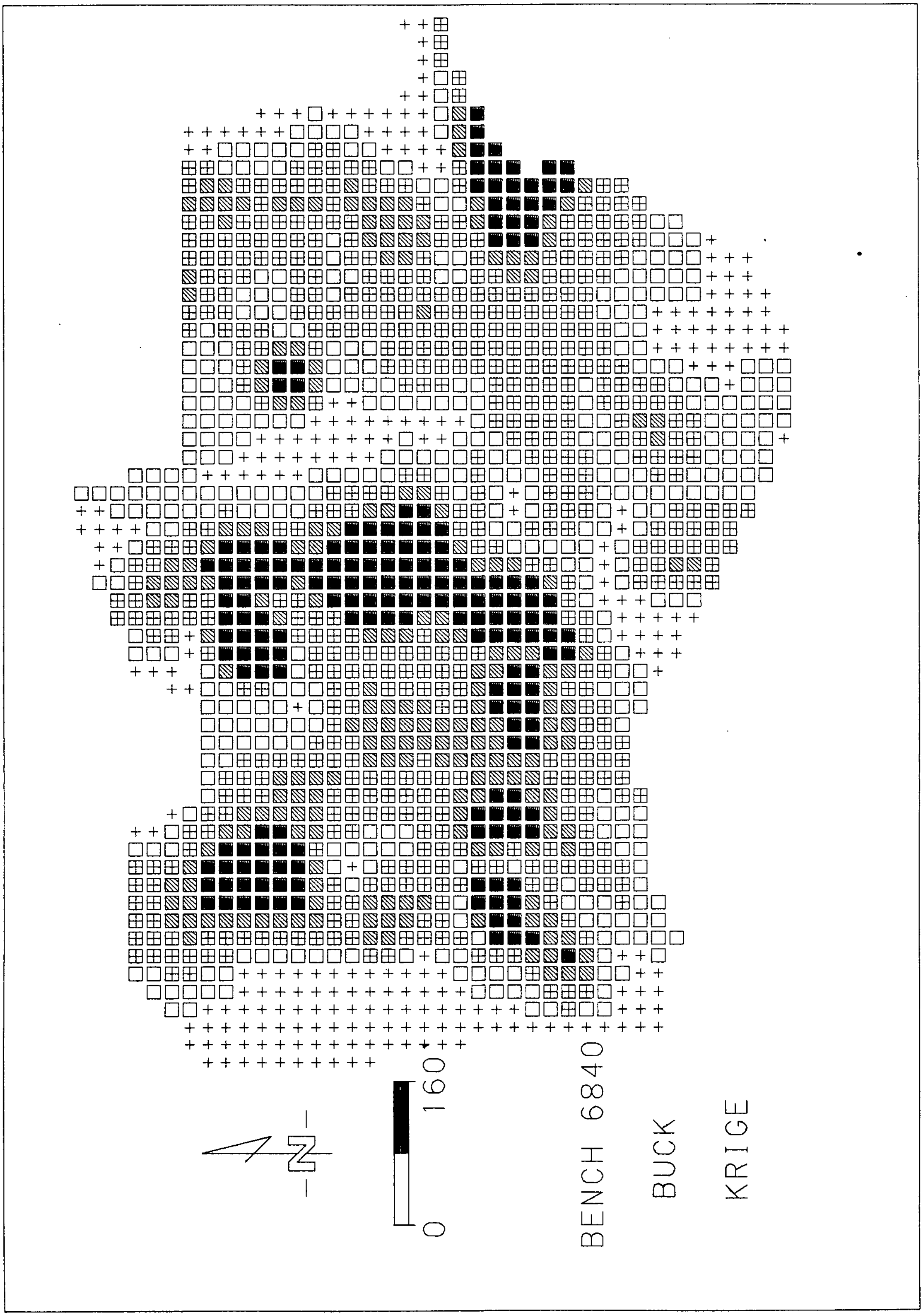
BUCK
IDO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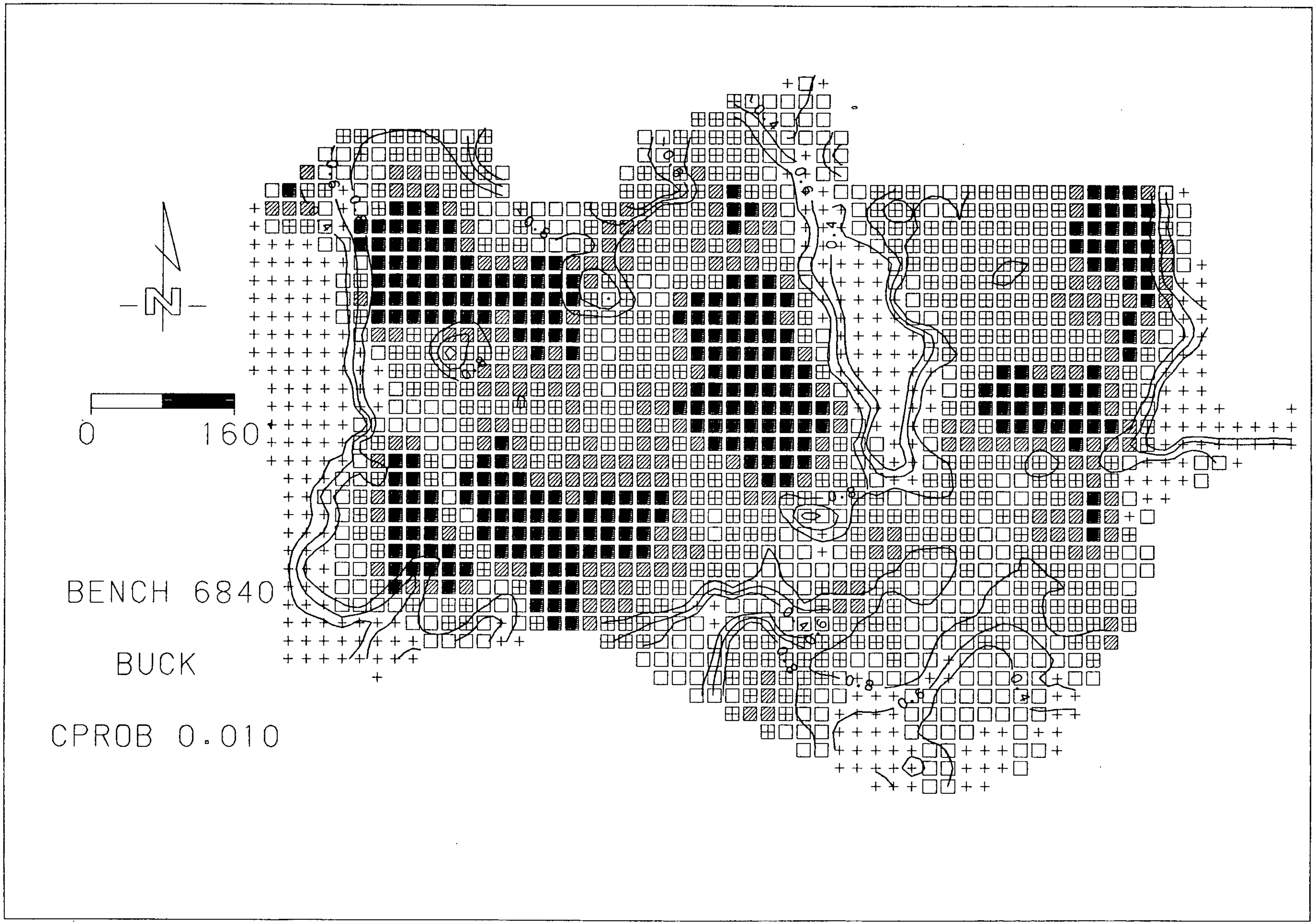
160
BENCH 6840
BUCK
KRIGE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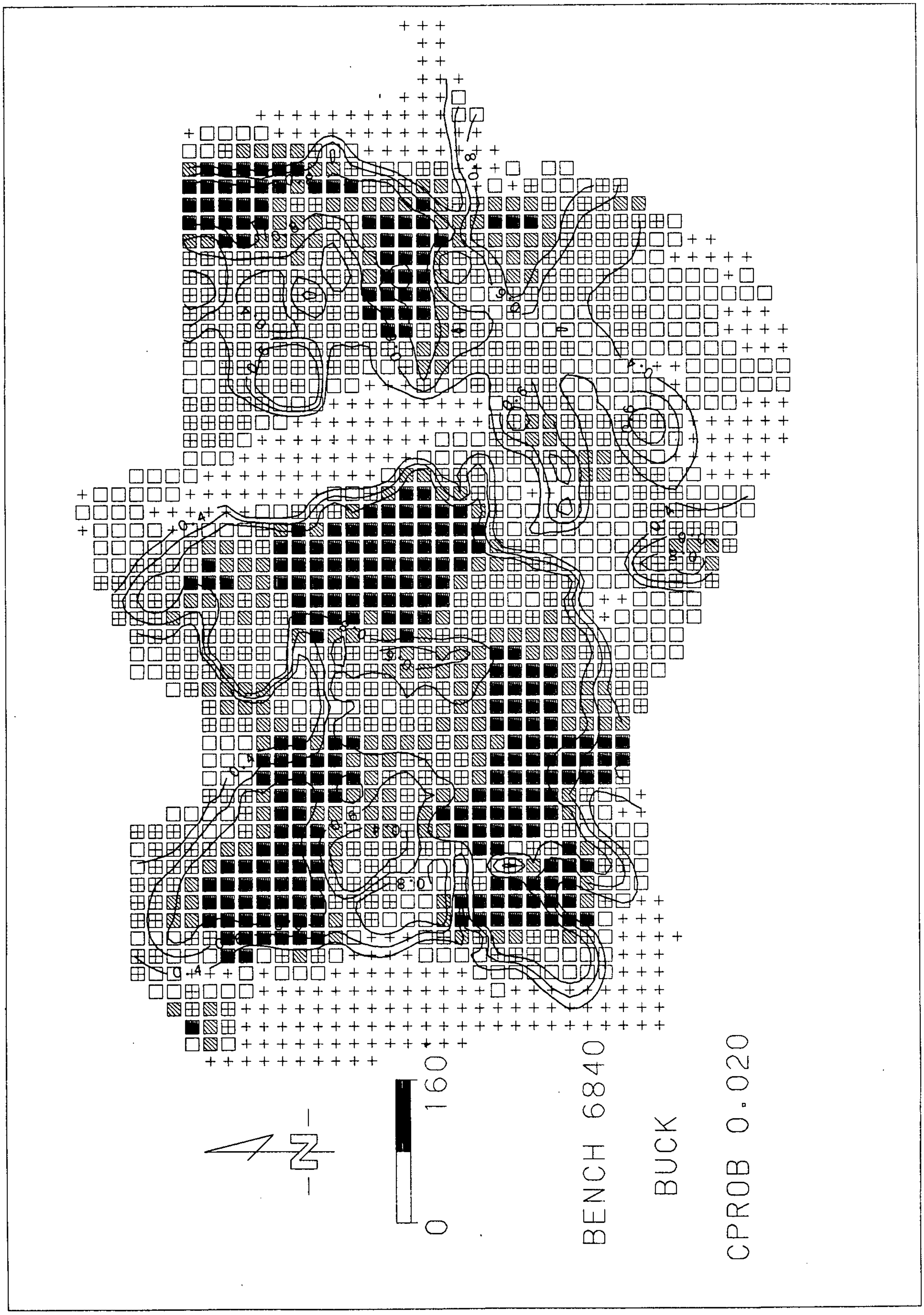
BUCK
CPROB 0.010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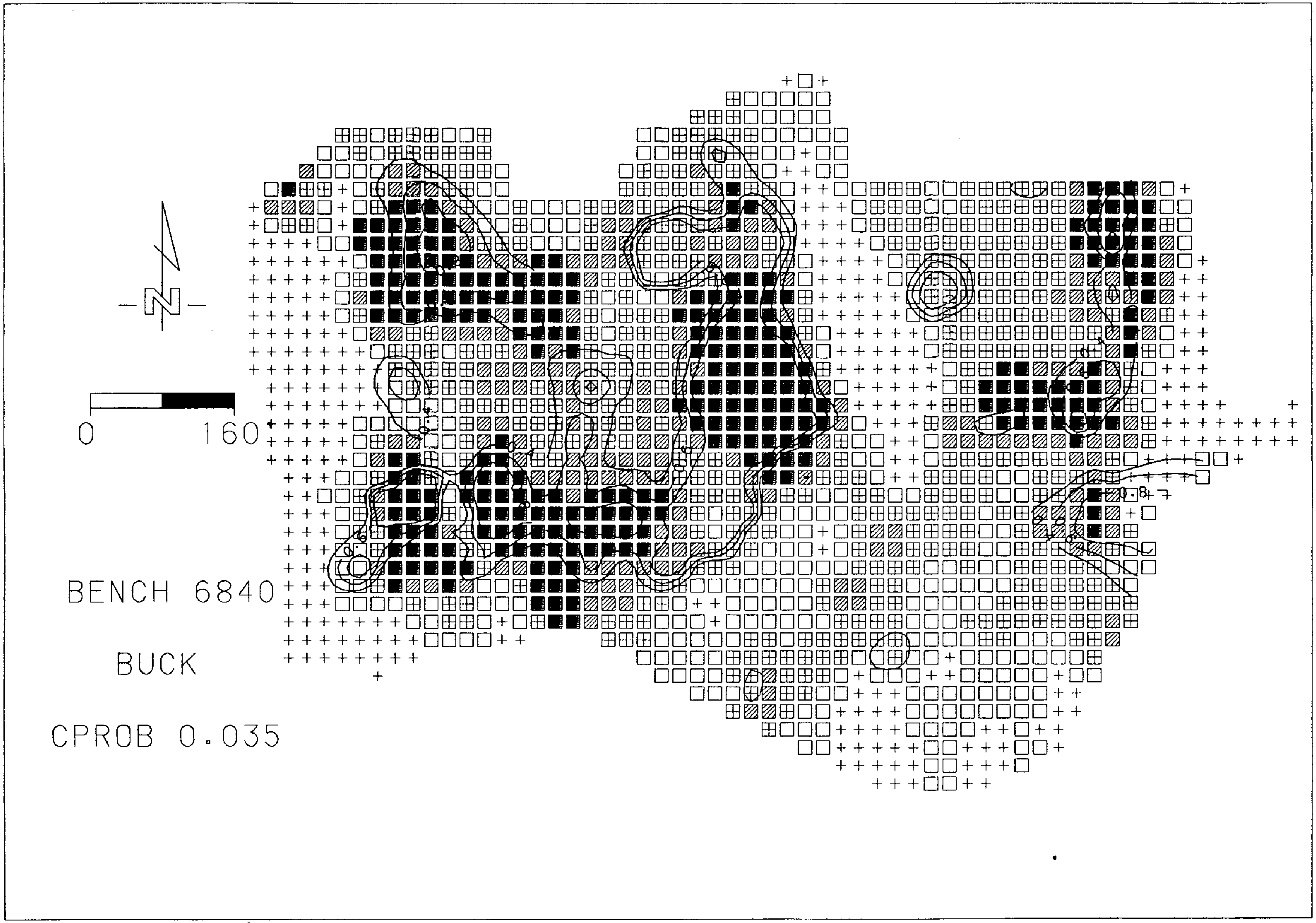

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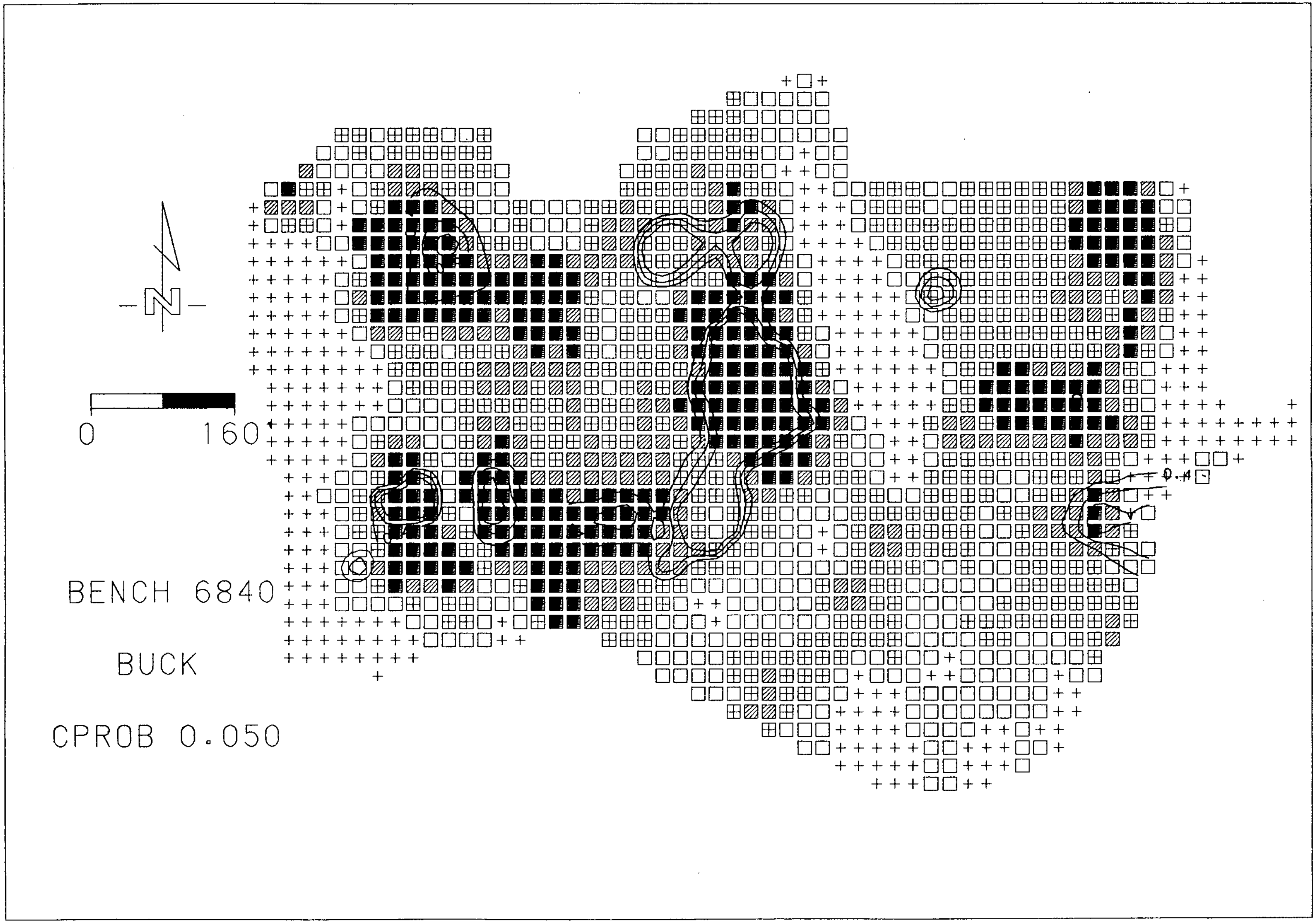
BENCH 6840
BUCK
CPROB 0.035
0.8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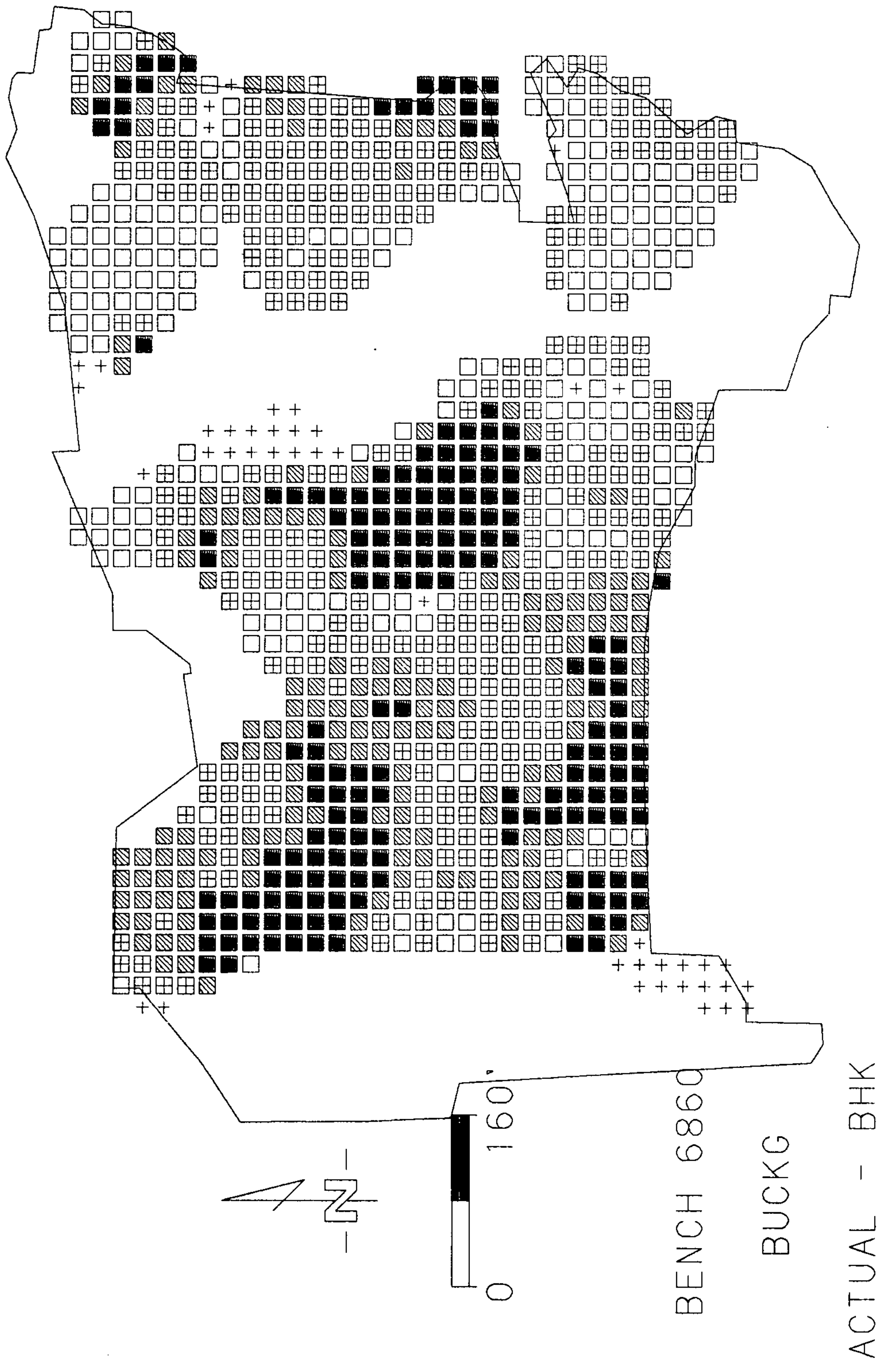
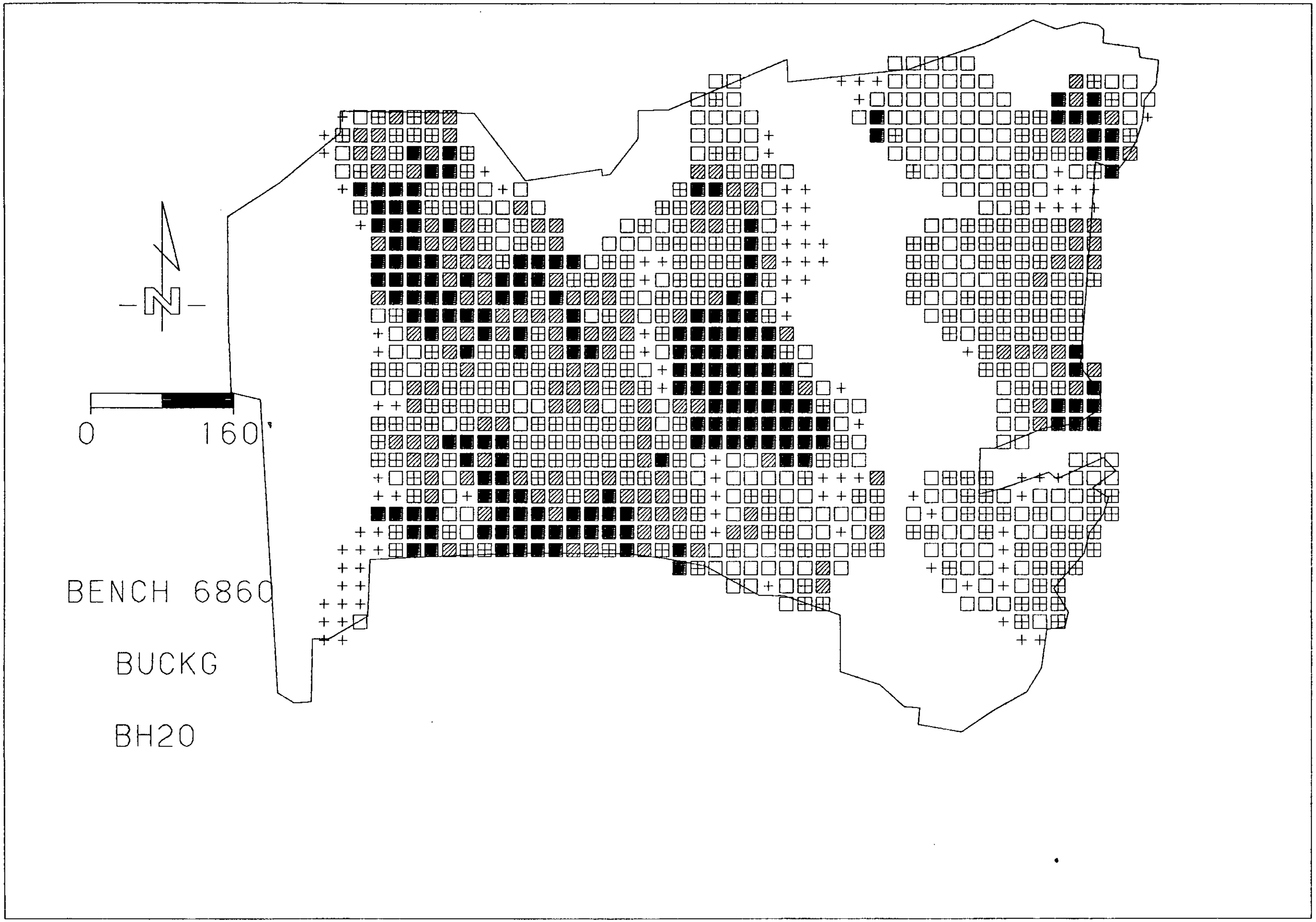

N
0
160
BENCH 6860
BUCKG
ACTUAL - BHK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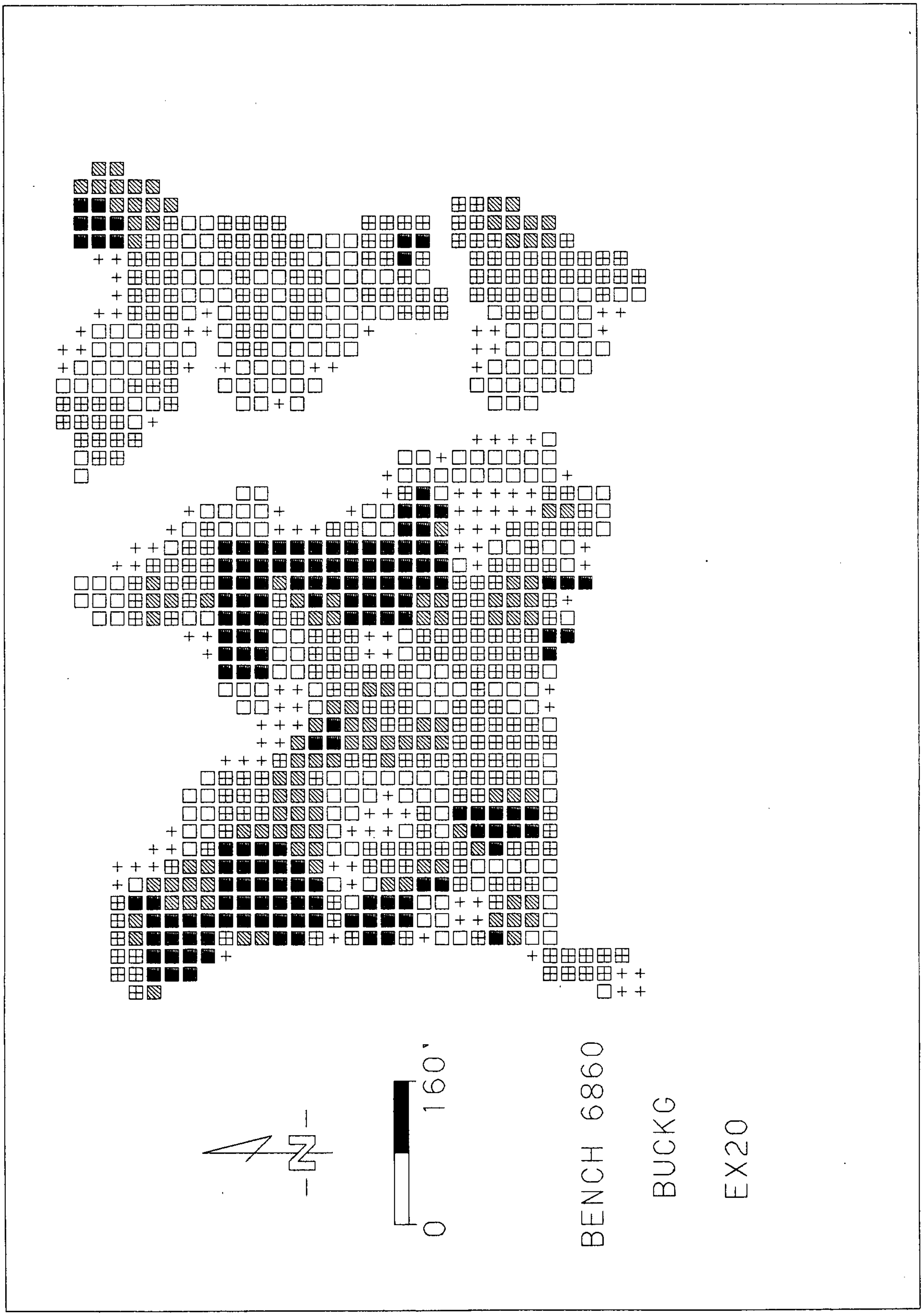

0
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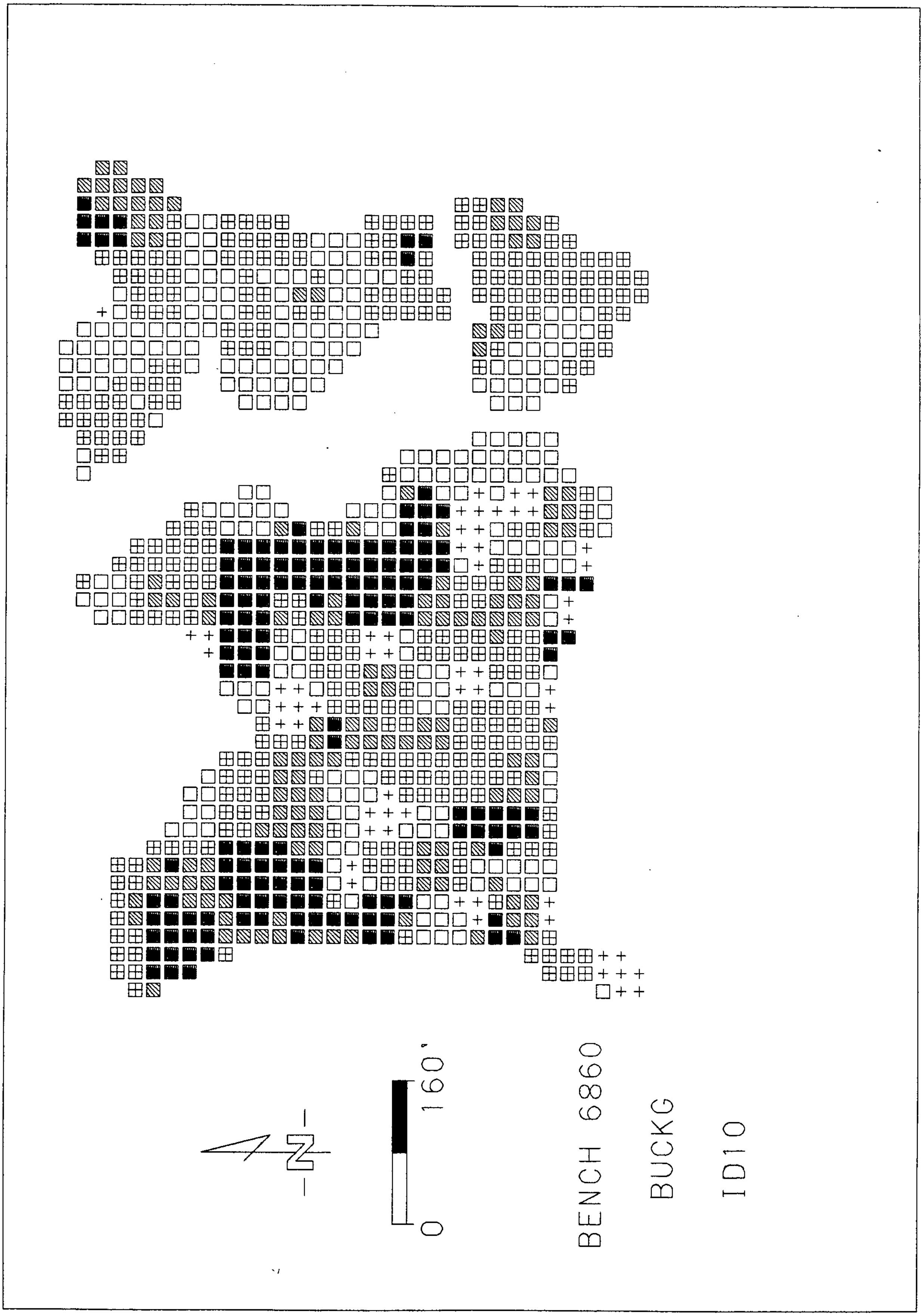
BENCH 6860
BUCKG
EX20



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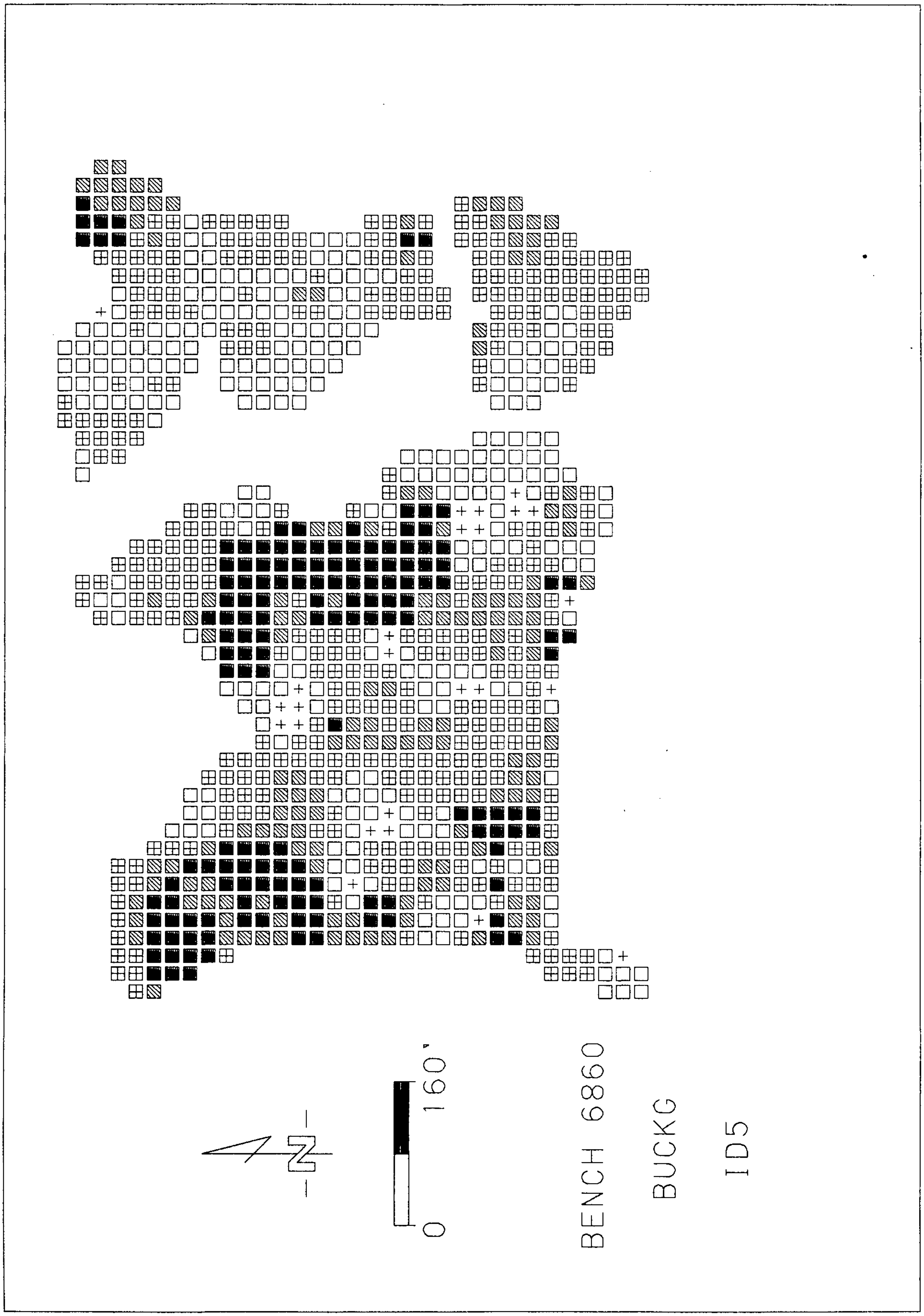
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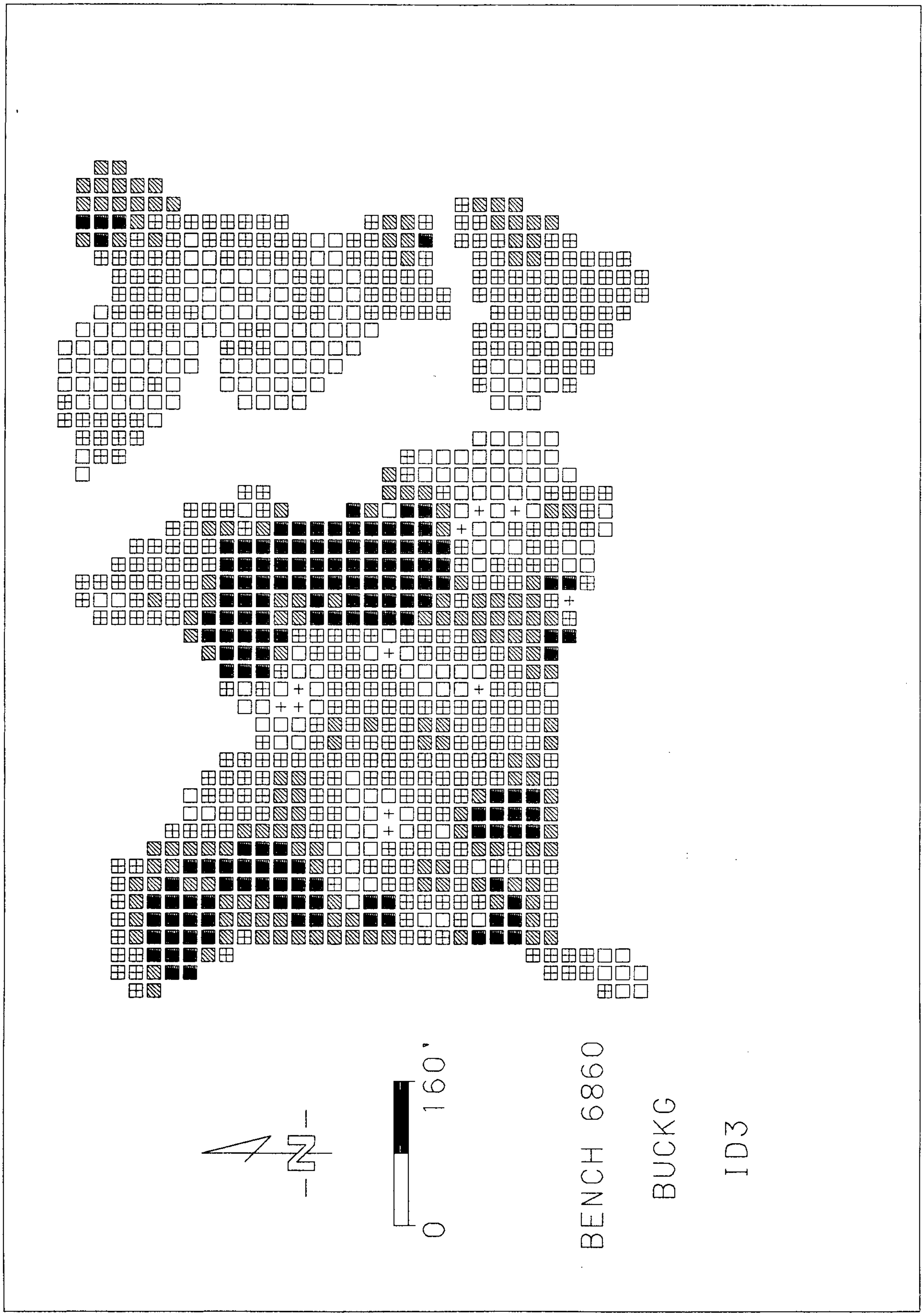
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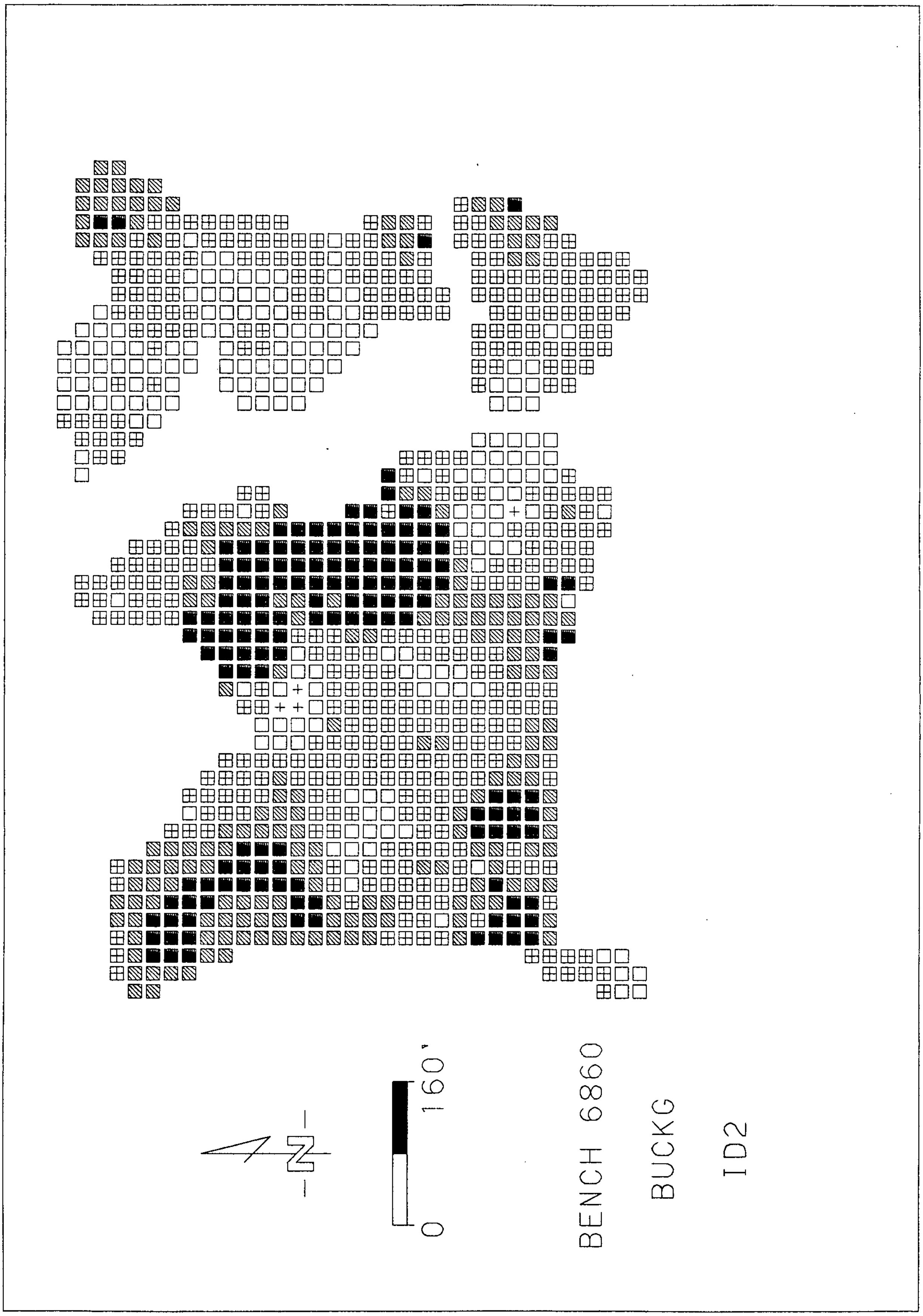
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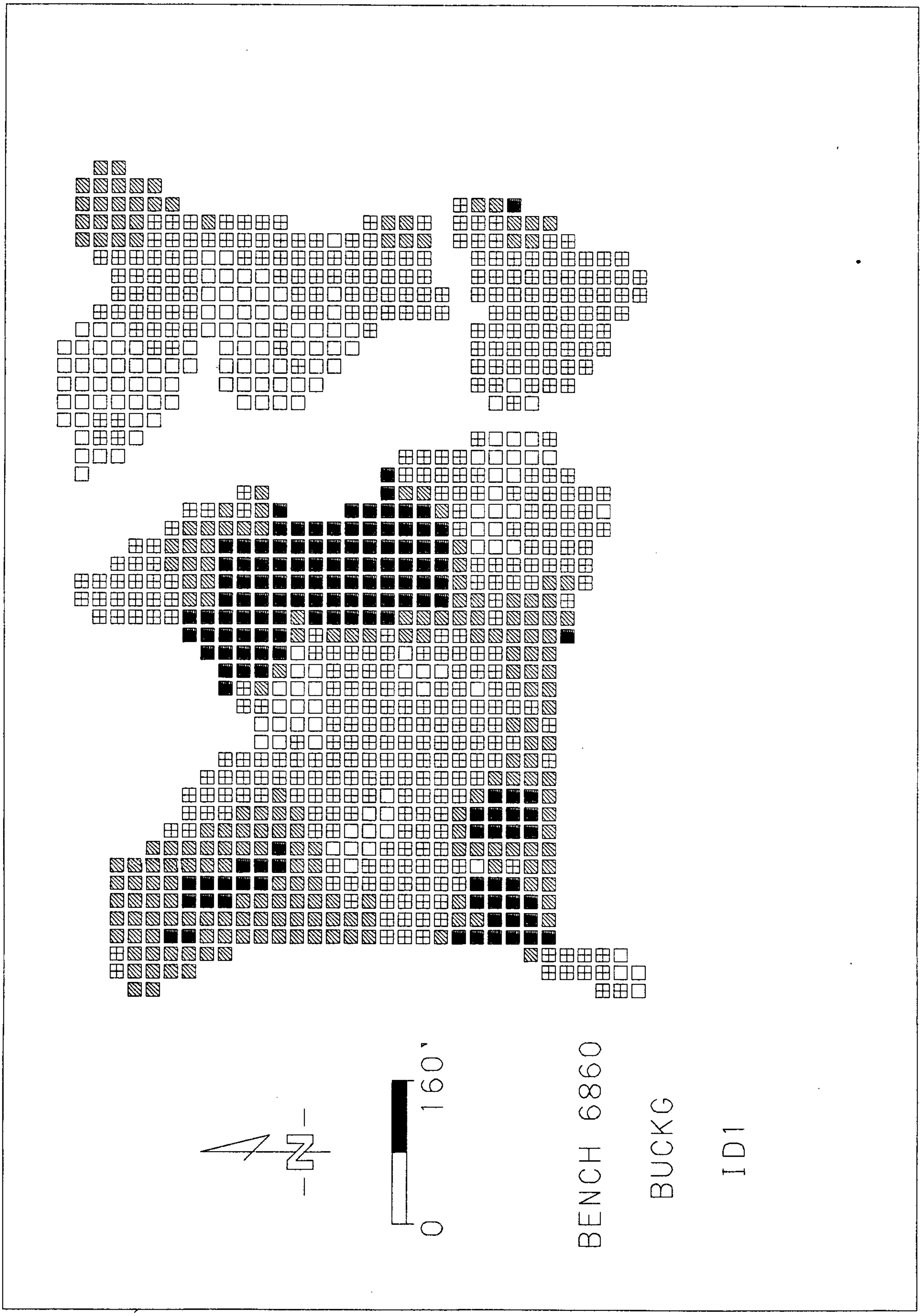
ID2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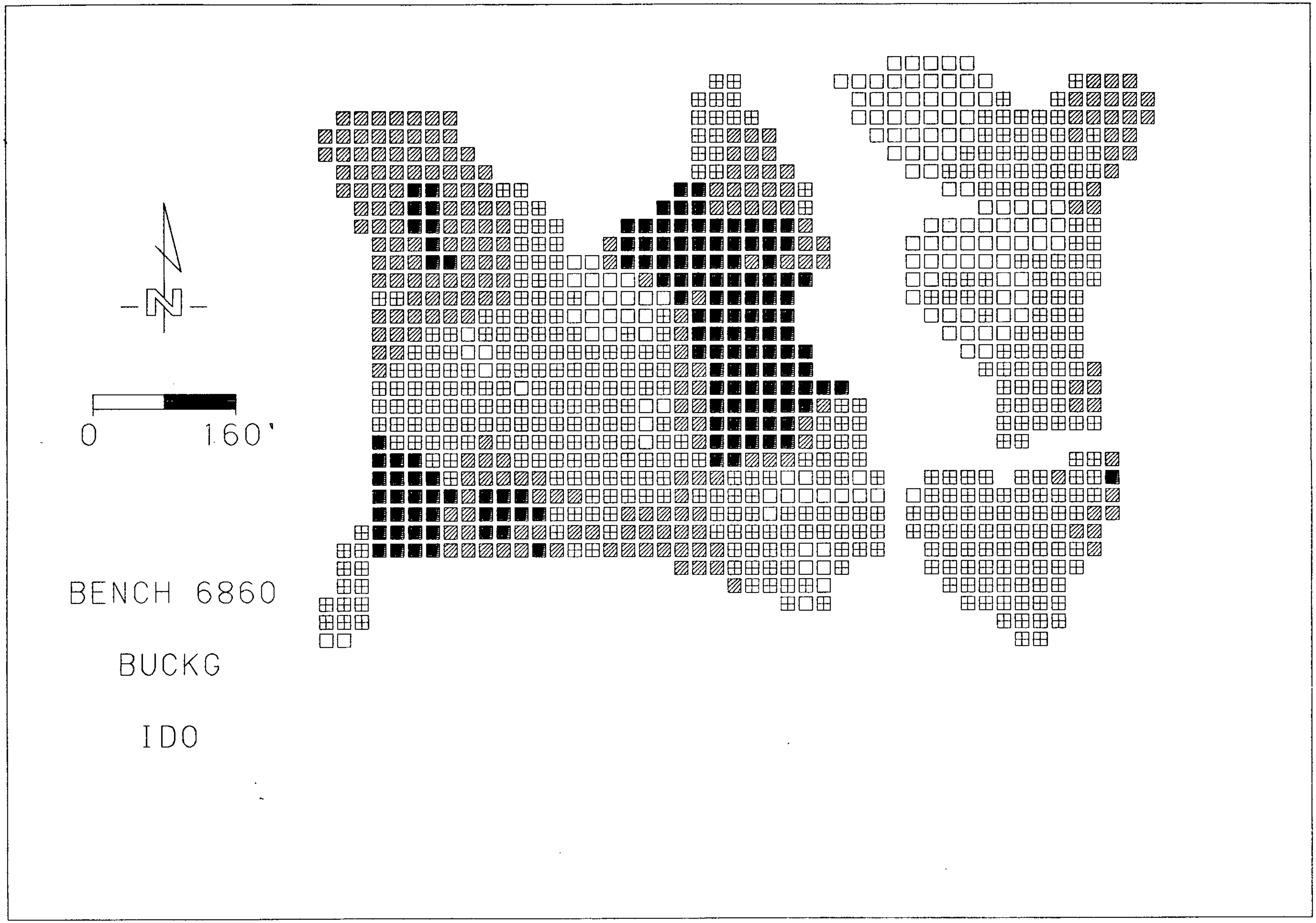
ID1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160'
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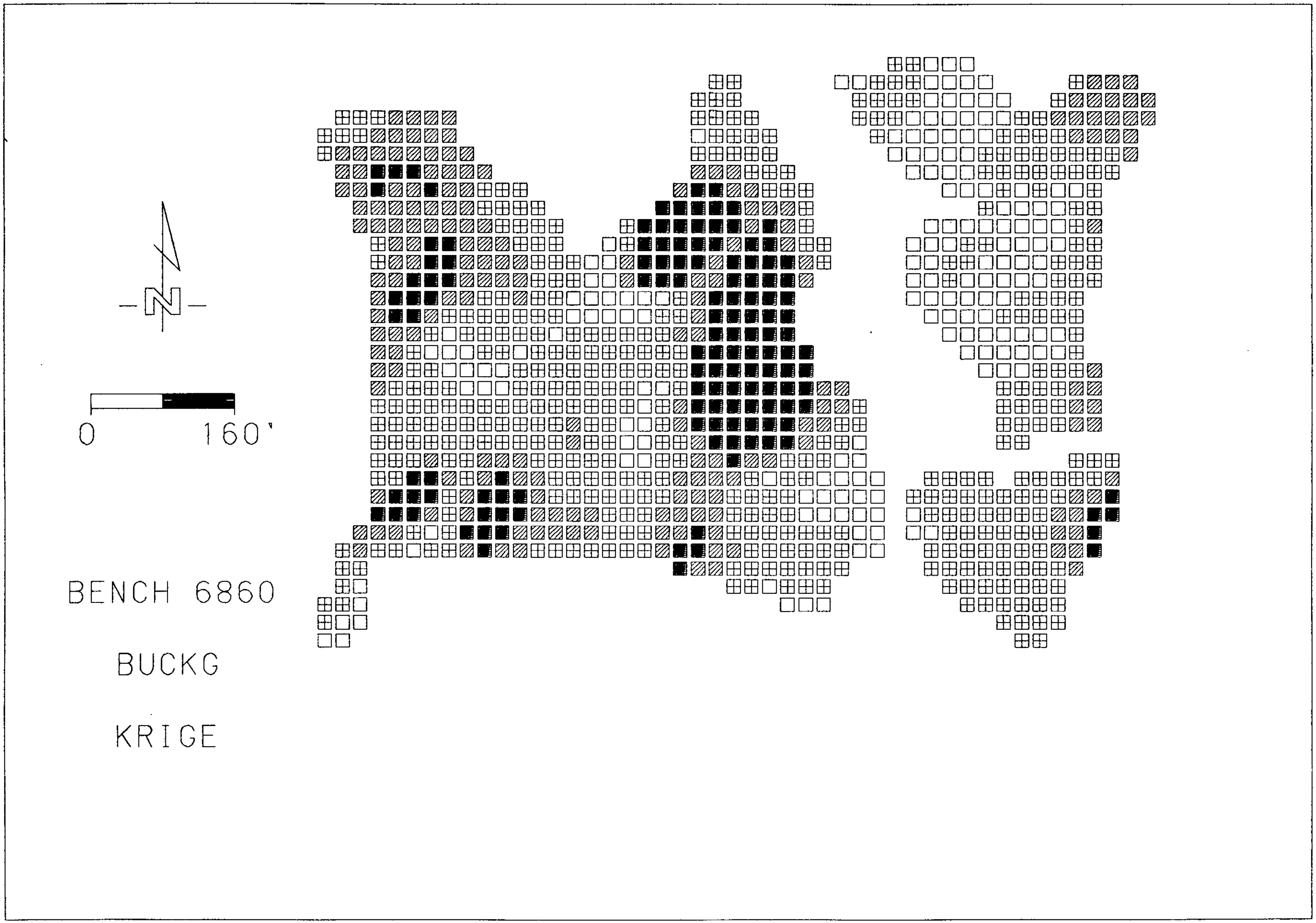
BUCKG
IDO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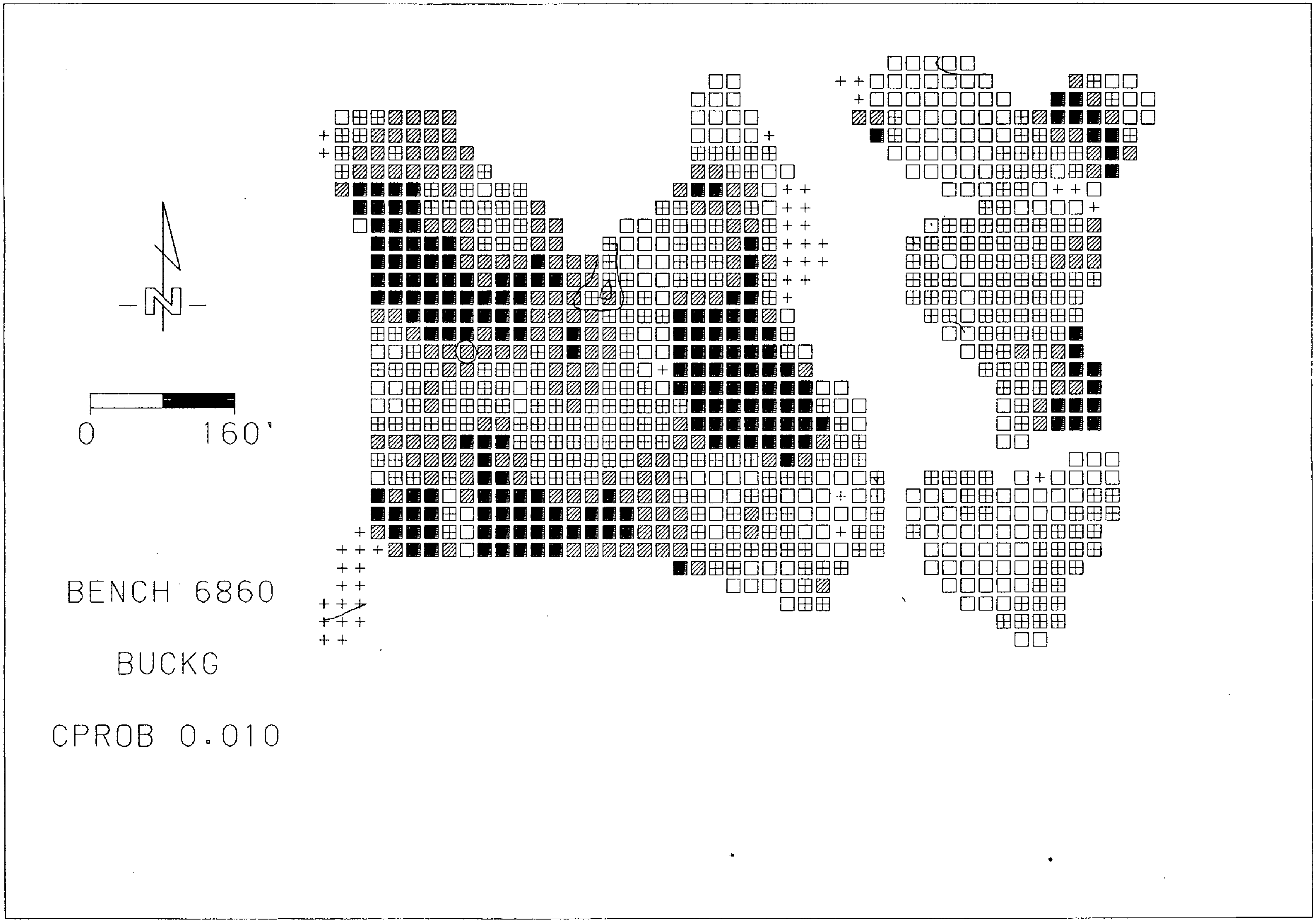
BENCH 6860
BUCKG
KRIGE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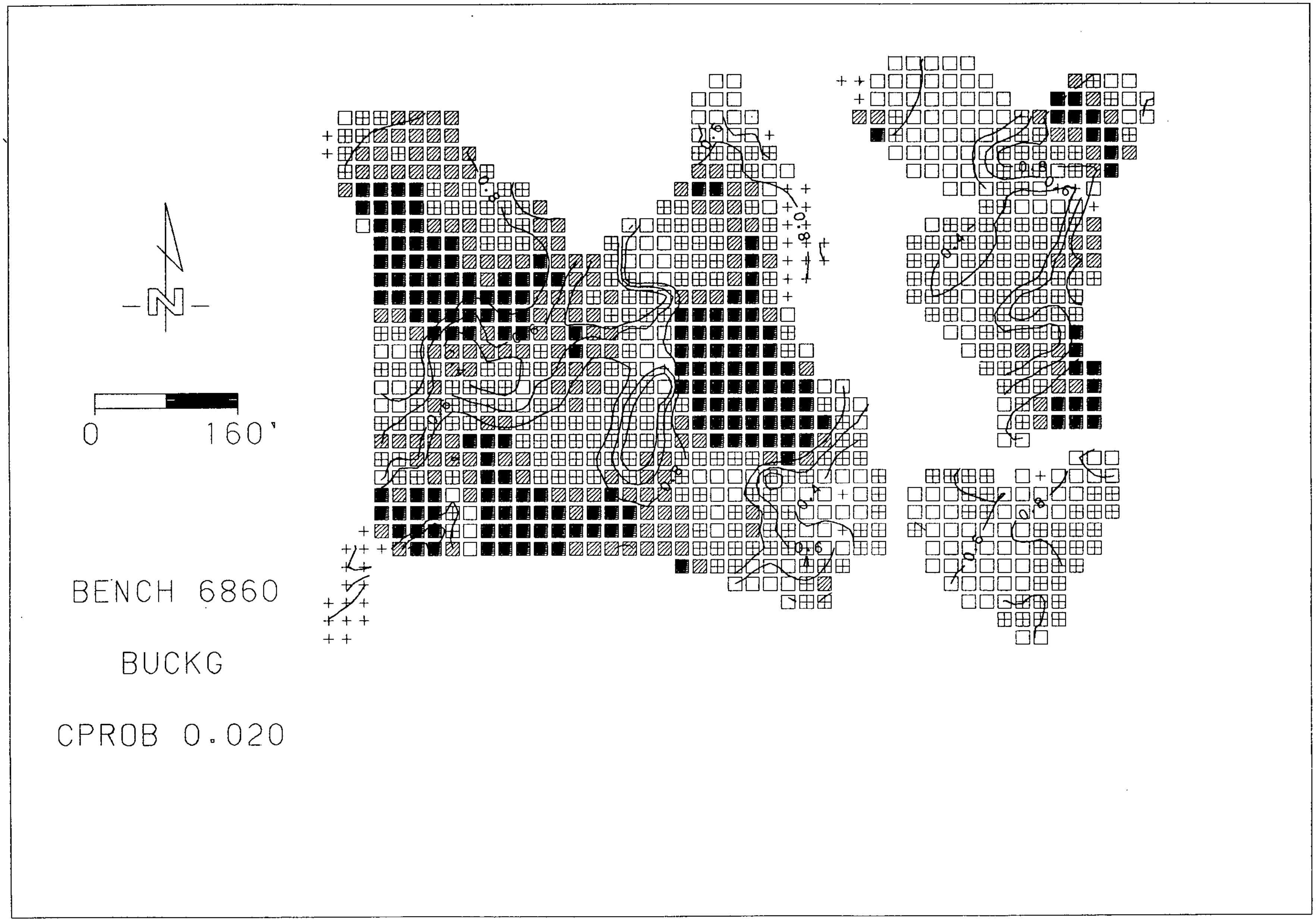
BUCKG
CPROB 0.010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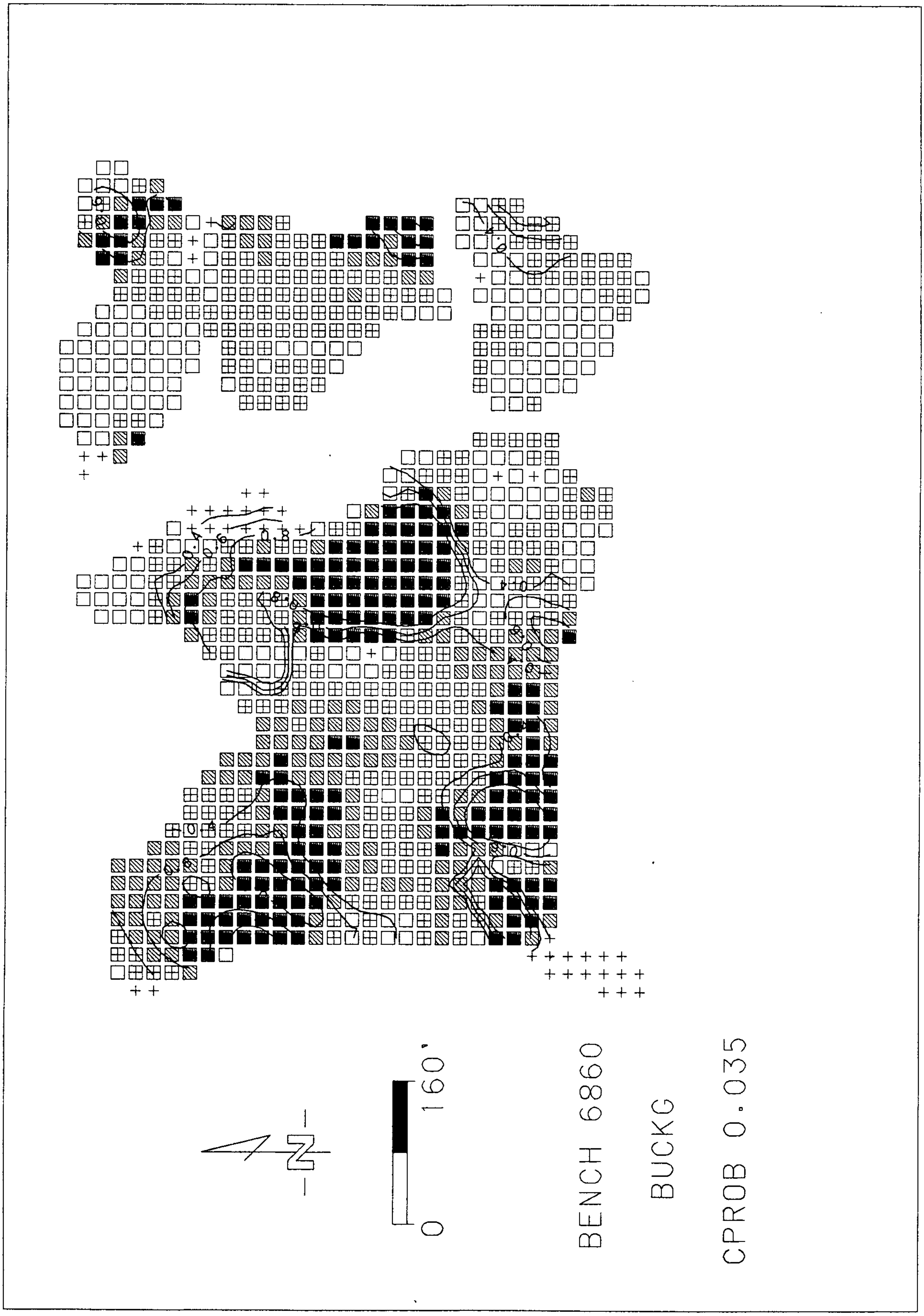
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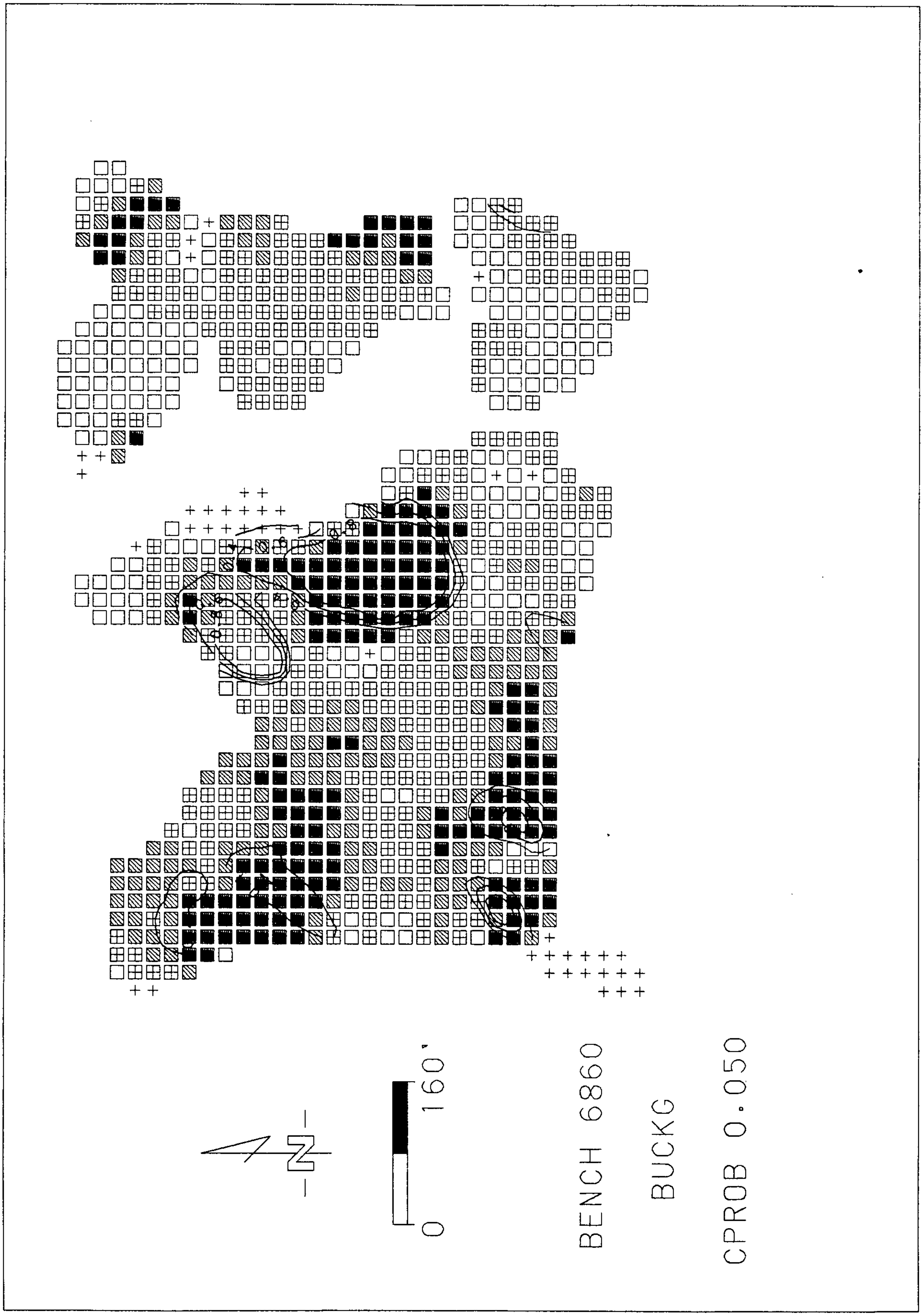
CPROB 0.035



N
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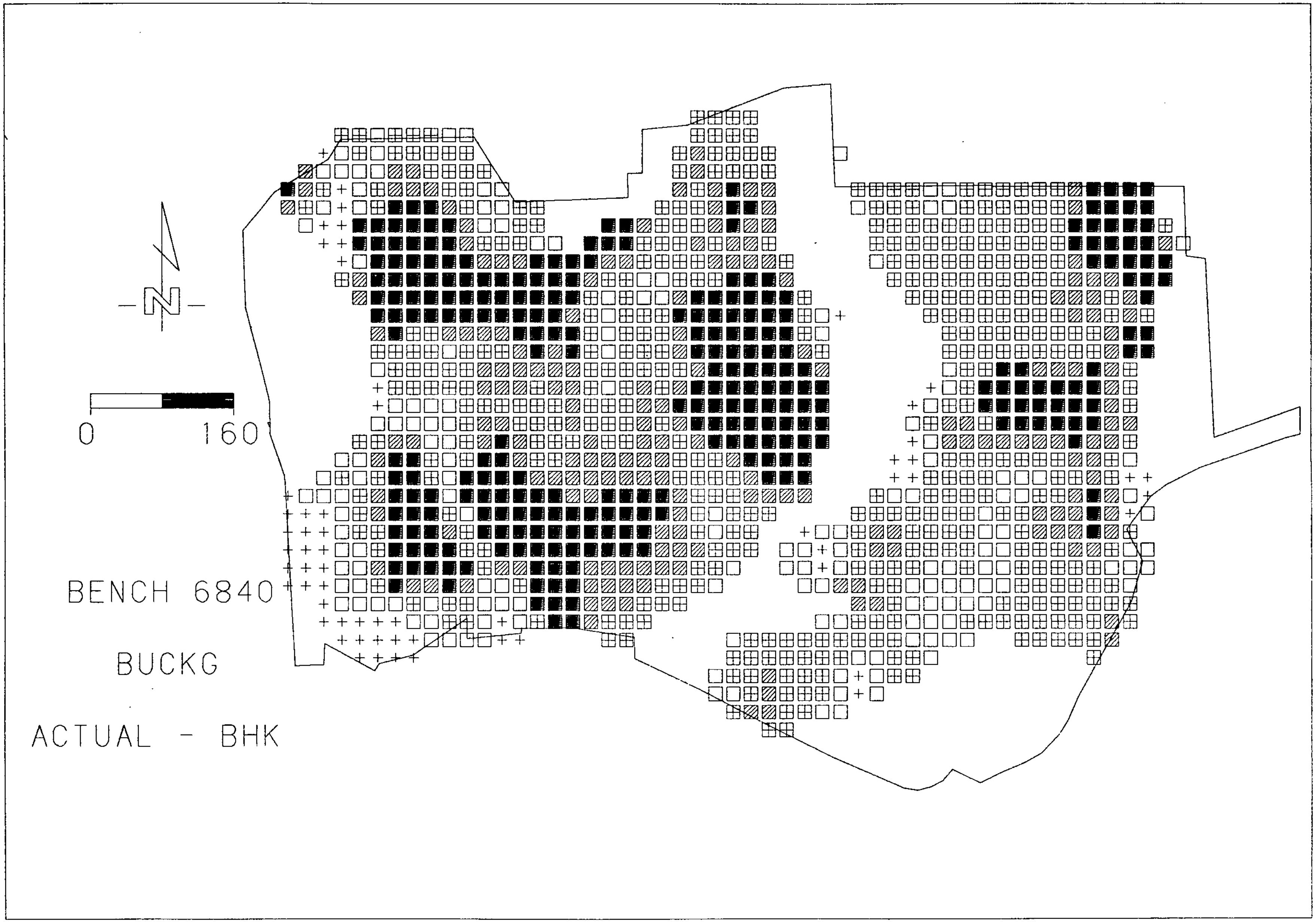
BUCKG
CPROB 0.050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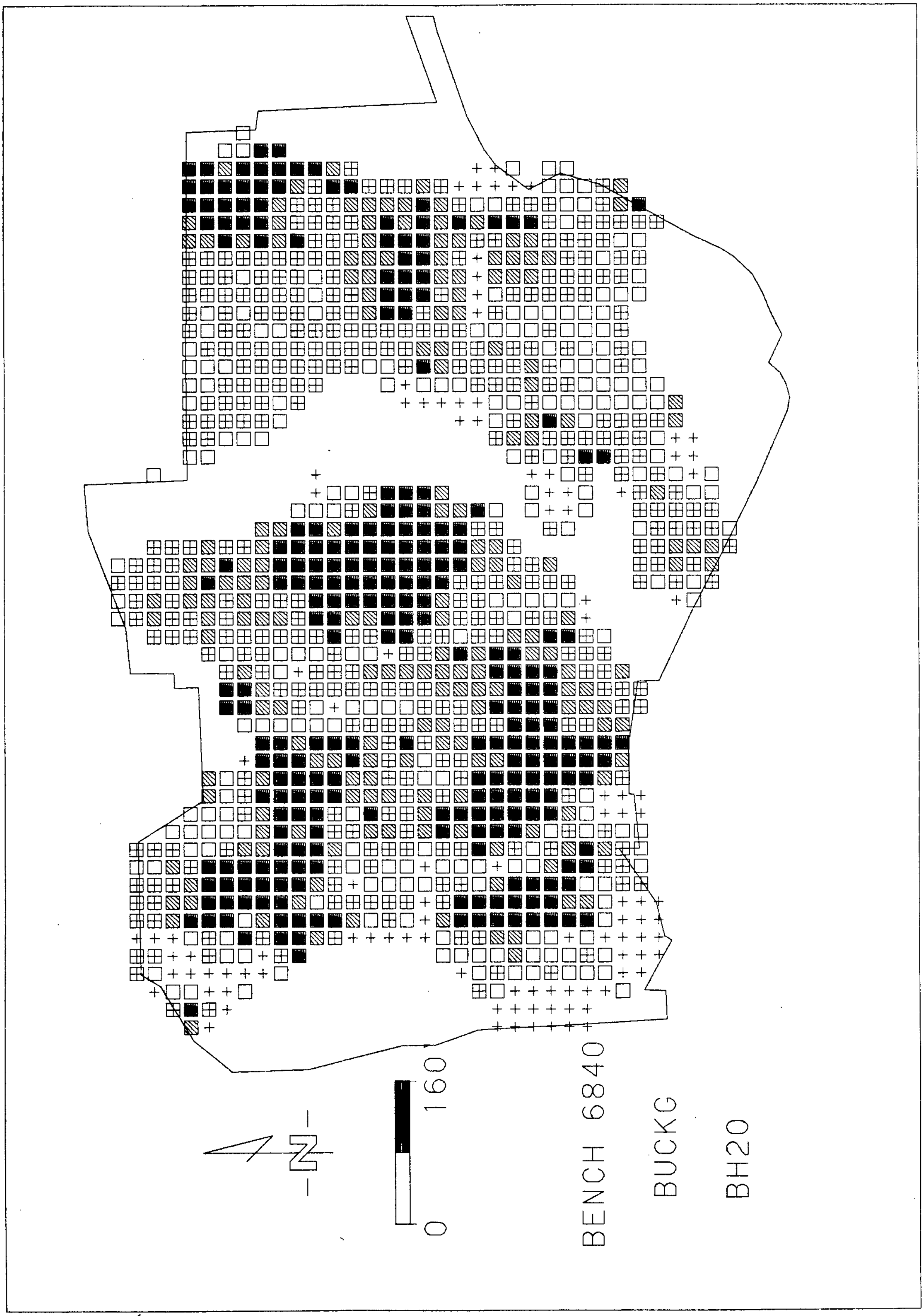
0
160
BENCH 6840
BUCKG
ACTUAL - BHK



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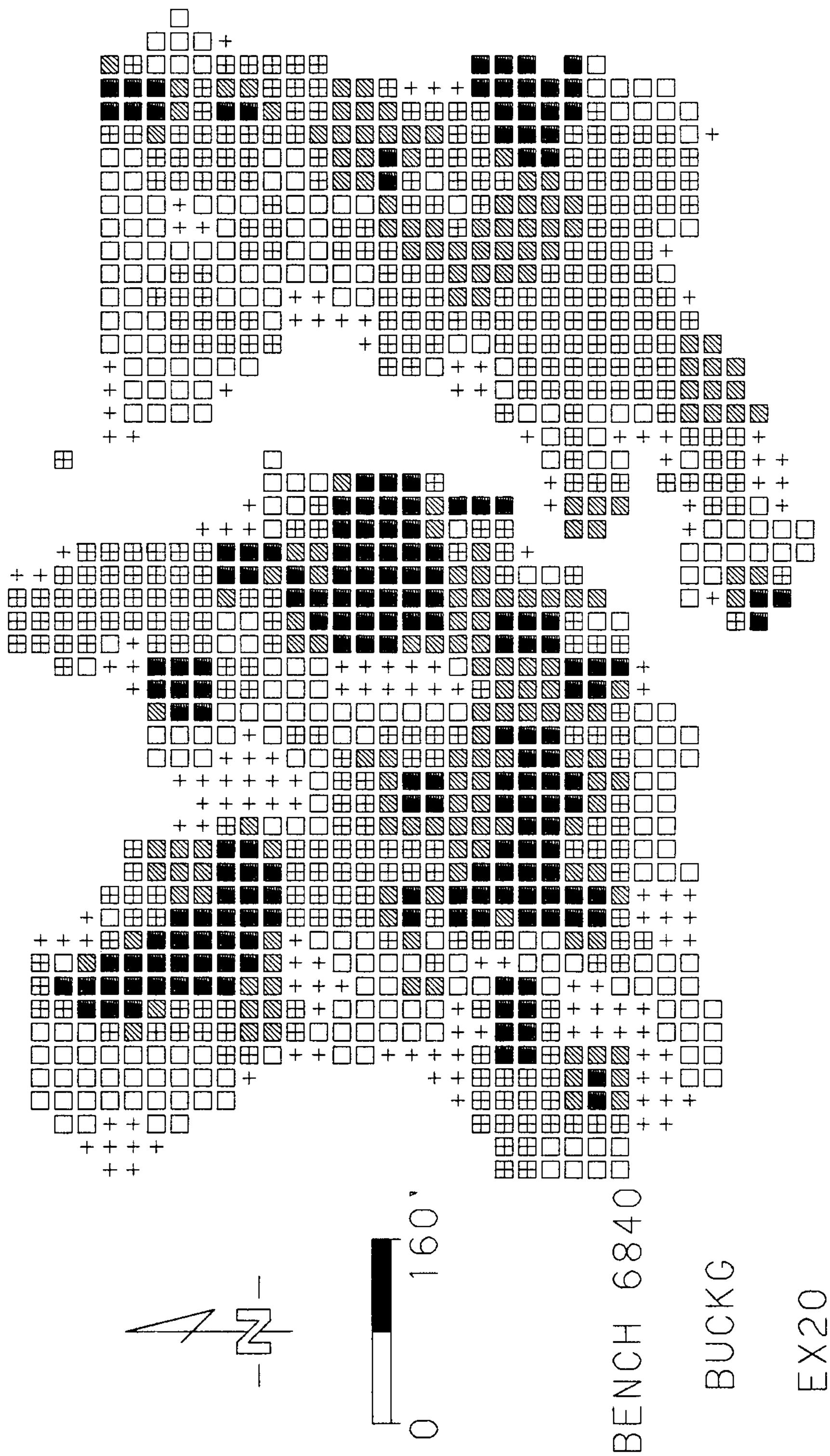
160
BENCH 6840
BUCKG
BH20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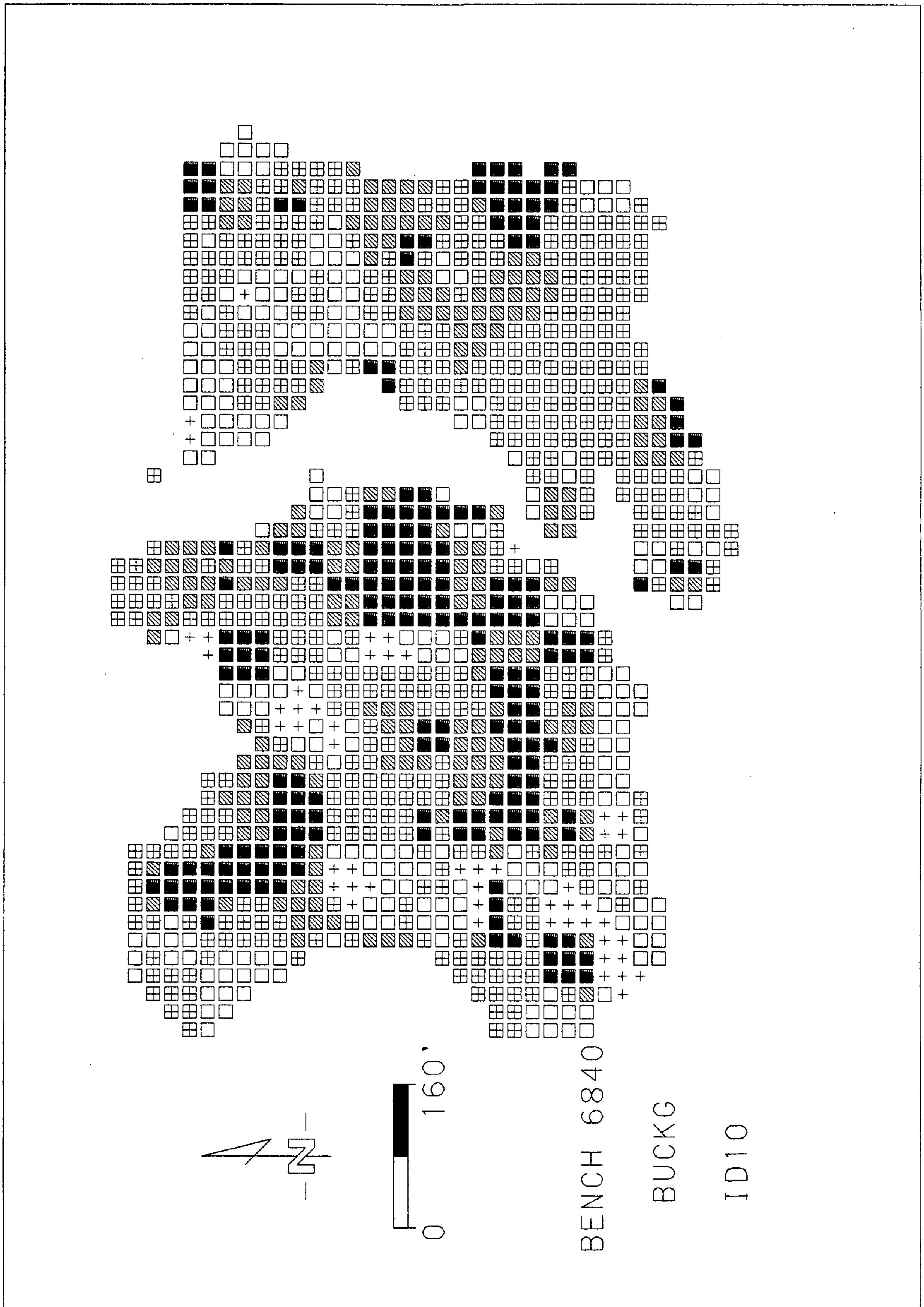
BENCH 6840
BUCKG
EX20



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BUCKG
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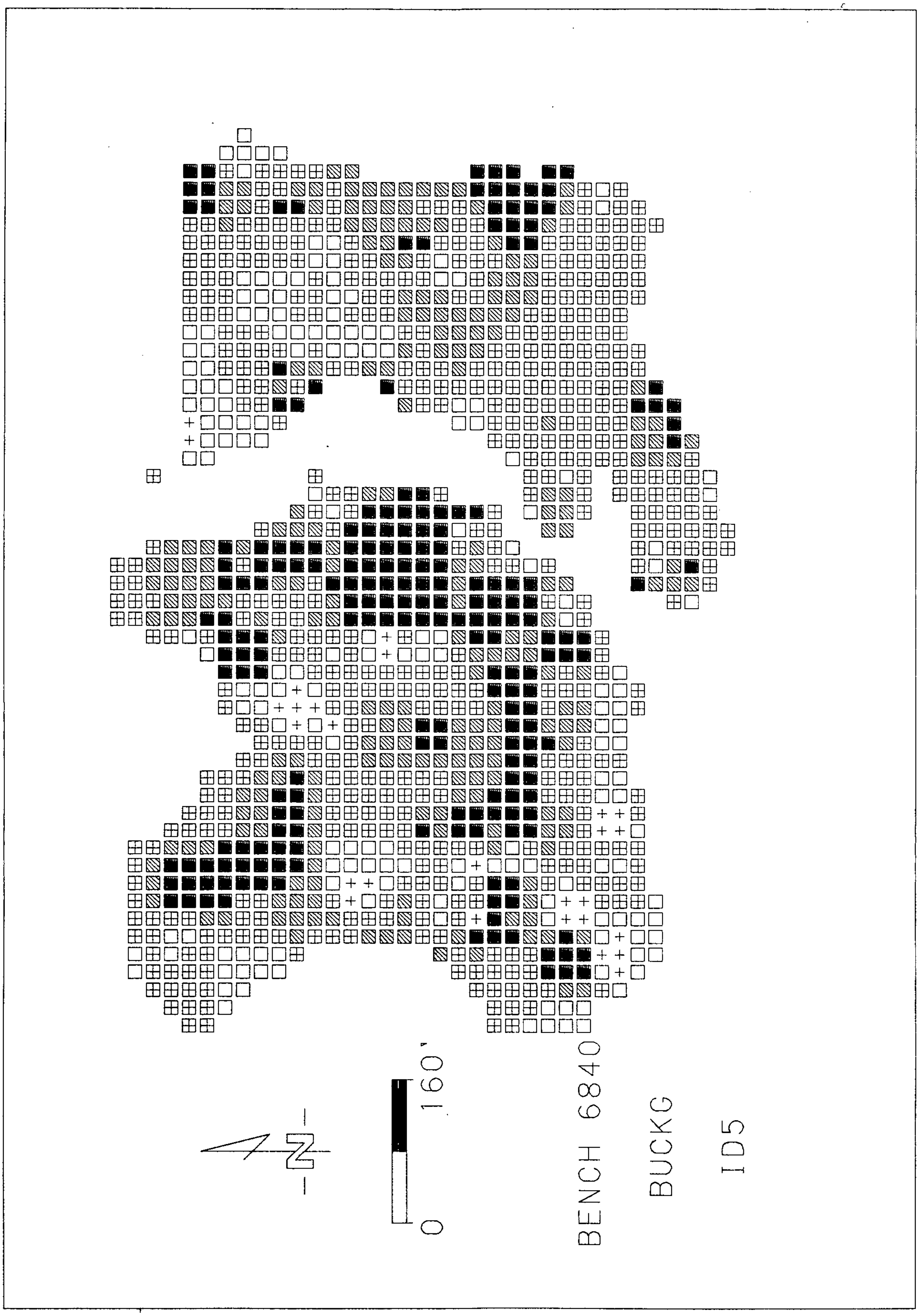
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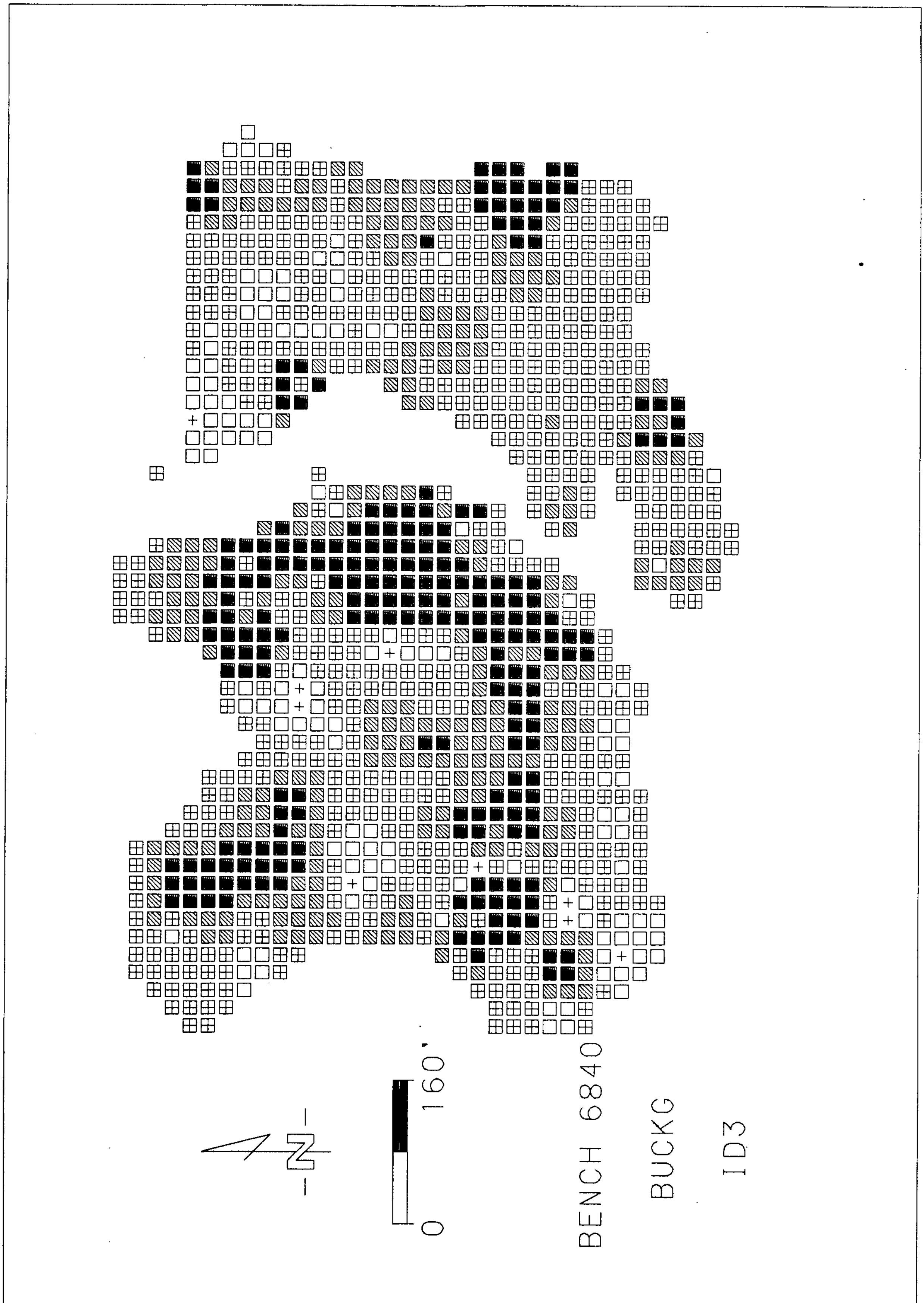
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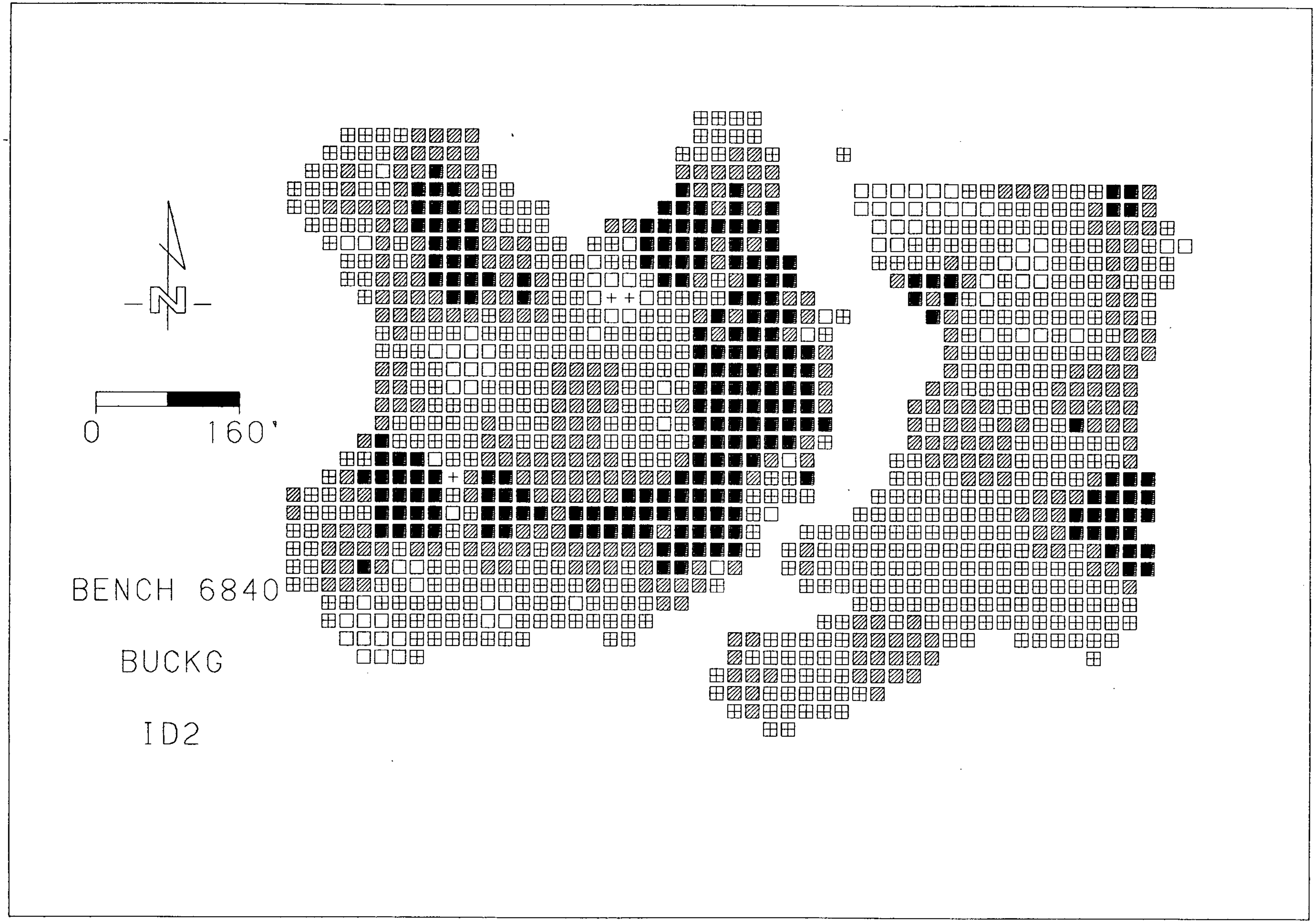
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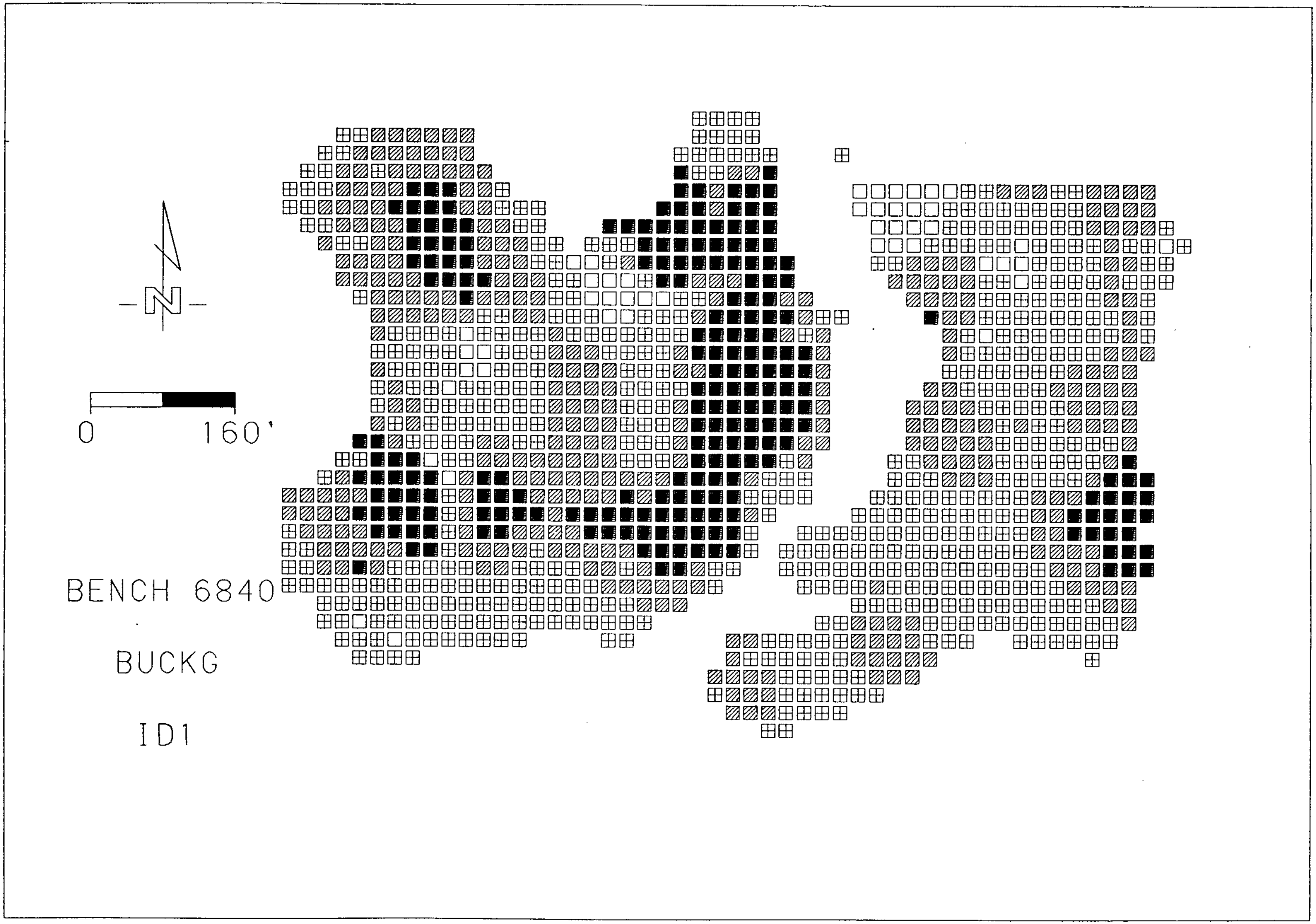
BENCH 6840
BUCKG
ID2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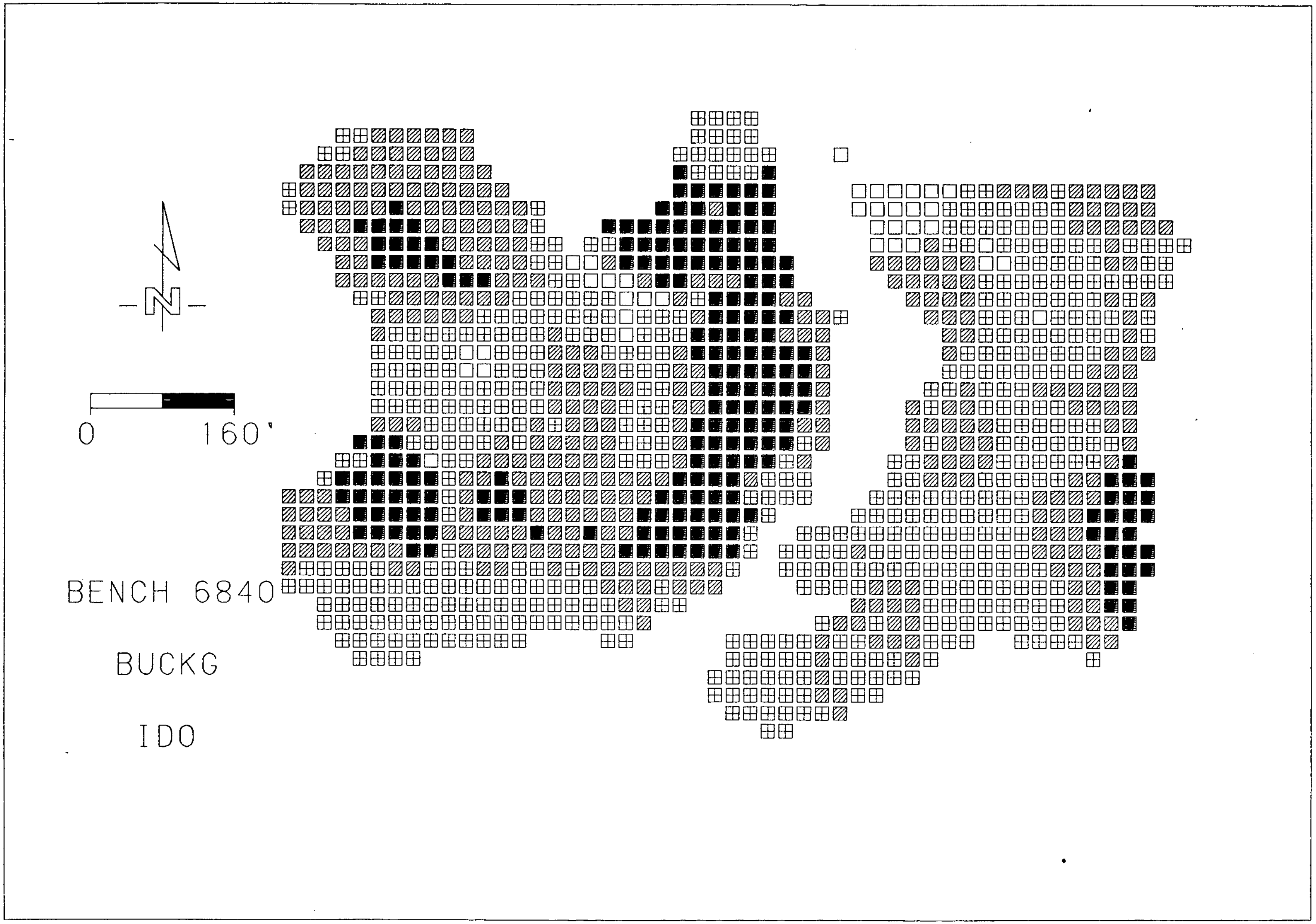
BUCKG
ID1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160'
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BUCKG
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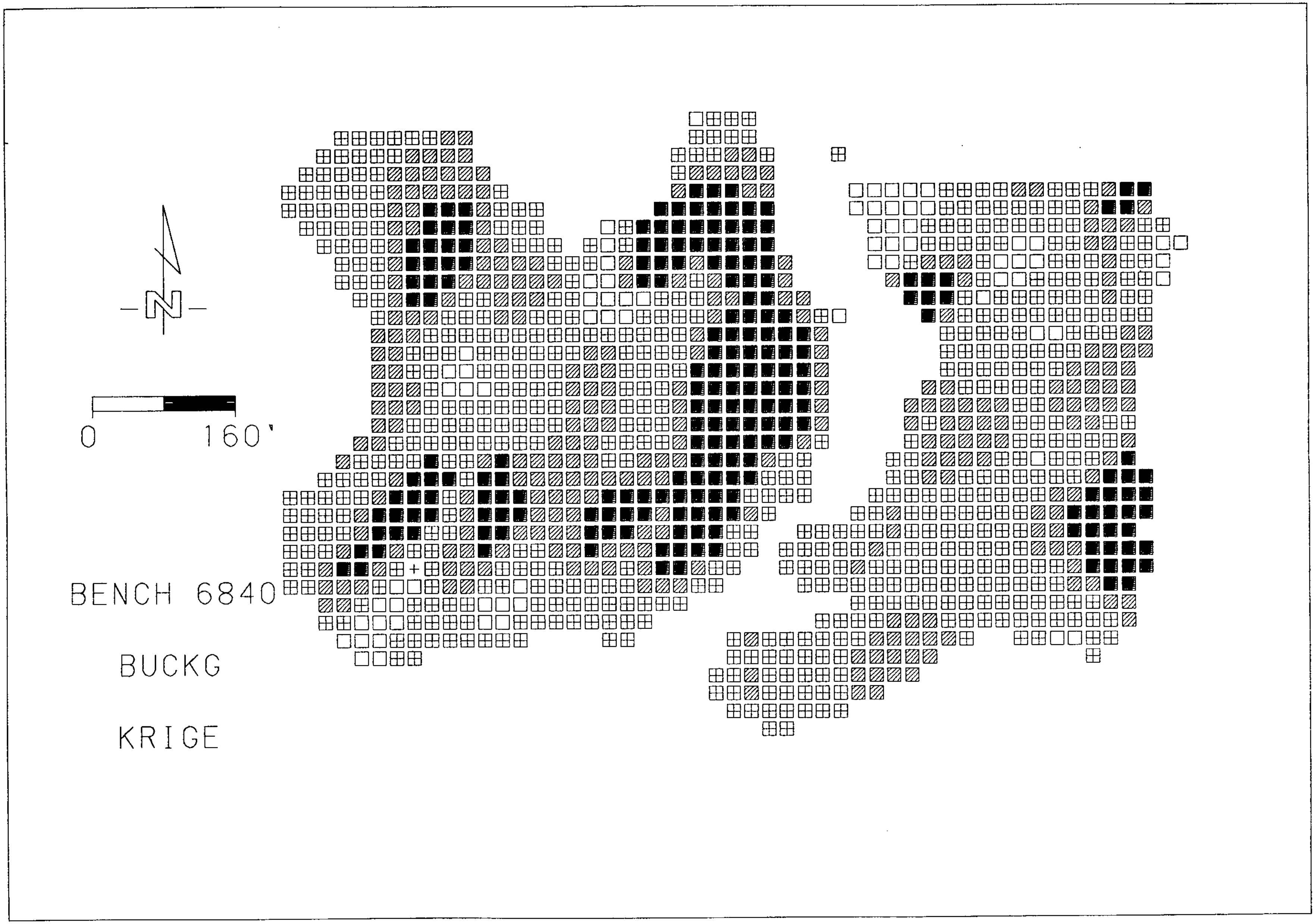
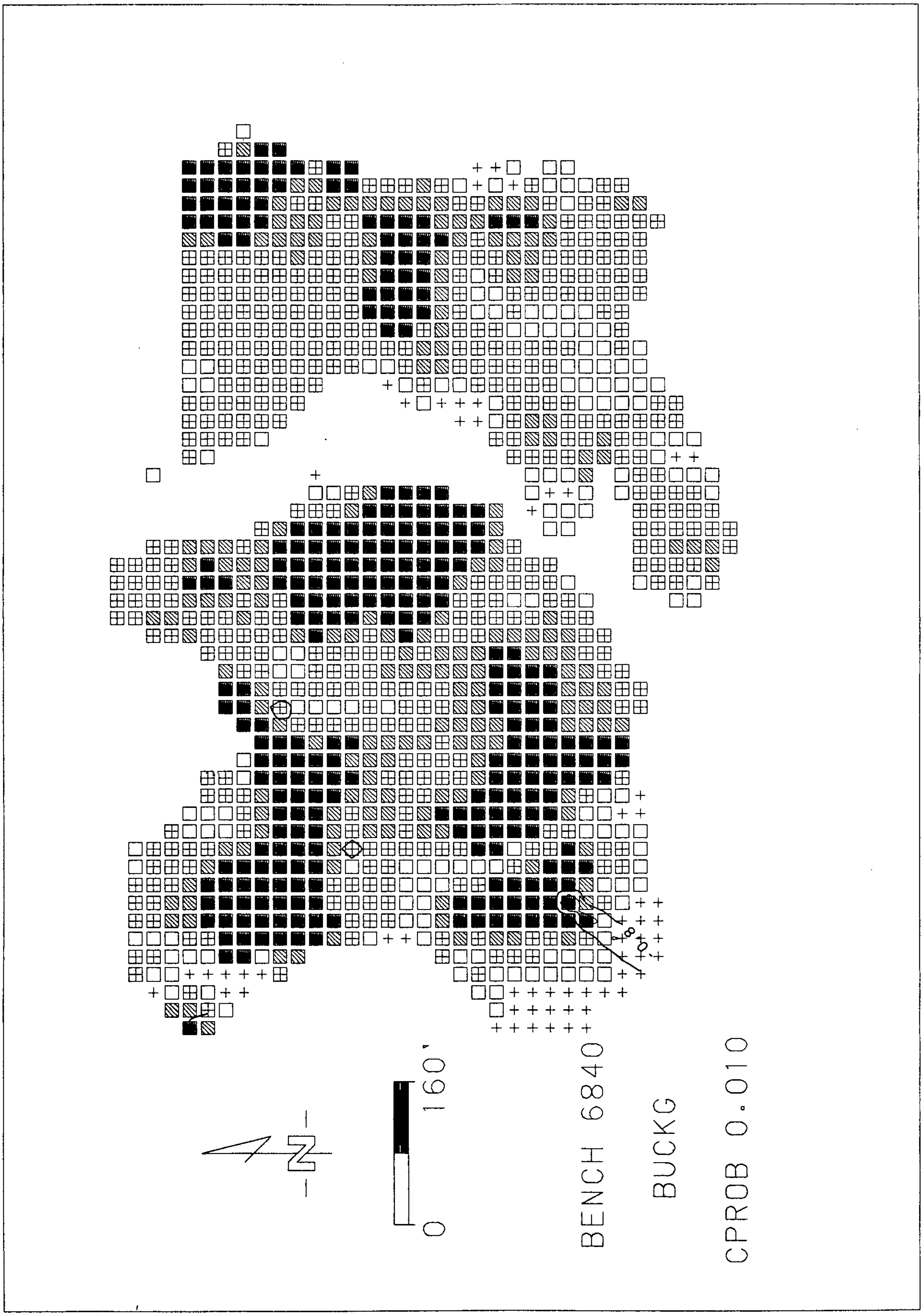
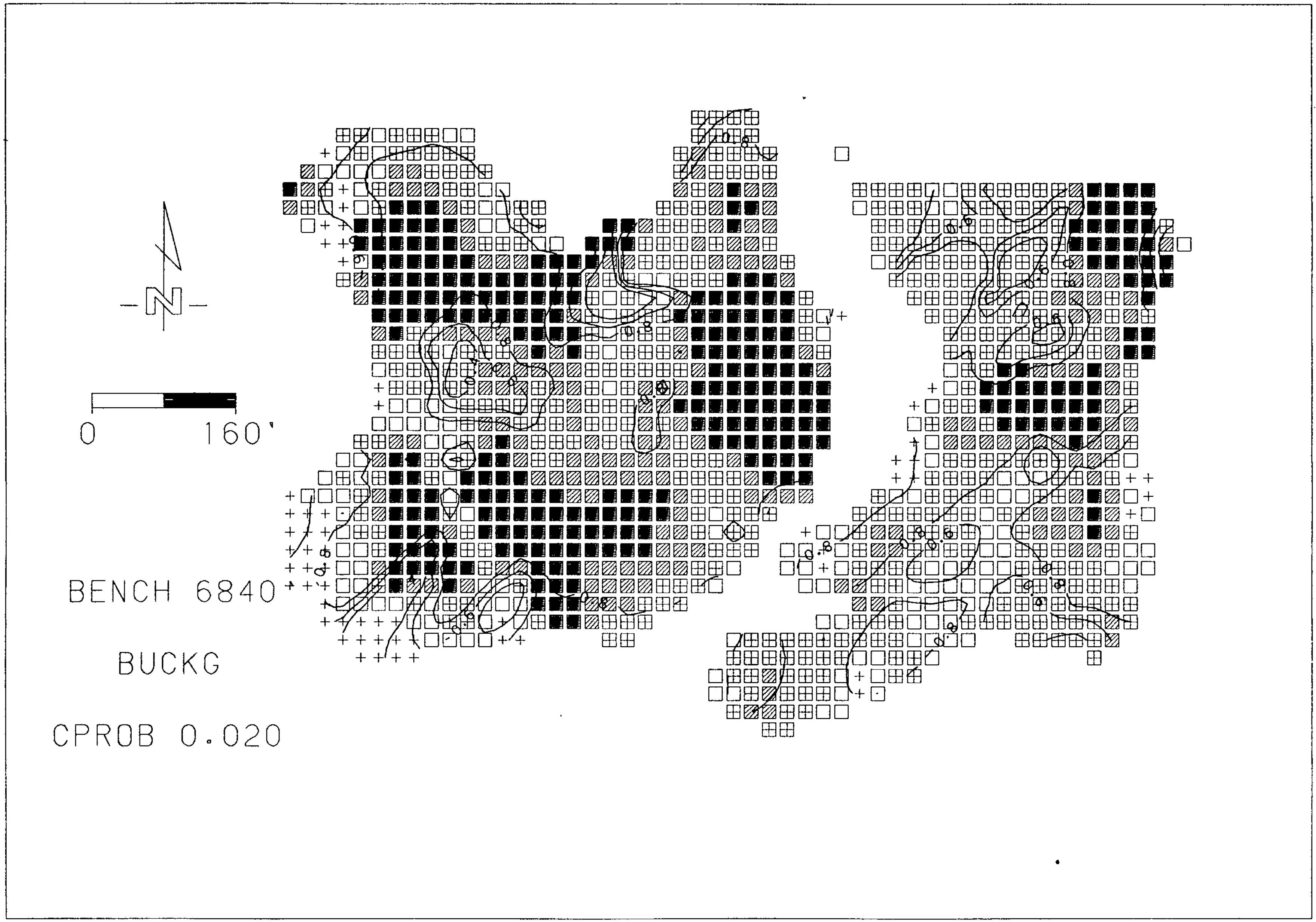

N
0
160'
BENCH 6840
BUCKG
KRIGE


N
0
160'
BENCH 6840
BUCKG
CPROB 0.010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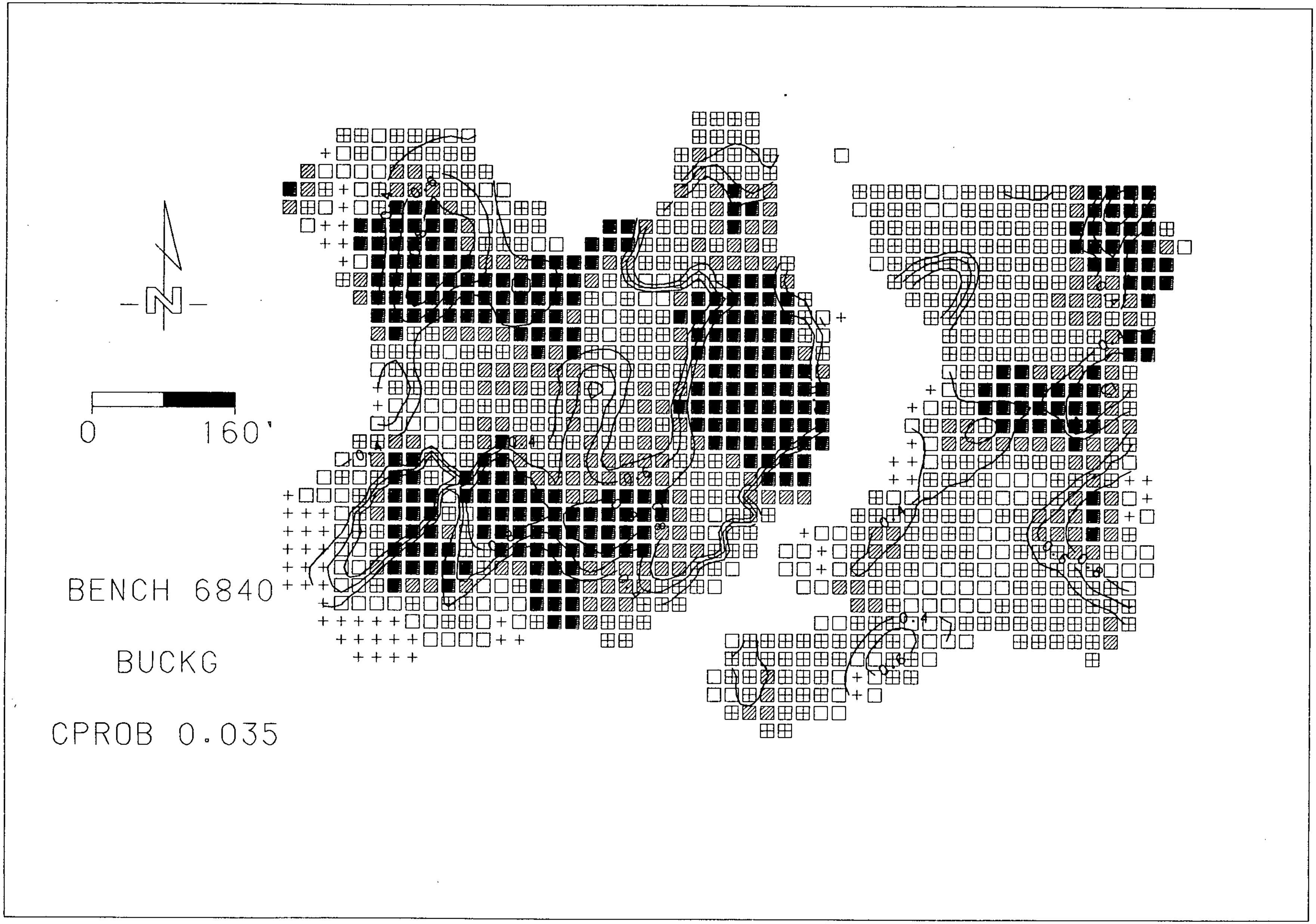
160'
BENCH 6840
BUCKG
CPROB 0.020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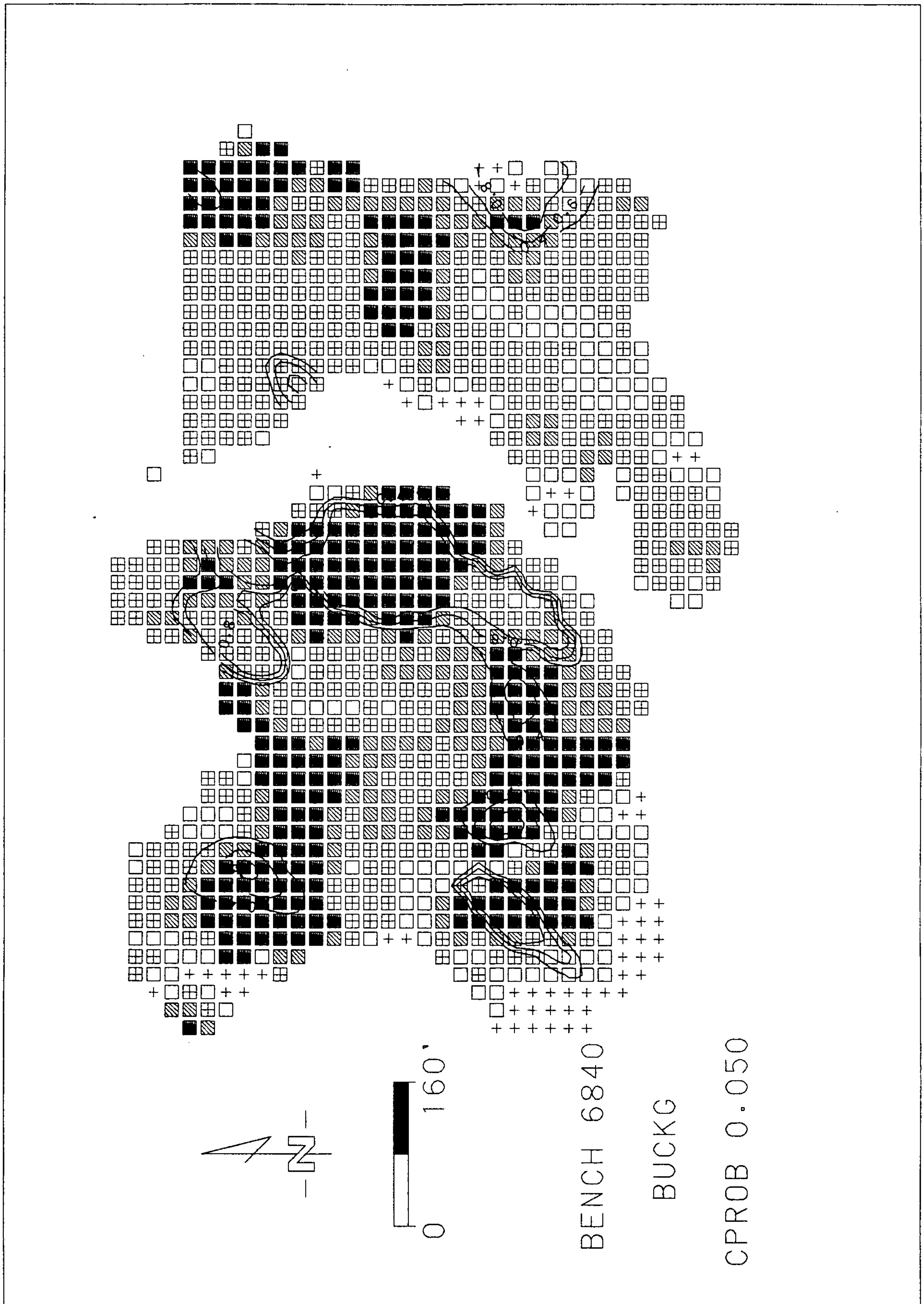
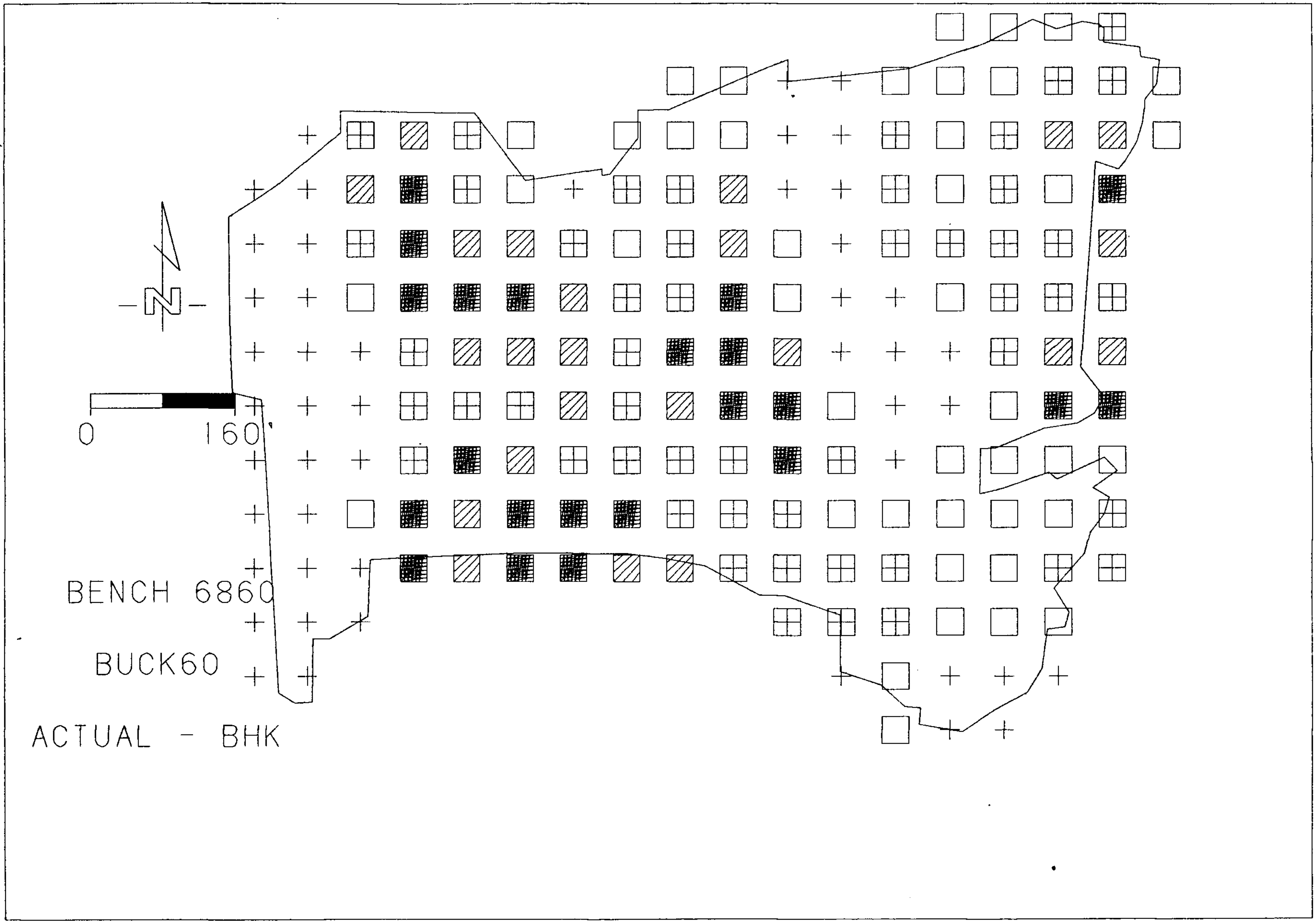
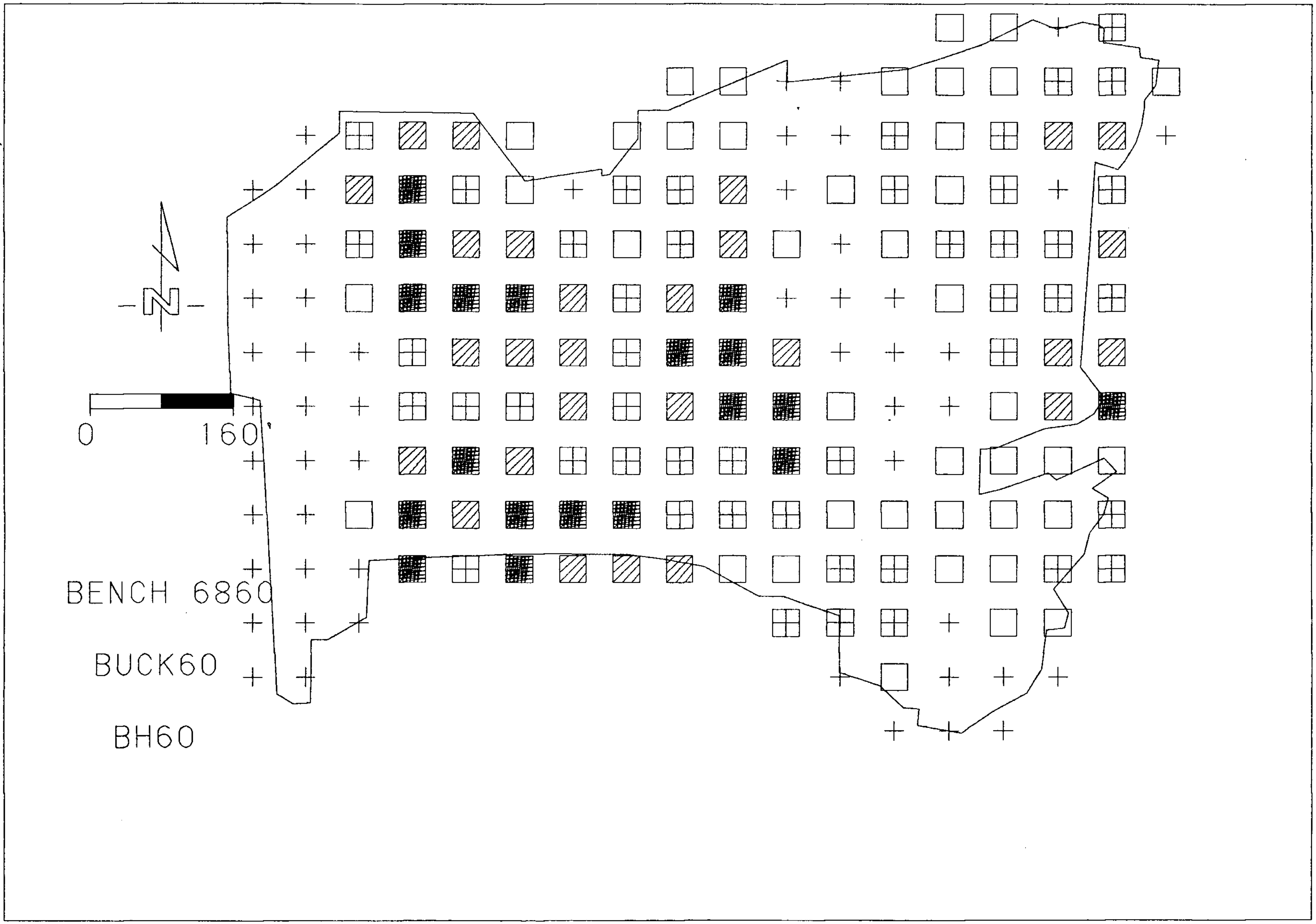
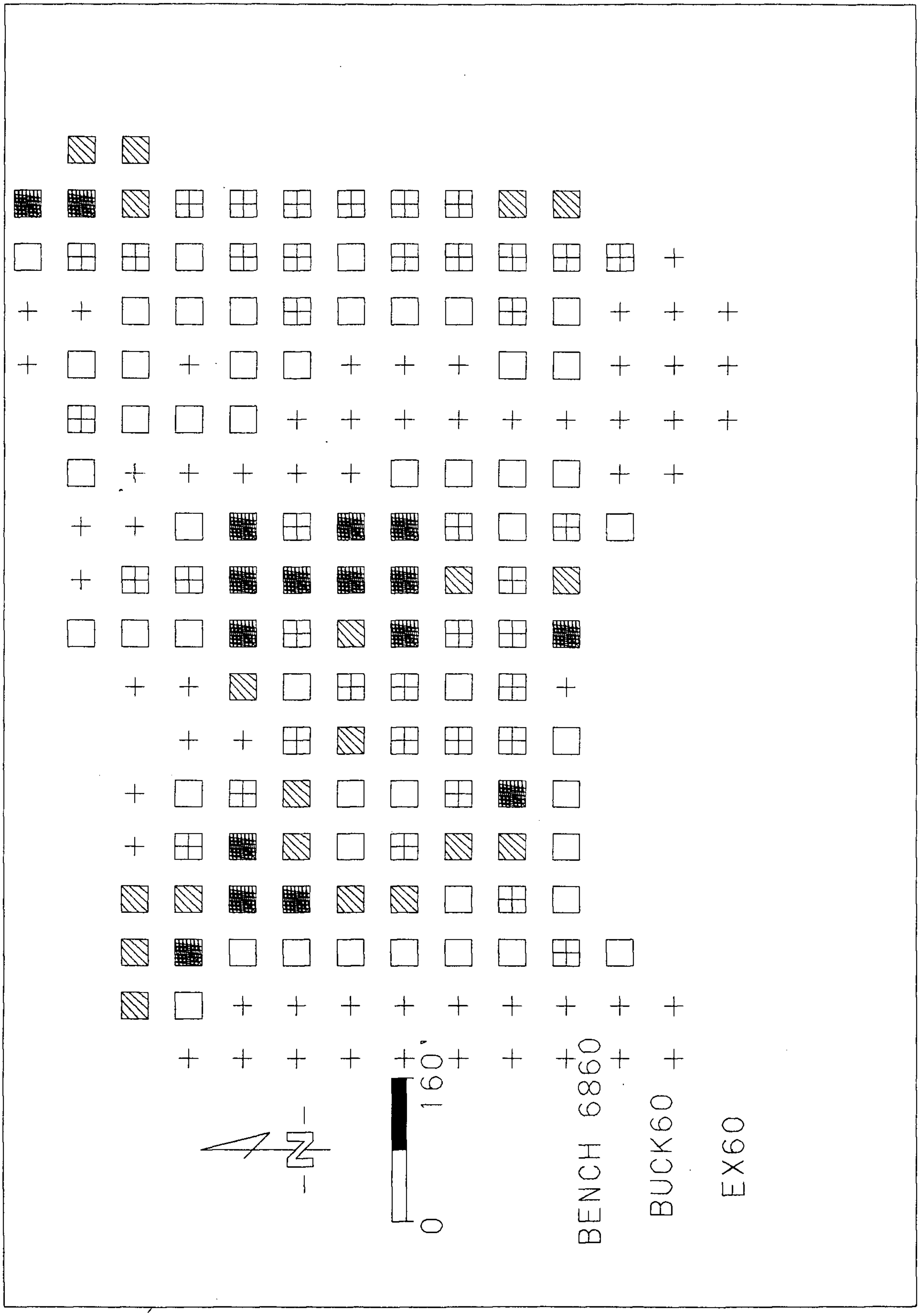
160'
BENCH 6840
BUCKG
CPROB 0.035

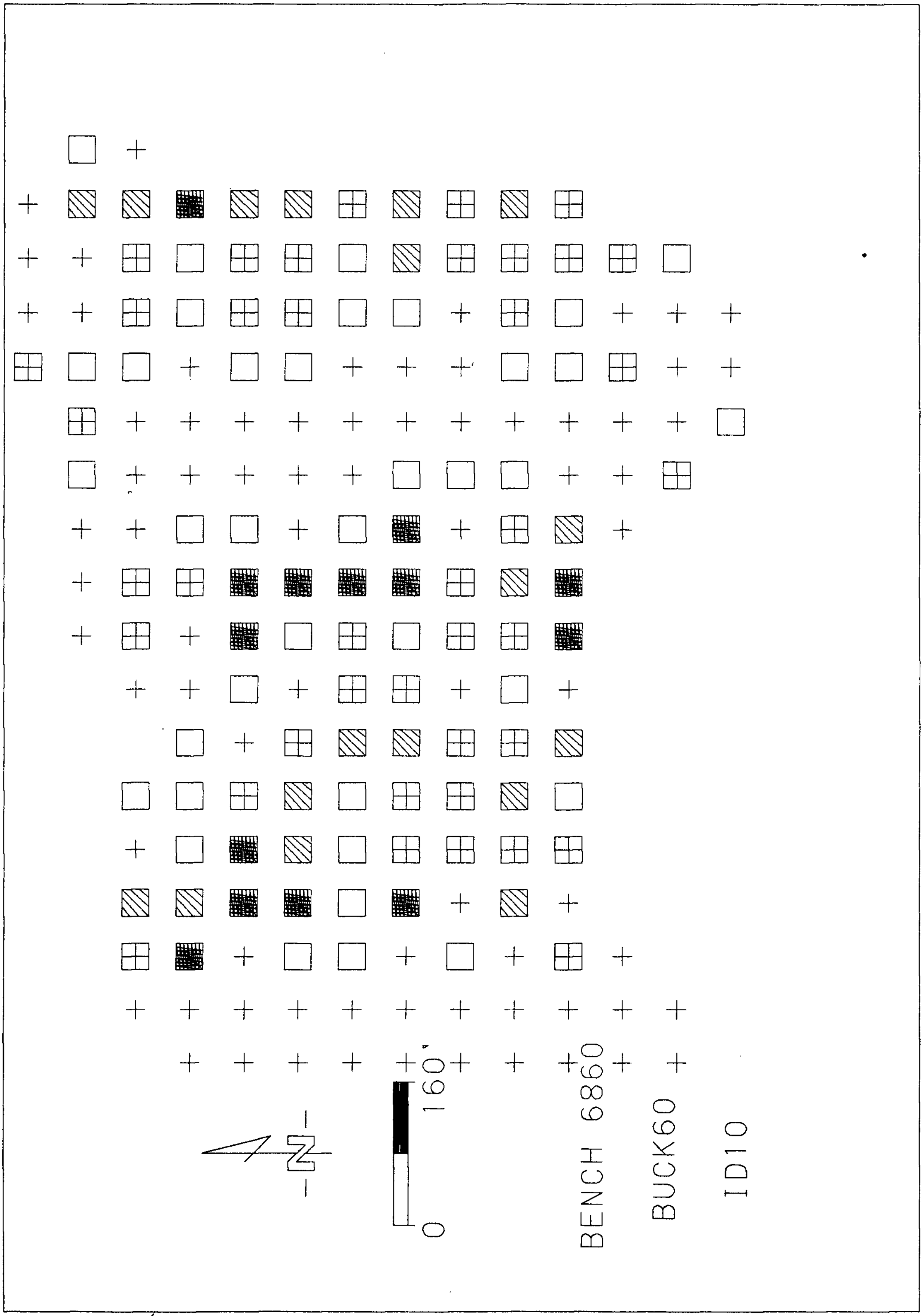


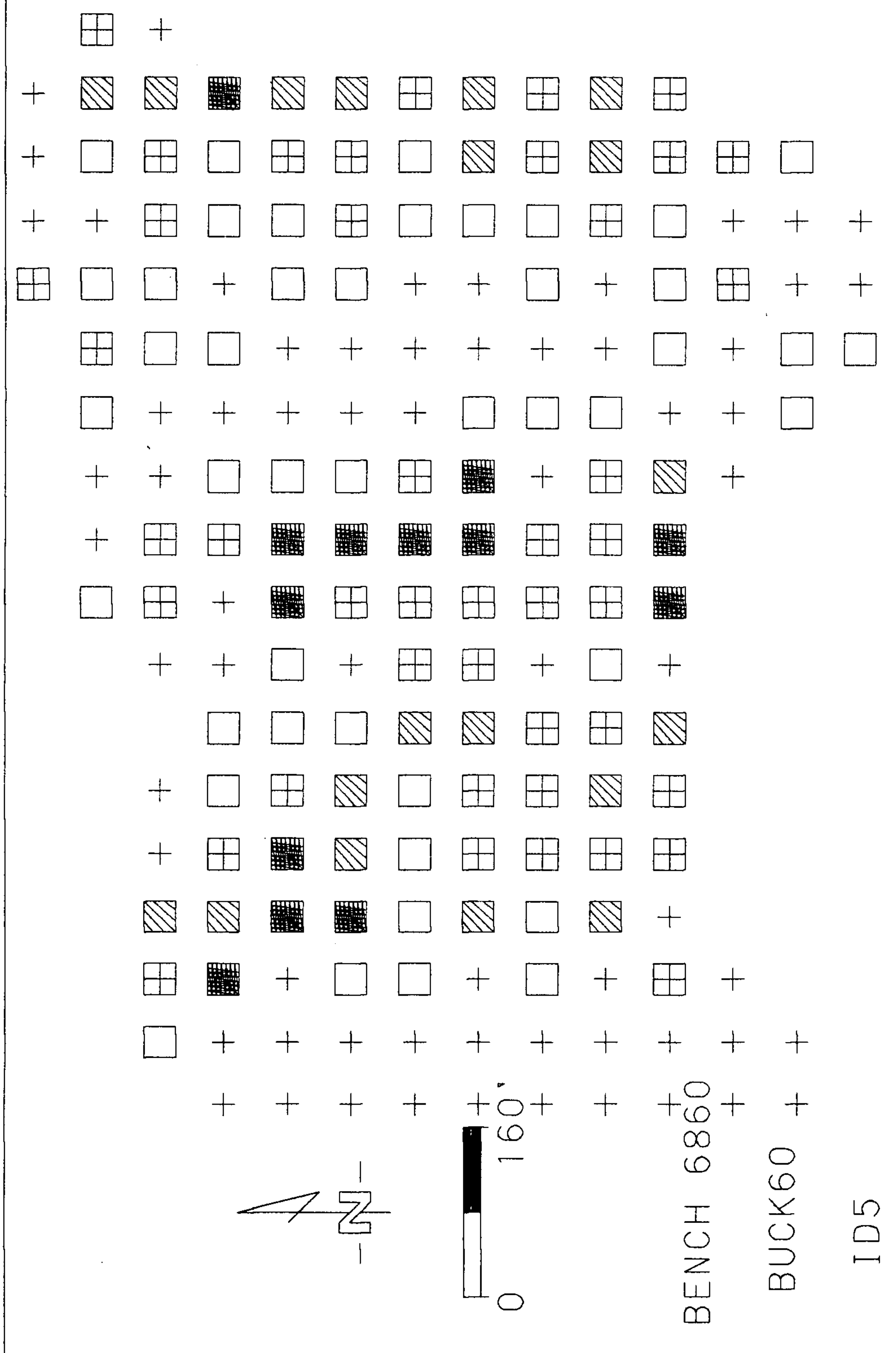
N
0
160'
BENCH 6840
BUCKG
CPROB 0.050


N
0
160
BENCH 6860
BUCK60
ACTUAL - BHK

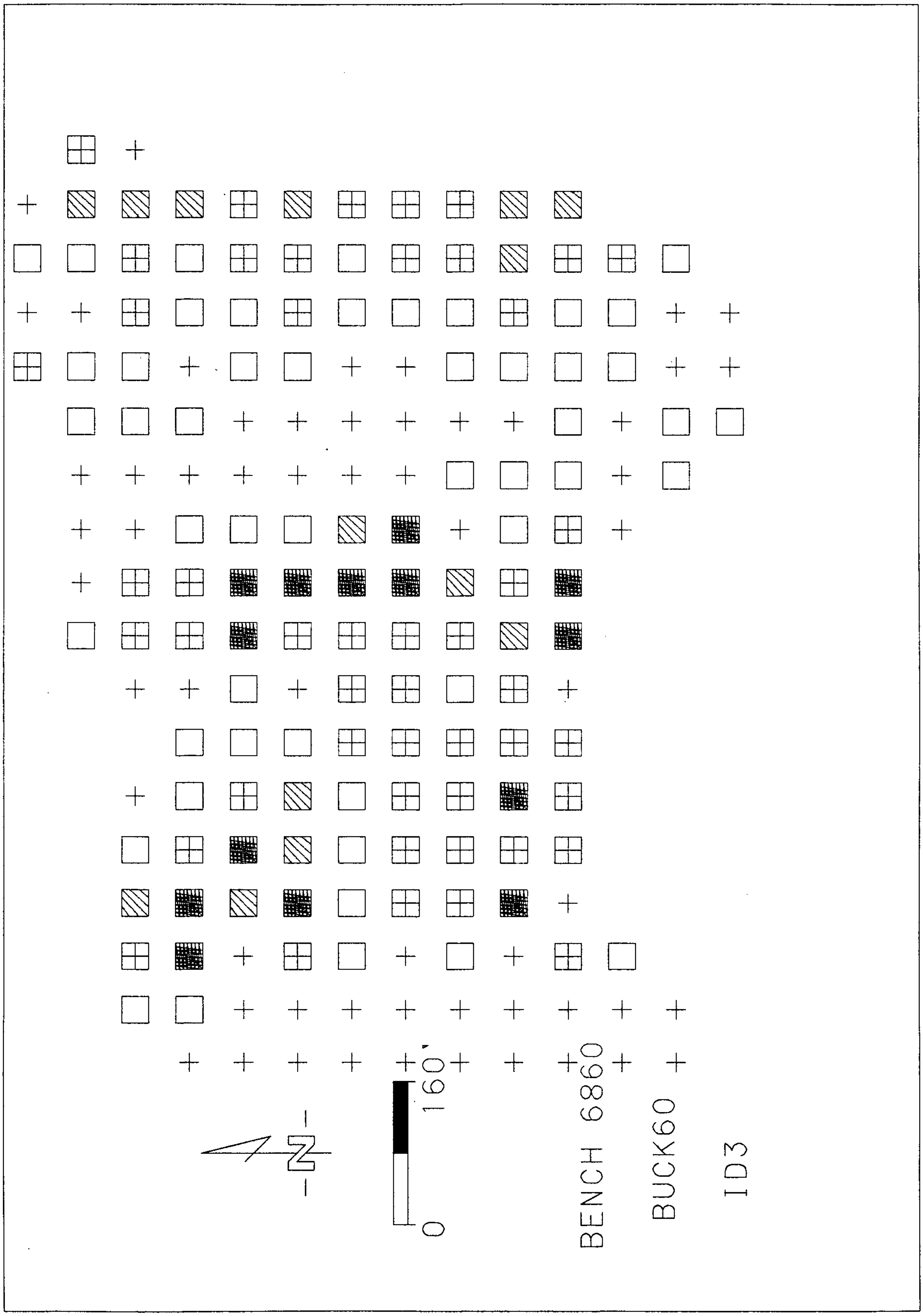

N
0
160'
BENCH 6860
BUCK60
BH60

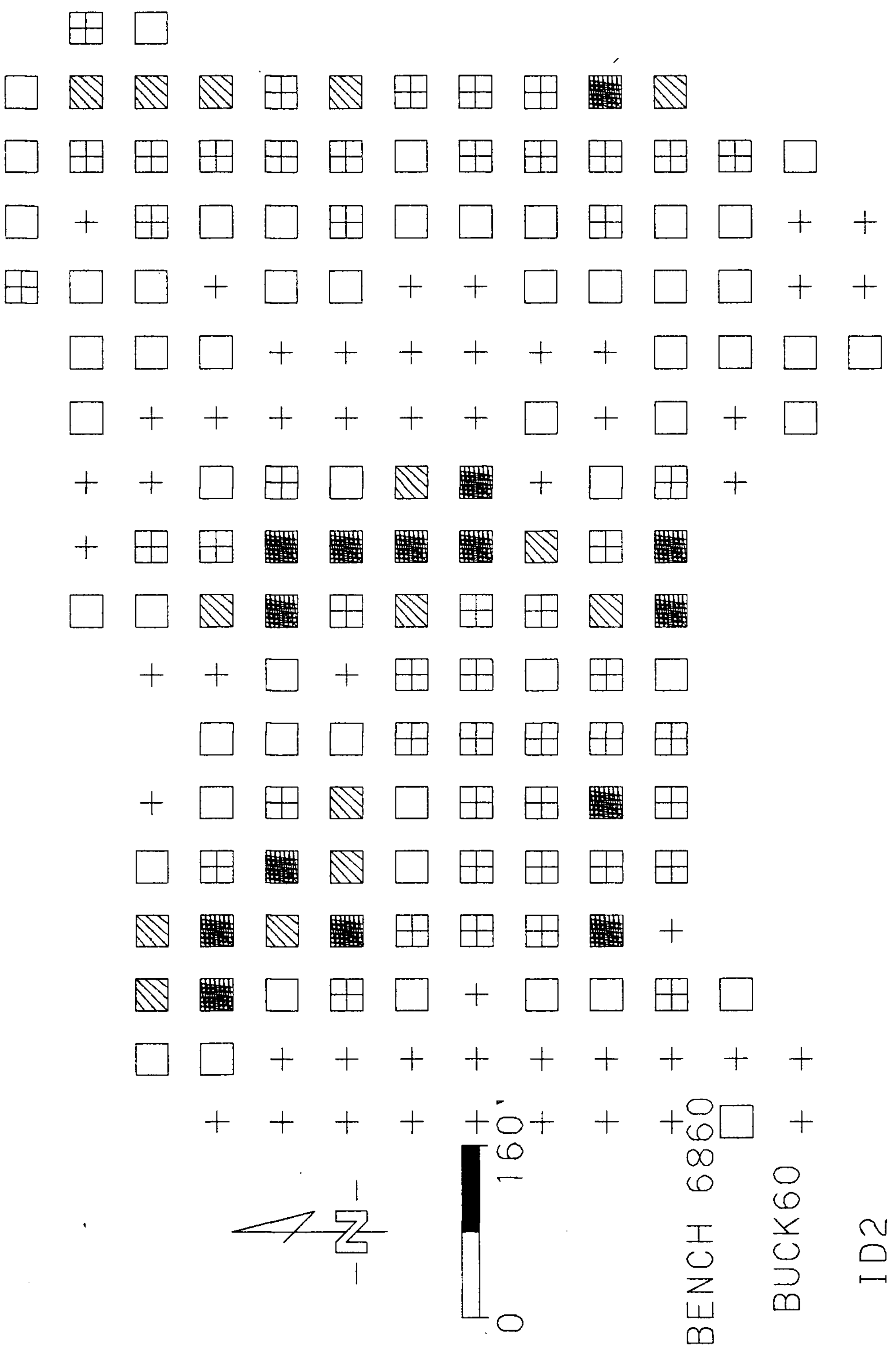

N
0
160
BENCH 6860
BUCK60
EX60


160
0
N
BENCH 6860
BUCK60
ID10



N
160'
0
BENCH 6860
BUCK60
ID5


160
0
BENCH 6860
BUCK60
ID3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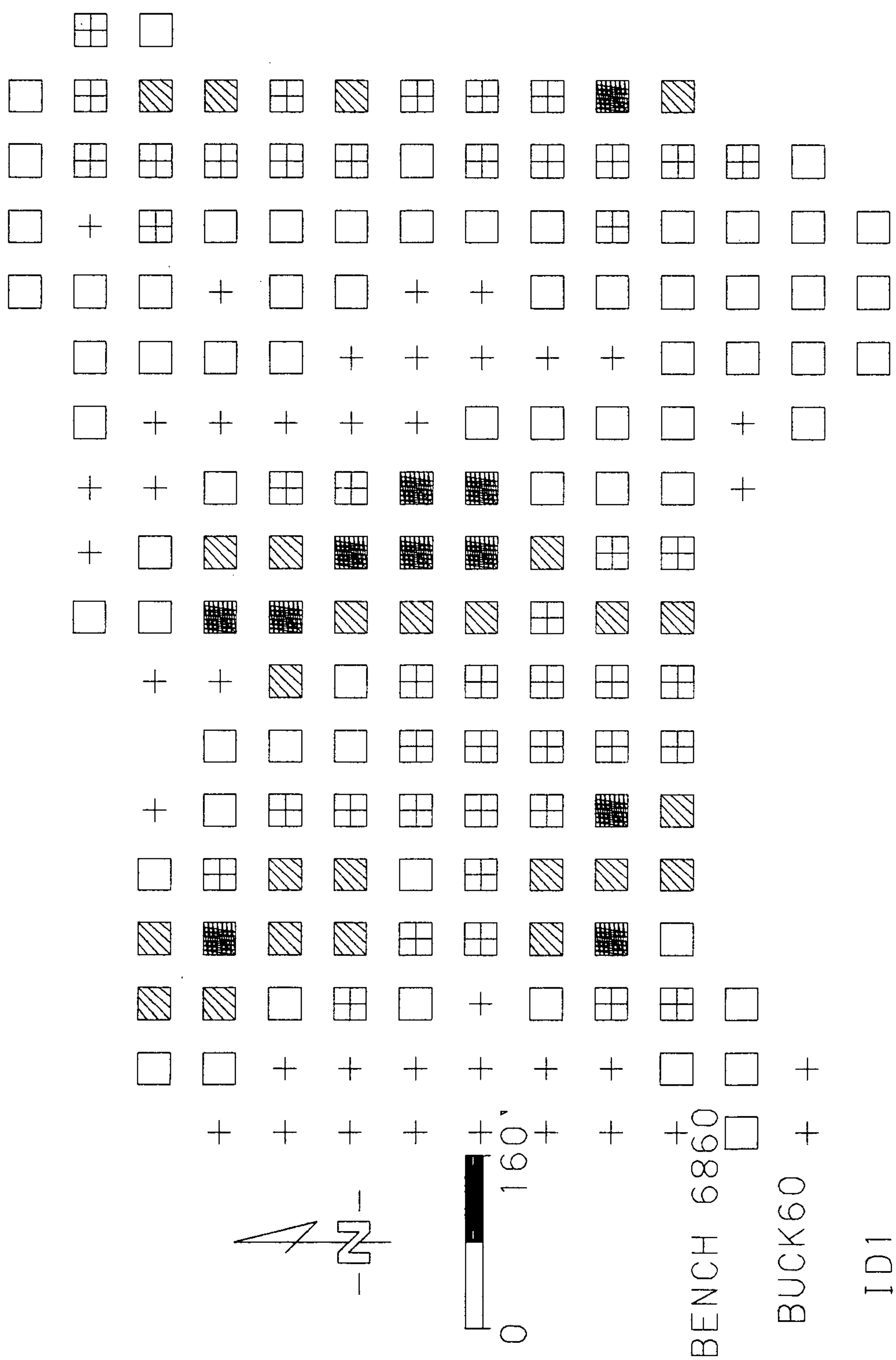
160
0
BENCH 6860
BUCK60
ID2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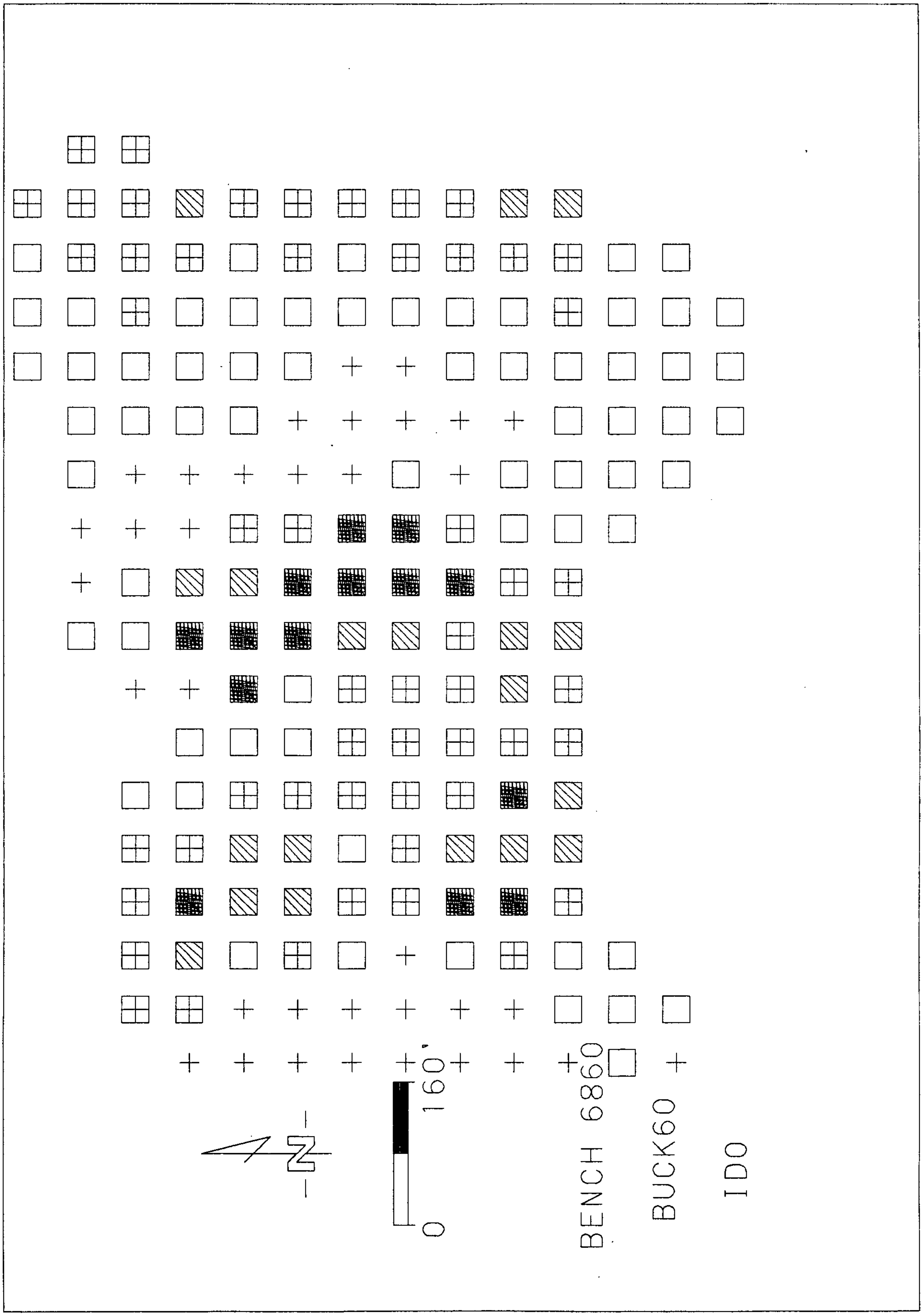
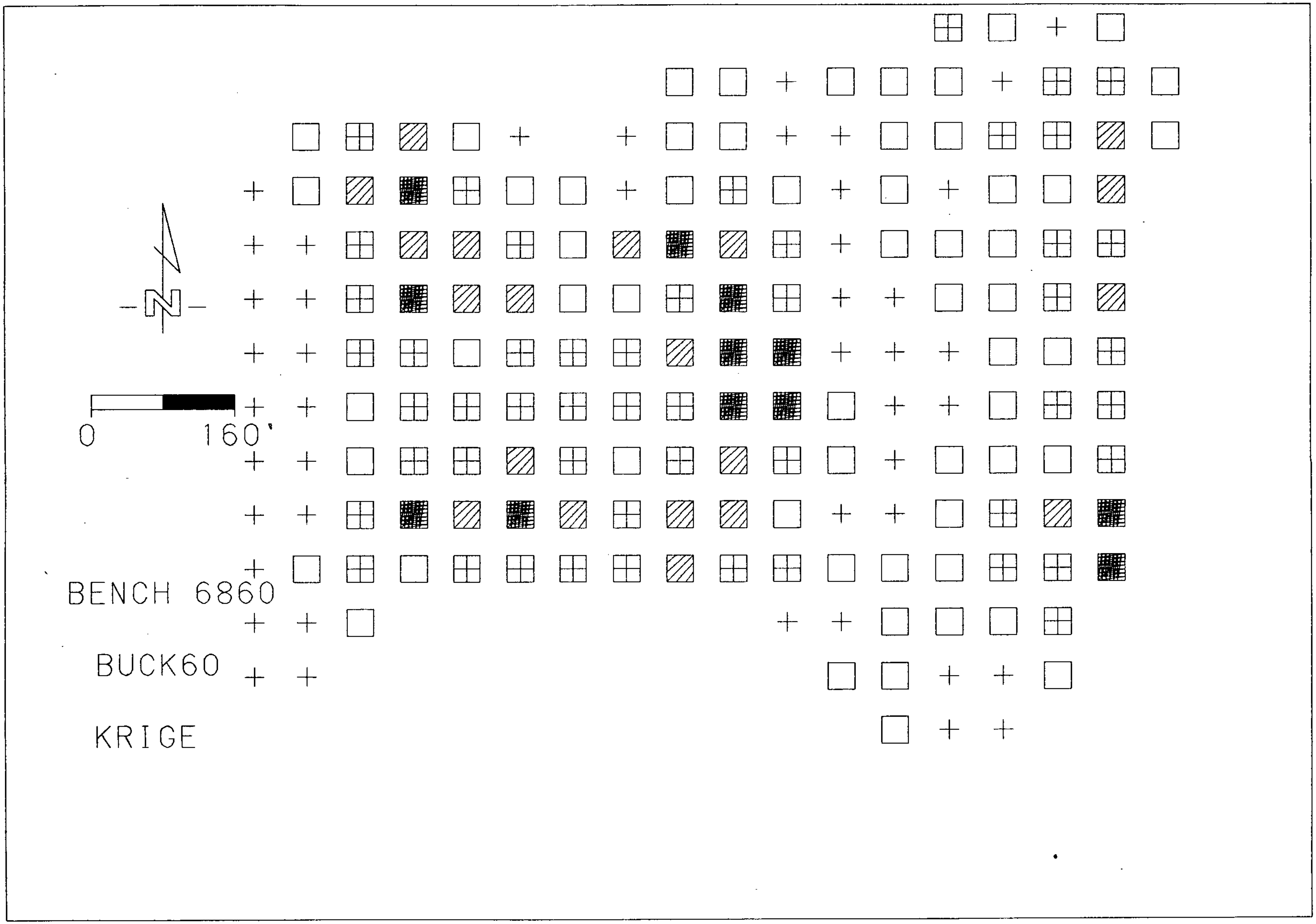
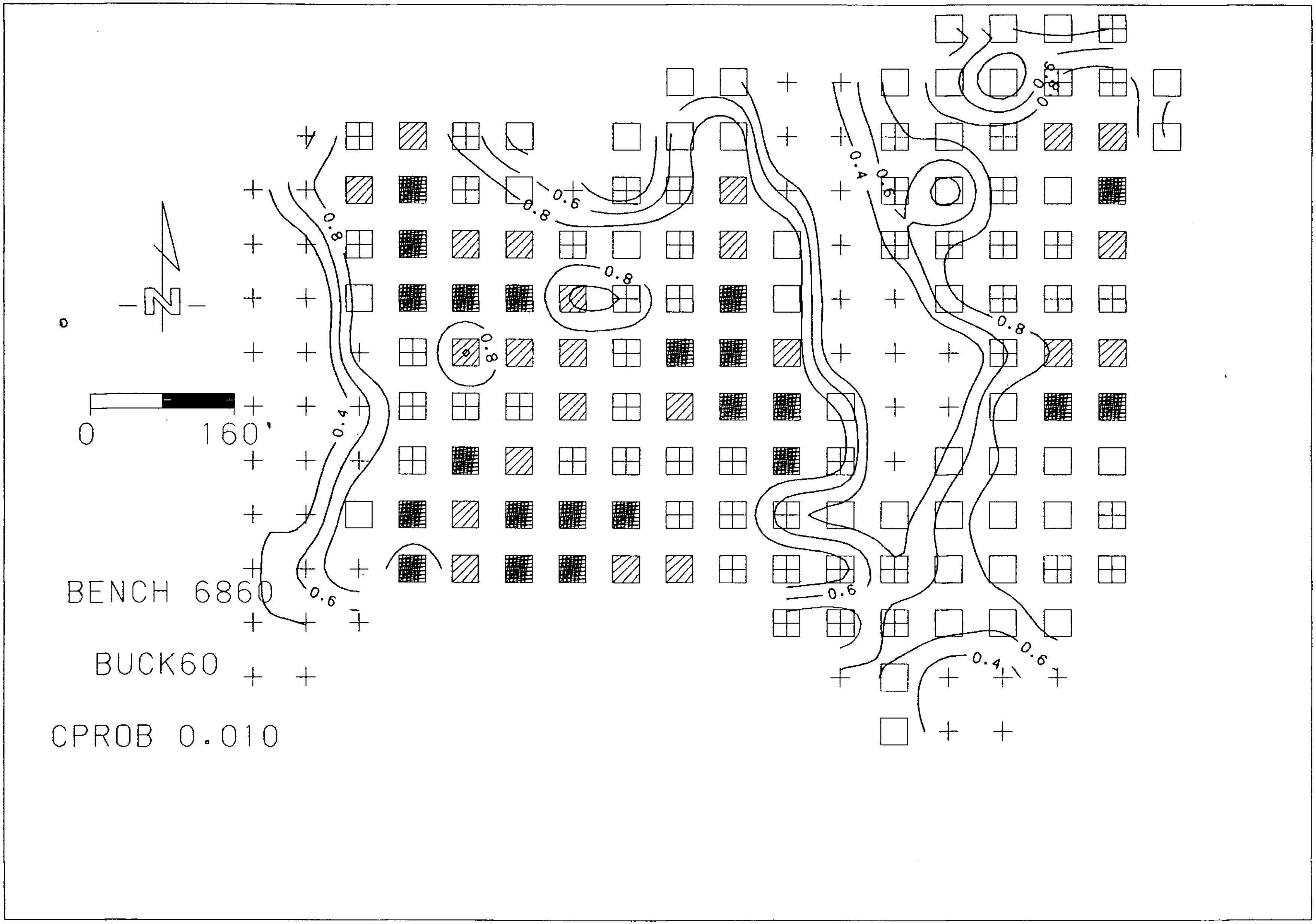
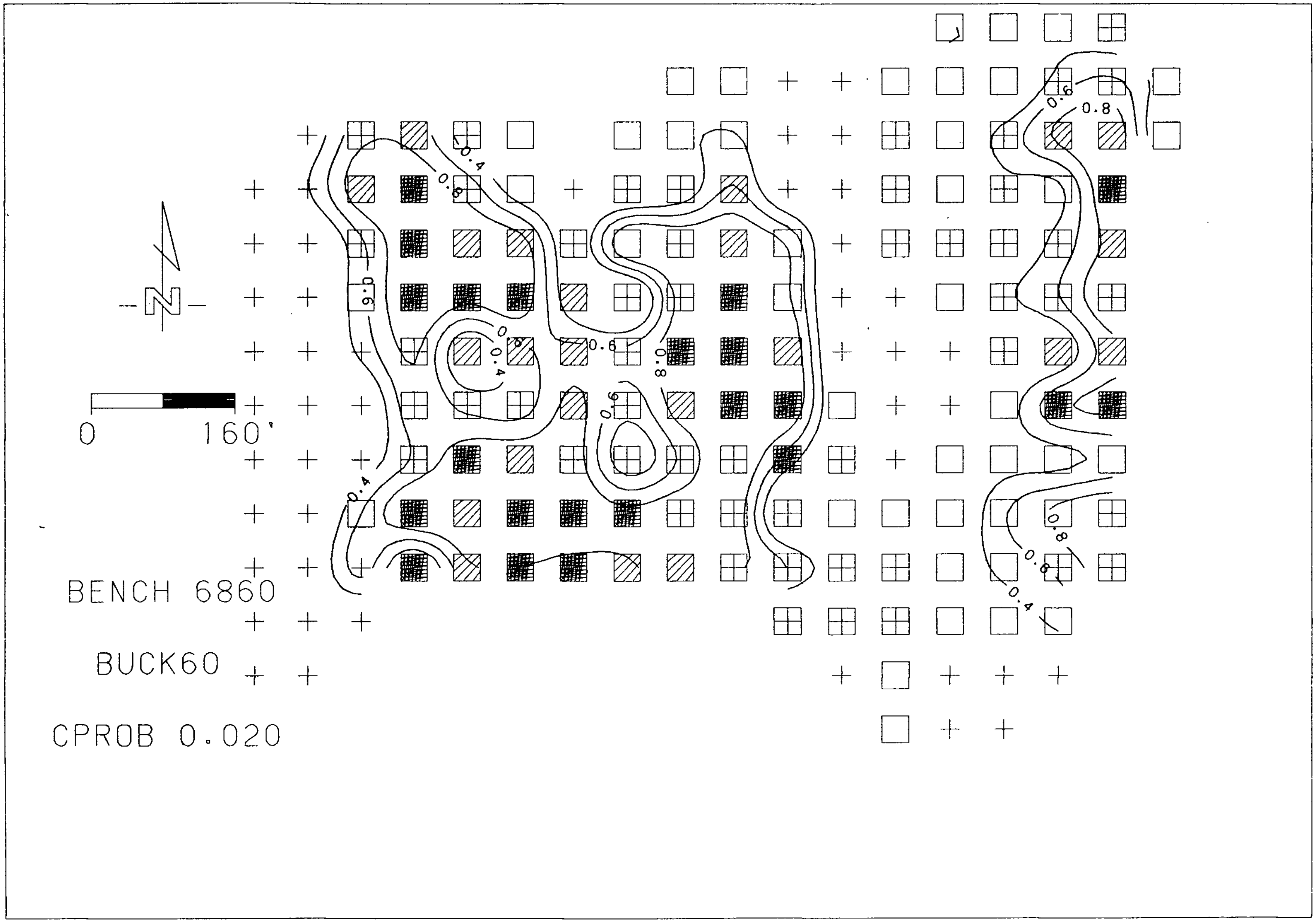
0
160'
BENCH 6860
BUCK60
ID1



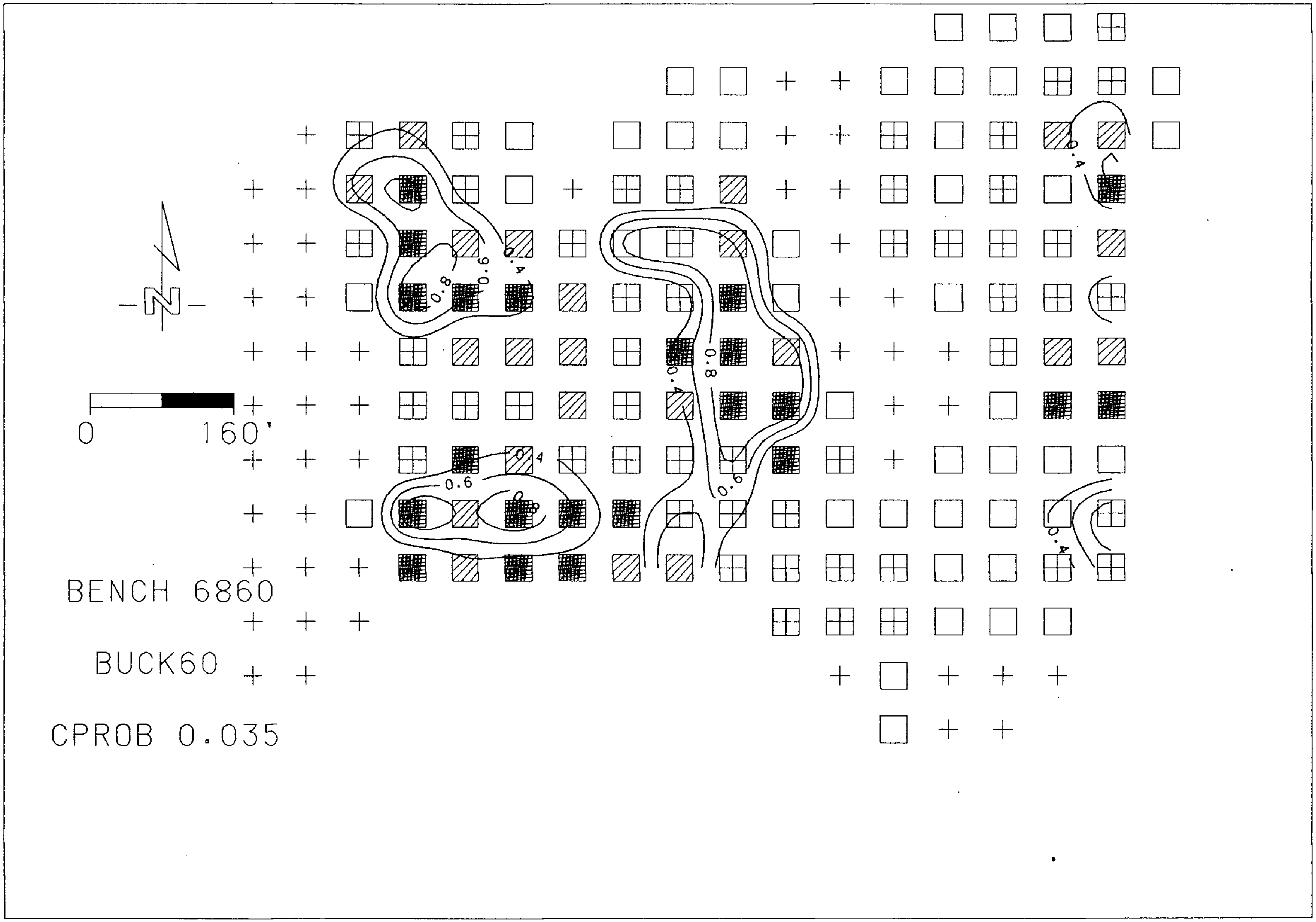
N
0
160'
BENCH 6860
BUCK60
IDO


N
0
160'
BENCH 6860
BUCK60
KRIGE

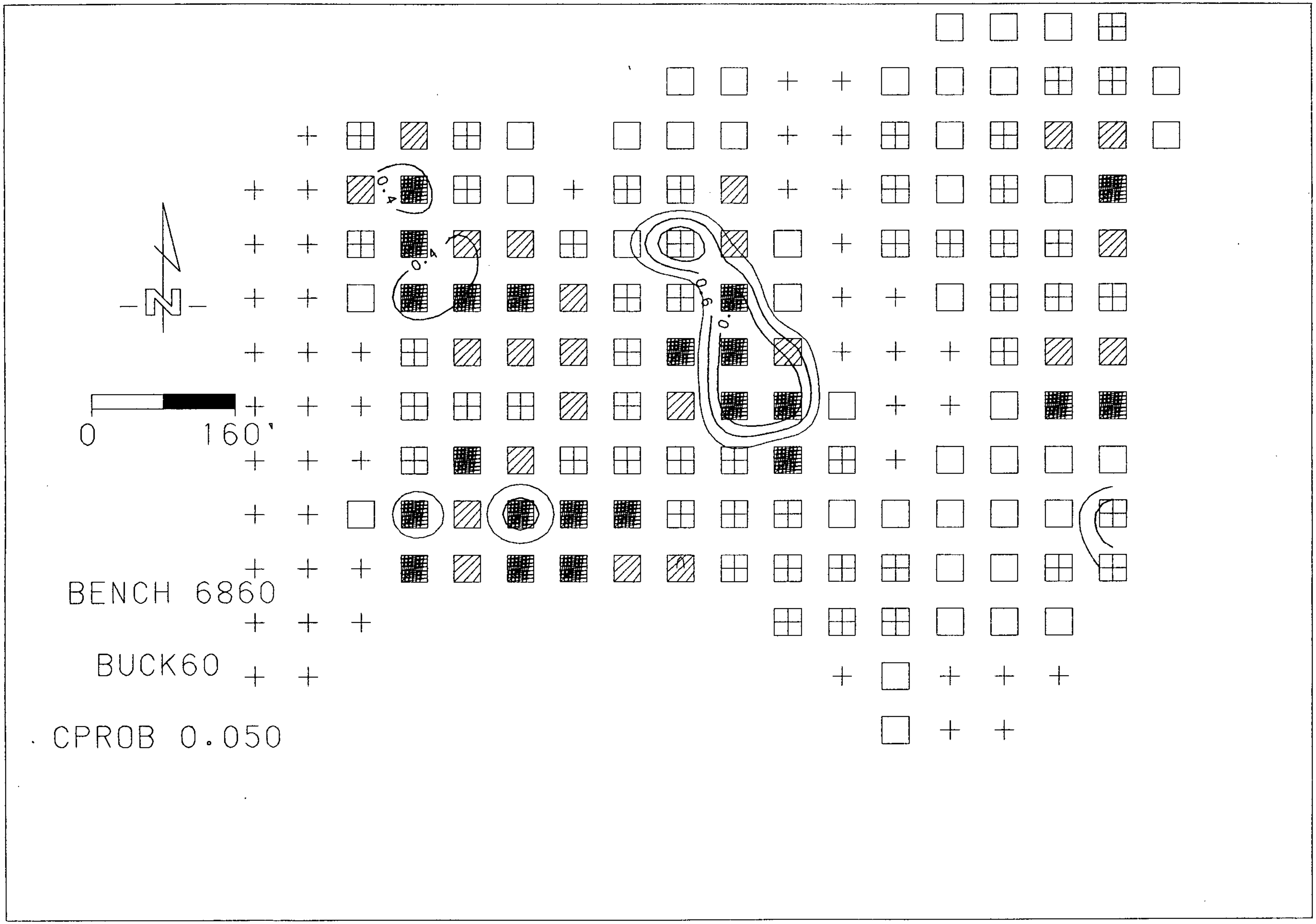

0.8
0.6
0.4
0 160'
BENCH 6860
BUCK60
CPROB 0.010

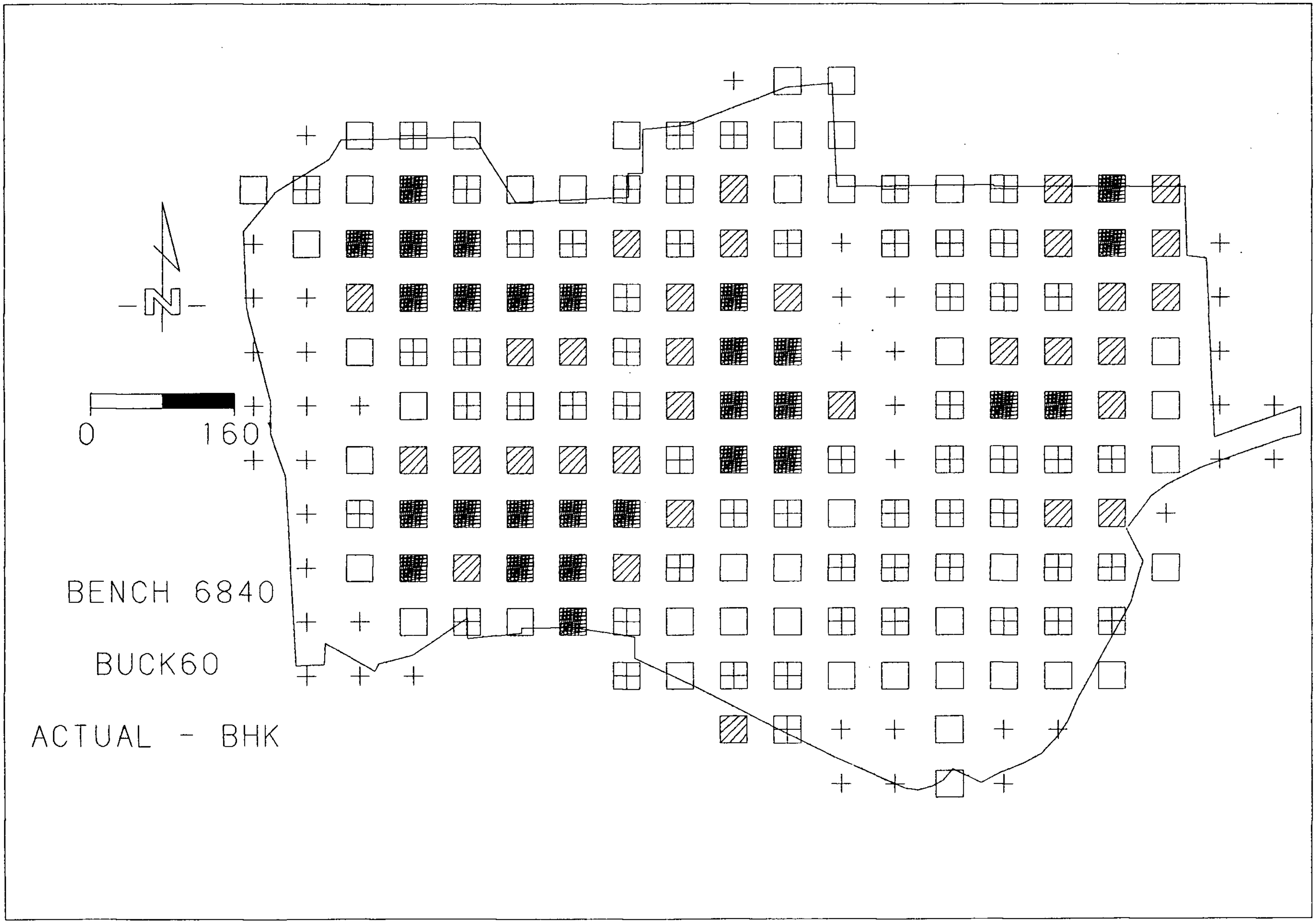


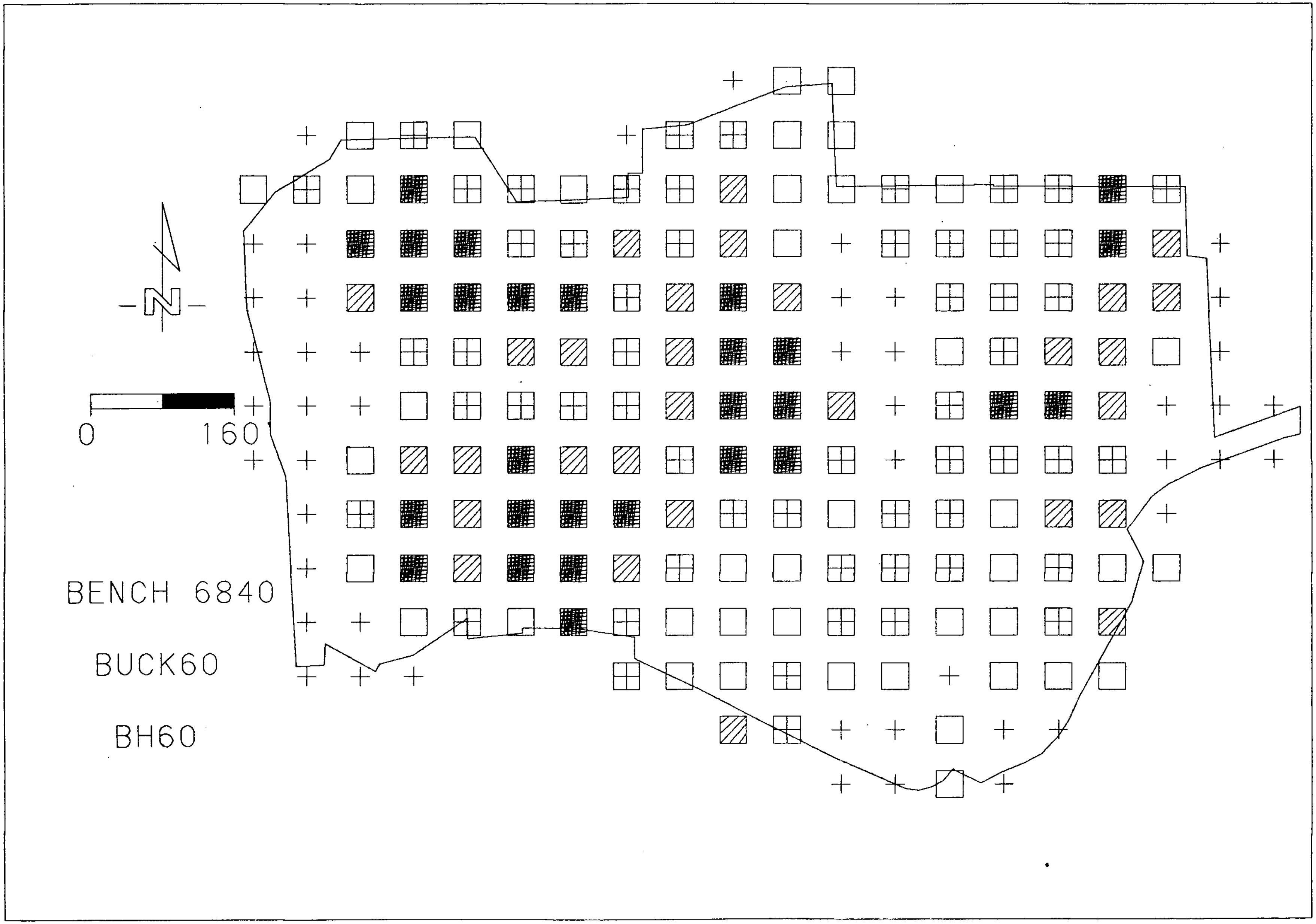
N
0
160'
BENCH 6860
BUCK60
CPROB 0.020
0.4
0.6
0.8

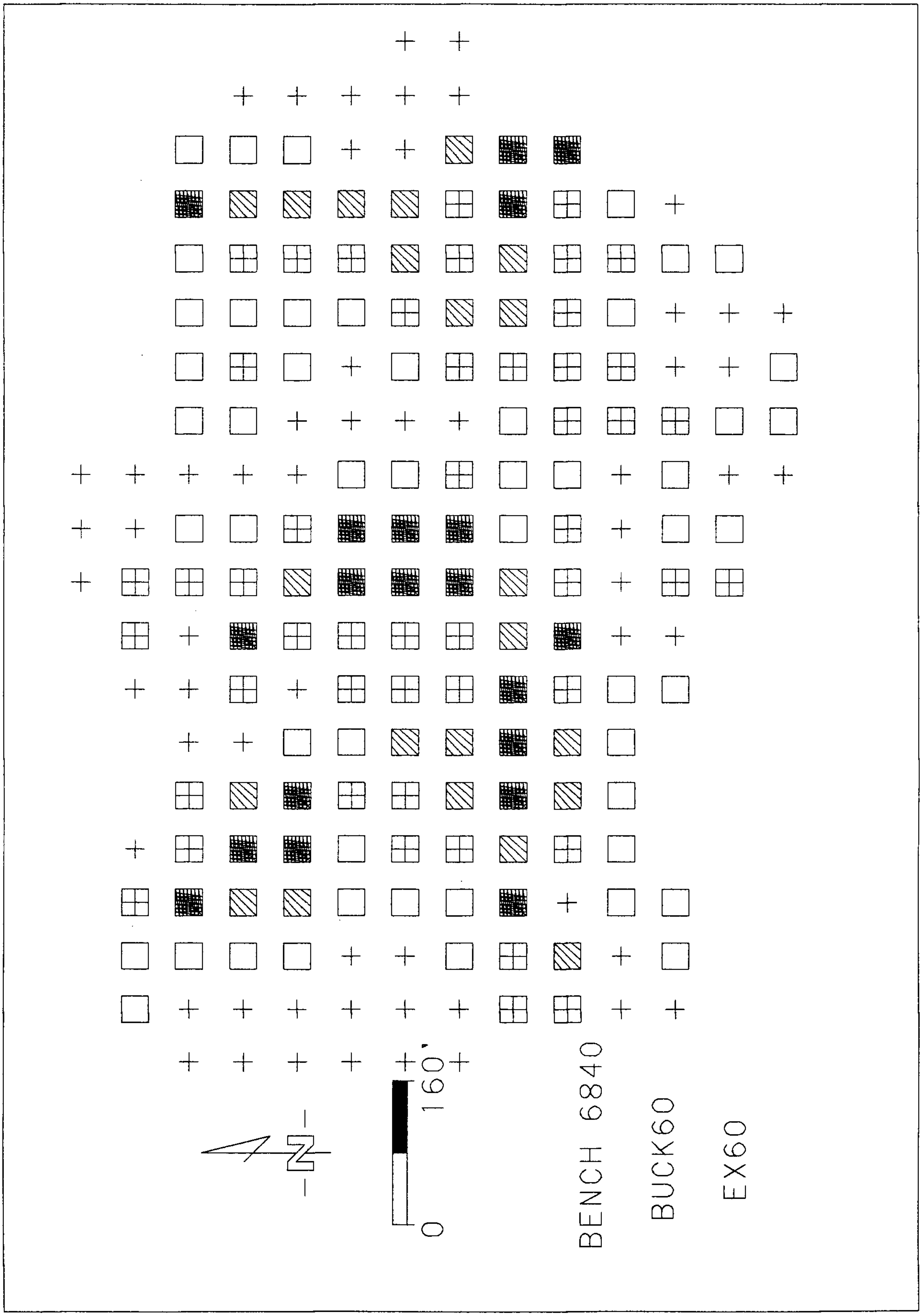


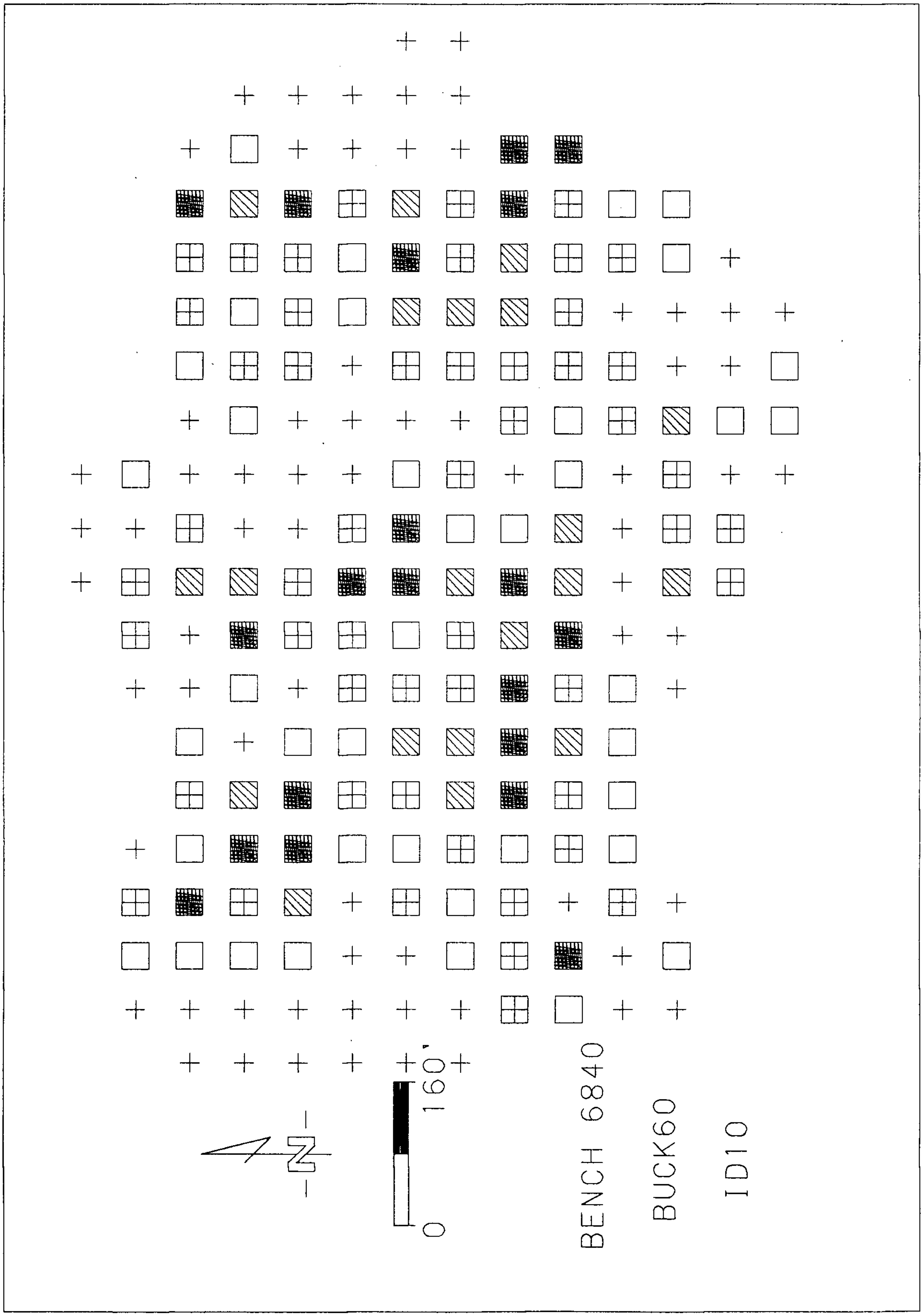
0 160'
BENCH 6860
BUCK60
CPROB 0.035
0.4
0.6
0.8

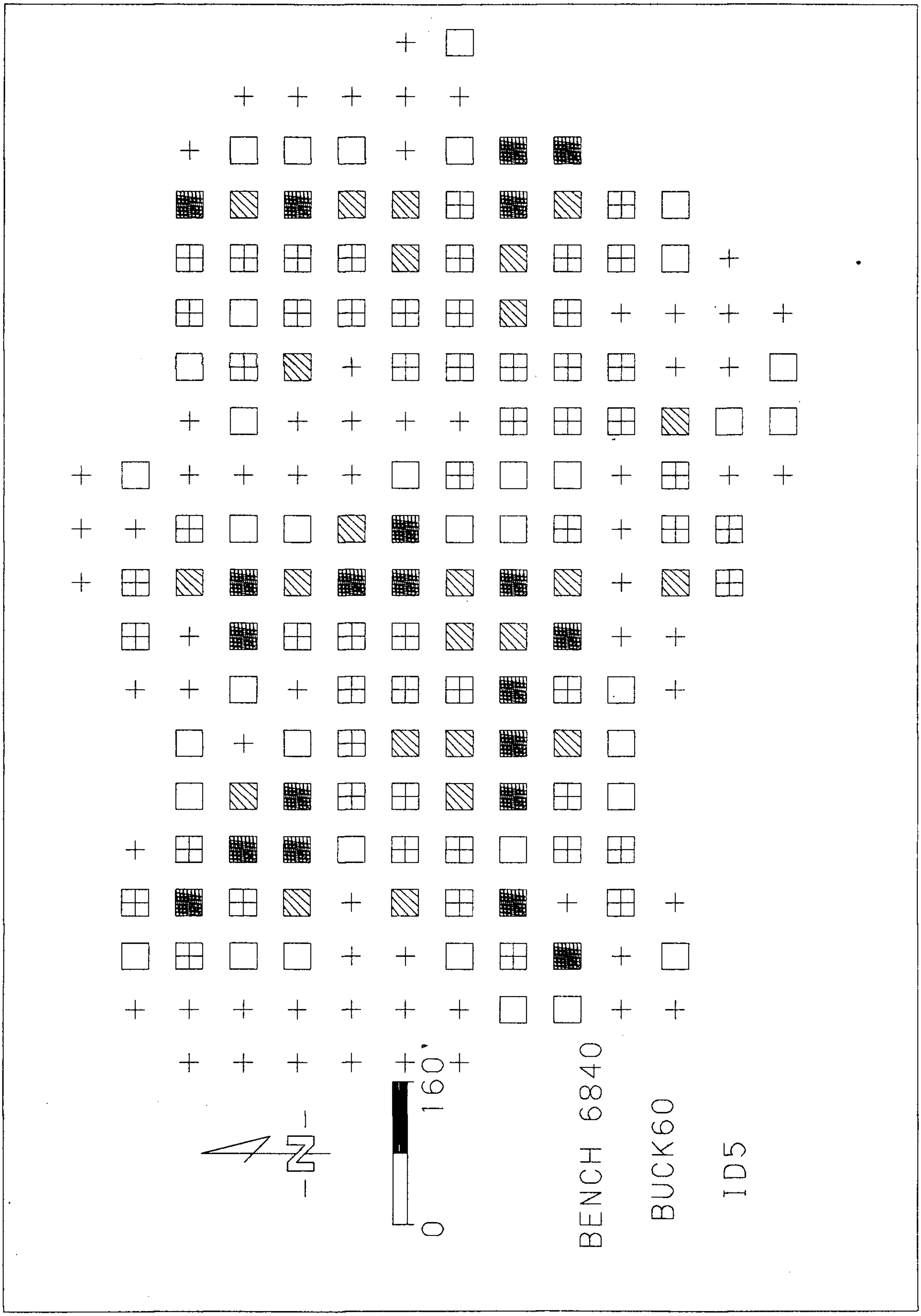

0
160'
0.4
0.4
0.6
0.6
BENCH 6860
BUCK60
CPROB 0.050


N
0
160
BENCH 6840
BUCK60
ACTUAL - BHK

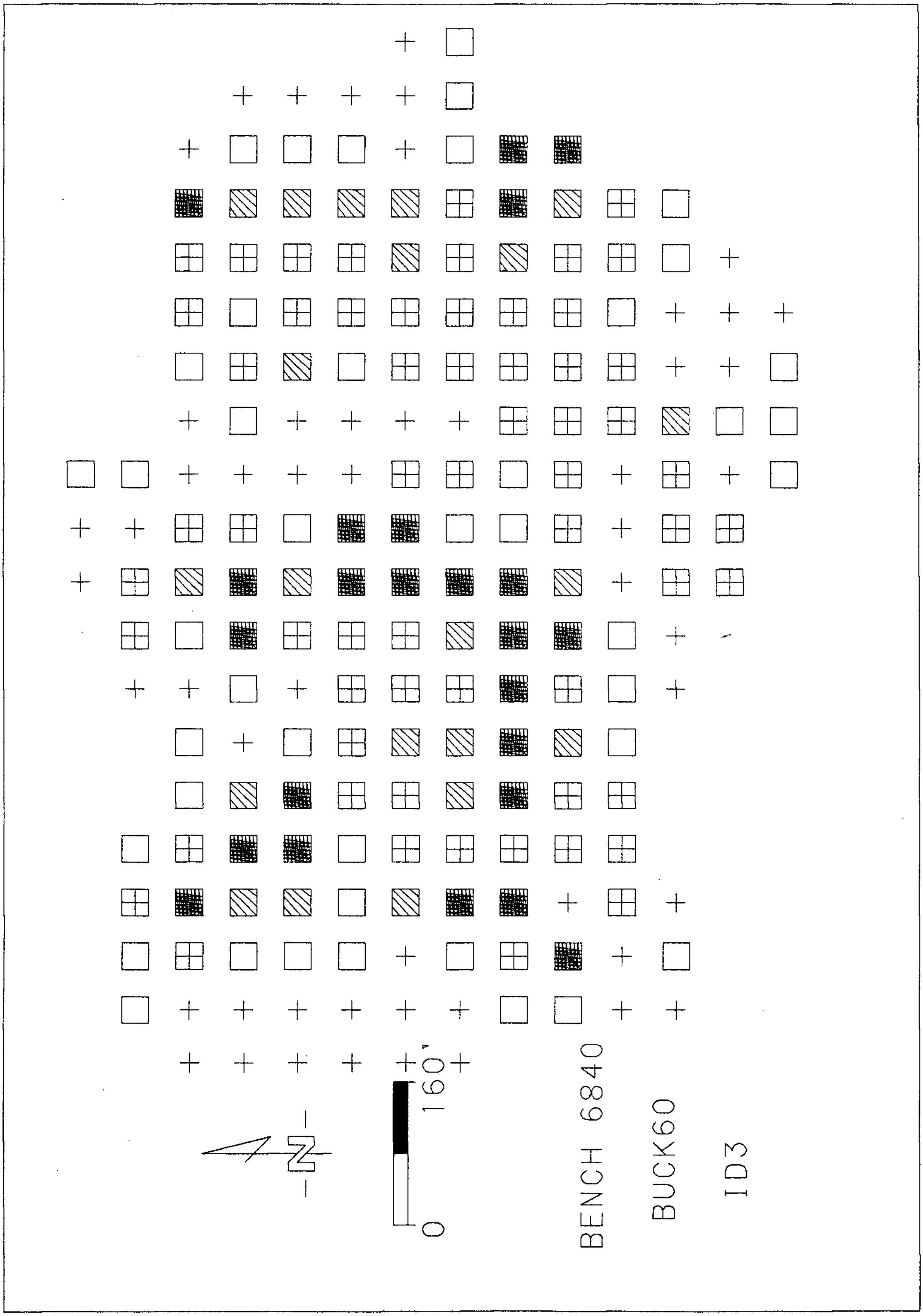

N
0
160
BENCH 6840
BUCK60
BH60

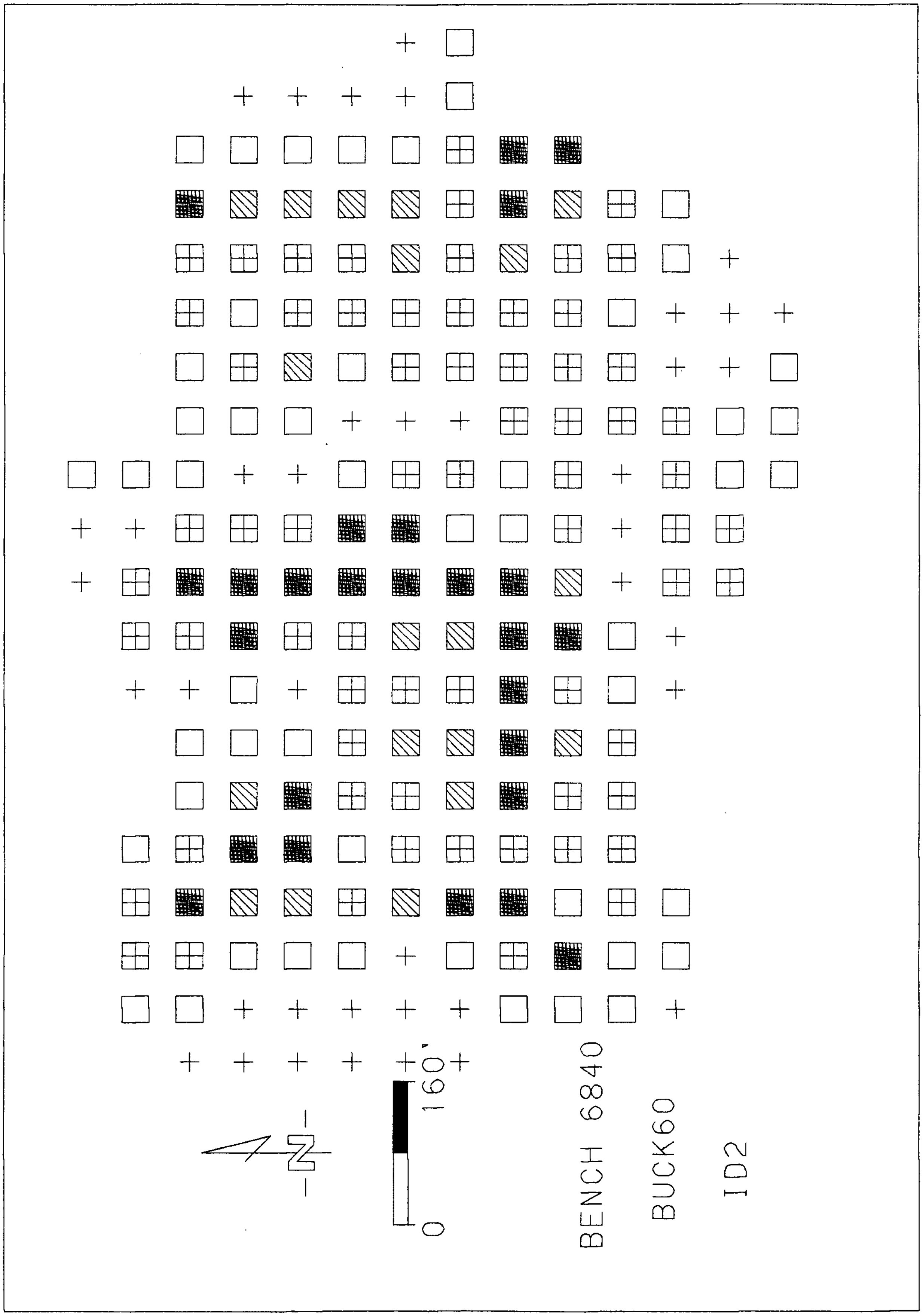

BENCH 6840
BUCK60
EX60
0
160'
N

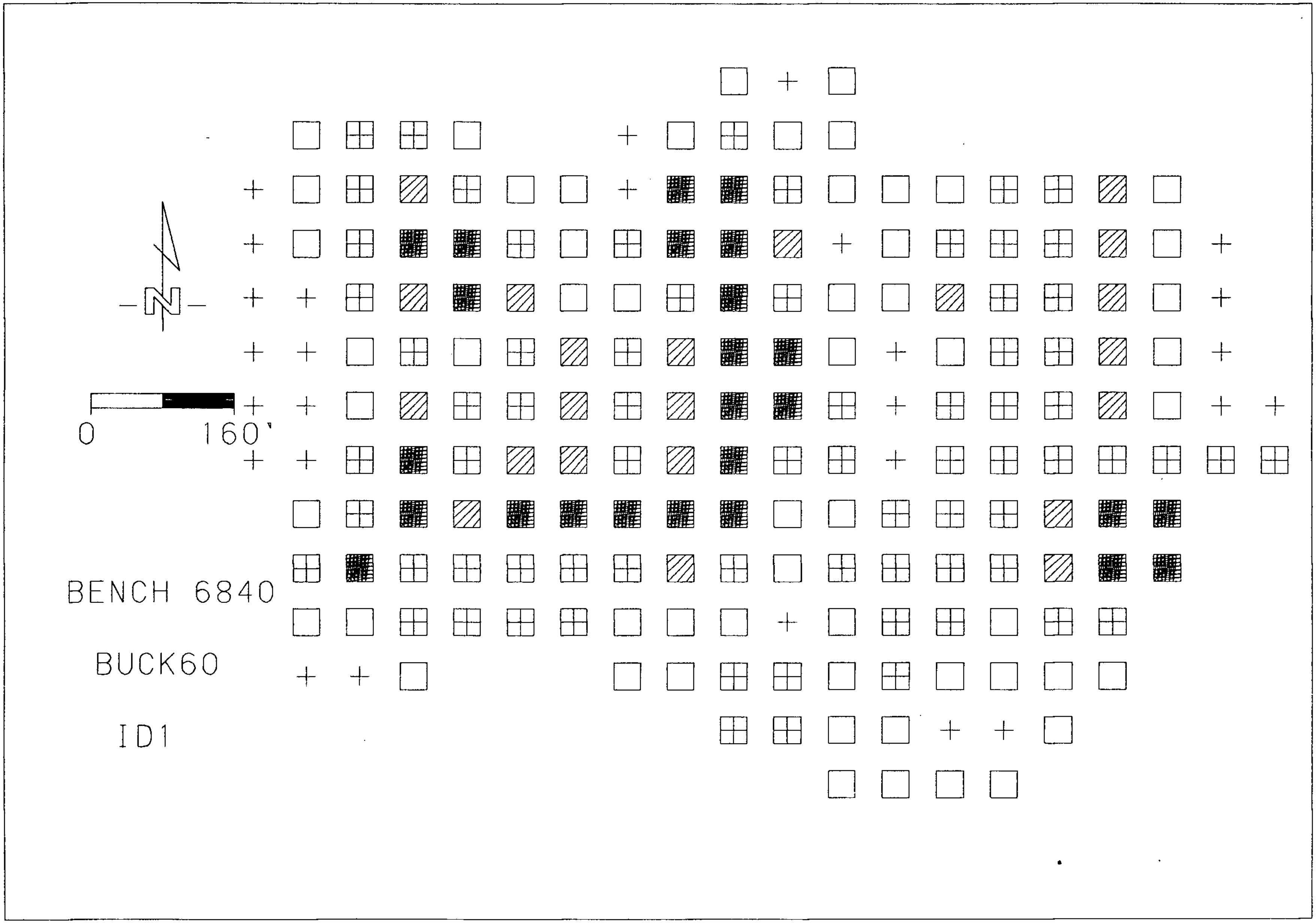

N
160'
0
BENCH 6840
BUCK60
ID10

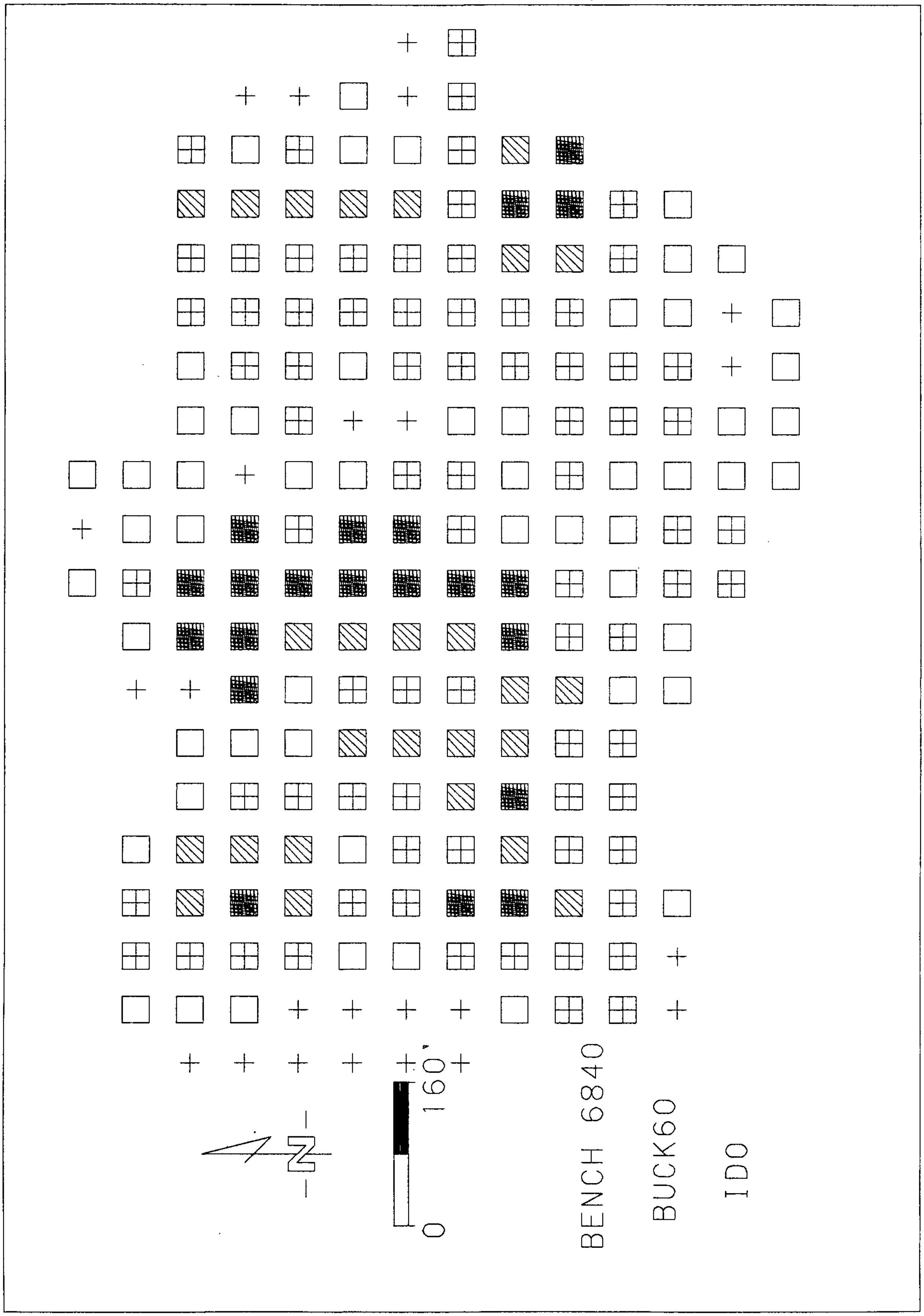


N
160
0
BENCH 6840
BUCK60
ID5

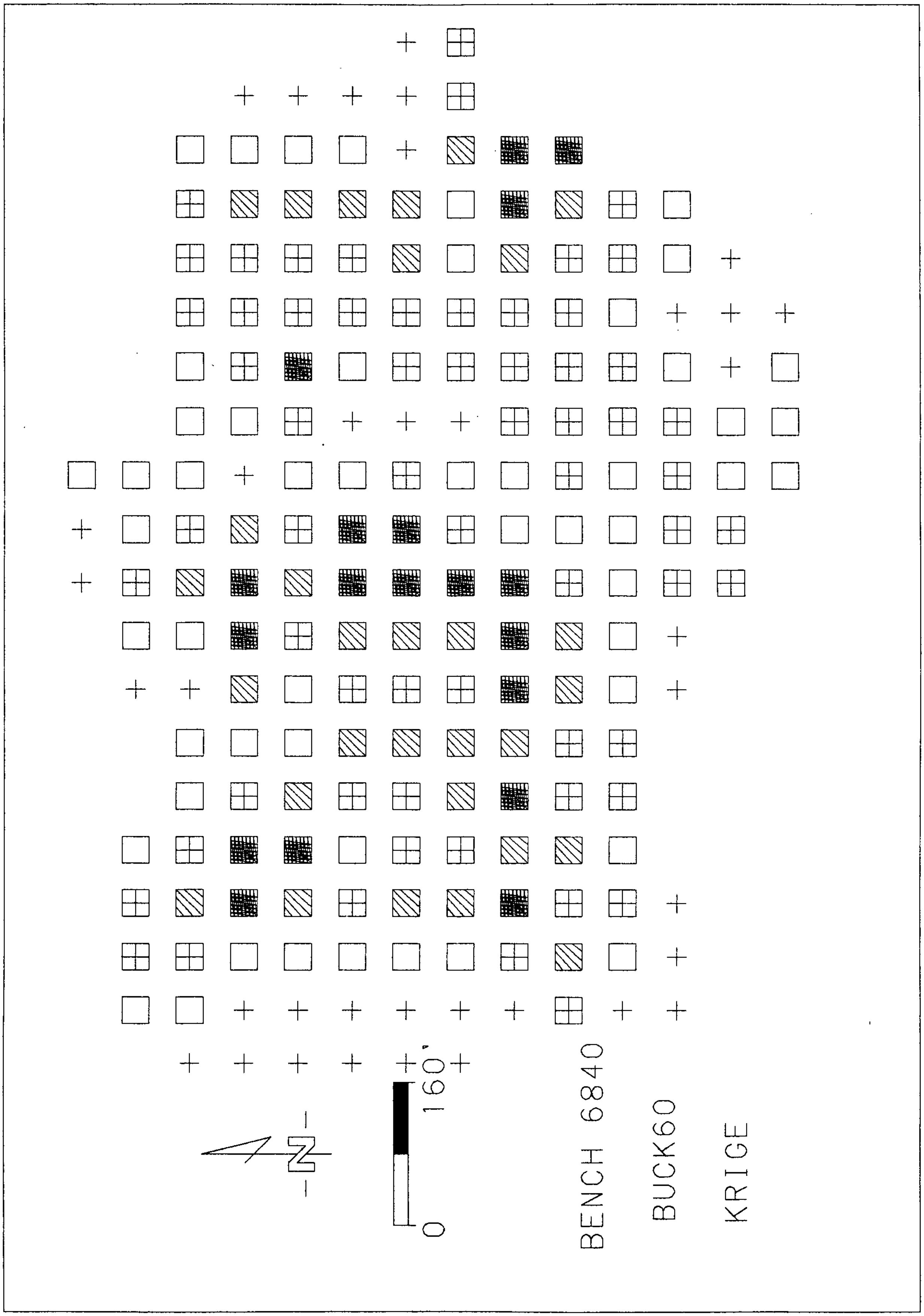

160'
0
BENCH 6840
BUCK60
ID3

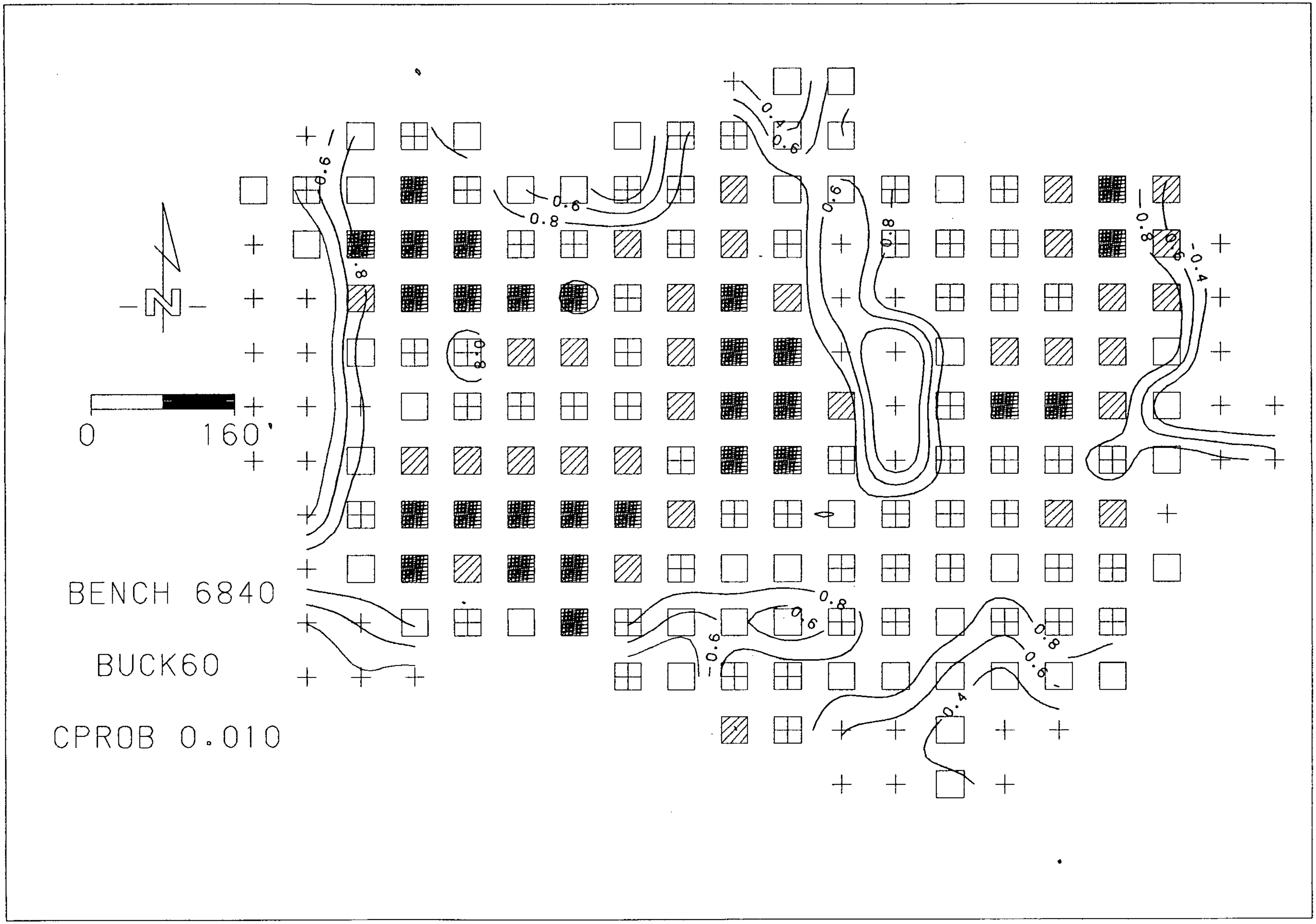

N
0
160'
BENCH 6840
BUCK60
ID2

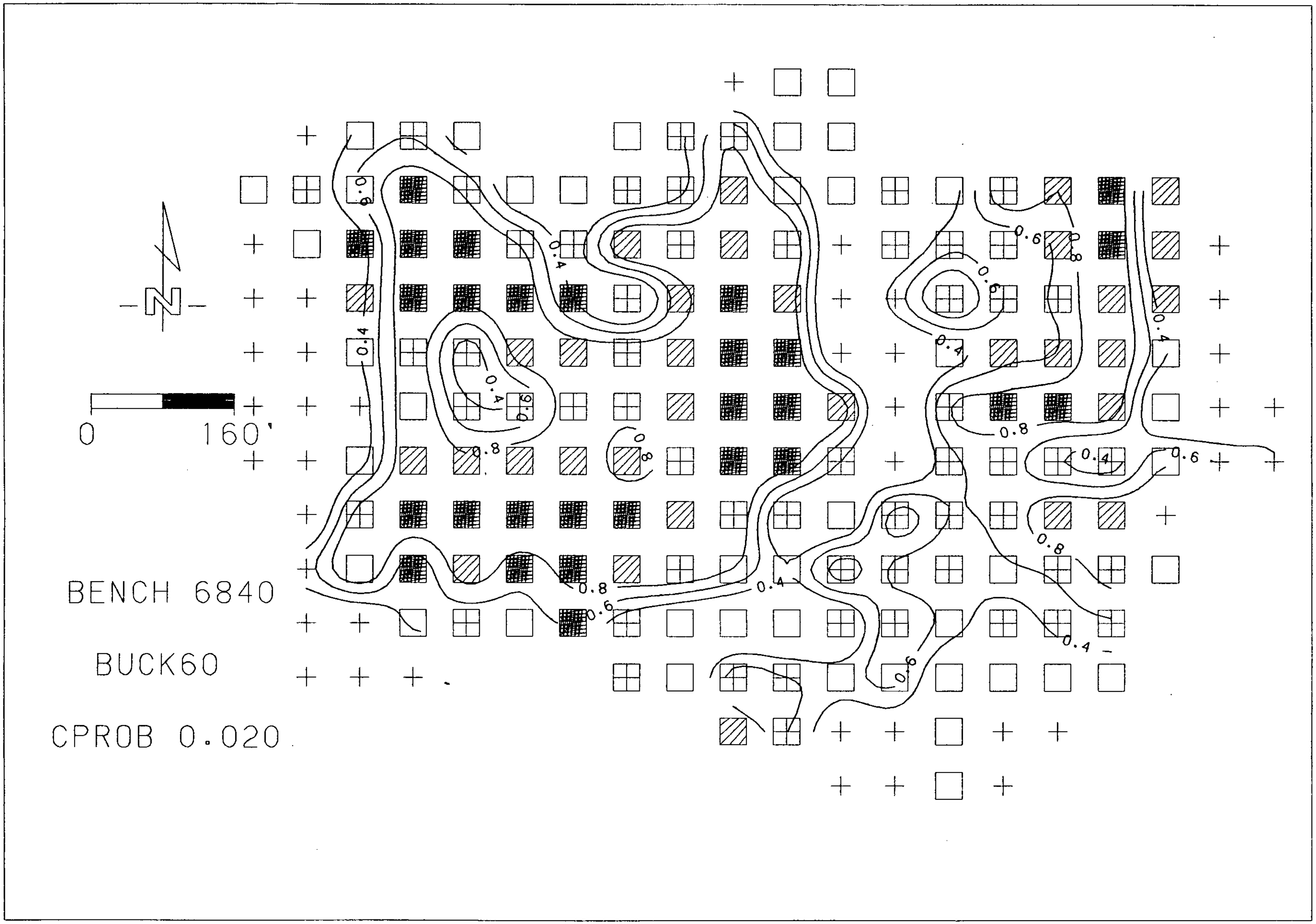

N
0
160'
BENCH 6840
BUCK60
ID1



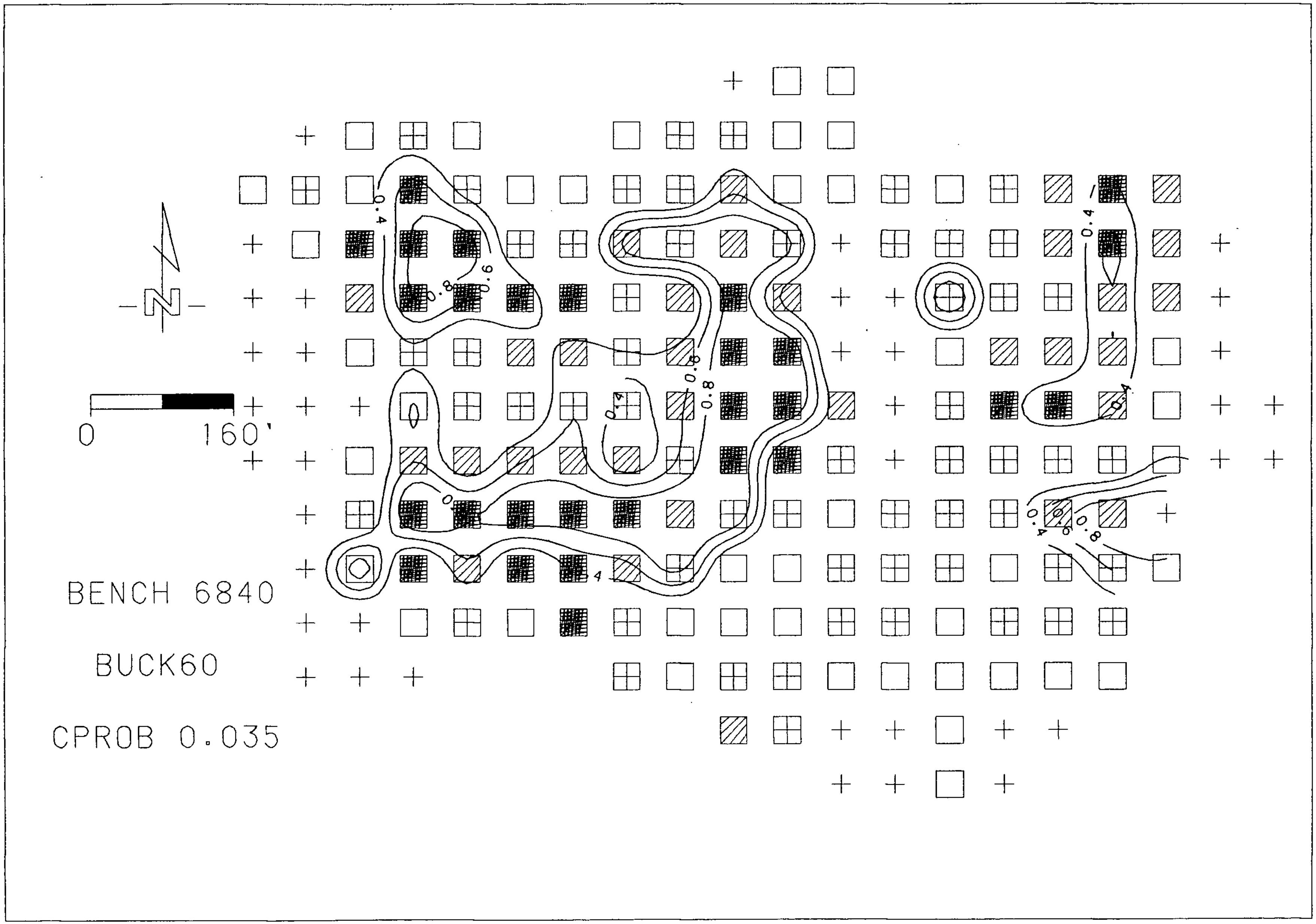
N
0
160
BENCH 6840
BUCK60
IDO

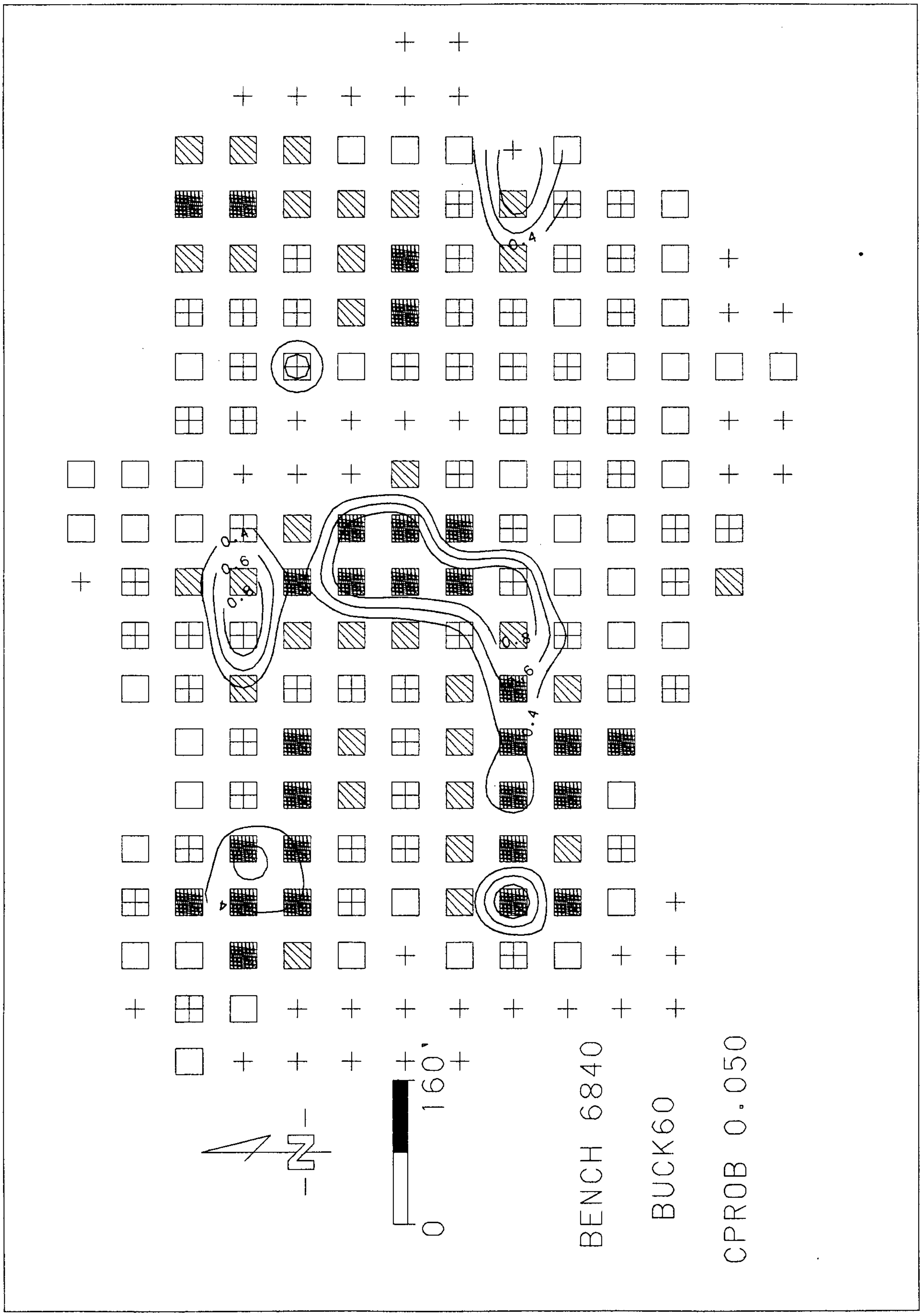

160'
0
N
BENCH 6840
BUCK60
KRIGE

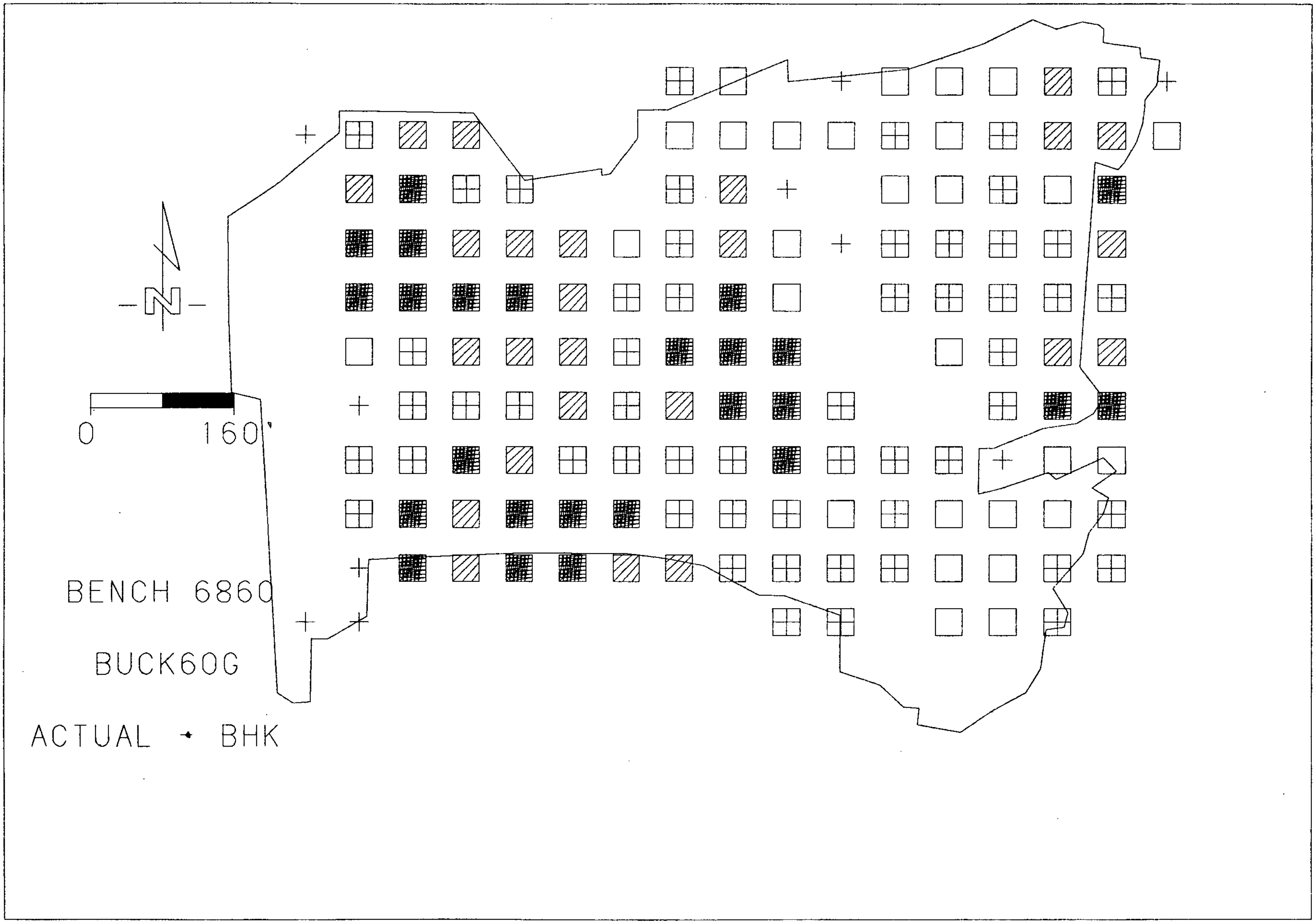

0
160'
BENCH 6840
BUCK60
CPROB 0.010

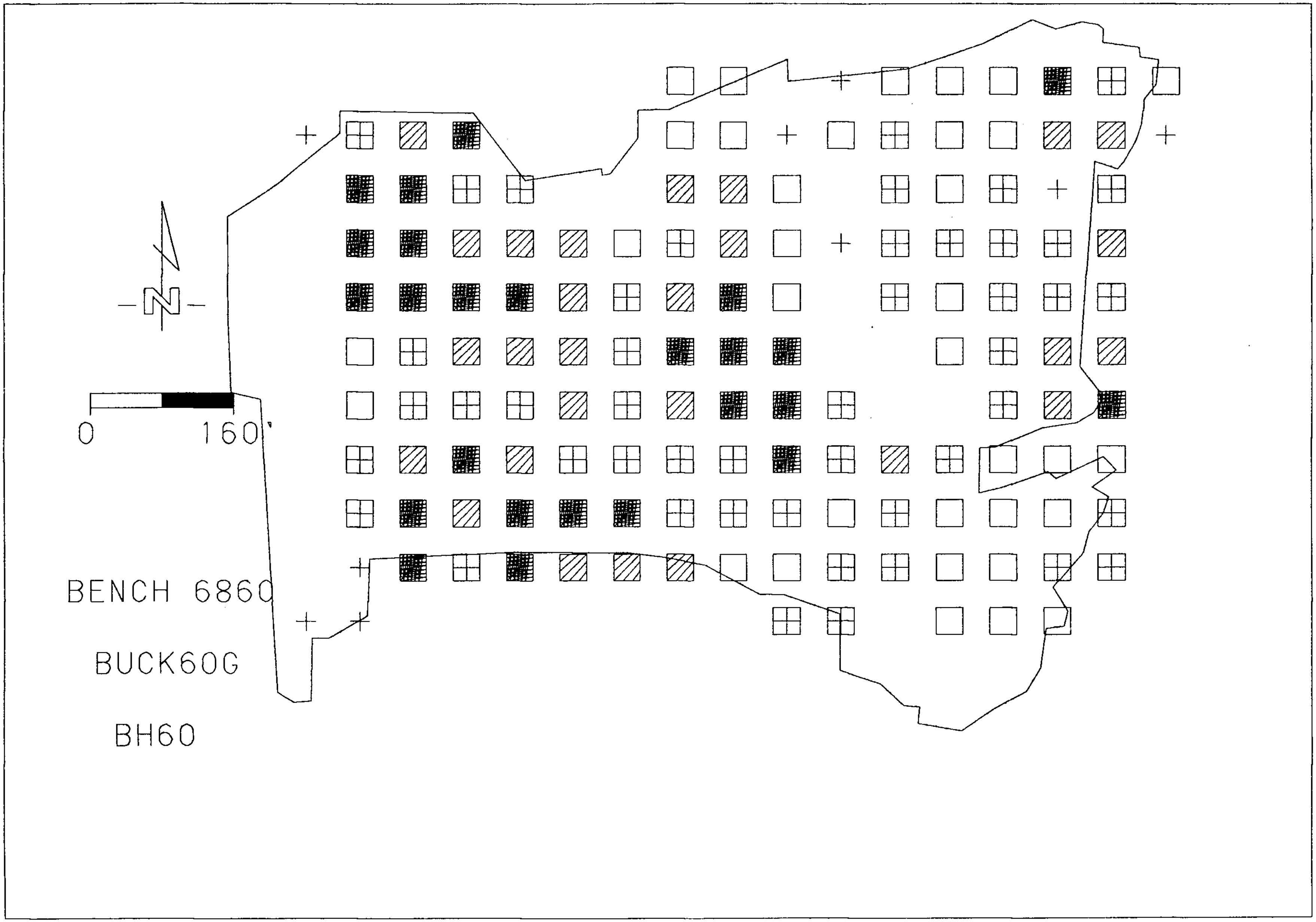


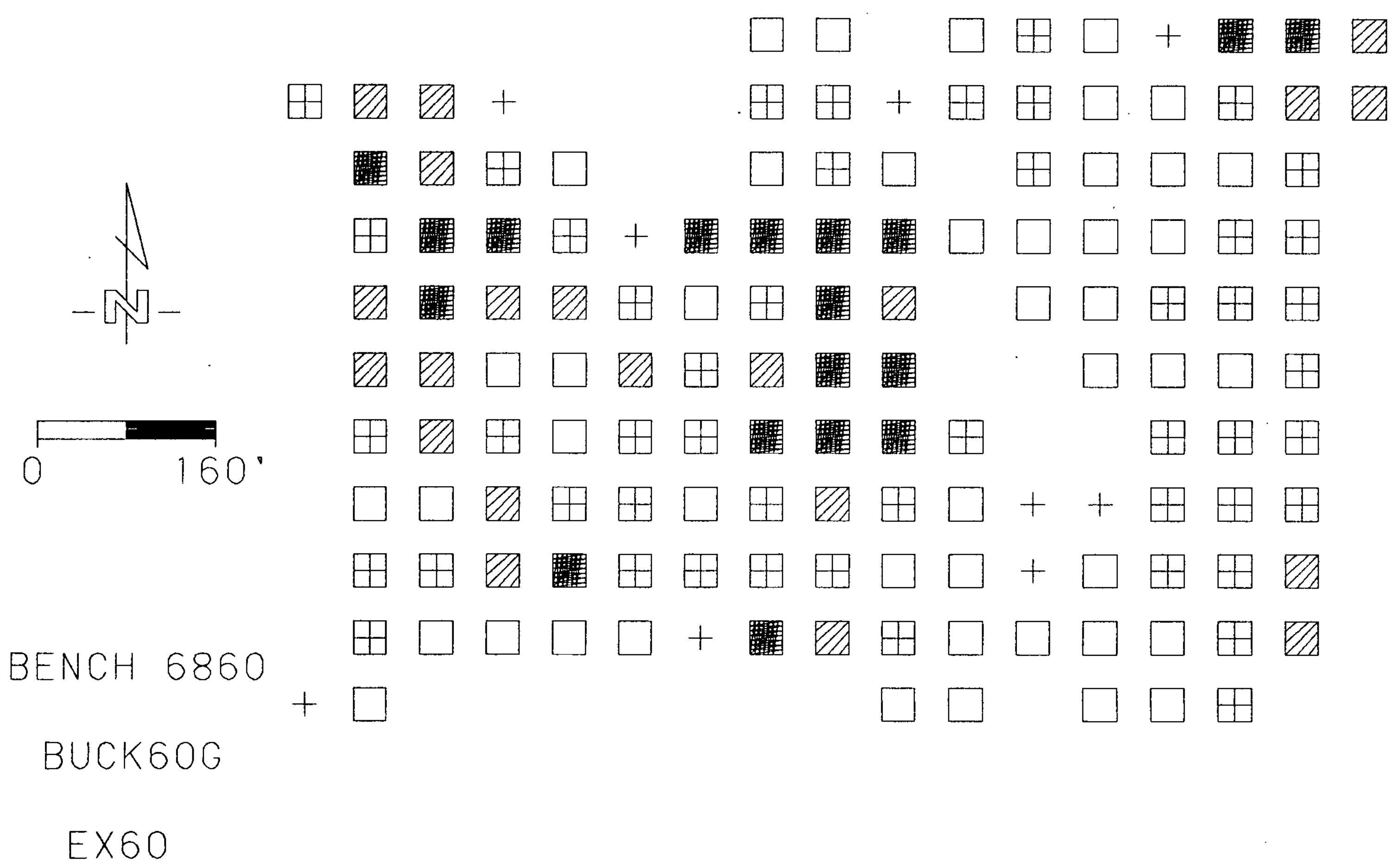
N
0
160'
BENCH 6840
BUCK60
CPROB 0.020
0.4
0.6
0.8

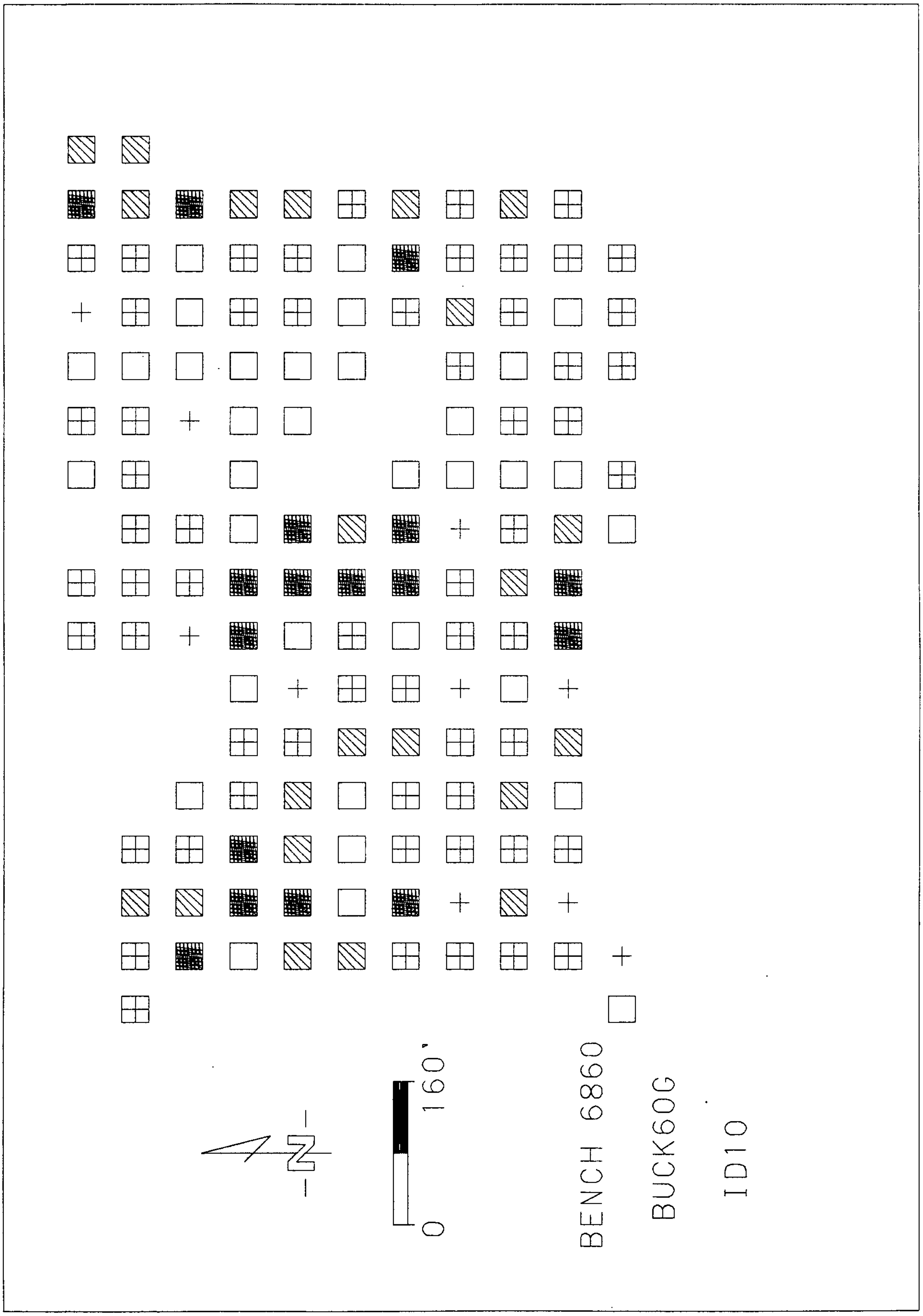

N
0
160'
BENCH 6840
BUCK60
CPROB 0.035
0.4
0.6
0.8

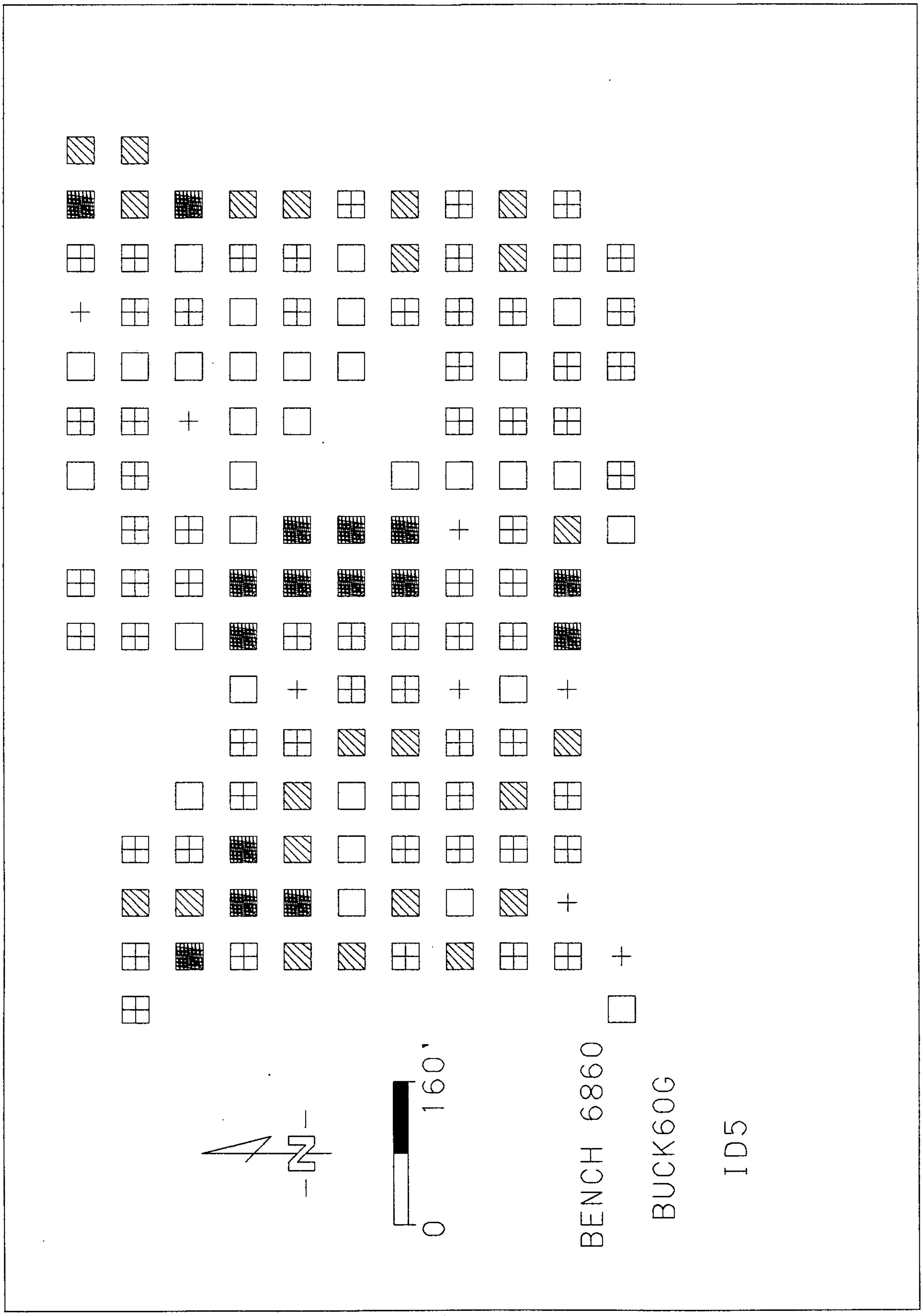

0.4
0.6
0.8
0.8
0.6
0.4
4
0.4
0
160'
N
BENCH 6840
BUCK60
CPROB 0.050


N
0
160'
BENCH 6860
BUCK60G
ACTUAL + BHK


N
0
160'
BENCH 6860
BUCK60G
BH60


N
0
160'
BENCH 6860
BUCK60G
EX60


N
0
160'
BENCH 6860
BUCK60G
ID10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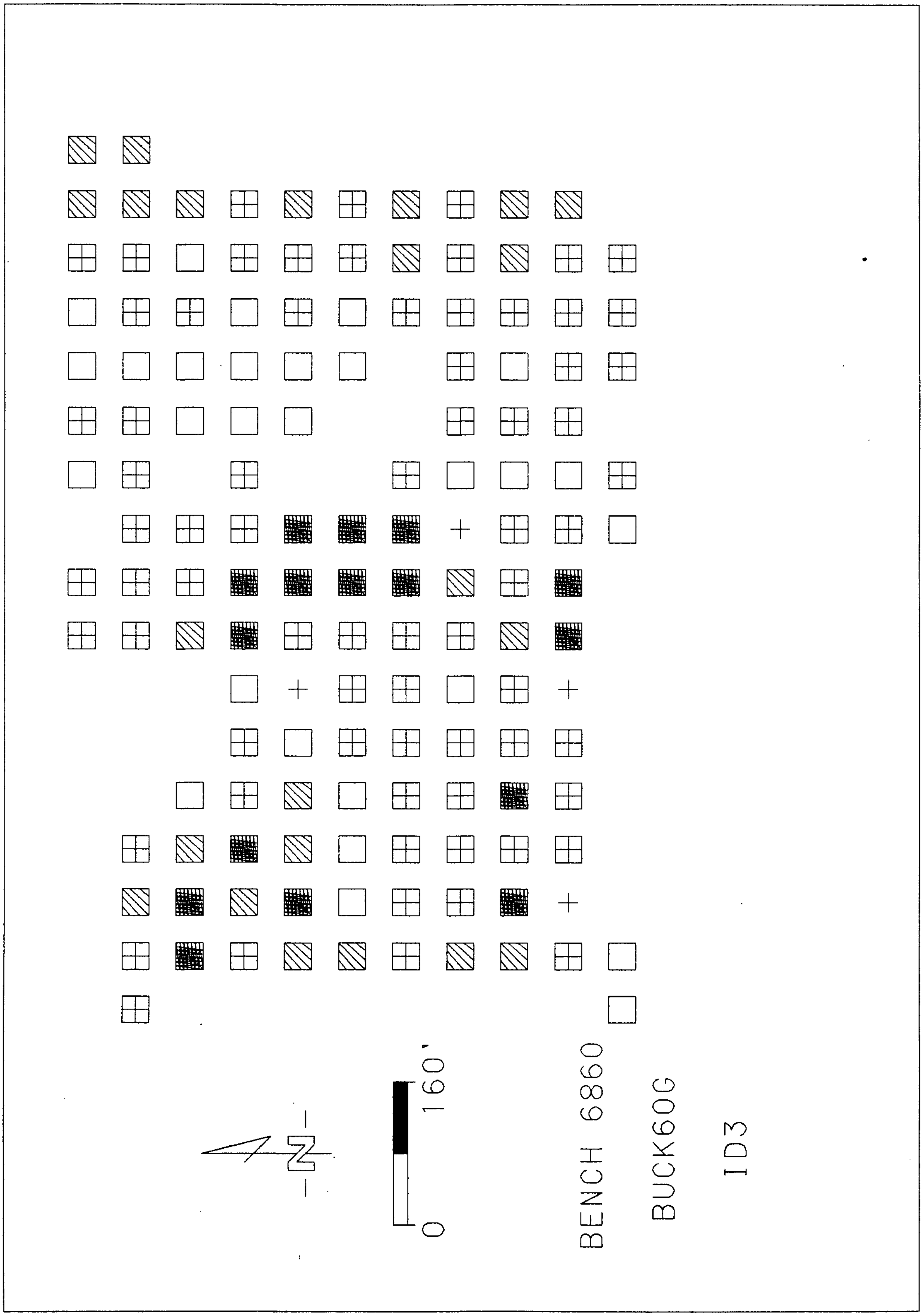
160'
BENCH 6860
BUCK60G
ID5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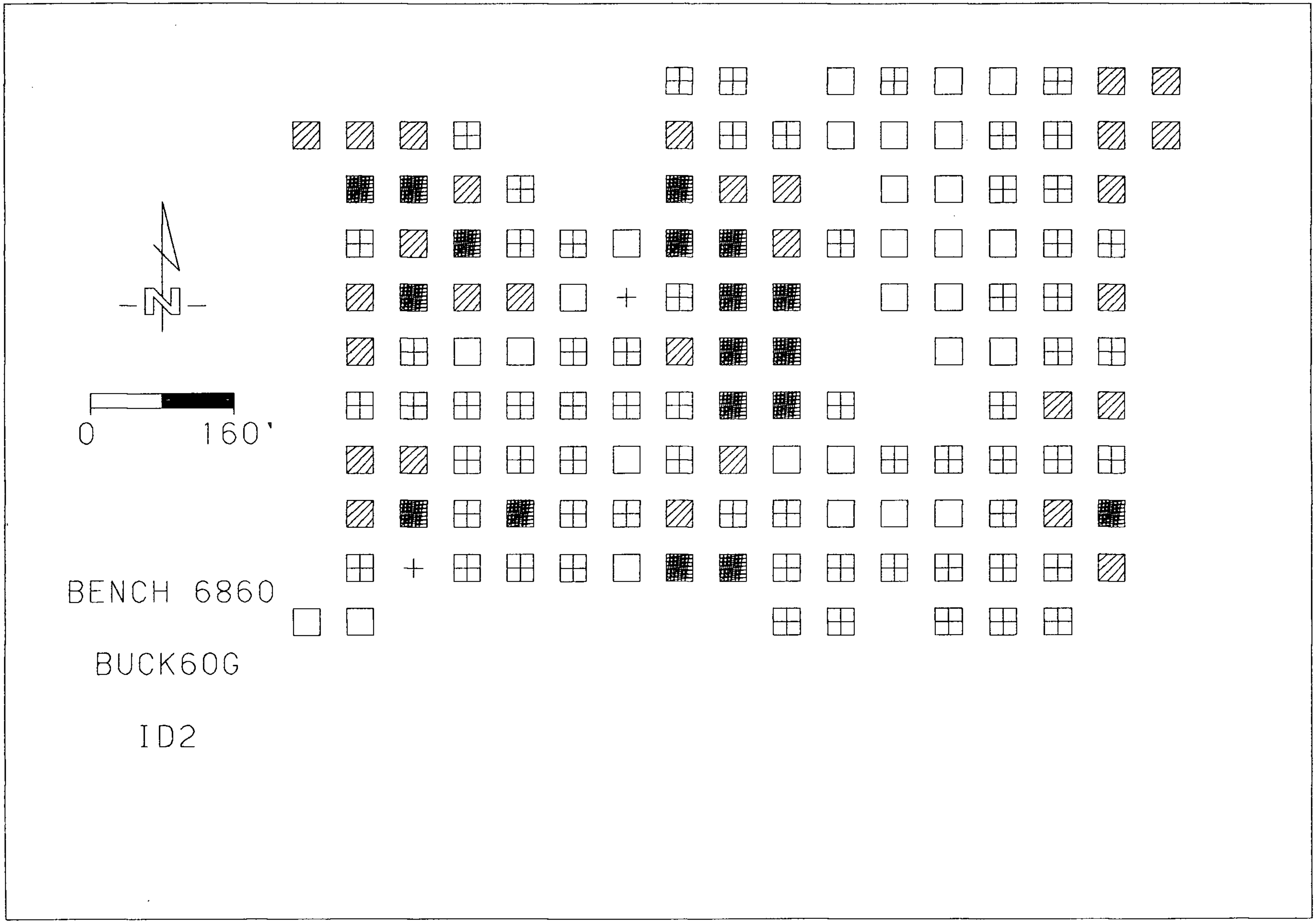
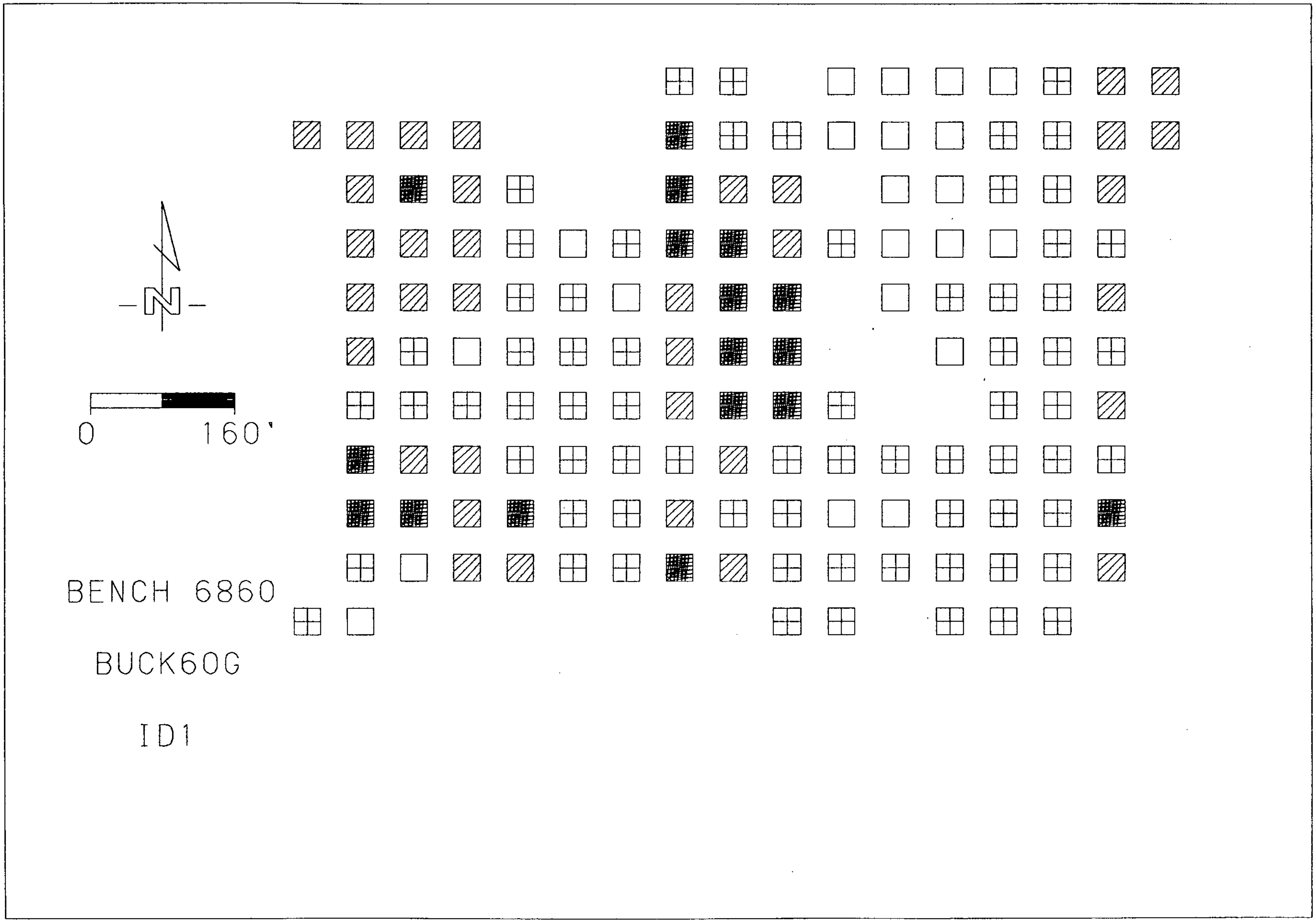
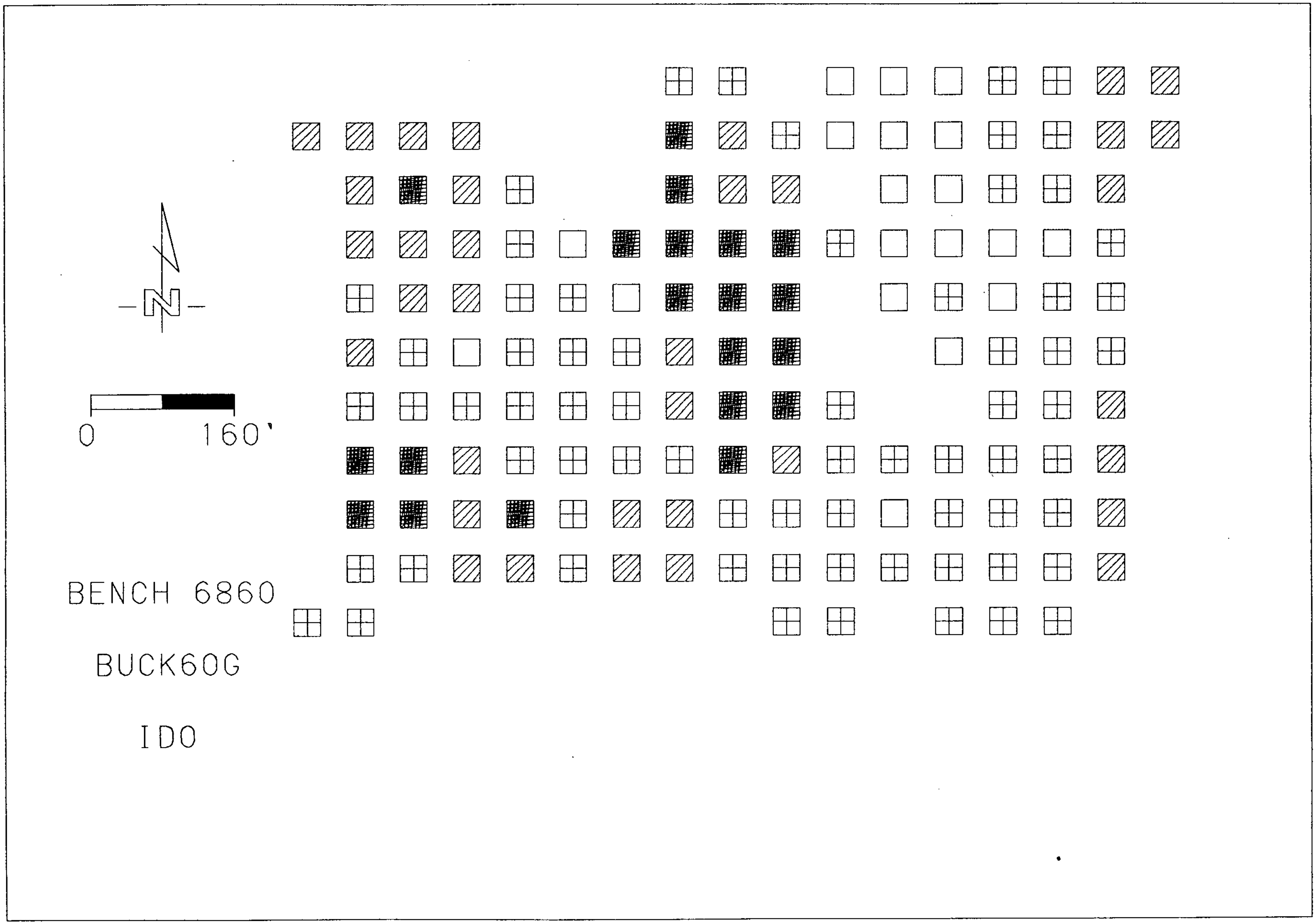
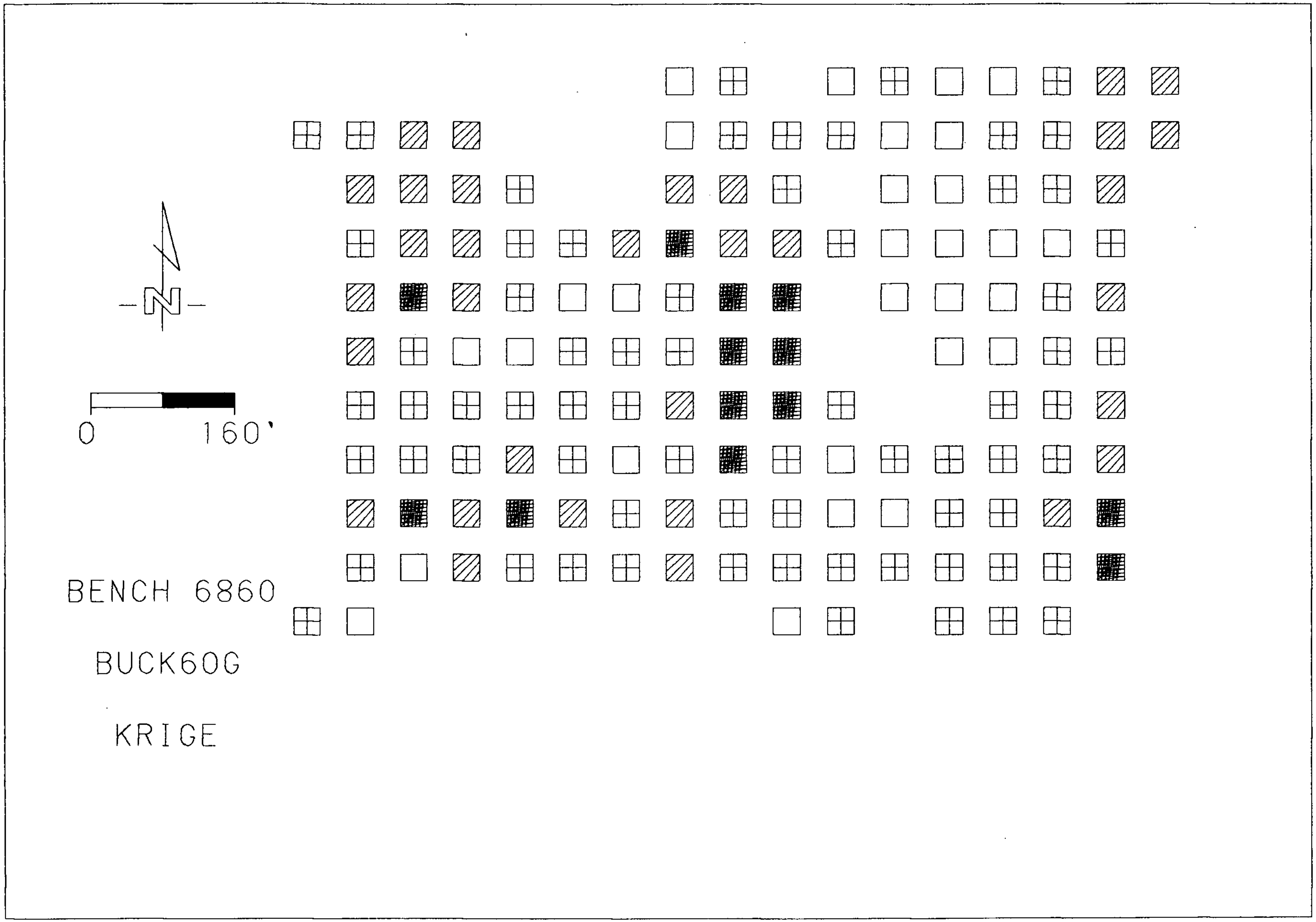
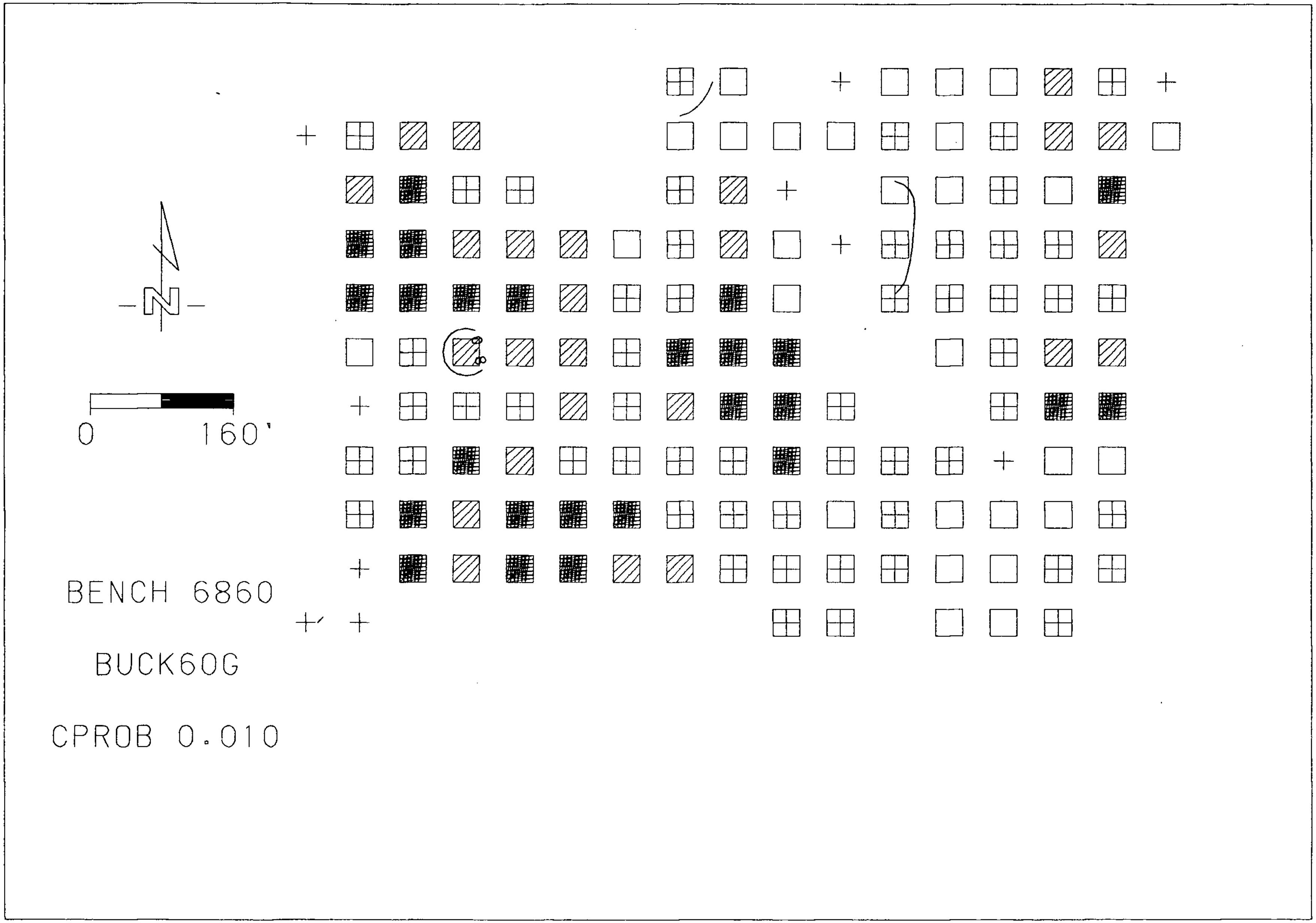
160'
BENCH 6860
BUCK60G
ID3

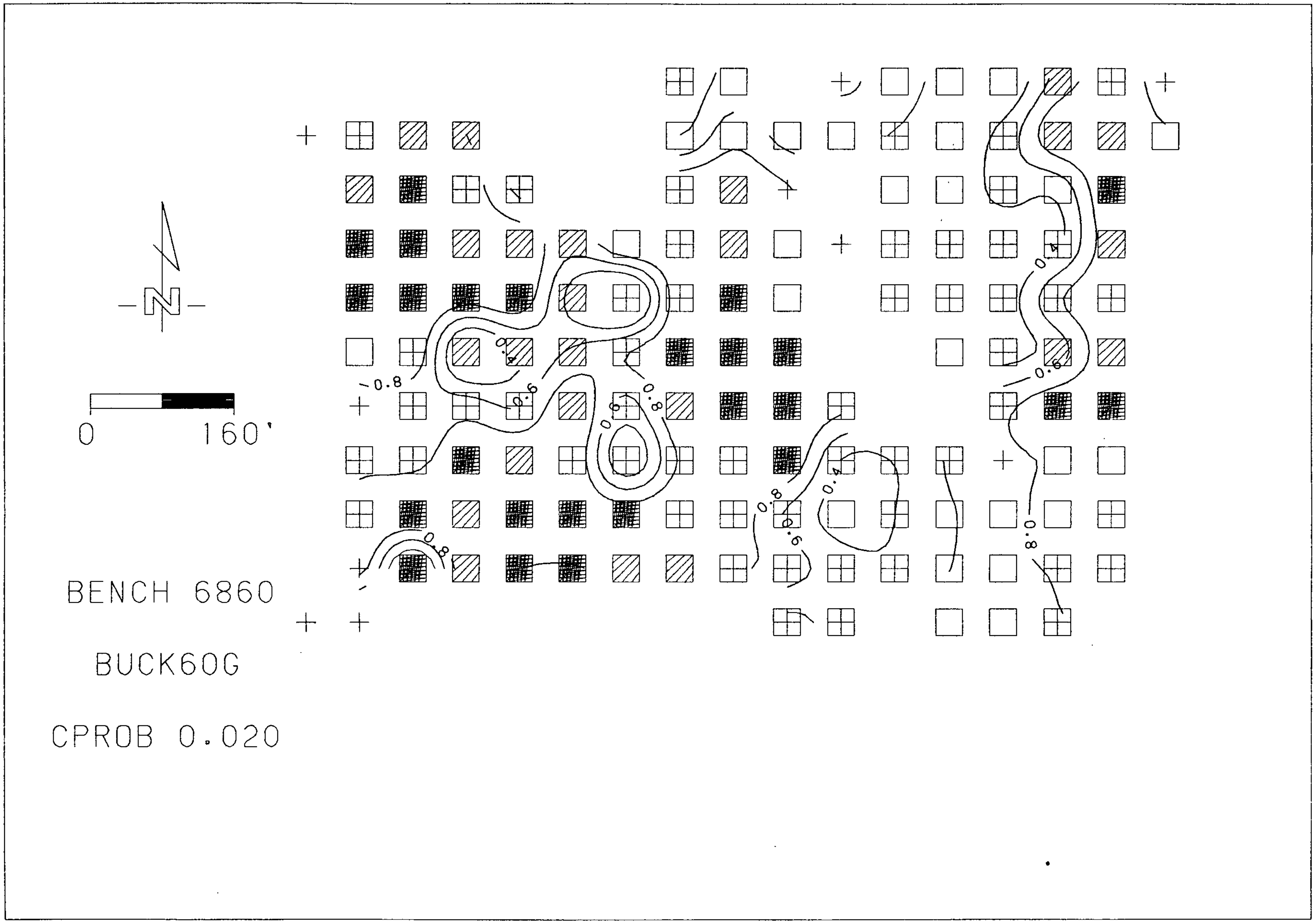

0
160'
BENCH 6860
BUCK60G
ID2


0
160'
BENCH 6860
BUCK60G
ID1


0
160'
BENCH 6860
BUCK60G
IDO


N
0
160'
BENCH 6860
BUCK60G
KRIGE


0
160'
BENCH 6860
BUCK60G
CPROB 0.010


N
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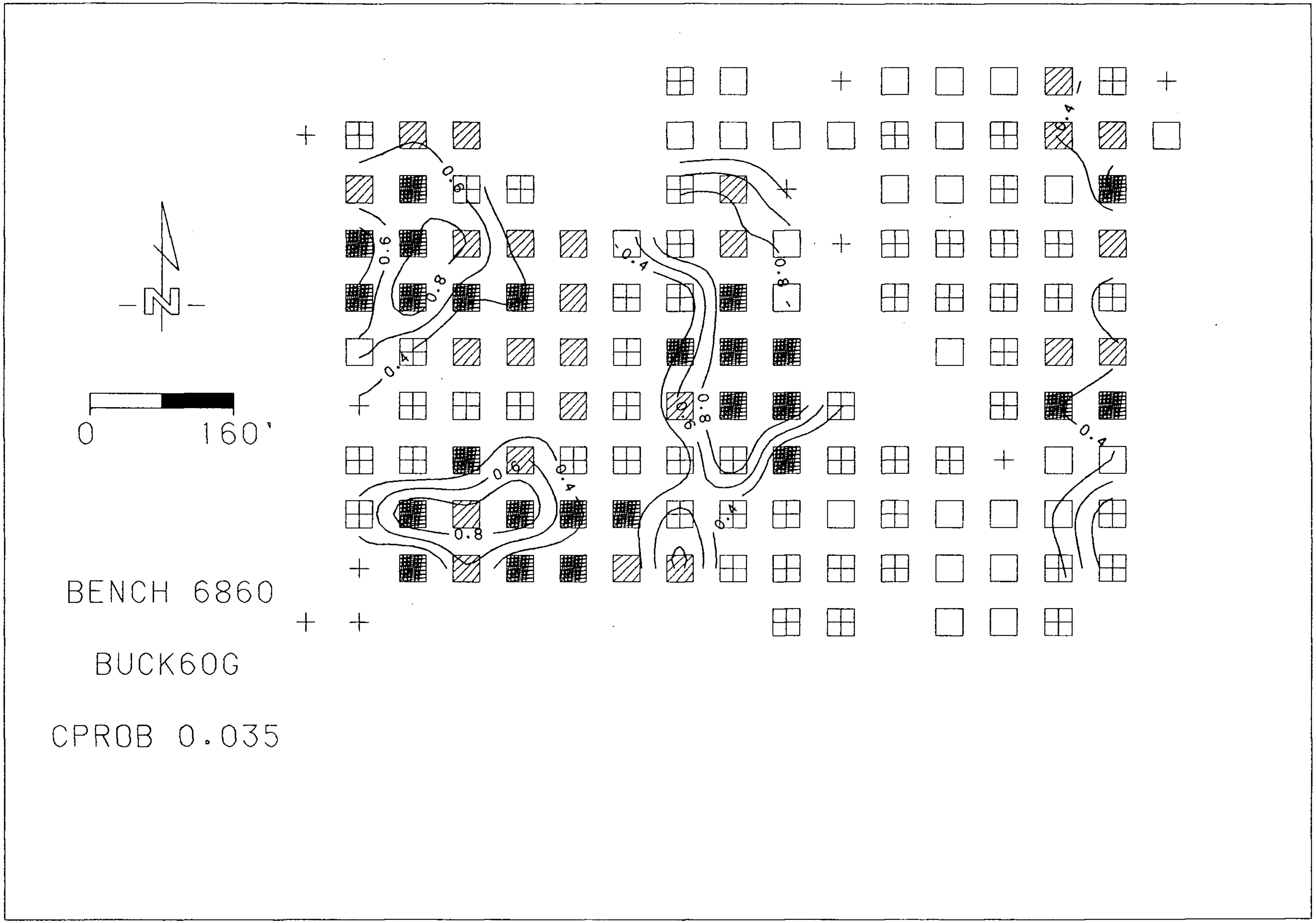
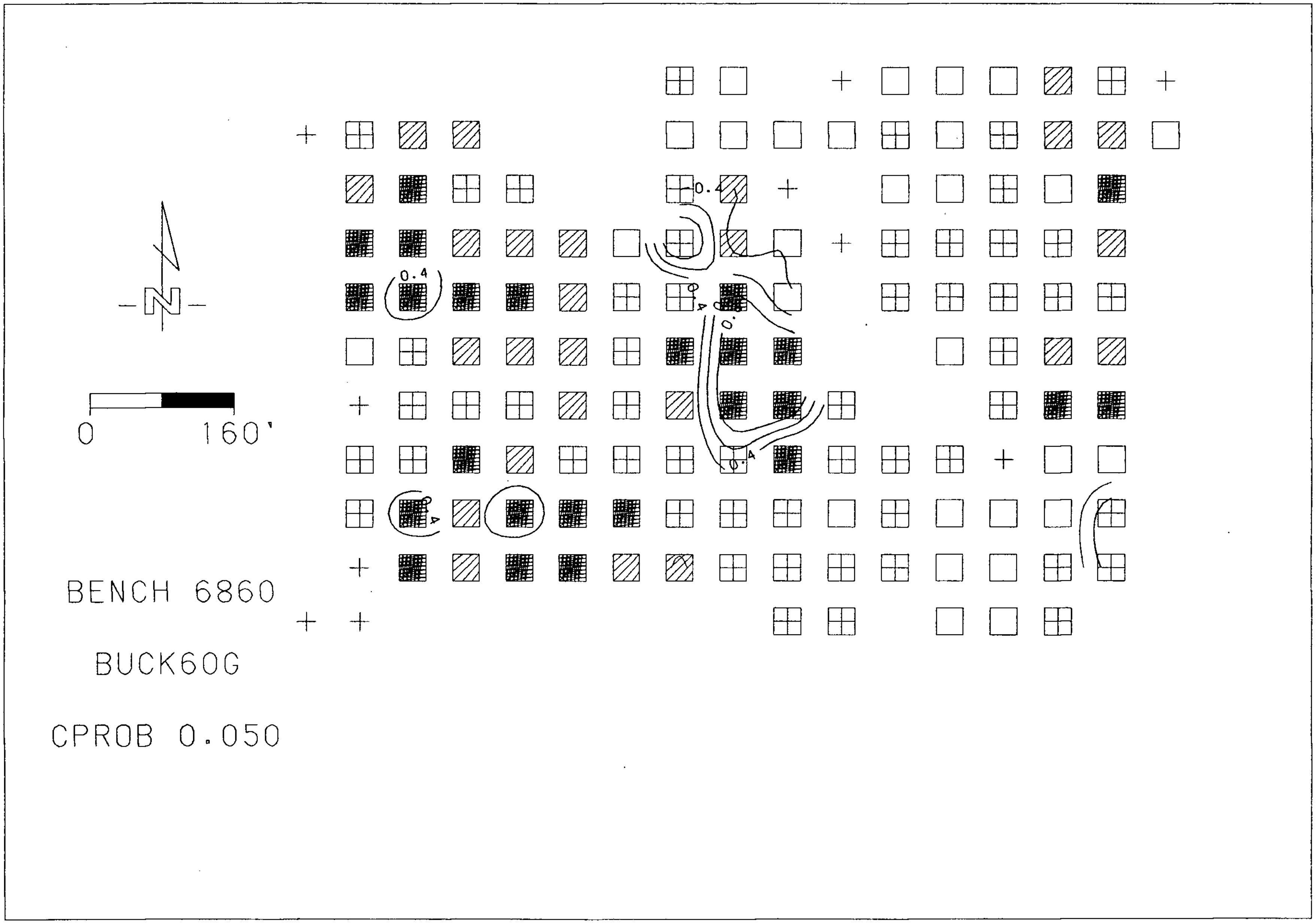
160'
BENCH 6860
BUCK60G
CPROB 0.020


N
0
160'
BENCH 6860
BUCK60G
CPROB 0.035
0.4
0.6
0.8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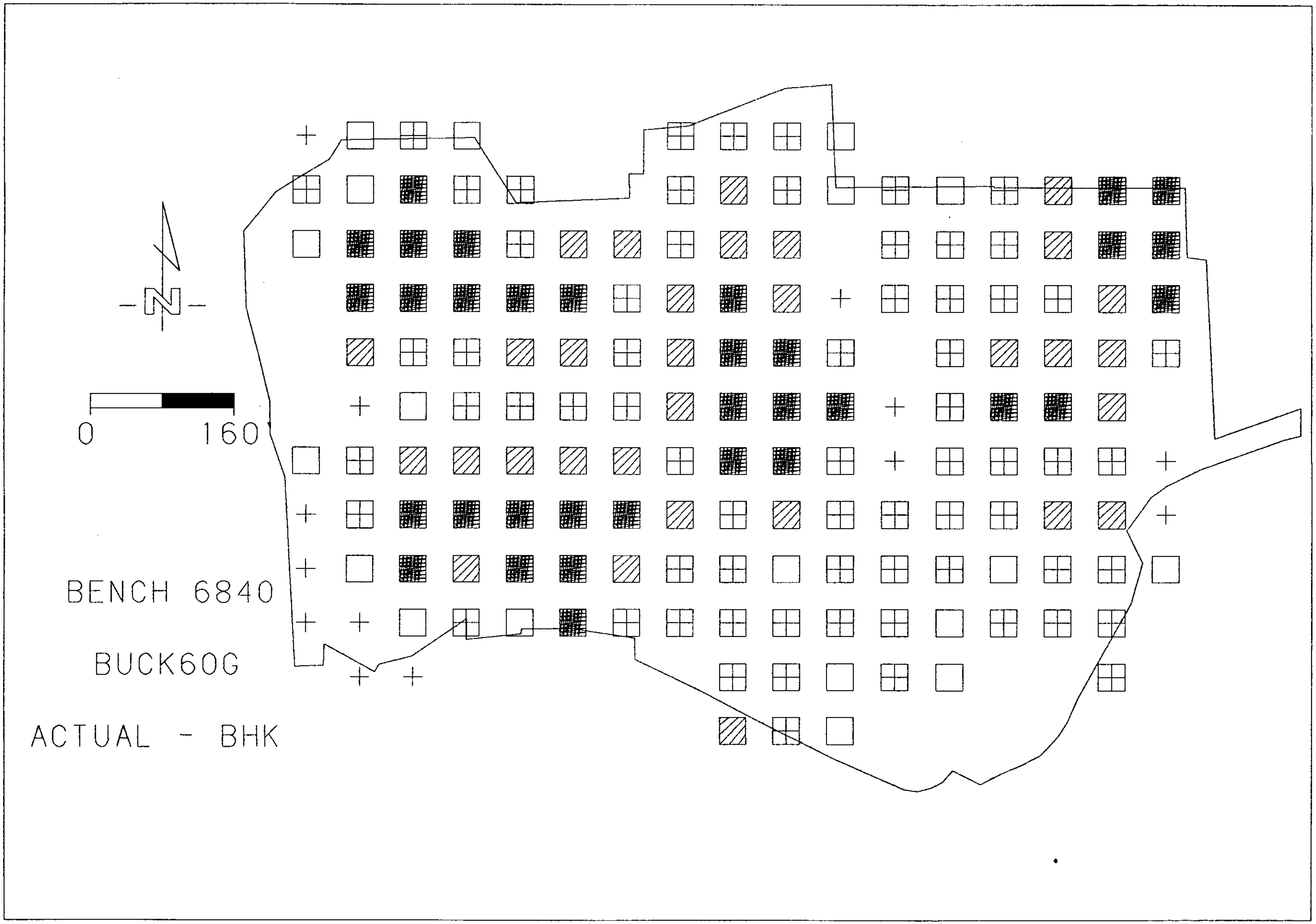
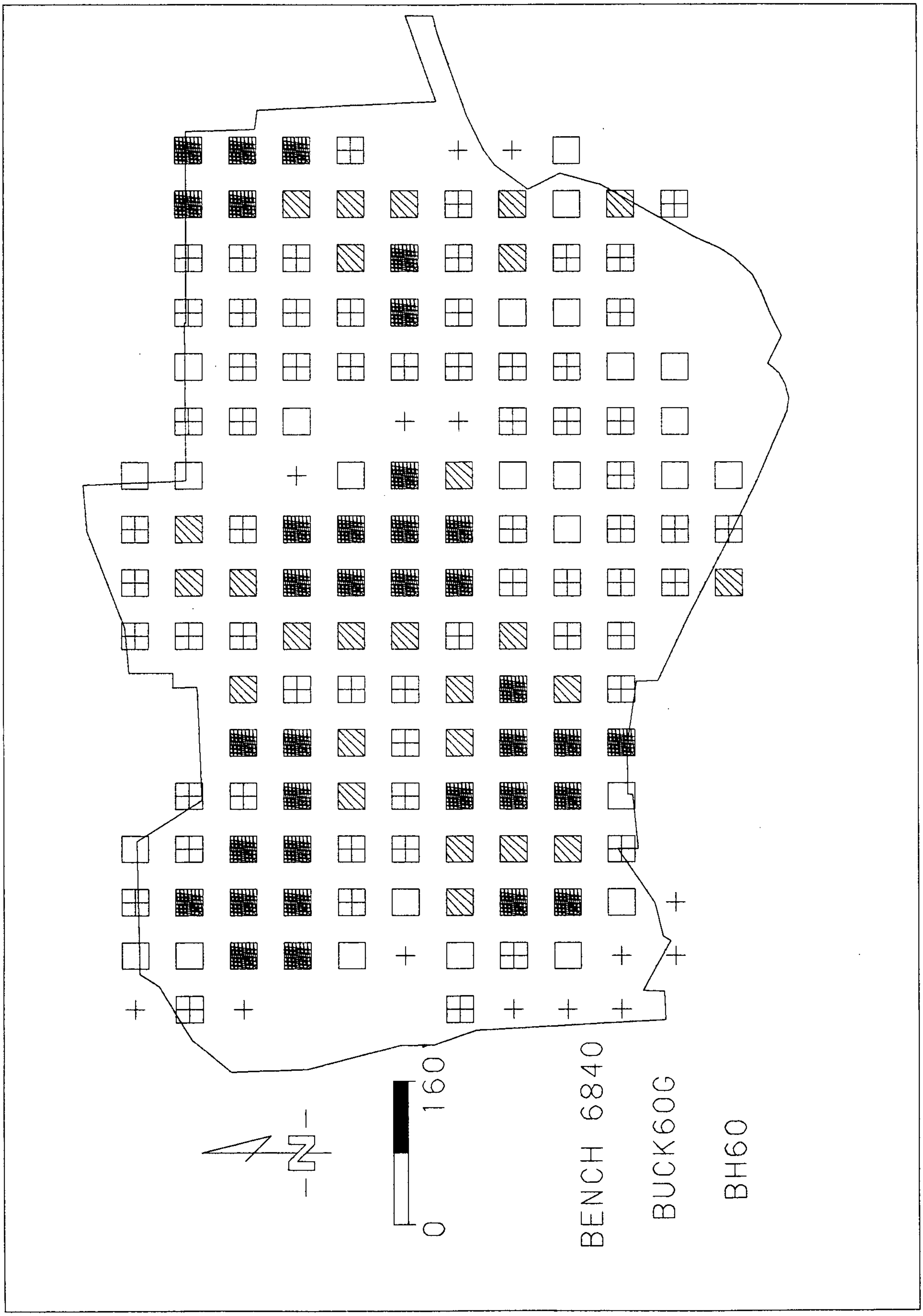
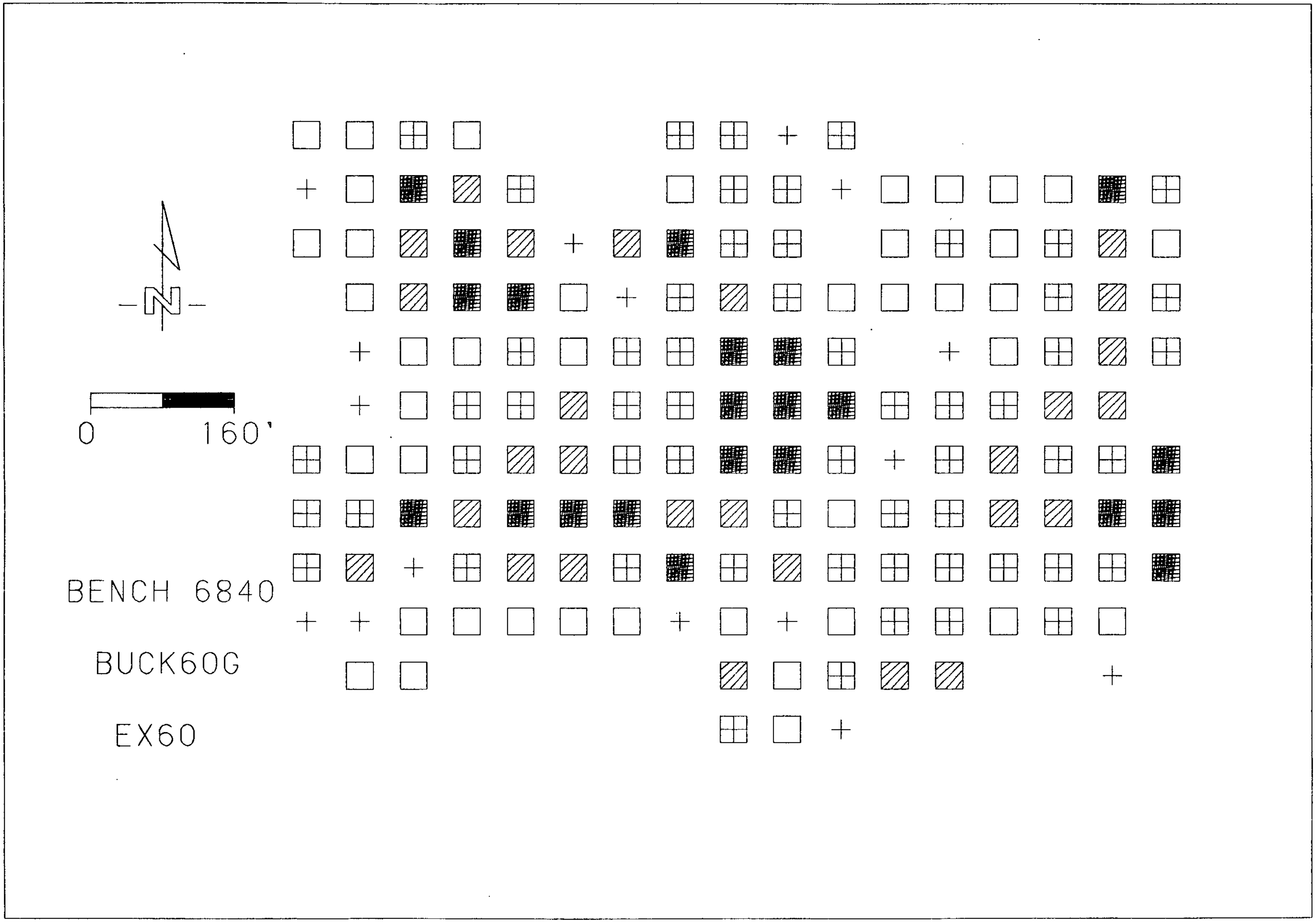
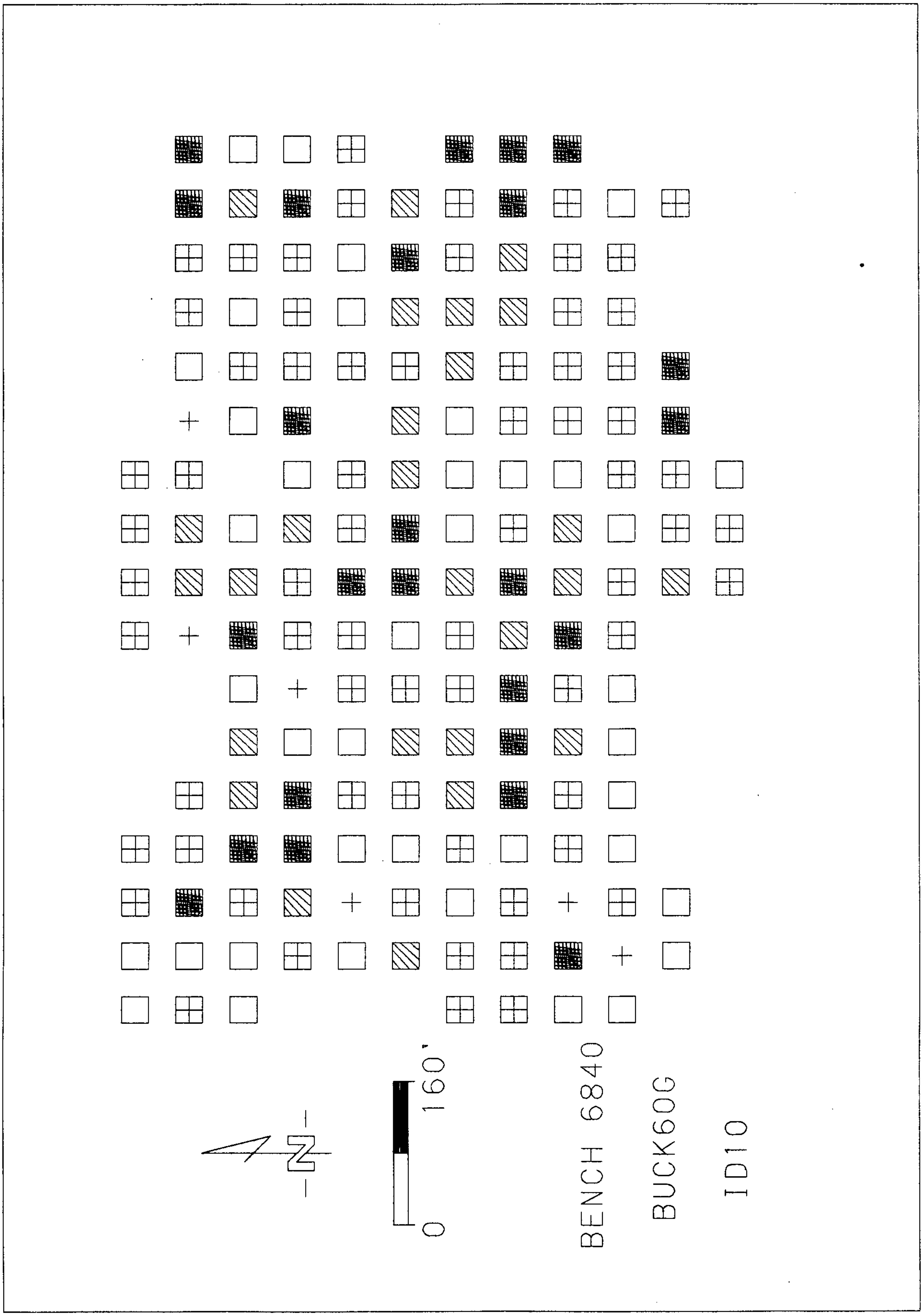
160'
BENCH 6860
BUCK60G
CPROB 0.050
0.4


N
0
160
BENCH 6840
BUCK60G
ACTUAL - BHK


N
0
160
BENCH 6840
BUCK60G
BH60


N
0
160'
BENCH 6840
BUCK60G
EX60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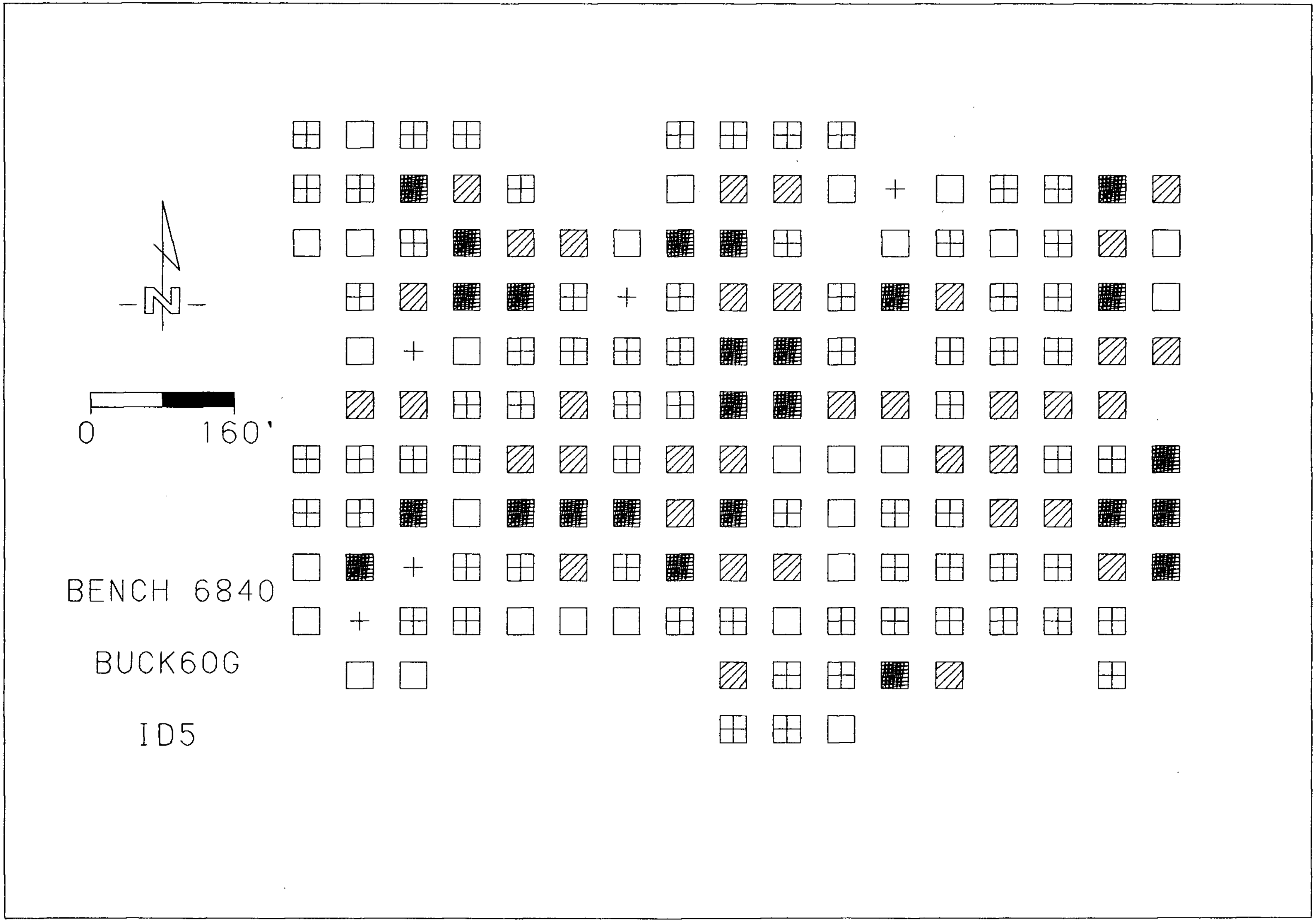
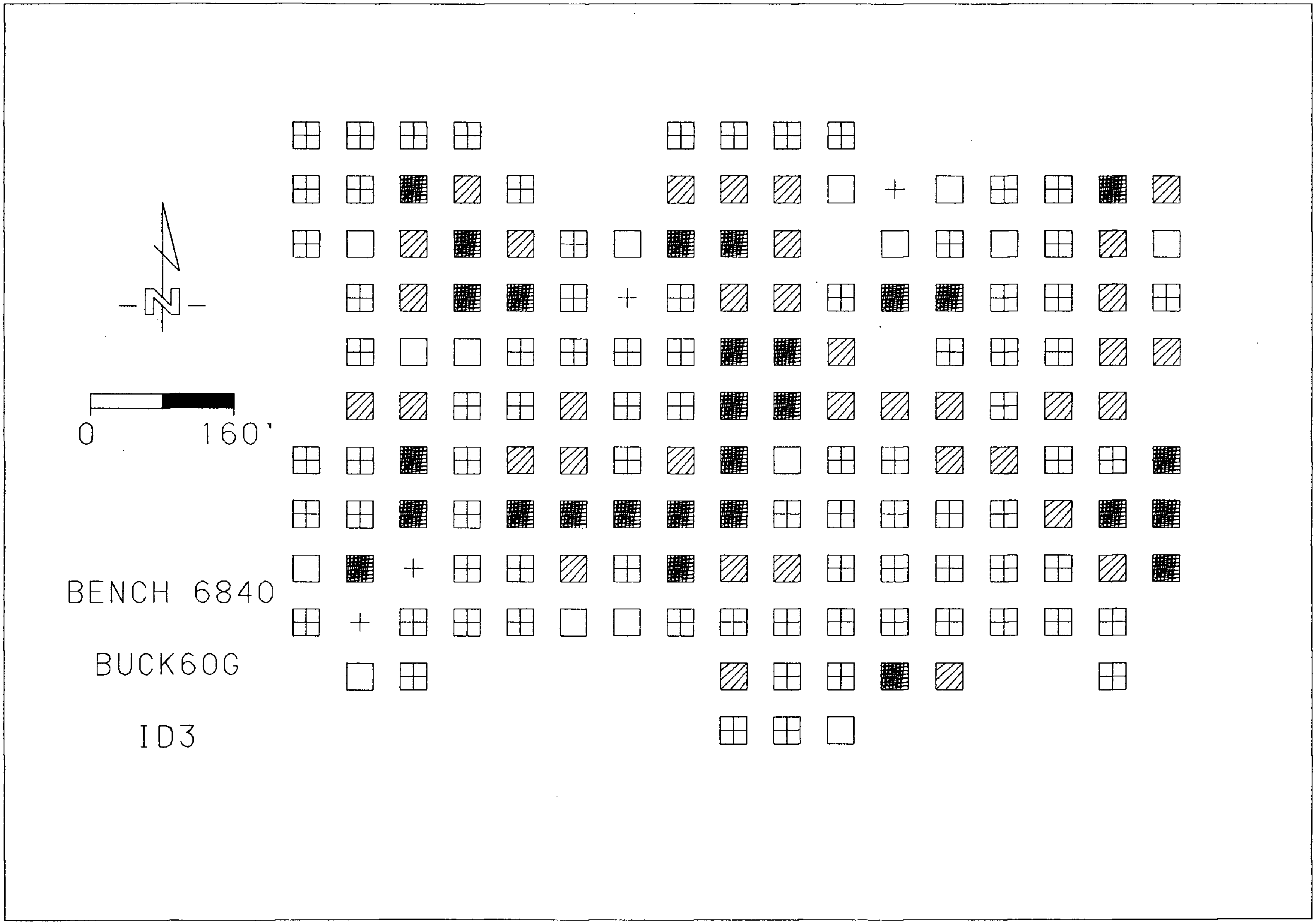
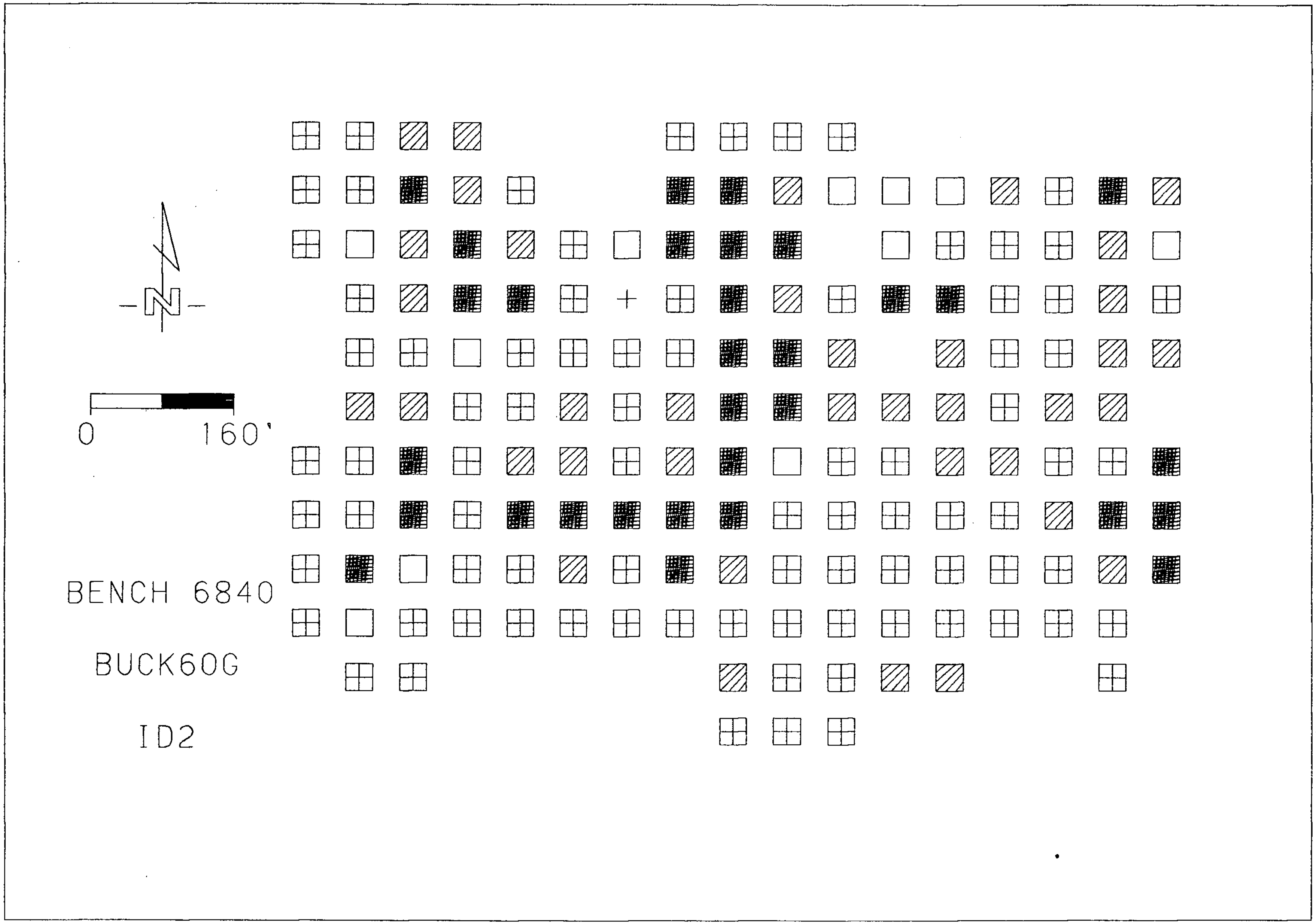
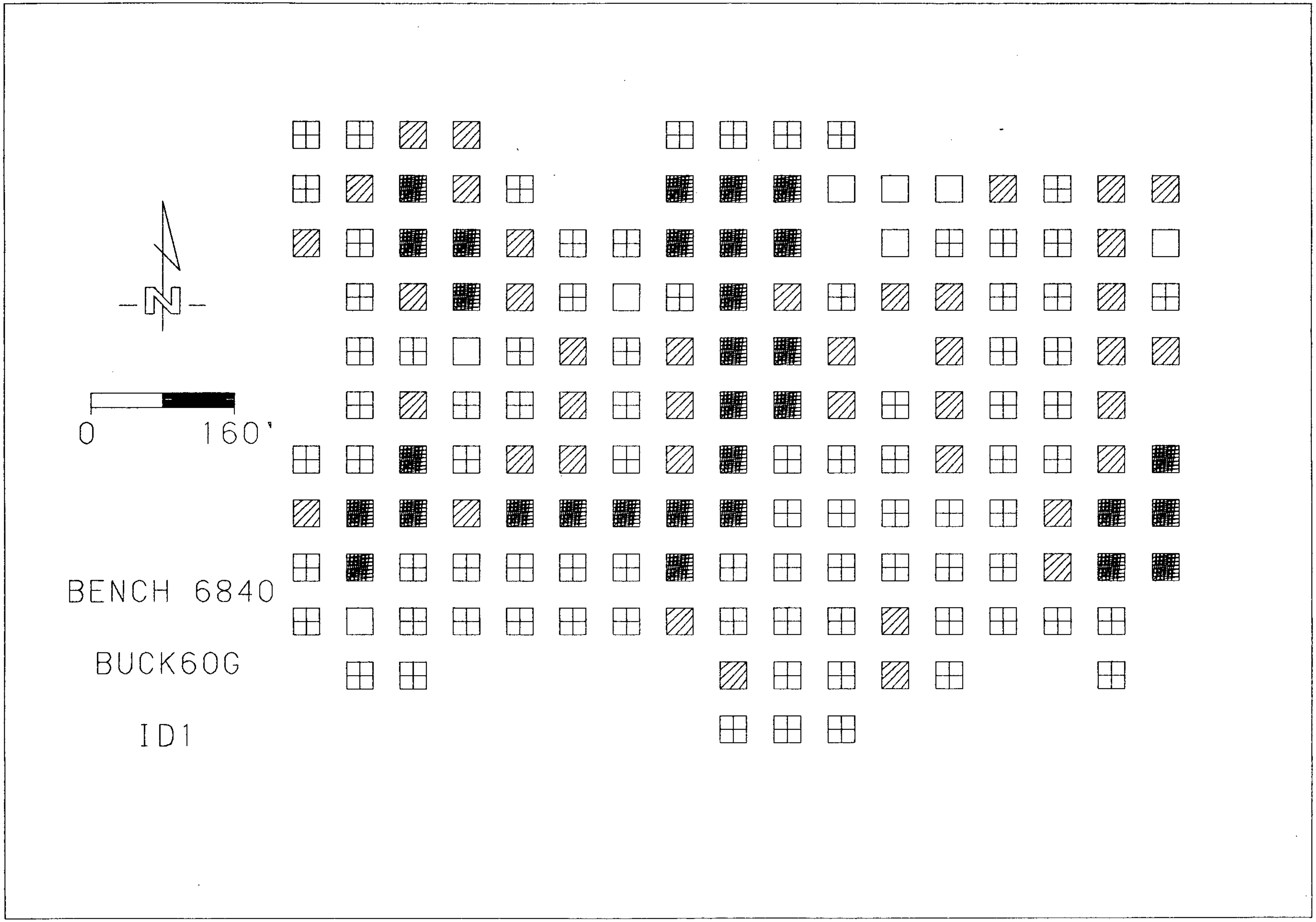
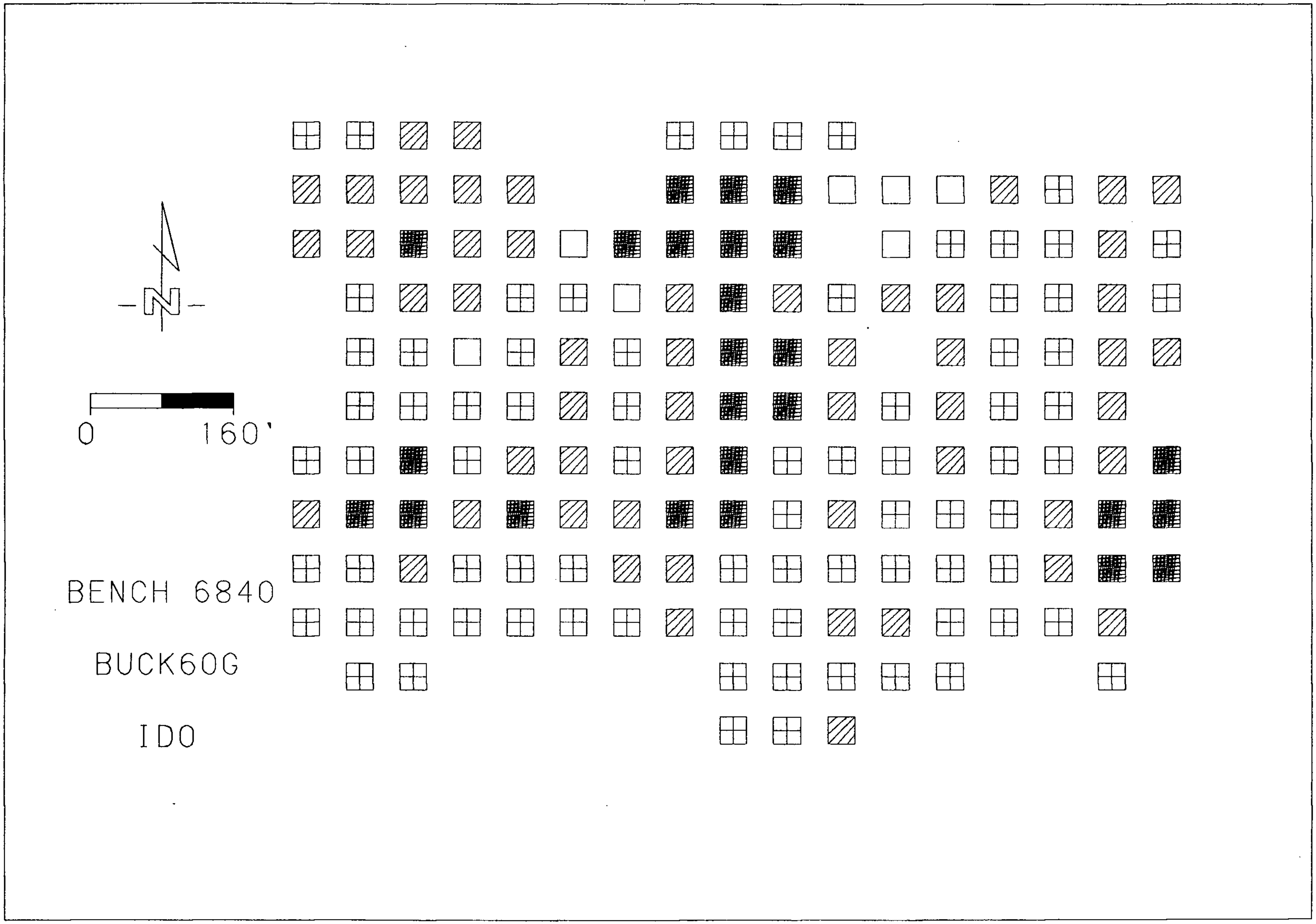
160'
BENCH 6840
BUCK60G
ID10

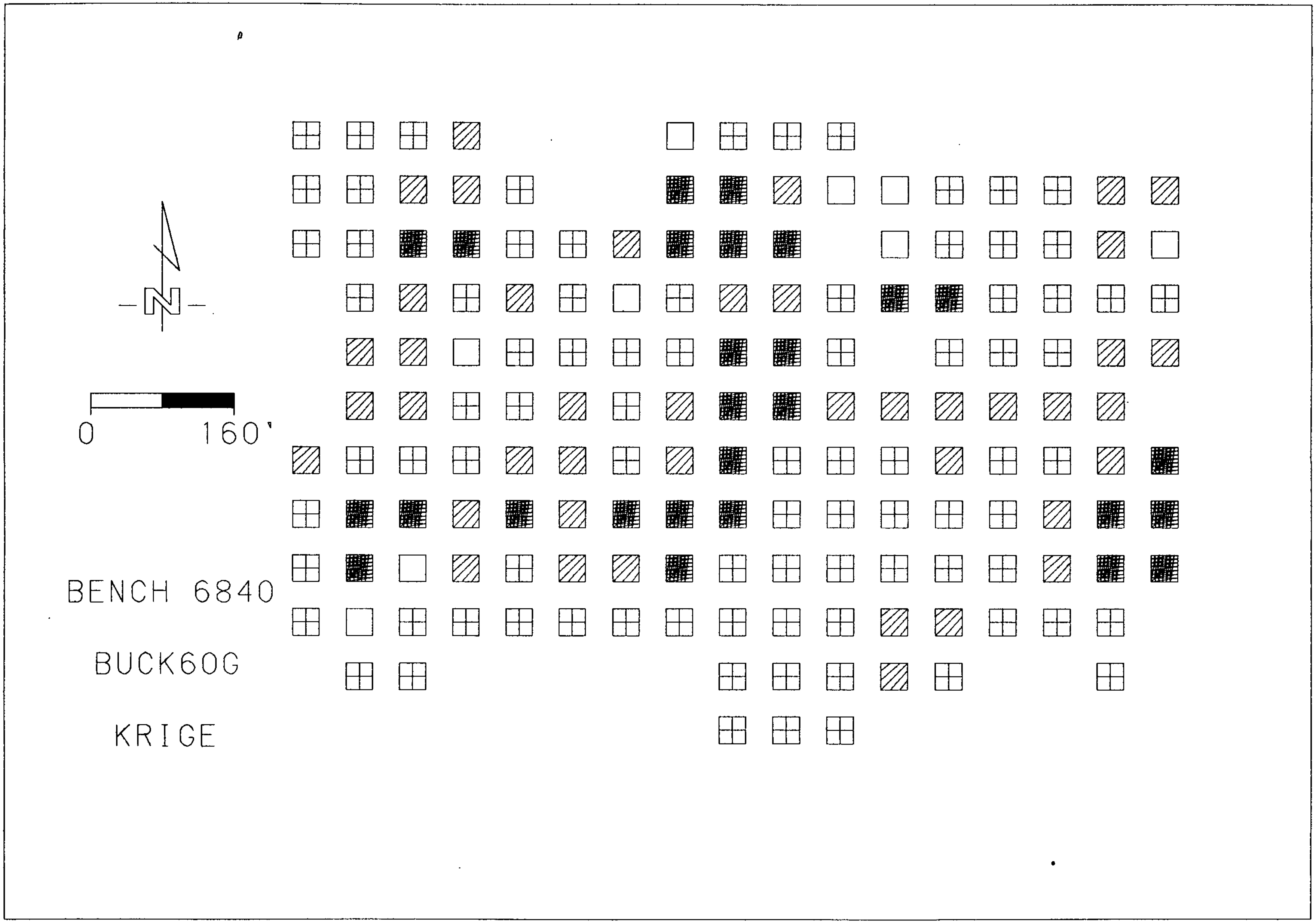

0
160'
BENCH 6840
BUCK60G
ID5

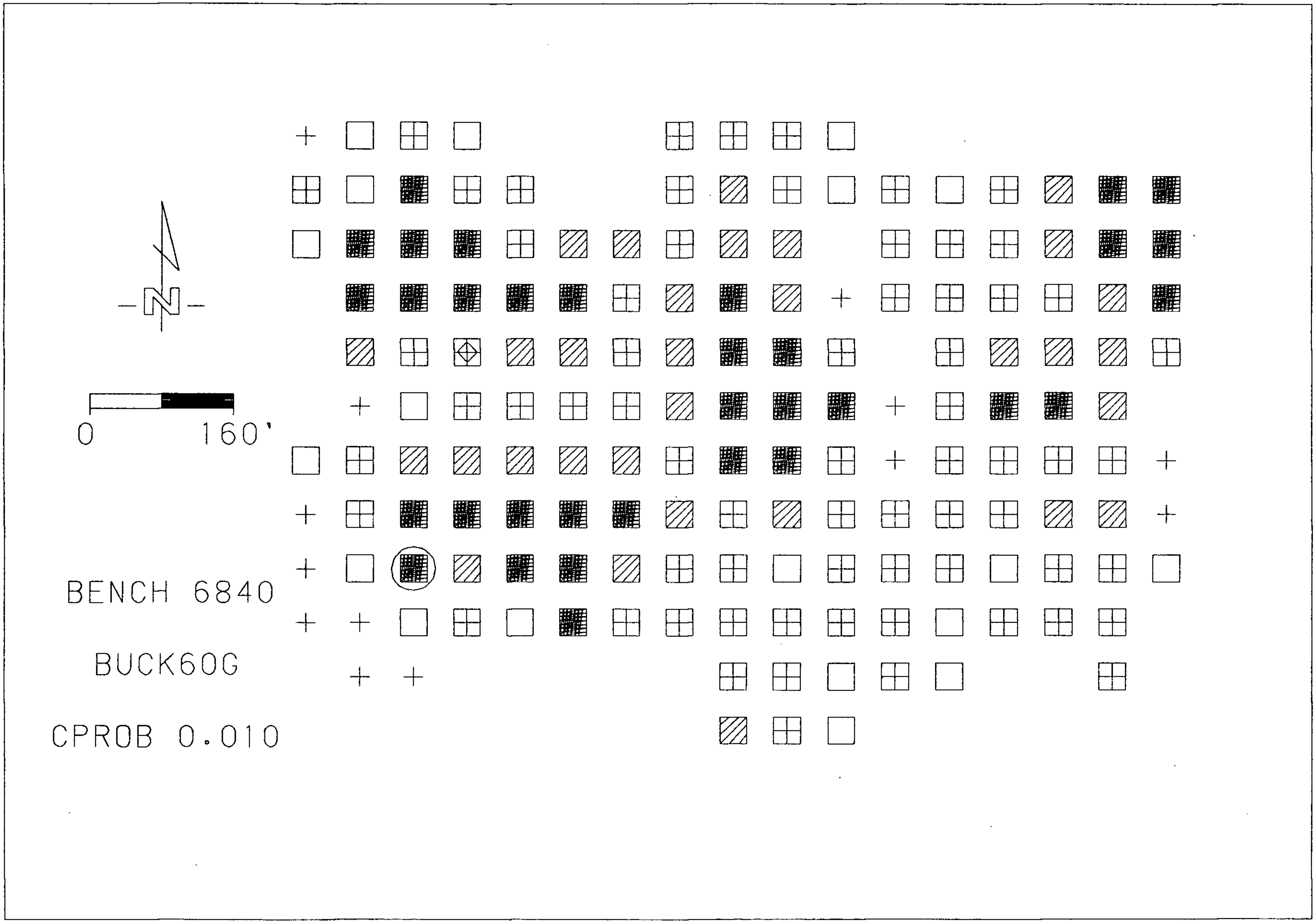

N
0
160'
BENCH 6840
BUCK60G
ID3

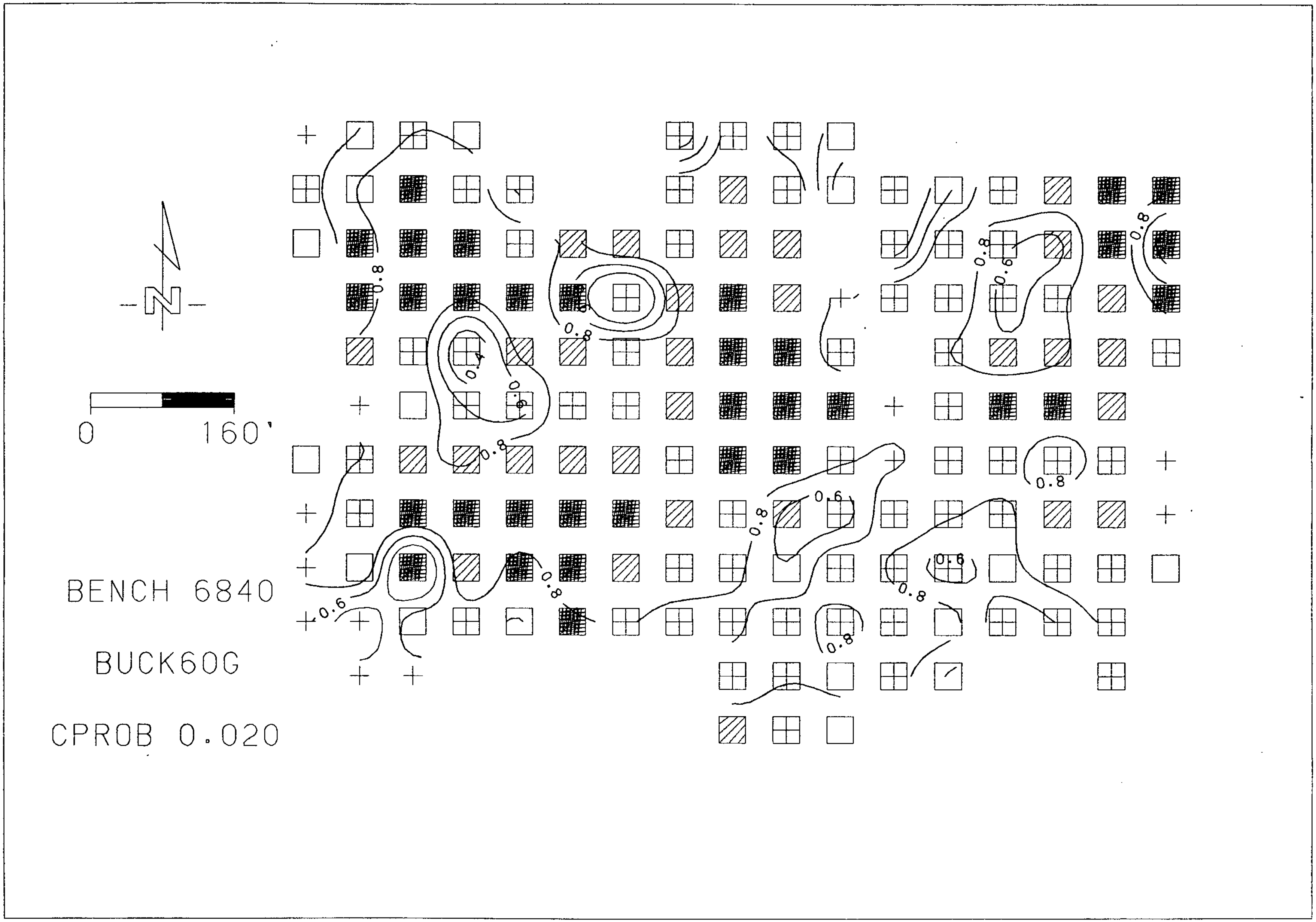

N
0
160'
BENCH 6840
BUCK60G
ID2

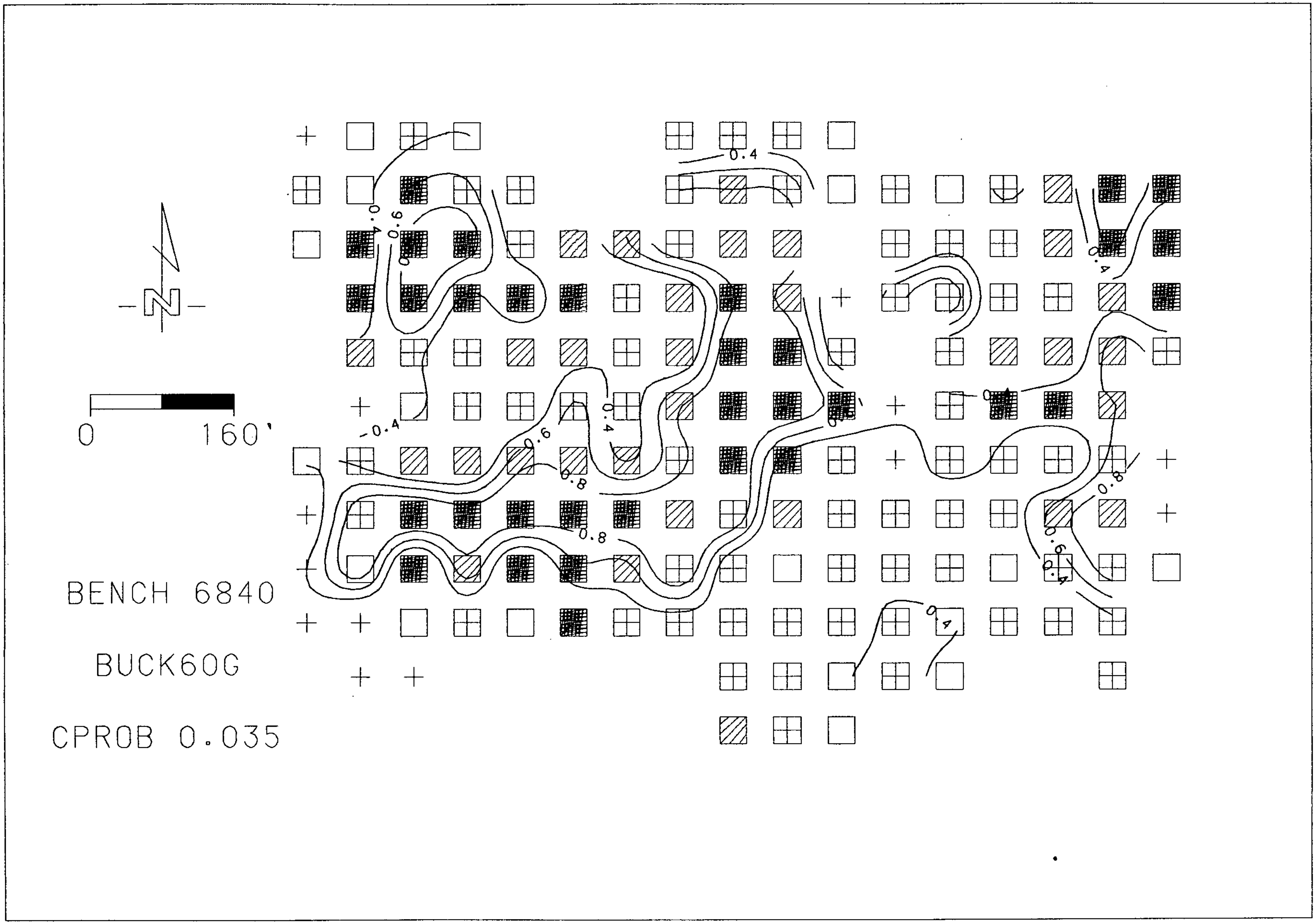

0
160'
BENCH 6840
BUCK60G
ID1

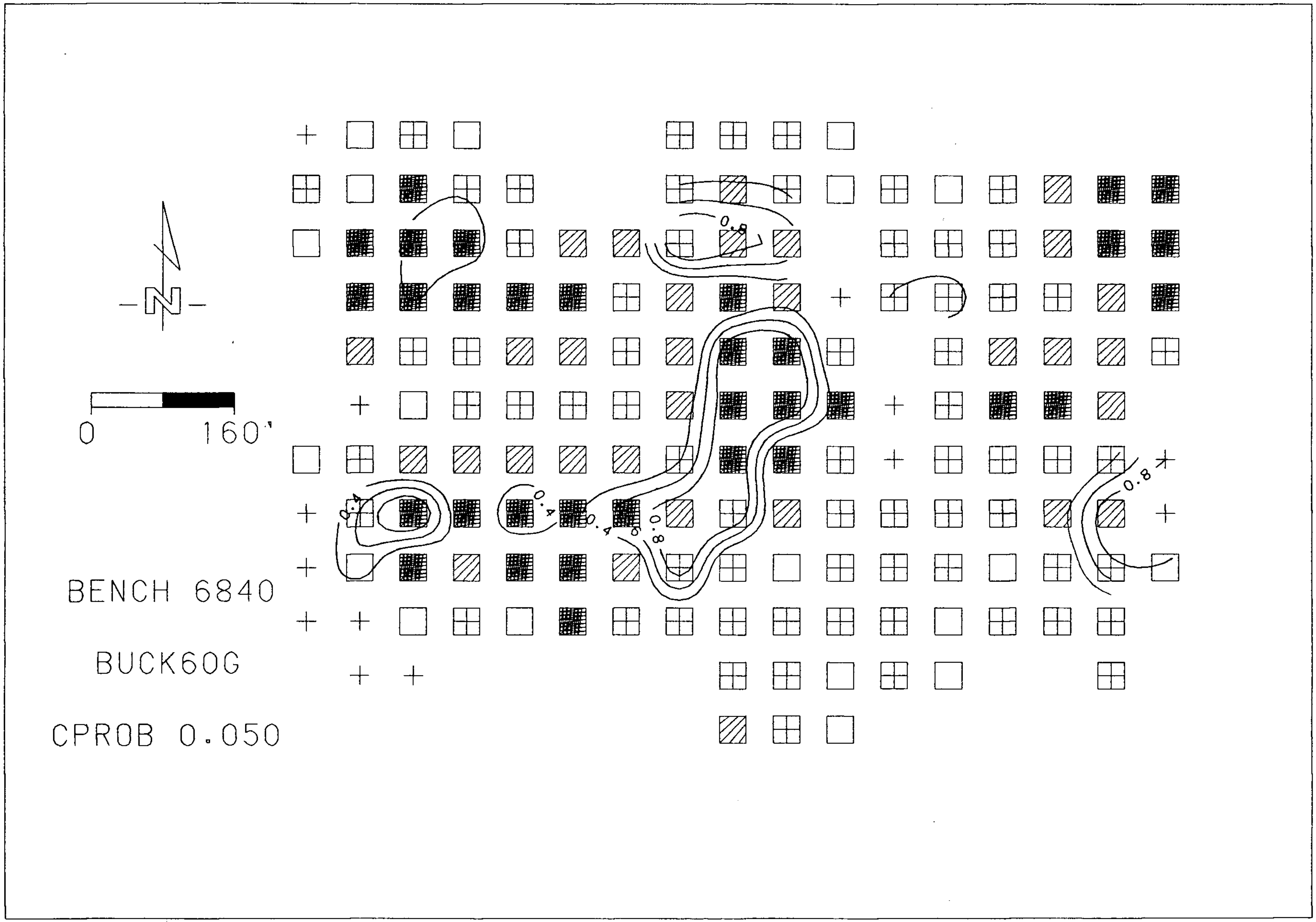

0
160'
BENCH 6840
BUCK60G
IDO


0
160'
BENCH 6840
BUCK60G
KRIGE


N
0
160'
BENCH 6840
BUCK60G
CPROB 0.010


0.8
0.6
0.4
0 160'
BENCH 6840
BUCK60G
CPROB 0.020


N
0
160'
BENCH 6840
BUCK60G
CPROB 0.035
0.4
0.6
0.8


N
0
160'
BENCH 6840
BUCK60G
CPROB 0.050
0.8
0.4
0.8

APPENDIX C

ORE RESERVE REPORTS

BLOCK MODEL: BUCK 20' BLOCKS - NO ORE OUTLINE
METHOD: BH4 BLASTHOLE POLYGONS

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	610972.06	0.032	19300.41	163657.00	0.004	688.05
6840.	0.010	447315.06	0.042	18612.36	131245.50	0.015	1934.85
6840.	0.020	316069.56	0.053	16677.51	144481.06	0.027	3848.28
6840.	0.035	171588.50	0.075	12829.23	70828.81	0.042	2952.16
6840.	0.050	100759.69	0.098	9877.07	100759.69	0.098	9877.07
6860.	0.000	544076.37	0.026	14184.09	187010.94	0.004	679.27
6860.	0.010	357065.44	0.038	13504.82	119690.94	0.015	1789.39
6860.	0.020	237374.50	0.049	11715.43	109507.25	0.027	2905.93
6860.	0.035	127867.25	0.069	8809.50	56842.62	0.041	2351.80
6860.	0.050	71024.62	0.091	6457.70	71024.62	0.091	6457.70
TOTAL	0.000	1155048.00	0.029	33484.47	350667.50	0.004	1367.30
TOTAL	0.010	804380.50	0.040	32117.18	250936.44	0.015	3724.24
TOTAL	0.020	553444.06	0.051	28392.94	253988.25	0.027	6754.20
TOTAL	0.035	299455.81	0.072	21638.73	127671.44	0.042	5303.95
TOTAL	0.050	171784.37	0.095	16334.79	171784.37	0.095	16334.79

BLOCK MODEL: BUCK 20' BLOCKS - NO ORE OUTLINE
METHOD: BH20 BLASTHOLE POLYGON WEIGHTED

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	610972.06	0.032	19297.97	139927.75	0.005	671.59
6840.	0.010	471044.31	0.040	18626.38	130005.12	0.015	1934.19
6840.	0.020	341039.19	0.049	16692.19	159642.31	0.026	4230.44
6840.	0.035	181396.87	0.069	12461.75	77585.31	0.042	3291.48
6840.	0.050	103811.56	0.088	9170.27	103811.56	0.088	9170.27
6860.	0.000	544076.37	0.026	14182.02	171082.62	0.004	713.67
6860.	0.010	372993.75	0.036	13468.36	117765.19	0.015	1792.14
6860.	0.020	255228.56	0.046	11676.21	125598.75	0.027	3371.29
6860.	0.035	129629.81	0.064	8304.92	58311.44	0.042	2425.91
6860.	0.050	71318.37	0.082	5879.01	71318.37	0.082	5879.01
TOTAL	0.000	1155048.00	0.029	33479.98	311009.87	0.004	1385.24
TOTAL	0.010	844038.12	0.038	32094.74	247770.37	0.015	3726.34
TOTAL	0.020	596267.75	0.048	28368.40	285241.06	0.027	7601.72
TOTAL	0.035	311026.69	0.067	20766.68	135896.75	0.042	5717.40
TOTAL	0.050	175129.94	0.086	15049.28	175129.94	0.086	15049.28

BLOCK MODEL: BUCK 20' BLOCKS - NO ORE OUTLINE
METHOD: BHKRIGE BLASTHOLE KRIGING - "ACTUAL"

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	610972.06	0.033	19939.61	107989.44	0.005	574.60
6840.	0.010	502982.62	0.039	19365.01	128928.06	0.015	1945.70
6840.	0.020	374054.56	0.047	17419.31	177480.12	0.027	4764.41
6840.	0.035	196574.44	0.064	12654.91	85108.81	0.042	3553.40
6840.	0.050	111465.62	0.082	9101.51	111465.62	0.082	9101.51
6860.	0.000	544076.37	0.027	14567.63	144464.69	0.005	669.94
6860.	0.010	399611.69	0.035	13897.69	122171.62	0.015	1880.05
6860.	0.020	277440.06	0.043	12017.64	144007.69	0.027	3920.42
6860.	0.035	133432.37	0.061	8097.21	65165.81	0.042	2752.90
6860.	0.050	68266.56	0.078	5344.31	68266.56	0.078	5344.31
TOTAL	0.000	1155048.00	0.030	34507.23	252453.69	0.005	1244.52
TOTAL	0.010	902594.31	0.037	33262.70	251099.62	0.015	3825.75
TOTAL	0.020	651494.69	0.045	29436.96	321487.87	0.027	8684.84
TOTAL	0.035	330006.81	0.063	20752.12	150274.62	0.042	6306.29
TOTAL	0.050	179732.19	0.080	14445.82	179732.19	0.080	14445.82

BLOCK MODEL: BUCK 20' BLOCKS - NO ORE OUTLINE
METHOD: EX4 EXPLORATION POLYGONS

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	610972.06	0.027	16613.69	213351.44	0.005	1019.52
6840.	0.010	397620.62	0.039	15594.17	118858.62	0.014	1699.32
6840.	0.020	278762.00	0.050	13894.85	135864.06	0.026	3544.12
6840.	0.035	142897.94	0.072	10350.73	63958.06	0.043	2730.02
6840.	0.050	78939.87	0.097	7620.71	78939.87	0.097	7620.71
6860.	0.000	544076.37	0.025	13460.14	236901.25	0.004	1003.89
6860.	0.010	307175.12	0.041	12456.24	96777.62	0.014	1388.49
6860.	0.020	210397.50	0.053	11067.75	96271.75	0.027	2587.77
6860.	0.035	114125.75	0.074	8479.98	46609.94	0.040	1865.02
6860.	0.050	67515.81	0.098	6614.96	67515.81	0.098	6614.96
TOTAL	0.000	1155048.00	0.026	30073.80	450252.19	0.004	2023.39
TOTAL	0.010	704795.81	0.040	28050.41	215636.25	0.014	3087.81
TOTAL	0.020	489159.56	0.051	24962.60	232135.81	0.026	6131.89
TOTAL	0.035	257023.75	0.073	18830.71	110568.06	0.042	4595.04
TOTAL	0.050	146455.69	0.097	14235.67	146455.69	0.097	14235.67

BLOCK MODEL: BUCK 20' BLOCKS - NO ORE OUTLINE
METHOD: EX20 EXPLORATION POLYGON WEIGHTED

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	610972.06	0.027	16611.42	188071.75	0.005	941.75
6840.	0.010	422900.31	0.037	15669.67	135162.31	0.014	1957.12
6840.	0.020	287738.00	0.048	13712.55	143061.19	0.027	3819.24
6840.	0.035	144676.81	0.068	9893.31	73064.62	0.042	3071.90
6840.	0.050	71612.19	0.095	6821.41	71612.19	0.095	6821.41
6860.	0.000	544076.37	0.025	13458.30	219210.31	0.005	992.43
6860.	0.010	324866.06	0.038	12465.87	103942.12	0.015	1510.69
6860.	0.020	220923.94	0.050	10955.18	111335.12	0.027	2965.61
6860.	0.035	109588.81	0.073	7989.58	46740.46	0.041	1924.91
6860.	0.050	62848.35	0.096	6064.67	62848.35	0.096	6064.67
TOTAL	0.000	1155048.00	0.026	30069.71	407281.62	0.005	1934.16
TOTAL	0.010	747766.37	0.038	28135.55	239104.44	0.015	3467.81
TOTAL	0.020	508661.94	0.048	24667.74	254396.25	0.027	6784.85
TOTAL	0.035	254265.69	0.070	17882.89	119805.19	0.042	4996.81
TOTAL	0.050	134460.50	0.096	12886.08	134460.50	0.096	12886.08

BLOCK MODEL: BUCK 20' BLOCKS - NO ORE OUTLINE
METHOD: ID10 INVERSE DISTANCE

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	610972.06	0.028	17132.94	170119.75	0.006	971.94
6840.	0.010	440852.31	0.037	16161.00	131963.56	0.014	1911.33
6840.	0.020	308888.75	0.046	14249.68	159626.00	0.026	4181.55
6840.	0.035	149262.75	0.067	10068.12	74256.00	0.042	3098.67
6840.	0.050	75006.75	0.093	6969.46	75006.75	0.093	6969.46
6860.	0.000	544076.37	0.025	13675.96	205158.81	0.005	1059.93
6860.	0.010	338917.56	0.037	12616.04	117340.87	0.014	1677.80
6860.	0.020	221576.69	0.049	10938.24	110927.06	0.027	3011.86
6860.	0.035	110649.62	0.072	7926.38	52501.44	0.042	2185.65
6860.	0.050	58148.18	0.099	5740.73	58148.18	0.099	5740.73
TOTAL	0.000	1155048.00	0.027	30808.89	375278.06	0.005	2031.85
TOTAL	0.010	779769.94	0.037	28777.05	249304.44	0.014	3589.13
TOTAL	0.020	530465.50	0.047	25187.91	270553.12	0.027	7193.42
TOTAL	0.035	259912.37	0.069	17994.50	126757.44	0.042	5284.30
TOTAL	0.050	133154.94	0.095	12710.19	133154.94	0.095	12710.19

BLOCK MODEL: BUCK 20' BLOCKS - NO ORE OUTLINE
METHOD: ID5 INVERSE DISTANCE

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	610972.06	0.029	17503.23	138883.25	0.006	824.06
6840.	0.010	472088.81	0.035	16679.17	136451.56	0.015	1995.50
6840.	0.020	335637.25	0.044	14683.68	181054.19	0.026	4764.59
6840.	0.035	154583.06	0.064	9919.09	78760.31	0.041	3252.19
6840.	0.050	75822.75	0.088	6666.90	75822.75	0.088	6666.90
6860.	0.000	544076.37	0.025	13500.41	176925.19	0.006	979.37
6860.	0.010	367151.19	0.034	12521.04	139405.50	0.014	2006.84
6860.	0.020	227745.69	0.046	10514.20	121453.50	0.027	3302.89
6860.	0.035	106292.19	0.068	7211.31	50592.00	0.041	2079.86
6860.	0.050	55700.18	0.092	5131.45	55700.18	0.092	5131.45
TOTAL	0.000	1155048.00	0.027	31003.63	315808.00	0.006	1803.41
TOTAL	0.010	839240.00	0.035	29200.21	275857.06	0.015	4002.34
TOTAL	0.020	563382.94	0.045	25197.87	302507.62	0.027	8067.46
TOTAL	0.035	260875.31	0.066	17130.41	129352.37	0.041	5332.05
TOTAL	0.050	131522.94	0.090	11798.36	131522.94	0.090	11798.36

BLOCK MODEL: BUCK 20' BLOCKS - NO ORE OUTLINE
METHOD: ID3 INVERSE DISTANCE

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	610972.06	0.029	17892.36	110323.25	0.006	684.20
6840.	0.010	500648.81	0.034	17208.15	142604.19	0.015	2110.25
6840.	0.020	358044.62	0.042	15097.90	199887.44	0.027	5309.55
6840.	0.035	158157.19	0.062	9788.36	80702.44	0.041	3340.52
6840.	0.050	77454.75	0.083	6447.84	77454.75	0.083	6447.84
6860.	0.000	544076.37	0.025	13439.79	152412.56	0.006	891.95
6860.	0.010	391663.81	0.032	12547.84	151988.19	0.014	2191.75
6860.	0.020	239675.62	0.043	10356.09	135178.62	0.027	3663.50
6860.	0.035	104497.00	0.064	6692.59	51652.82	0.041	2136.23
6860.	0.050	52844.18	0.086	4556.36	52844.18	0.086	4556.36
TOTAL	0.000	1155048.00	0.027	31332.14	262735.31	0.006	1576.14
TOTAL	0.010	892312.69	0.033	29756.00	294592.44	0.015	4302.01
TOTAL	0.020	597720.25	0.043	25453.99	335066.06	0.027	8973.04
TOTAL	0.035	262654.19	0.063	16480.95	132355.25	0.041	5476.75
TOTAL	0.050	130298.94	0.084	11004.20	130298.94	0.084	11004.20

BLOCK MODEL: BUCK 20' BLOCKS - NO ORE OUTLINE
METHOD: ID2 INVERSE DISTANCE

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	610972.06	0.030	18178.04	92632.31	0.007	611.13
6840.	0.010	518339.75	0.034	17566.91	141478.19	0.015	2127.39
6840.	0.020	376861.56	0.041	15439.52	212959.75	0.027	5652.74
6840.	0.035	163901.81	0.060	9786.78	88095.44	0.041	3630.66
6840.	0.050	75806.37	0.081	6156.12	75806.37	0.081	6156.12
6860.	0.000	544076.37	0.025	13418.90	135602.94	0.006	833.87
6860.	0.010	408473.44	0.031	12585.02	163249.06	0.014	2367.10
6860.	0.020	245224.37	0.042	10217.93	136794.25	0.027	3700.68
6860.	0.035	108430.12	0.060	6517.25	59812.82	0.041	2466.07
6860.	0.050	48617.30	0.083	4051.18	48617.30	0.083	4051.18
TOTAL	0.000	1155048.00	0.027	31596.93	228234.81	0.006	1445.00
TOTAL	0.010	926813.19	0.033	30151.94	304727.19	0.015	4494.49
TOTAL	0.020	622086.00	0.041	25657.45	349754.06	0.027	9353.41
TOTAL	0.035	272331.94	0.060	16304.04	147908.25	0.041	6096.73
TOTAL	0.050	124423.69	0.082	10207.30	124423.69	0.082	10207.30

BLOCK MODEL: BUCK 20' BLOCKS - NO ORE OUTLINE
METHOD: ID1 INVERSE DISTANCE

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	610972.06	0.030	18474.07	68103.37	0.007	447.27
6840.	0.010	542868.69	0.033	18026.80	140172.56	0.015	2121.19
6840.	0.020	402696.12	0.039	15905.61	236117.81	0.026	6238.11
6840.	0.035	166578.31	0.058	9667.50	88536.06	0.041	3645.70
6840.	0.050	78042.25	0.077	6021.80	78042.25	0.077	6021.80
6860.	0.000	544076.37	0.025	13414.34	111514.62	0.006	706.81
6860.	0.010	432561.75	0.029	12707.53	182686.12	0.014	2635.60
6860.	0.020	249875.62	0.040	10071.93	140531.62	0.027	3807.56
6860.	0.035	109344.00	0.057	6264.37	63207.34	0.042	2628.49
6860.	0.050	46136.66	0.079	3635.89	46136.66	0.079	3635.89
TOTAL	0.000	1155048.00	0.028	31888.40	179617.50	0.006	1154.07
TOTAL	0.010	975430.50	0.032	30734.33	322858.69	0.015	4756.78
TOTAL	0.020	652571.81	0.040	25977.55	376649.50	0.027	10045.68
TOTAL	0.035	275922.31	0.058	15931.87	151743.44	0.041	6274.18
TOTAL	0.050	124178.87	0.078	9657.69	124178.87	0.078	9657.69

BLOCK MODEL: BUCK 20' BLOCKS - NO ORE OUTLINE
METHOD: ID0 INVERSE DISTANCE

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	610972.06	0.031	18658.23	58947.87	0.007	391.27
6840.	0.010	552024.19	0.033	18266.96	138850.56	0.016	2162.00
6840.	0.020	413173.62	0.039	16104.95	245044.94	0.027	6509.42
6840.	0.035	168128.69	0.057	9595.54	94133.81	0.042	3925.21
6840.	0.050	73994.87	0.077	5670.32	73994.87	0.077	5670.32
6860.	0.000	544076.37	0.025	13439.38	102913.94	0.007	674.73
6860.	0.010	441162.44	0.029	12764.64	188039.12	0.015	2749.88
6860.	0.020	253123.31	0.040	10014.76	150144.12	0.027	4111.04
6860.	0.035	102979.19	0.057	5903.73	54280.29	0.041	2240.03
6860.	0.050	48698.90	0.075	3663.70	48698.90	0.075	3663.70
TOTAL	0.000	1155048.00	0.028	32097.59	161861.37	0.007	1065.99
TOTAL	0.010	993186.62	0.031	31031.61	326889.69	0.015	4911.89
TOTAL	0.020	666296.94	0.039	26119.71	395189.00	0.027	10620.45
TOTAL	0.035	271107.94	0.057	15499.27	148414.12	0.042	6165.25
TOTAL	0.050	122693.81	0.076	9334.02	122693.81	0.076	9334.02

BLOCK MODEL: BUCK 20' BLOCKS - NO ORE OUTLINE
METHOD: KRIGE EXPLORATION KRIGED ESTIMATE

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	610972.06	0.030	18052.25	90869.75	0.006	557.58
6840.	0.010	520102.31	0.034	17494.66	149785.06	0.015	2276.53
6840.	0.020	370317.25	0.041	15218.14	209859.00	0.027	5582.90
6840.	0.035	160458.25	0.060	9635.23	87148.81	0.041	3565.57
6840.	0.050	73309.44	0.083	6069.66	73309.44	0.083	6069.66
6860.	0.000	544076.37	0.024	12994.03	137789.81	0.006	838.07
6860.	0.010	406286.56	0.030	12155.95	166219.31	0.015	2436.57
6860.	0.020	240067.25	0.040	9719.38	140629.50	0.027	3770.74
6860.	0.035	99437.75	0.060	5948.64	52093.41	0.041	2137.92
6860.	0.050	47344.34	0.080	3810.72	47344.34	0.080	3810.72
TOTAL	0.000	1155048.00	0.027	31046.27	228659.12	0.006	1395.65
TOTAL	0.010	926388.87	0.032	29650.62	316004.31	0.015	4713.09
TOTAL	0.020	610384.56	0.041	24937.52	350488.50	0.027	9353.64
TOTAL	0.035	259896.06	0.060	15583.88	139242.25	0.041	5703.50
TOTAL	0.050	120653.81	0.082	9880.37	120653.81	0.082	9880.37

BLOCK MODEL: BUCK 20' BLOCKS - NO ORE OUTLINE
METHOD: CPROB CONDITIONAL PROBABILITY

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	610972.06	0.030	18052.25	141275.44	0.005	734.14
6840.	0.010	469696.62	0.037	17318.10	148412.87	0.015	2206.54
6840.	0.020	321283.75	0.047	15111.56	154524.25	0.027	4131.00
6840.	0.035	166759.50	0.066	10980.57	76548.75	0.042	3186.00
6840.	0.050	90210.75	0.086	7794.57	90210.75	0.086	7794.57
6860.	0.000	544076.37	0.024	12994.03	184398.00	0.005	919.47
6860.	0.010	359678.37	0.034	12074.56	138627.19	0.015	2027.75
6860.	0.020	221051.19	0.045	10046.81	113321.75	0.027	3009.57
6860.	0.035	107729.44	0.065	7037.25	49927.98	0.042	2080.40
6860.	0.050	57801.45	0.086	4956.84	57801.45	0.086	4956.84
TOTAL	0.000	1155048.00	0.027	31046.27	325673.00	0.005	1653.60
TOTAL	0.010	829375.00	0.035	29392.66	287040.00	0.015	4234.29
TOTAL	0.020	542335.00	0.046	25158.38	267846.00	0.027	7140.55
TOTAL	0.035	274489.00	0.066	18017.82	126476.81	0.042	5266.41
TOTAL	0.050	148012.19	0.086	12751.41	148012.19	0.086	12751.41

BLOCK MODEL: BUCKG 20' BLOCKS - WITHIN ORE ZONE OUTLINE
METHOD: BH4 BLASTHOLE POLYGONS

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	422900.31	0.041	17212.70	48503.06	0.005	247.21
6840.	0.010	374397.25	0.045	16965.49	86398.12	0.015	1300.43
6840.	0.020	287999.12	0.054	15665.06	124064.69	0.027	3327.88
6840.	0.035	163934.44	0.075	12337.18	66242.87	0.042	2768.82
6840.	0.050	97691.56	0.098	9568.37	97691.56	0.098	9568.37
6860.	0.000	333221.87	0.037	12279.08	42742.12	0.005	224.80
6860.	0.010	290479.75	0.041	12054.28	77634.25	0.015	1168.28
6860.	0.020	212845.50	0.051	10886.00	92077.50	0.027	2471.22
6860.	0.035	120768.00	0.070	8414.78	51881.25	0.041	2151.11
6860.	0.050	68886.75	0.091	6263.66	68886.75	0.091	6263.66
TOTAL	0.000	756122.25	0.039	29491.80	91245.19	0.005	472.04
TOTAL	0.010	664877.06	0.044	29019.77	164032.37	0.015	2468.70
TOTAL	0.020	500844.69	0.053	26551.06	216142.19	0.027	5799.09
TOTAL	0.035	284702.50	0.073	20751.98	118124.19	0.042	4919.95
TOTAL	0.050	166578.31	0.095	15832.03	166578.31	0.095	15832.03

BLOCK MODEL: BUCKG 20' BLOCKS - WITHIN ORE ZONE OUTLINE
METHOD: BH20 BLASTHOLE POLYGON WEIGHTED

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	422900.31	0.041	17210.97	32280.94	0.006	196.75
6840.	0.010	390619.37	0.044	17014.23	75953.37	0.015	1159.88
6840.	0.020	314666.00	0.050	15854.34	138899.56	0.027	3714.05
6840.	0.035	175766.44	0.069	12140.29	74190.75	0.042	3139.78
6840.	0.050	101575.69	0.089	9000.51	101575.69	0.089	9000.51
6860.	0.000	333221.87	0.037	12277.66	28462.06	0.006	178.27
6860.	0.010	304759.81	0.040	12099.39	73717.50	0.016	1149.42
6860.	0.020	231042.31	0.047	10949.97	105982.12	0.027	2865.48
6860.	0.035	125060.19	0.065	8084.48	55275.87	0.042	2315.61
6860.	0.050	69784.31	0.083	5768.87	69784.31	0.083	5768.87
TOTAL	0.000	756122.25	0.039	29488.64	60743.06	0.006	375.02
TOTAL	0.010	695379.19	0.042	29113.62	149670.81	0.015	2309.30
TOTAL	0.020	545708.37	0.049	26804.32	244881.69	0.027	6579.53
TOTAL	0.035	300826.69	0.067	20224.79	129466.62	0.042	5455.40
TOTAL	0.050	171360.06	0.086	14769.39	171360.06	0.086	14769.39

BLOCK MODEL: BUCKG 20' BLOCKS - WITHIN ORE ZONE OUTLINE
METHOD: BHKRIGE BLASTHOLE KRIGING - "ACTUAL"

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	422900.31	0.042	17737.18	16483.19	0.007	113.38
6840.	0.010	406417.12	0.043	17623.80	55928.69	0.016	900.15
6840.	0.020	350488.44	0.048	16723.65	159691.25	0.027	4302.34
6840.	0.035	190797.19	0.065	12421.31	77748.50	0.041	3210.00
6840.	0.050	113048.69	0.081	9211.31	113048.69	0.081	9211.31
6860.	0.000	333221.87	0.038	12598.95	11587.19	0.006	71.21
6860.	0.010	321634.69	0.039	12527.74	69001.00	0.016	1112.00
6860.	0.020	252633.69	0.045	11415.73	117030.75	0.027	3185.25
6860.	0.035	135602.94	0.061	8230.49	65590.12	0.042	2742.25
6860.	0.050	70012.81	0.078	5488.24	70012.81	0.078	5488.24
TOTAL	0.000	756122.25	0.040	30336.14	28070.44	0.007	184.60
TOTAL	0.010	728051.81	0.041	30151.54	124929.62	0.016	2012.15
TOTAL	0.020	603122.19	0.047	28139.39	276722.06	0.027	7487.60
TOTAL	0.035	326400.12	0.063	20651.79	143338.62	0.042	5952.25
TOTAL	0.050	183061.50	0.080	14699.55	183061.50	0.080	14699.55

BLOCK MODEL: BUCKG 20' BLOCKS - WITHIN ORE ZONE OUTLINE
METHOD: EX4 EXPLORATION POLYGONS

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	422900.31	0.036	15151.52	56630.44	0.006	324.36
6840.	0.010	366269.87	0.040	14827.16	98458.56	0.014	1415.63
6840.	0.020	267811.31	0.050	13411.53	128977.06	0.026	3355.19
6840.	0.035	138834.25	0.072	10056.34	61395.87	0.043	2619.04
6840.	0.050	77438.37	0.096	7437.31	77438.37	0.096	7437.31
6860.	0.000	333221.87	0.036	12055.03	45288.00	0.005	236.92
6860.	0.010	287933.87	0.041	11818.11	87915.87	0.014	1255.94
6860.	0.020	200018.00	0.053	10562.17	92811.87	0.027	2492.69
6860.	0.035	107206.12	0.075	8069.48	44096.66	0.040	1774.54
6860.	0.050	63109.46	0.100	6294.95	63109.46	0.100	6294.95
TOTAL	0.000	756122.25	0.036	27206.55	101918.44	0.006	561.28
TOTAL	0.010	654203.81	0.041	26645.28	186374.50	0.014	2671.57
TOTAL	0.020	467829.31	0.051	23973.71	221788.94	0.026	5847.88
TOTAL	0.035	246040.37	0.074	18125.83	105492.50	0.042	4393.57
TOTAL	0.050	140547.87	0.098	13732.26	140547.87	0.098	13732.26

BLOCK MODEL: BUCKG 20' BLOCKS - WITHIN ORE ZONE OUTLINE
METHOD: EX20 EXPLORATION POLYGON WEIGHTED

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	422900.31	0.036	15149.92	41991.37	0.007	276.38
6840.	0.010	380908.94	0.039	14873.54	102293.81	0.015	1515.27
6840.	0.020	278615.12	0.048	13358.27	136304.69	0.027	3631.97
6840.	0.035	142310.44	0.068	9726.30	71367.37	0.042	3007.43
6840.	0.050	70943.06	0.095	6718.87	70943.06	0.095	6718.87
6860.	0.000	333221.87	0.036	12053.87	31644.50	0.006	203.90
6860.	0.010	301577.37	0.039	11849.98	90804.50	0.015	1322.01
6860.	0.020	210772.87	0.050	10527.96	107630.44	0.027	2867.71
6860.	0.035	103142.44	0.074	7660.25	42758.41	0.041	1763.88
6860.	0.050	60384.02	0.098	5896.37	60384.02	0.098	5896.37
TOTAL	0.000	756122.25	0.036	27203.80	73635.87	0.007	480.28
TOTAL	0.010	682486.37	0.039	26723.52	193098.37	0.015	2837.28
TOTAL	0.020	489388.00	0.049	23886.23	243935.12	0.027	6499.67
TOTAL	0.035	245452.87	0.071	17386.56	114125.81	0.042	4771.32
TOTAL	0.050	131327.06	0.096	12615.24	131327.06	0.096	12615.24

BLOCK MODEL: BUCKG 20' BLOCKS - WITHIN ORE ZONE OUTLINE
METHOD: ID10 INVERSE DISTANCE

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	422900.31	0.038	16178.18	19224.94	0.007	131.73
6840.	0.010	403675.37	0.040	16046.45	83199.44	0.015	1260.13
6840.	0.020	320475.94	0.046	14786.32	166235.56	0.026	4379.07
6840.	0.035	154240.37	0.067	10407.25	77046.75	0.042	3236.73
6840.	0.050	77193.62	0.093	7170.52	77193.62	0.093	7170.52
6860.	0.000	333221.87	0.038	12612.59	20171.50	0.006	130.37
6860.	0.010	313050.37	0.040	12482.22	86626.62	0.015	1320.17
6860.	0.020	226423.75	0.049	11162.05	114338.00	0.027	3092.50
6860.	0.035	112085.75	0.072	8069.55	52680.93	0.041	2176.84
6860.	0.050	59404.82	0.099	5892.71	59404.82	0.099	5892.71
TOTAL	0.000	756122.25	0.038	28790.77	39396.50	0.007	262.10
TOTAL	0.010	716725.75	0.040	28528.67	169826.00	0.015	2580.30
TOTAL	0.020	546899.75	0.047	25948.37	280573.56	0.027	7471.57
TOTAL	0.035	266326.19	0.069	18476.80	129727.75	0.042	5413.58
TOTAL	0.050	136598.44	0.096	13063.22	136598.44	0.096	13063.22

BLOCK MODEL: BUCKG 20' BLOCKS - WITHIN ORE ZONE OUTLINE
METHOD: ID5 INVERSE DISTANCE

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	422900.31	0.039	16644.41	10608.00	0.008	82.00
6840.	0.010	412292.31	0.040	16562.41	60938.87	0.016	948.97
6840.	0.020	351353.44	0.044	15613.44	179324.25	0.027	4806.42
6840.	0.035	172029.19	0.063	10807.02	90869.81	0.041	3740.13
6840.	0.050	81159.37	0.087	7066.89	81159.37	0.087	7066.89
6860.	0.000	333221.87	0.037	12487.85	9335.06	0.007	64.48
6860.	0.010	323886.81	0.038	12423.37	89449.94	0.016	1436.91
6860.	0.020	234436.87	0.047	10986.46	122334.75	0.028	3368.05
6860.	0.035	112102.12	0.068	7618.41	53023.70	0.041	2190.83
6860.	0.050	59078.43	0.092	5427.57	59078.43	0.092	5427.57
TOTAL	0.000	756122.25	0.039	29132.26	19943.06	0.007	146.48
TOTAL	0.010	736179.19	0.039	28985.78	150388.87	0.016	2385.88
TOTAL	0.020	585790.31	0.045	26599.90	301659.00	0.027	8174.46
TOTAL	0.035	284131.31	0.065	18425.43	143893.50	0.041	5930.96
TOTAL	0.050	140237.81	0.089	12494.47	140237.81	0.089	12494.47

BLOCK MODEL: BUCKG 20' BLOCKS - WITHIN ORE ZONE OUTLINE
METHOD: ID3 INVERSE DISTANCE

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	422900.31	0.040	17060.00	3508.81	0.007	25.83
6840.	0.010	419391.50	0.041	17034.17	44618.87	0.016	710.65
6840.	0.020	374772.62	0.044	16323.52	187745.37	0.027	5145.30
6840.	0.035	187027.25	0.060	11178.21	101135.06	0.041	4151.78
6840.	0.050	85892.19	0.082	7026.43	85892.19	0.082	7026.43
6860.	0.000	333221.87	0.037	12469.78	4341.12	0.008	32.79
6860.	0.010	328880.75	0.038	12436.99	74076.50	0.017	1237.93
6860.	0.020	254804.25	0.044	11199.06	136973.81	0.027	3736.60
6860.	0.035	117830.44	0.063	7462.46	58768.33	0.041	2420.30
6860.	0.050	59062.11	0.085	5042.16	59062.11	0.085	5042.16
TOTAL	0.000	756122.25	0.039	29529.79	7849.94	0.007	58.63
TOTAL	0.010	748272.31	0.039	29471.16	118695.44	0.016	1948.58
TOTAL	0.020	629576.87	0.044	27522.58	324719.19	0.027	8881.89
TOTAL	0.035	304857.69	0.061	18640.68	159903.44	0.041	6572.09
TOTAL	0.050	144954.25	0.083	12068.59	144954.25	0.083	12068.59

BLOCK MODEL: BUCKG 20' BLOCKS - WITHIN ORE ZONE OUTLINE
METHOD: ID2 INVERSE DISTANCE

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	422900.31	0.041	17339.06	1224.00	0.008	9.75
6840.	0.010	421676.31	0.041	17329.31	31611.87	0.017	525.27
6840.	0.020	390064.44	0.043	16804.04	186896.69	0.028	5188.77
6840.	0.035	203167.75	0.057	11615.26	118532.25	0.041	4839.10
6840.	0.050	84635.50	0.080	6776.16	84635.50	0.080	6776.16
6860.	0.000	333221.87	0.037	12473.97	1632.00	0.008	13.38
6860.	0.010	331589.87	0.038	12460.59	64251.87	0.017	1107.20
6860.	0.020	267338.00	0.042	11353.40	142033.00	0.027	3861.61
6860.	0.035	125305.00	0.060	7491.79	68070.69	0.041	2794.67
6860.	0.050	57234.27	0.082	4697.12	57234.27	0.082	4697.12
TOTAL	0.000	756122.25	0.039	29813.04	2856.00	0.008	23.13
TOTAL	0.010	753266.25	0.040	29789.91	95863.75	0.017	1632.46
TOTAL	0.020	657402.50	0.043	28157.44	328929.75	0.028	9050.39
TOTAL	0.035	328472.75	0.058	19107.05	186602.94	0.041	7633.77
TOTAL	0.050	141869.81	0.081	11473.29	141869.81	0.081	11473.29

BLOCK MODEL: BUCKG 20' BLOCKS - WITHIN ORE ZONE OUTLINE
METHOD: ID1 INVERSE DISTANCE

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	422900.31	0.042	17612.74	0.00	0.000	0.00
6840.	0.010	422900.31	0.042	17612.74	17495.06	0.017	301.67
6840.	0.020	405405.25	0.043	17311.07	186962.00	0.028	5283.32
6840.	0.035	218443.25	0.055	12027.75	132028.81	0.041	5369.51
6840.	0.050	86414.44	0.077	6658.24	86414.44	0.077	6658.24
6860.	0.000	333221.87	0.037	12475.58	0.00	0.000	0.00
6860.	0.010	333221.87	0.037	12475.58	51701.75	0.018	917.42
6860.	0.020	281520.12	0.041	11558.16	151253.87	0.027	4102.67
6860.	0.035	130266.25	0.057	7455.49	78025.87	0.042	3260.91
6860.	0.050	52240.34	0.080	4194.58	52240.34	0.080	4194.58
TOTAL	0.000	756122.25	0.040	30088.32	0.00	0.000	0.00
TOTAL	0.010	756122.25	0.040	30088.32	69196.87	0.018	1219.09
TOTAL	0.020	686925.37	0.042	28869.23	338215.81	0.028	9385.99
TOTAL	0.035	348709.56	0.056	19483.24	210054.81	0.041	8630.42
TOTAL	0.050	138654.75	0.078	10852.82	138654.75	0.078	10852.82

BLOCK MODEL: BUCKG 20' BLOCKS - WITHIN ORE ZONE OUTLINE
METHOD: ID0 INVERSE DISTANCE

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	422900.31	0.042	17770.50	0.00	0.000	0.00
6840.	0.010	422900.31	0.042	17770.50	13464.00	0.018	239.57
6840.	0.020	409436.31	0.043	17530.93	184008.06	0.028	5232.05
6840.	0.035	225428.25	0.055	12298.87	143828.25	0.042	5992.10
6840.	0.050	81600.00	0.077	6306.77	81600.00	0.077	6306.77
6860.	0.000	333221.87	0.037	12467.73	0.00	0.000	0.00
6860.	0.010	333221.87	0.037	12467.73	46969.00	0.018	832.79
6860.	0.020	286252.87	0.041	11634.94	151710.75	0.027	4138.44
6860.	0.035	134542.12	0.056	7496.50	80245.44	0.041	3316.92
6860.	0.050	54296.66	0.077	4179.58	54296.66	0.077	4179.58
TOTAL	0.000	756122.25	0.040	30238.24	0.00	0.000	0.00
TOTAL	0.010	756122.25	0.040	30238.24	60433.00	0.018	1072.37
TOTAL	0.020	695689.25	0.042	29165.87	335718.87	0.028	9370.50
TOTAL	0.035	359970.37	0.055	19795.37	224073.69	0.042	9309.02
TOTAL	0.050	135896.69	0.077	10486.36	135896.69	0.077	10486.36

BLOCK MODEL: BUCKG 20' BLOCKS - WITHIN ORE ZONE OUTLINE
METHOD: KRIGE EXPLORATION KRIGED ESTIMATE

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	422900.31	0.041	17383.05	408.00	0.009	3.73
6840.	0.010	422492.31	0.041	17379.32	25165.44	0.017	430.02
6840.	0.020	397326.87	0.043	16949.30	201943.75	0.028	5654.53
6840.	0.035	195383.12	0.058	11294.77	111351.44	0.041	4550.21
6840.	0.050	84031.69	0.080	6744.56	84031.69	0.080	6744.56
6860.	0.000	333221.87	0.036	12140.83	0.00	0.000	0.00
6860.	0.010	333221.87	0.036	12140.83	61020.50	0.018	1070.23
6860.	0.020	272201.37	0.041	11070.59	148871.12	0.027	3999.77
6860.	0.035	123330.25	0.057	7070.83	71644.75	0.042	2980.93
6860.	0.050	51685.46	0.079	4089.89	51685.46	0.079	4089.89
TOTAL	0.000	756122.25	0.039	29523.88	408.00	0.009	3.73
TOTAL	0.010	755714.25	0.039	29520.15	86186.00	0.017	1500.25
TOTAL	0.020	669528.25	0.042	28019.90	350814.87	0.028	9654.29
TOTAL	0.035	318713.37	0.058	18365.61	182996.25	0.041	7531.16
TOTAL	0.050	135717.12	0.080	10834.45	135717.12	0.080	10834.45

BLOCK MODEL:	BUCKG	20' BLOCKS - WITHIN ORE ZONE OUTLINE					
METHOD:	CPROB	CONDITIONAL PROBABILITY					
RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	422900.31	0.041	17383.05	6261.19	0.008	52.94
6840.	0.010	416639.12	0.042	17330.11	70203.81	0.016	1117.34
6840.	0.020	346435.31	0.047	16212.77	156921.25	0.027	4265.10
6840.	0.035	189514.06	0.063	11947.67	90029.56	0.042	3741.62
6840.	0.050	99484.50	0.082	8206.05	99484.50	0.082	8206.05
6860.	0.000	333221.87	0.036	12140.83	8502.37	0.008	72.02
6860.	0.010	324719.50	0.037	12068.81	82564.62	0.016	1288.20
6860.	0.020	242154.87	0.045	10780.61	122275.81	0.027	3269.89
6860.	0.035	119879.06	0.063	7510.72	57832.39	0.042	2404.70
6860.	0.050	62046.67	0.082	5106.02	62046.67	0.082	5106.02
TOTAL	0.000	756122.25	0.039	29523.88	14763.62	0.008	124.95
TOTAL	0.010	741358.62	0.040	29398.93	152768.44	0.016	2405.55
TOTAL	0.020	588590.19	0.046	26993.38	279197.00	0.027	7535.00
TOTAL	0.035	309393.19	0.063	19458.38	147862.06	0.042	6146.30
TOTAL	0.050	161531.12	0.082	13312.07	161531.12	0.082	13312.07

BLOCK MODEL: BUCK60 60' BLOCKS - NO ORE OUTLINE
METHOD: BH4 BLASTHOLE POLYGONS

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	610972.06	0.032	19300.41	163657.00	0.004	688.05
6840.	0.010	447315.06	0.042	18612.36	131245.50	0.015	1934.85
6840.	0.020	316069.56	0.053	16677.51	144481.06	0.027	3848.28
6840.	0.035	171588.50	0.075	12829.23	70828.81	0.042	2952.16
6840.	0.050	100759.69	0.098	9877.07	100759.69	0.098	9877.07
6860.	0.000	544076.37	0.026	14184.09	187010.94	0.004	679.27
6860.	0.010	357065.44	0.038	13504.82	119690.94	0.015	1789.39
6860.	0.020	237374.50	0.049	11715.43	109507.25	0.027	2905.93
6860.	0.035	127867.25	0.069	8809.50	56842.62	0.041	2351.80
6860.	0.050	71024.62	0.091	6457.70	71024.62	0.091	6457.70
TOTAL	0.000	1155048.00	0.029	33484.47	350667.50	0.004	1367.30
TOTAL	0.010	804380.50	0.040	32117.18	250936.44	0.015	3724.24
TOTAL	0.020	553444.06	0.051	28392.94	253988.25	0.027	6754.20
TOTAL	0.035	299455.81	0.072	21638.73	127671.44	0.042	5303.95
TOTAL	0.050	171784.37	0.095	16334.79	171784.37	0.095	16334.79

BLOCK MODEL: BUCK60 60' BLOCKS - NO ORE OUTLINE
METHOD: BH60 BLASTHOLE POLYGON WEIGHTED

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	610972.06	0.032	19300.17	108071.06	0.005	572.45
6840.	0.010	502901.00	0.037	18727.71	117650.94	0.016	1834.18
6840.	0.020	385250.06	0.044	16893.54	184187.62	0.027	4978.32
6840.	0.035	201062.44	0.059	11915.21	101347.25	0.042	4228.17
6840.	0.050	99715.19	0.077	7687.04	99715.19	0.077	7687.04
6860.	0.000	544076.37	0.026	14183.92	142767.44	0.005	690.74
6860.	0.010	401308.94	0.034	13493.18	113407.75	0.015	1687.73
6860.	0.020	287901.19	0.041	11805.45	144366.75	0.027	3830.37
6860.	0.035	143534.44	0.056	7975.07	82334.37	0.041	3360.28
6860.	0.050	61200.03	0.075	4614.79	61200.03	0.075	4614.79
TOTAL	0.000	1155048.00	0.029	33484.07	250838.00	0.005	1263.18
TOTAL	0.010	904210.00	0.036	32220.90	231058.69	0.015	3521.91
TOTAL	0.020	673151.31	0.043	28698.99	328554.37	0.027	8808.70
TOTAL	0.035	344596.94	0.058	19890.29	183681.69	0.041	7588.45
TOTAL	0.050	160915.25	0.076	12301.84	160915.25	0.076	12301.84

BLOCK MODEL: BUCK60 60' BLOCKS - NO ORE OUTLINE
METHOD: BHKRIGE BLASTHOLE KRIGING - "ACTUAL"

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	610972.06	0.033	20033.43	89531.56	0.006	494.13
6840.	0.010	521440.50	0.037	19539.30	119544.00	0.015	1808.67
6840.	0.020	401896.50	0.044	17730.63	192249.69	0.027	5194.79
6840.	0.035	209646.81	0.060	12535.84	109931.62	0.042	4652.30
6840.	0.050	99715.19	0.079	7883.54	99715.19	0.079	7883.54
6860.	0.000	544076.37	0.027	14425.90	133187.56	0.005	661.96
6860.	0.010	410888.81	0.033	13763.95	112934.50	0.015	1692.16
6860.	0.020	297954.31	0.041	12071.79	163167.37	0.027	4411.92
6860.	0.035	134786.94	0.057	7659.87	68935.75	0.041	2860.61
6860.	0.050	65851.19	0.073	4799.26	65851.19	0.073	4799.26
TOTAL	0.000	1155048.00	0.030	34459.32	222718.62	0.005	1156.07
TOTAL	0.010	932329.37	0.036	33303.25	232478.56	0.015	3500.83
TOTAL	0.020	699850.81	0.043	29802.42	355417.06	0.027	9606.71
TOTAL	0.035	344433.75	0.059	20195.71	178867.31	0.042	7512.90
TOTAL	0.050	165566.44	0.077	12682.80	165566.44	0.077	12682.80

BLOCK MODEL: BUCK60 60' BLOCKS - NO ORE OUTLINE
METHOD: EX4 EXPLORATION POLYGONS

RESERVES -

BENCH	CUTOFF	ABOVE CUTOFF GRADE TONS	GRADE	OUNCES	INSIDE GRADE BOUNDARIES TONS	GRADE	OUNCES
6840.	0.000	610972.06	0.027	16613.69	213351.44	0.005	1019.52
6840.	0.010	397620.62	0.039	15594.17	118858.62	0.014	1699.32
6840.	0.020	278762.00	0.050	13894.85	135864.06	0.026	3544.12
6840.	0.035	142897.94	0.072	10350.73	63958.06	0.043	2730.02
6840.	0.050	78939.87	0.097	7620.71	78939.87	0.097	7620.71
6860.	0.000	544076.37	0.025	13460.14	236901.25	0.004	1003.89
6860.	0.010	307175.12	0.041	12456.24	96777.62	0.014	1388.49
6860.	0.020	210397.50	0.053	11067.75	96271.75	0.027	2587.77
6860.	0.035	114125.75	0.074	8479.98	46609.94	0.040	1865.02
6860.	0.050	67515.81	0.098	6614.96	67515.81	0.098	6614.96
TOTAL	0.000	1155048.00	0.026	30073.80	450252.19	0.004	2023.39
TOTAL	0.010	704795.81	0.040	28050.41	215636.25	0.014	3087.81
TOTAL	0.020	489159.56	0.051	24962.60	232135.81	0.026	6131.89
TOTAL	0.035	257023.75	0.073	18830.71	110568.06	0.042	4595.04
TOTAL	0.050	146455.69	0.097	14235.67	146455.69	0.097	14235.67

BLOCK MODEL: BUCK60 60' BLOCKS - NO ORE OUTLINE
METHOD: EX60 EXPLORATION POLYGON WEIGHTED

RESERVES -

BENCH	CUTOFF	ABOVE CUTOFF GRADE TONS	GRADE	OUNCES	INSIDE GRADE BOUNDARIES TONS	GRADE	OUNCES
6840.	0.000	610972.06	0.027	16613.35	150193.00	0.006	856.76
6840.	0.010	460779.06	0.034	15756.59	149670.81	0.015	2199.74
6840.	0.020	311108.25	0.044	13556.84	166039.75	0.027	4417.37
6840.	0.035	145068.50	0.063	9139.47	80522.81	0.041	3333.88
6840.	0.050	64545.63	0.090	5805.59	64545.63	0.090	5805.59
6860.	0.000	544076.37	0.025	13459.68	159299.56	0.004	687.82
6860.	0.010	384776.81	0.033	12771.87	152624.75	0.015	2241.86
6860.	0.020	232152.06	0.045	10530.01	119119.75	0.027	3225.09
6860.	0.035	113032.31	0.065	7304.92	55487.97	0.043	2393.77
6860.	0.050	57544.34	0.085	4911.15	57544.34	0.085	4911.15
TOTAL	0.000	1155048.00	0.026	30073.02	309492.12	0.005	1544.57
TOTAL	0.010	845555.87	0.034	28528.46	302295.50	0.015	4441.60
TOTAL	0.020	543260.37	0.044	24086.86	285159.50	0.027	7642.46
TOTAL	0.035	258100.87	0.064	16444.40	136010.94	0.042	5727.65
TOTAL	0.050	122089.94	0.088	10716.75	122089.94	0.088	10716.75

BLOCK MODEL: BUCK60 60' BLOCKS - NO ORE OUTLINE
METHOD: ID10 INVERSE DISTANCE

RESERVES -

BENCH	CUTOFF	ABOVE CUTOFF GRADE TONS	GRADE	OUNCES	INSIDE GRADE BOUNDARIES TONS	GRADE	OUNCES
6840.	0.000	610972.06	0.026	15911.70	182637.19	0.006	1004.65
6840.	0.010	428334.87	0.035	14907.05	117553.00	0.015	1739.86
6840.	0.020	310781.87	0.042	13167.20	172943.12	0.026	4462.40
6840.	0.035	137838.75	0.063	8704.79	73293.06	0.042	3081.34
6840.	0.050	64545.63	0.087	5623.46	64545.63	0.087	5623.46
6860.	0.000	544076.37	0.023	12536.46	213171.94	0.005	1086.34
6860.	0.010	330904.44	0.035	11450.12	116769.62	0.014	1662.68
6860.	0.020	214134.81	0.046	9787.45	119609.37	0.027	3214.55
6860.	0.035	94525.44	0.070	6572.90	49367.98	0.042	2090.43
6860.	0.050	45157.46	0.099	4482.46	45157.46	0.099	4482.46
TOTAL	0.000	1155048.00	0.025	28448.16	395808.62	0.005	2090.97
TOTAL	0.010	759239.37	0.035	26357.18	234322.69	0.015	3402.54
TOTAL	0.020	524916.69	0.044	22954.64	292552.44	0.026	7676.94
TOTAL	0.035	232364.25	0.066	15277.70	122661.19	0.042	5171.79
TOTAL	0.050	109703.06	0.092	10105.91	109703.06	0.092	10105.91

BLOCK MODEL: BUCK60 60' BLOCKS - NO ORE OUTLINE
METHOD: ID5 INVERSE DISTANCE

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	610972.06	0.027	16617.16	160197.19	0.006	960.51
6840.	0.010	450774.87	0.035	15656.65	106634.94	0.014	1524.40
6840.	0.020	344139.94	0.041	14132.25	188039.12	0.026	4817.10
6840.	0.035	156100.81	0.060	9315.15	87883.19	0.041	3596.41
6840.	0.050	68217.62	0.084	5718.74	68217.62	0.084	5718.74
6860.	0.000	544076.37	0.023	12448.25	182865.69	0.005	962.66
6860.	0.010	361210.69	0.032	11485.59	139062.75	0.014	1963.08
6860.	0.020	222147.94	0.043	9522.51	127622.50	0.026	3364.81
6860.	0.035	94525.44	0.065	6157.70	53039.98	0.041	2196.64
6860.	0.050	41485.46	0.095	3961.06	41485.46	0.095	3961.06
TOTAL	0.000	1155048.00	0.025	29065.41	343062.37	0.006	1923.16
TOTAL	0.010	811985.62	0.033	27142.25	245697.75	0.014	3487.49
TOTAL	0.020	566287.87	0.042	23654.76	315661.56	0.026	8181.91
TOTAL	0.035	250626.31	0.062	15472.85	140923.25	0.041	5793.06
TOTAL	0.050	109703.06	0.088	9679.79	109703.06	0.088	9679.79

BLOCK MODEL: BUCK60 60' BLOCKS - NO ORE OUTLINE
METHOD: ID3 INVERSE DISTANCE

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	610972.06	0.028	17326.97	133938.25	0.007	879.78
6840.	0.010	477033.81	0.034	16447.20	115741.50	0.015	1692.46
6840.	0.020	361292.31	0.041	14754.73	205044.56	0.026	5309.41
6840.	0.035	156247.75	0.060	9445.33	77014.12	0.042	3226.20
6840.	0.050	79233.62	0.078	6219.13	79233.62	0.078	6219.13
6860.	0.000	544076.37	0.023	12592.44	160523.62	0.006	915.39
6860.	0.010	383552.75	0.030	11677.05	156655.75	0.014	2244.30
6860.	0.020	226897.00	0.042	9432.75	140841.62	0.027	3860.05
6860.	0.035	86055.37	0.065	5572.69	37911.36	0.041	1549.31
6860.	0.050	48144.02	0.084	4023.38	48144.02	0.084	4023.38
TOTAL	0.000	1155048.00	0.026	29919.41	294461.37	0.006	1795.16
TOTAL	0.010	860586.62	0.033	28124.25	272397.25	0.014	3936.76
TOTAL	0.020	588189.37	0.041	24187.49	345886.25	0.027	9169.46
TOTAL	0.035	242303.12	0.062	15018.02	114925.50	0.042	4775.52
TOTAL	0.050	127377.62	0.080	10242.51	127377.62	0.080	10242.51

BLOCK MODEL: BUCK60 60' BLOCKS - NO ORE OUTLINE
METHOD: ID2 INVERSE DISTANCE

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	610972.06	0.029	17832.84	96108.50	0.007	647.62
6840.	0.010	514863.56	0.033	17185.22	135439.75	0.014	1914.53
6840.	0.020	379423.81	0.040	15270.69	223176.06	0.026	5897.93
6840.	0.035	156247.75	0.060	9372.76	69670.12	0.041	2859.58
6840.	0.050	86577.62	0.075	6513.18	86577.62	0.075	6513.18
6860.	0.000	544076.37	0.024	12820.79	147157.50	0.006	923.52
6860.	0.010	396918.87	0.030	11897.27	159005.81	0.014	2276.62
6860.	0.020	237913.06	0.040	9620.65	144970.62	0.028	4004.55
6860.	0.035	92942.44	0.060	5616.09	43851.86	0.040	1766.41
6860.	0.050	49090.58	0.078	3849.69	49090.58	0.078	3849.69
TOTAL	0.000	1155048.00	0.027	30653.62	243265.56	0.006	1571.12
TOTAL	0.010	911782.44	0.032	29082.50	294445.56	0.014	4191.16
TOTAL	0.020	617336.87	0.040	24891.34	368146.69	0.027	9902.48
TOTAL	0.035	249190.19	0.060	14988.86	113522.00	0.041	4625.99
TOTAL	0.050	135668.19	0.076	10362.86	135668.19	0.076	10362.86

BLOCK MODEL: BUCK60 60' BLOCKS - NO ORE OUTLINE
METHOD: ID1 INVERSE DISTANCE

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	610972.06	0.030	18457.41	58295.06	0.006	363.42
6840.	0.010	552677.00	0.033	18093.99	151922.94	0.015	2240.08
6840.	0.020	400754.06	0.040	15853.91	237162.31	0.026	6284.63
6840.	0.035	163591.75	0.058	9569.28	79070.44	0.042	3290.36
6840.	0.050	84521.31	0.074	6278.91	84521.31	0.074	6278.91
6860.	0.000	544076.37	0.024	13224.52	111416.69	0.006	713.00
6860.	0.010	432659.69	0.029	12511.52	186668.25	0.014	2665.45
6860.	0.020	245991.44	0.040	9846.07	135635.56	0.027	3688.43
6860.	0.035	110355.87	0.056	6157.63	72689.25	0.042	3064.47
6860.	0.050	37666.57	0.082	3093.16	37666.57	0.082	3093.16
TOTAL	0.000	1155048.00	0.027	31681.93	169711.25	0.006	1076.41
TOTAL	0.010	985336.75	0.031	30605.51	338591.19	0.014	4905.53
TOTAL	0.020	646745.56	0.040	25699.98	372797.94	0.027	9973.07
TOTAL	0.035	273947.62	0.057	15726.91	151759.75	0.042	6354.85
TOTAL	0.050	122187.87	0.077	9372.07	122187.87	0.077	9372.07

BLOCK MODEL: BUCK60 60' BLOCKS - NO ORE OUTLINE
METHOD: ID0 INVERSE DISTANCE

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	610972.06	0.031	18924.66	49727.06	0.006	320.41
6840.	0.010	561245.00	0.033	18604.24	145101.19	0.016	2265.37
6840.	0.020	416143.81	0.039	16338.87	252568.44	0.027	6716.43
6840.	0.035	163575.37	0.059	9622.45	90429.12	0.043	3847.75
6840.	0.050	73146.25	0.079	5774.70	73146.25	0.079	5774.70
6860.	0.000	544076.37	0.025	13591.05	106357.50	0.007	745.62
6860.	0.010	437718.87	0.029	12845.43	187076.25	0.014	2678.77
6860.	0.020	250642.62	0.041	10166.66	146716.87	0.028	4072.28
6860.	0.035	103925.75	0.059	6094.39	52517.73	0.042	2204.86
6860.	0.050	51408.02	0.076	3889.53	51408.02	0.076	3889.53
TOTAL	0.000	1155048.00	0.028	32515.70	156084.06	0.007	1066.02
TOTAL	0.010	998963.94	0.031	31449.68	332177.44	0.015	4944.14
TOTAL	0.020	666786.50	0.040	26505.54	399285.31	0.027	10788.70
TOTAL	0.035	267501.19	0.059	15716.84	142946.94	0.042	6052.61
TOTAL	0.050	124554.25	0.078	9664.23	124554.25	0.078	9664.23

BLOCK MODEL: BUCK60 60' BLOCKS - NO ORE OUTLINE
METHOD: KRIGE EXPLORATION KRIGING

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	610972.06	0.030	18042.68	77373.12	0.006	480.54
6840.	0.010	533598.94	0.033	17562.14	153734.50	0.015	2329.79
6840.	0.020	379864.44	0.040	15232.35	207476.25	0.026	5363.81
6840.	0.035	172388.19	0.057	9868.54	109800.94	0.042	4617.30
6840.	0.050	62587.23	0.084	5251.24	62587.23	0.084	5251.24
6860.	0.000	544076.37	0.024	12860.89	124668.56	0.006	788.38
6860.	0.010	419407.81	0.029	12072.50	167720.69	0.014	2418.86
6860.	0.020	251687.12	0.038	9653.65	149980.87	0.026	3909.45
6860.	0.035	101706.25	0.056	5744.20	64023.36	0.042	2668.53
6860.	0.050	37682.89	0.082	3075.67	37682.89	0.082	3075.67
TOTAL	0.000	1155048.00	0.027	30903.56	202041.19	0.006	1268.91
TOTAL	0.010	953006.81	0.031	29634.65	321455.19	0.015	4748.65
TOTAL	0.020	631551.62	0.039	24886.00	357457.12	0.026	9273.26
TOTAL	0.035	274094.50	0.057	15612.74	173824.37	0.042	7285.83
TOTAL	0.050	100270.12	0.083	8326.91	100270.12	0.083	8326.91

BLOCK MODEL: BUCK60 60' BLOCKS - NO ORE OUTLINE
METHOD: CPROB CONDITIONAL PROBABILITY

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	610972.06	0.030	18042.68	113827.25	0.006	633.06
6840.	0.010	497144.81	0.035	17409.62	156231.87	0.015	2332.91
6840.	0.020	340912.94	0.044	15076.71	170762.44	0.027	4564.67
6840.	0.035	170150.50	0.062	10512.04	83876.00	0.042	3489.61
6840.	0.050	86274.50	0.081	7022.43	86274.50	0.081	7022.43
6860.	0.000	544076.37	0.024	12860.89	161263.56	0.005	884.77
6860.	0.010	382812.81	0.031	11976.12	151008.25	0.015	2213.35
6860.	0.020	231804.56	0.042	9762.77	125040.81	0.027	3318.82
6860.	0.035	106763.75	0.060	6443.95	54762.33	0.042	2277.93
6860.	0.050	52001.42	0.080	4166.02	52001.42	0.080	4166.02
TOTAL	0.000	1155048.00	0.027	30903.56	275090.31	0.006	1517.82
TOTAL	0.010	879957.69	0.033	29385.74	307240.12	0.015	4546.25
TOTAL	0.020	572717.56	0.043	24839.49	295803.25	0.027	7883.49
TOTAL	0.035	276914.31	0.061	16956.00	138638.44	0.042	5767.54
TOTAL	0.050	138275.87	0.081	11188.45	138275.87	0.081	11188.45

BLOCK MODEL: BUCK60G 60' BLOCKS - WITHIN ORE ZONE OUTLINE
METHOD: BH4 BLASTHOLE POLYGONS

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	422900.31	0.041	17212.70	48503.06	0.005	247.21
6840.	0.010	374397.25	0.045	16965.49	86398.12	0.015	1300.43
6840.	0.020	287999.12	0.054	15665.06	124064.69	0.027	3327.88
6840.	0.035	163934.44	0.075	12337.18	66242.87	0.042	2768.82
6840.	0.050	97691.56	0.098	9568.37	97691.56	0.098	9568.37
6860.	0.000	333221.87	0.037	12279.08	42742.12	0.005	224.80
6860.	0.010	290479.75	0.041	12054.28	77634.25	0.015	1168.28
6860.	0.020	212845.50	0.051	10886.00	92077.50	0.027	2471.22
6860.	0.035	120768.00	0.070	8414.78	51881.25	0.041	2151.11
6860.	0.050	68886.75	0.091	6263.66	68886.75	0.091	6263.66
TOTAL	0.000	756122.25	0.039	29491.80	91245.19	0.005	472.04
TOTAL	0.010	664877.06	0.044	29019.77	164032.37	0.015	2468.70
TOTAL	0.020	500844.69	0.053	26551.06	216142.19	0.027	5799.09
TOTAL	0.035	284702.50	0.073	20751.98	118124.19	0.042	4919.95
TOTAL	0.050	166578.31	0.095	15832.03	166578.31	0.095	15832.03

BLOCK MODEL: BUCK60G 60' BLOCKS - WITHIN ORE ZONE OUTLINE
METHOD: BH60 BLASTHOLE POLYGON WEIGHTED

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	422900.31	0.041	17212.47	13349.75	0.005	70.79
6840.	0.010	409550.56	0.042	17141.68	51832.37	0.017	891.49
6840.	0.020	357718.19	0.045	16250.20	165811.25	0.027	4541.51
6840.	0.035	191906.94	0.061	11708.68	83232.06	0.042	3474.77
6840.	0.050	108674.87	0.076	8233.92	108674.87	0.076	8233.92
6860.	0.000	333221.87	0.037	12278.81	9057.62	0.006	57.66
6860.	0.010	324164.25	0.038	12221.14	68462.44	0.016	1094.43
6860.	0.020	255701.81	0.044	11126.71	111841.00	0.027	3009.38
6860.	0.035	143860.81	0.056	8117.33	74223.37	0.041	3031.89
6860.	0.050	69637.44	0.073	5085.44	69637.44	0.073	5085.44
TOTAL	0.000	756122.25	0.039	29491.28	22407.37	0.006	128.45
TOTAL	0.010	733714.87	0.040	29362.83	120294.81	0.017	1985.92
TOTAL	0.020	613420.06	0.045	27376.91	277652.25	0.027	7550.89
TOTAL	0.035	335767.81	0.059	19826.02	157455.44	0.041	6506.65
TOTAL	0.050	178312.37	0.075	13319.37	178312.37	0.075	13319.37

BLOCK MODEL: BUCK60G 60' BLOCKS - WITHIN ORE ZONE OUTLINE
METHOD: BHKRIGE BLASTHOLE KRIGING - "ACTUAL"

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	422900.31	0.042	17779.30	12778.56	0.006	82.46
6840.	0.010	410121.75	0.043	17696.84	34451.56	0.017	571.64
6840.	0.020	375670.19	0.046	17125.20	174819.87	0.027	4762.26
6840.	0.035	200850.31	0.062	12362.94	95863.75	0.043	4087.16
6840.	0.050	104986.56	0.079	8275.78	104986.56	0.079	8275.78
6860.	0.000	333221.87	0.037	12403.29	8453.75	0.007	59.14
6860.	0.010	324768.12	0.038	12344.15	54149.81	0.016	862.18
6860.	0.020	270618.31	0.042	11481.96	133954.62	0.027	3633.92
6860.	0.035	136663.69	0.057	7848.04	66357.12	0.042	2771.85
6860.	0.050	70306.56	0.072	5076.20	70306.56	0.072	5076.20
TOTAL	0.000	756122.25	0.040	30182.59	21232.37	0.007	141.59
TOTAL	0.010	734889.87	0.041	30041.00	88601.31	0.016	1433.82
TOTAL	0.020	646288.56	0.044	28607.17	308774.50	0.027	8396.19
TOTAL	0.035	337514.06	0.060	20210.98	162220.87	0.042	6859.00
TOTAL	0.050	175293.19	0.076	13351.98	175293.19	0.076	13351.98

BLOCK MODEL: BUCK60G 60' BLOCKS - WITHIN ORE ZONE OUTLINE
METHOD: EX4 EXPLORATION POLYGONS

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	422900.31	0.036	15151.52	56630.44	0.006	324.36
6840.	0.010	366269.87	0.040	14827.16	98458.56	0.014	1415.63
6840.	0.020	267811.31	0.050	13411.53	128977.06	0.026	3355.19
6840.	0.035	138834.25	0.072	10056.34	61395.87	0.043	2619.04
6840.	0.050	77438.37	0.096	7437.31	77438.37	0.096	7437.31
6860.	0.000	333221.87	0.036	12055.03	45288.00	0.005	236.92
6860.	0.010	287933.87	0.041	11818.11	87915.87	0.014	1255.94
6860.	0.020	200018.00	0.053	10562.17	92811.87	0.027	2492.69
6860.	0.035	107206.12	0.075	8069.48	44096.66	0.040	1774.54
6860.	0.050	63109.46	0.100	6294.95	63109.46	0.100	6294.95
TOTAL	0.000	756122.25	0.036	27206.55	101918.44	0.006	561.28
TOTAL	0.010	654203.81	0.041	26645.28	186374.50	0.014	2671.57
TOTAL	0.020	467829.31	0.051	23973.71	221788.94	0.026	5847.88
TOTAL	0.035	246040.37	0.074	18125.83	105492.50	0.042	4393.57
TOTAL	0.050	140547.87	0.098	13732.26	140547.87	0.098	13732.26

BLOCK MODEL: BUCK60G 60' BLOCKS - WITHIN ORE ZONE OUTLINE
METHOD: EX60 EXPLORATION POLYGON WEIGHTED

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	422900.31	0.036	15151.29	20367.37	0.008	164.72
6840.	0.010	402532.94	0.037	14986.57	93791.06	0.015	1408.72
6840.	0.020	308741.87	0.044	13577.85	155203.25	0.026	4102.15
6840.	0.035	153538.62	0.062	9475.70	88699.19	0.041	3640.17
6840.	0.050	64839.39	0.090	5835.53	64839.39	0.090	5835.53
6860.	0.000	333221.87	0.036	12054.71	4634.87	0.007	31.89
6860.	0.010	328587.00	0.037	12022.81	97609.94	0.015	1509.67
6860.	0.020	230977.06	0.046	10513.14	121437.19	0.027	3332.18
6860.	0.035	109539.87	0.066	7180.96	53709.13	0.043	2314.40
6860.	0.050	55830.74	0.087	4866.56	55830.74	0.087	4866.56
TOTAL	0.000	756122.25	0.036	27206.00	25002.25	0.008	196.61
TOTAL	0.010	731120.00	0.037	27009.39	191401.06	0.015	2918.39
TOTAL	0.020	539718.94	0.045	24091.00	276640.44	0.027	7434.35
TOTAL	0.035	263078.50	0.063	16656.65	142408.37	0.042	5954.55
TOTAL	0.050	120670.12	0.089	10702.09	120670.12	0.089	10702.09

BLOCK MODEL: BUCK60G 60' BLOCKS - WITHIN ORE ZONE OUTLINE
METHOD: ID10 INVERSE DISTANCE

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	422900.31	0.035	14955.87	18180.50	0.006	112.66
6840.	0.010	404719.81	0.037	14843.20	85712.69	0.015	1318.86
6840.	0.020	319007.12	0.042	13524.34	178442.94	0.026	4667.20
6840.	0.035	140564.19	0.063	8857.14	73211.56	0.042	3073.03
6840.	0.050	67352.62	0.086	5784.12	67352.62	0.086	5784.12
6860.	0.000	333221.87	0.035	11797.02	20138.87	0.006	119.81
6860.	0.010	313083.00	0.037	11677.21	81616.37	0.016	1282.29
6860.	0.020	231466.62	0.045	10394.92	133383.44	0.027	3588.45
6860.	0.035	98083.19	0.069	6806.46	46724.12	0.042	1954.94
6860.	0.050	51359.06	0.094	4851.53	51359.06	0.094	4851.53
TOTAL	0.000	756122.25	0.035	26752.89	38319.37	0.006	232.48
TOTAL	0.010	717802.87	0.037	26520.41	167329.06	0.016	2601.14
TOTAL	0.020	550473.81	0.043	23919.27	311826.37	0.026	8255.66
TOTAL	0.035	238647.44	0.066	15663.61	119935.75	0.042	5027.96
TOTAL	0.050	118711.69	0.090	10635.65	118711.69	0.090	10635.65

BLOCK MODEL:		BUCK60G	60' BLOCKS - WITHIN ORE ZONE OUTLINE				
METHOD:		ID5	INVERSE DISTANCE				
RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	422900.31	0.037	15764.52	16189.44	0.008	122.47
6840.	0.010	406710.87	0.038	15642.05	51946.56	0.016	826.61
6840.	0.020	354764.31	0.042	14815.45	181870.19	0.026	4755.66
6840.	0.035	172894.12	0.058	10059.79	98670.75	0.040	3991.79
6840.	0.050	74223.37	0.082	6068.00	74223.37	0.082	6068.00
6860.	0.000	333221.87	0.035	11749.78	14965.44	0.006	96.54
6860.	0.010	318256.44	0.037	11653.23	77928.06	0.017	1297.48
6860.	0.020	240328.37	0.043	10355.75	141690.31	0.027	3818.07
6860.	0.035	98638.06	0.066	6537.68	51522.20	0.042	2171.55
6860.	0.050	47115.86	0.093	4366.13	47115.86	0.093	4366.13
TOTAL	0.000	756122.25	0.036	27514.30	31154.94	0.007	219.01
TOTAL	0.010	724967.31	0.038	27295.29	129874.62	0.016	2124.09
TOTAL	0.020	595092.69	0.042	25171.20	323560.44	0.026	8573.71
TOTAL	0.035	271532.25	0.061	16597.48	150193.00	0.041	6163.35
TOTAL	0.050	121339.25	0.086	10434.14	121339.25	0.086	10434.14

BLOCK MODEL:		BUCK60G	60' BLOCKS - WITHIN ORE ZONE OUTLINE				
METHOD:		ID3	INVERSE DISTANCE				
RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	422900.31	0.039	16487.60	12517.44	0.008	106.06
6840.	0.010	410382.87	0.040	16381.54	36491.56	0.016	586.85
6840.	0.020	373891.31	0.042	15794.69	194779.25	0.027	5295.65
6840.	0.035	179112.06	0.059	10499.04	94346.00	0.041	3904.74
6840.	0.050	84766.06	0.078	6594.30	84766.06	0.078	6594.30
6860.	0.000	333221.87	0.036	11894.65	9318.75	0.006	60.24
6860.	0.010	323903.12	0.037	11834.41	65328.94	0.017	1096.15
6860.	0.020	258574.19	0.042	10738.26	162302.50	0.028	4476.30
6860.	0.035	96271.69	0.065	6261.96	44602.55	0.042	1856.47
6860.	0.050	51669.14	0.085	4405.49	51669.14	0.085	4405.49
TOTAL	0.000	756122.25	0.038	28382.26	21836.19	0.008	166.30
TOTAL	0.010	734286.06	0.038	28215.96	101820.50	0.017	1683.00
TOTAL	0.020	632465.56	0.042	26532.96	357081.81	0.027	9771.95
TOTAL	0.035	275383.75	0.061	16761.01	138948.50	0.041	5761.21
TOTAL	0.050	136435.25	0.081	10999.80	136435.25	0.081	10999.80

BLOCK MODEL:		BUCK60G	60' BLOCKS - WITHIN ORE ZONE OUTLINE				
METHOD:		ID2	INVERSE DISTANCE				
RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	422900.31	0.040	16946.35	3672.00	0.010	34.96
6840.	0.010	419228.31	0.040	16911.39	30338.87	0.016	477.14
6840.	0.020	388889.44	0.042	16434.25	201062.50	0.028	5603.50
6840.	0.035	187826.94	0.058	10830.75	94362.31	0.041	3827.71
6840.	0.050	93464.62	0.075	7003.05	93464.62	0.075	7003.05
6860.	0.000	333221.87	0.036	12071.93	4798.06	0.009	42.77
6860.	0.010	328423.81	0.037	12029.16	61803.87	0.017	1054.77
6860.	0.020	266619.94	0.041	10974.40	148903.75	0.027	4076.49
6860.	0.035	117716.19	0.059	6897.91	63599.05	0.040	2526.18
6860.	0.050	54117.14	0.081	4371.73	54117.14	0.081	4371.73
TOTAL	0.000	756122.25	0.038	29018.29	8470.12	0.009	77.72
TOTAL	0.010	747652.12	0.039	28940.56	92142.75	0.017	1531.91
TOTAL	0.020	655509.37	0.042	27408.65	349966.25	0.028	9679.98
TOTAL	0.035	305543.12	0.058	17728.67	157961.31	0.040	6353.88
TOTAL	0.050	147581.81	0.077	11374.79	147581.81	0.077	11374.79

BLOCK MODEL: BUCK60G 60' BLOCKS - WITHIN ORE ZONE OUTLINE
METHOD: ID1 INVERSE DISTANCE

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	422900.31	0.041	17483.48	0.00	0.000	0.00
6840.	0.010	422900.31	0.041	17483.48	20318.37	0.017	339.06
6840.	0.020	402581.94	0.043	17144.42	195725.87	0.029	5626.14
6840.	0.035	206856.06	0.056	11518.27	111220.87	0.040	4491.75
6840.	0.050	95635.19	0.073	7026.53	95635.19	0.073	7026.53
6860.	0.000	333221.87	0.037	12375.63	0.00	0.000	0.00
6860.	0.010	333221.87	0.037	12375.63	38172.50	0.017	649.23
6860.	0.020	295049.37	0.040	11726.40	169336.37	0.027	4563.92
6860.	0.035	125713.00	0.057	7162.48	81257.25	0.042	3436.90
6860.	0.050	44455.70	0.084	3725.58	44455.70	0.084	3725.58
TOTAL	0.000	756122.25	0.039	29859.12	0.00	0.000	0.00
TOTAL	0.010	756122.25	0.039	29859.12	58490.94	0.017	988.30
TOTAL	0.020	697631.31	0.041	28870.82	365062.25	0.028	10190.06
TOTAL	0.035	332569.06	0.056	18680.76	192478.12	0.041	7928.65
TOTAL	0.050	140090.94	0.077	10752.11	140090.94	0.077	10752.11

BLOCK MODEL: BUCK60G 60' BLOCKS - WITHIN ORE ZONE OUTLINE
METHOD: ID0 INVERSE DISTANCE

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	422900.31	0.042	17864.58	0.00	0.000	0.00
6840.	0.010	422900.31	0.042	17864.58	15977.25	0.018	287.56
6840.	0.020	406923.06	0.043	17577.02	189279.50	0.029	5472.30
6840.	0.035	217643.56	0.056	12104.72	144611.56	0.042	6139.39
6840.	0.050	73032.00	0.082	5965.32	73032.00	0.082	5965.32
6860.	0.000	333221.87	0.038	12671.93	0.00	0.000	0.00
6860.	0.010	333221.87	0.038	12671.93	38890.56	0.017	671.32
6860.	0.020	294331.31	0.041	12000.61	156965.81	0.027	4285.69
6860.	0.035	137365.50	0.056	7714.92	77928.00	0.041	3213.84
6860.	0.050	59437.46	0.076	4501.09	59437.46	0.076	4501.09
TOTAL	0.000	756122.25	0.040	30536.51	0.00	0.000	0.00
TOTAL	0.010	756122.25	0.040	30536.51	54867.87	0.017	958.89
TOTAL	0.020	701254.37	0.042	29577.62	346245.31	0.028	9757.98
TOTAL	0.035	355009.06	0.056	19819.64	222539.62	0.042	9353.23
TOTAL	0.050	132469.44	0.079	10466.41	132469.44	0.079	10466.41

BLOCK MODEL: BUCK60G 60' BLOCKS - WITHIN ORE ZONE OUTLINE
METHOD: KRIGE EXPLORATION KRIGING

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	422900.31	0.040	17120.96	0.00	0.000	0.00
6840.	0.010	422900.31	0.040	17120.96	22782.75	0.016	354.04
6840.	0.020	400117.56	0.042	16766.92	201307.25	0.028	5582.57
6840.	0.035	198810.31	0.056	11184.35	118418.00	0.041	4826.31
6840.	0.050	80392.31	0.079	6358.04	80392.31	0.079	6358.04
6860.	0.000	333221.87	0.035	11716.03	0.00	0.000	0.00
6860.	0.010	333221.87	0.035	11716.03	64382.44	0.018	1129.20
6860.	0.020	268839.44	0.039	10586.83	155692.87	0.027	4274.99
6860.	0.035	113146.56	0.056	6311.84	74533.37	0.042	3128.55
6860.	0.050	38613.14	0.082	3183.29	38613.14	0.082	3183.29
TOTAL	0.000	756122.25	0.038	28837.00	0.00	0.000	0.00
TOTAL	0.010	756122.25	0.038	28837.00	87165.19	0.017	1483.24
TOTAL	0.020	668957.06	0.041	27353.75	357000.12	0.028	9857.56
TOTAL	0.035	311956.94	0.056	17496.20	192951.50	0.041	7954.87
TOTAL	0.050	119005.44	0.080	9541.32	119005.44	0.080	9541.32

BLOCK MODEL: BUCK60G 60' BLOCKS - WITHIN ORE ZONE OUTLINE
METHOD: CPROB CONDITIONAL PROBABILITY

RESERVES -		ABOVE CUTOFF GRADE			INSIDE GRADE BOUNDARIES		
BENCH	CUTOFF	TONS	GRADE	OUNCES	TONS	GRADE	OUNCES
6840.	0.000	422900.31	0.040	17120.96	4534.00	0.009	39.94
6840.	0.010	418366.31	0.041	17081.02	64447.19	0.016	1030.20
6840.	0.020	353919.12	0.045	16050.83	162382.25	0.027	4438.71
6840.	0.035	191536.87	0.061	11612.12	97680.50	0.041	4050.96
6840.	0.050	93856.37	0.081	7561.16	93856.37	0.081	7561.16
6860.	0.000	333221.87	0.035	11716.03	5613.75	0.009	48.77
6860.	0.010	327608.12	0.036	11667.26	80900.75	0.016	1277.23
6860.	0.020	246707.37	0.042	10390.03	131230.44	0.027	3520.76
6860.	0.035	115476.94	0.059	6869.27	62086.79	0.041	2573.35
6860.	0.050	53390.14	0.080	4295.92	53390.14	0.080	4295.92
TOTAL	0.000	756122.25	0.038	28837.00	10147.81	0.009	88.71
TOTAL	0.010	745974.44	0.039	28748.28	145347.87	0.016	2307.41
TOTAL	0.020	600626.56	0.044	26440.87	293612.69	0.027	7959.47
TOTAL	0.035	307013.87	0.060	18481.39	159767.31	0.041	6624.31
TOTAL	0.050	147246.56	0.081	11857.09	147246.56	0.081	11857.09

APPENDIX D

LISTING OF CALCULATED SEMI-VARIOGRAM VALUES

note: raw grades were multiplied by 100.

LEGEND:

LAG	Lag distance.
N	Number of pairs for arithmetic and relative variograms.
LN	Number of samples for lognormal variogram.
AR MEAN	Arithmetic mean grade of samples.
LG MEAN	Lognormal mean grade of samples.
VG	Calculated variogram value.
LOG VG	Lognormal variogram.
REL VG	Relative variogram.

FILE= BEX
ANGLE= 90
VERT ANG= 0

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
30	831	819	48.7	1.4211	2476.1	0.1675	1.0458
57	5553	5410	39.5	1.3067	2775.8	0.2186	1.7757
105	11622	11326	36.8	1.2981	2634.6	0.2402	1.9432
137	6235	6104	37.3	1.2750	2818.6	0.3011	2.0308

FILE= BEX
ANGLE= 45
VERT ANG= 0

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
29	578	567	49.2	1.3704	2785.0	0.2100	1.1516
66	5289	5166	39.0	1.3163	2576.6	0.2109	1.6900
105	9457	9224	37.2	1.2911	2791.5	0.2416	2.0173
137	6758	6625	36.8	1.2872	2595.1	0.2661	1.9209

FILE= BEX
ANGLE= 0
VERT ANG= 0

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
31	527	524	46.0	1.3760	2578.0	0.1858	1.2172
57	5707	5561	38.9	1.3176	2378.7	0.1881	1.5684
105	11524	11230	36.7	1.2958	2459.2	0.2134	1.8283
139	4969	4879	37.3	1.2816	2516.1	0.2395	1.8044

FILE= BEX
ANGLE= 135
VERT ANG= 0

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
32	554	547	45.5	1.3027	2556.0	0.2498	1.2367
66	5538	5417	38.1	1.3039	2219.3	0.2039	1.5268
106	9010	8791	36.9	1.2848	2685.9	0.2285	1.9704
137	6885	6746	36.8	1.2913	2549.8	0.2539	1.8832

FILE= BEX
ANGLE= 0
VERT ANG= 90

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
21	2020	1970	32.4	1.2164	1134.7	0.0883	1.0778
41	1591	1547	32.9	1.2200	1799.8	0.1421	1.6602
61	1185	1144	32.0	1.2133	1812.1	0.1744	1.7701
81	825	788	32.1	1.2107	2095.1	0.2117	2.0325
101	530	501	31.0	1.1830	2242.3	0.2300	2.3290

FILE= BEXG
ANGLE= 90
VERT ANG= 0

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
29	329	327	49.8	1.5063	2510.9	0.1451	1.0130
56	2278	2269	46.8	1.4751	3665.6	0.1523	1.6755
105	4759	4730	44.8	1.4678	2984.2	0.1606	1.4886
137	2215	2210	46.2	1.4765	3105.2	0.1819	1.4520

FILE= BEXG
ANGLE= 45
VERT ANG= 0

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
26	191	190	47.3	1.4501	2827.0	0.1911	1.2648
67	2172	2159	45.4	1.4727	3070.3	0.1475	1.4878
106	3781	3769	45.3	1.4629	3344.6	0.1646	1.6322
137	2586	2576	45.5	1.4742	2985.6	0.1631	1.4431

FILE= BEXG
ANGLE= 0
VERT ANG= 0

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
27	167	166	52.4	1.5412	2795.7	0.1403	1.0171
55	2575	2559	46.7	1.4829	2991.9	0.1445	1.3695
106	5067	5038	45.9	1.4704	3198.2	0.1608	1.5196
140	1923	1914	49.1	1.4947	3686.8	0.1752	1.5318

FILE= BEXG
ANGLE= 135
VERT ANG= 0

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
29	165	164	58.8	1.5707	2549.7	0.1790	0.7364
66	2408	2395	43.9	1.4626	2401.2	0.1425	1.2486
108	3704	3676	46.2	1.4725	3449.1	0.1627	1.6171
138	2681	2671	45.7	1.4799	2899.3	0.1732	1.3868

FILE= BEXG
ANGLE= 0
VERT ANG= 90

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
21	759	755	45.9	1.4864	1835.2	0.0741	0.8717
41	530	526	45.7	1.4856	2779.5	0.1068	1.3308
61	337	332	44.3	1.4741	2481.4	0.1203	1.2622
81	179	174	43.3	1.4663	1915.6	0.1115	1.0237
101	55	53	42.5	1.4773	1086.8	0.1200	0.6012

FILE= BBH
ANGLE= 90
VERT ANG= 0

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
14	6891	6874	36.7	1.3012	1560.6	0.0739	1.1590
32	43651	43538	39.5	1.3139	2636.9	0.1381	1.6904
51	78256	77990	39.7	1.3211	2872.5	0.1759	1.8234
70	105621	105302	39.9	1.3288	3084.2	0.2087	1.9378
90	130096	129677	40.2	1.3359	3261.3	0.2387	2.0223
110	155677	155142	40.1	1.3363	3302.3	0.2640	2.0535
130	177403	176798	39.7	1.3360	3140.7	0.2789	1.9952
145	96894	96539	39.7	1.3375	3126.9	0.2863	1.9837

FILE= BBH
ANGLE= 45
VERT ANG= 0

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
15	5854	5838	36.2	1.2780	1610.8	0.0777	1.2309
32	41865	41743	39.3	1.3077	2589.2	0.1343	1.6790
51	76334	76108	39.7	1.3177	2800.5	0.1649	1.7799
70	104405	104079	39.6	1.3242	2867.4	0.1920	1.8309
90	128193	127825	39.7	1.3261	3121.0	0.2205	1.9812
110	152144	151671	39.5	1.3282	3131.9	0.2414	2.0054
130	171886	171339	39.1	1.3271	3054.7	0.2578	1.9953
145	92933	92630	39.1	1.3276	3086.7	0.2678	2.0241

FILE= BBH
ANGLE= 0
VERT ANG= 0

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
14	6822	6793	36.1	1.2619	1440.2	0.0638	1.1043
32	43712	43571	39.0	1.2983	2475.1	0.1119	1.6283
51	77950	77710	39.2	1.3086	2546.9	0.1320	1.6533
70	105823	105514	39.3	1.3110	2796.7	0.1507	1.8070
90	129943	129529	39.2	1.3106	2966.2	0.1675	1.9287
110	154452	153922	39.3	1.3143	3052.7	0.1823	1.9721
130	172351	171765	38.7	1.3102	2995.9	0.1934	1.9977
145	92854	92510	38.8	1.3110	3070.2	0.2001	2.0443

FILE= BBH
ANGLE= 135
VERT ANG= 0

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
15	5888	5872	36.4	1.2870	1468.5	0.0660	1.1097
32	42168	42053	38.9	1.3021	2348.8	0.1202	1.5528
51	76343	76119	39.5	1.3151	2623.4	0.1470	1.6824
70	106062	105723	39.6	1.3191	2943.9	0.1713	1.8756
90	130890	130458	39.8	1.3238	3116.9	0.1927	1.9705
110	155512	154958	39.7	1.3265	3124.7	0.2124	1.9832
130	177977	177307	39.7	1.3285	3250.2	0.2282	2.0628
145	96231	95874	39.6	1.3300	3186.5	0.2381	2.0345

FILE= BBH
ANGLE= 0
VERT ANG= 90

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
21	3257	3248	40.6	1.3264	2433.6	0.1048	1.4742
41	2022	2013	43.7	1.3672	3236.9	0.1615	1.6928
61	958	956	48.1	1.4342	3956.4	0.1824	1.7098
81	295	295	50.4	1.5066	2887.7	0.1425	1.1376
101	10	10	43.2	1.6039	294.9	0.0377	0.1580

FILE= BBHG
ANGLE= 90
VERT ANG= 0

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
14	4889	4882	46.3	1.4958	2003.6	0.0675	0.9335
32	29179	29148	51.1	1.5216	3533.6	0.1182	1.3529
51	50550	50478	51.2	1.5234	3800.3	0.1367	1.4523
70	66620	66515	50.4	1.5180	3879.9	0.1442	1.5272
90	79856	79708	49.8	1.5128	3891.3	0.1528	1.5707
110	92777	92611	49.3	1.5071	3916.0	0.1599	1.6081
130	102971	102784	48.6	1.5030	3714.5	0.1567	1.5734
145	55137	55029	48.7	1.5062	3716.9	0.1530	1.5644

FILE= BBHG
ANGLE= 45
VERT ANG= 0

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
15	4030	4023	46.7	1.4896	2193.6	0.0683	1.0038
32	28023	27982	51.1	1.5209	3552.1	0.1155	1.3586
51	50309	50233	51.2	1.5240	3739.1	0.1342	1.4263
70	67296	67186	50.5	1.5215	3663.4	0.1440	1.4354
90	80422	80297	50.2	1.5176	3915.5	0.1540	1.5523
110	93246	93108	49.4	1.5119	3802.8	0.1577	1.5553
130	102624	102475	48.6	1.5056	3658.2	0.1570	1.5469
145	54439	54356	48.6	1.5051	3703.1	0.1562	1.5702

FILE= BBHG
ANGLE= 0
VERT ANG= 0

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
14	4664	4649	47.4	1.4878	1989.6	0.0571	0.8858
32	29092	29029	51.3	1.5204	3430.3	0.1016	1.3028
51	51551	51443	51.4	1.5272	3536.2	0.1170	1.3372
70	68941	68825	51.5	1.5274	3868.0	0.1314	1.4593
90	82601	82461	51.4	1.5273	4102.0	0.1441	1.5535
110	96665	96525	51.2	1.5265	4106.9	0.1517	1.5684
130	105743	105572	50.2	1.5199	3967.8	0.1546	1.5756
145	56167	56078	50.1	1.5182	4012.8	0.1561	1.5995

FILE= BBHG
ANGLE= 135
VERT ANG= 0

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
15	4086	4079	46.4	1.4894	1858.4	0.0589	0.8632
32	27954	27921	50.9	1.5216	3142.4	0.1070	1.2112
51	49847	49780	51.4	1.5247	3635.6	0.1266	1.3759
70	67564	67466	51.1	1.5217	3959.6	0.1387	1.5165
90	81719	81592	50.7	1.5194	4073.6	0.1473	1.5831
110	94394	94257	50.1	1.5166	3860.2	0.1525	1.5400
130	106126	105939	49.6	1.5137	3930.2	0.1546	1.5961
145	56604	56511	49.0	1.5110	3730.9	0.1557	1.5509

FILE= BBHG
ANGLE= 0
VERT ANG= 90

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
21	2204	2200	53.0	1.5384	3445.6	0.0951	1.2278
41	1397	1391	55.0	1.5620	4013.2	0.1404	1.3262
61	743	741	54.9	1.5644	4621.7	0.1399	1.5354
81	241	241	54.6	1.5696	3371.3	0.1391	1.1319
101	10	10	43.2	1.6039	294.9	0.0377	0.1580

APPENDIX E

LISTING OF VARIOGRAMS GENERATED BY MAXIMUM DIFFERENCE METHOD

These variograms were created from the BEXG dataset. Any sample pair difference (regardless of grades), at a given lag, was examined and if the absolute difference exceeded the maximum value shown for each variogram, it was not used in the computation of $\gamma(h)$.

Results show that the only variograms which showed the 135° anisotropy were the ones that used all sample pairs. This was determined by examining the lowest first lag value. In most of the other cases, the lowest value of γ at the first lag was either in the 0° (N-S) or the 45° direction.

Note that approximately 50% of all sample pairs had absolute differences of less than 0.020 opt. (raw grades were multiplied by 100. to produce these reports). Almost 90% of all pairs had absolute differences of less than 0.080 opt. For horizontal directions, the lowest values of $\gamma(1)$ for the variogram that used all sample pairs was in the 135° direction for actual, lognormal and relative variograms. In the other cases, the lognormal variogram consistently indicated that anisotropy was in the 45° direction. The actual and relative variograms showed lowest $\gamma(1)$ in the N-S direction for the lowest grade differences and varied for the next 2 variograms. Only the actual variogram with maximum pair differences of 0.080 opt. showed the 135° direction as lowest. Lowest semi-variogram values at the first lag for each horizontal variogram are underlined in the listings.

Notice also how much lower the indicated variance of the data is when the maximum pair differences decrease. The relative variogram sills decrease from about 1.5 to less than 0.4 for sample pairs which vary by less than 0.08 opt. -- this represents nearly 90% of all pairs.

FILE= BEXG - MAXIMUM SAMPLE PAIR DIFFERENCE = 2.0
ANGLE= 90
VERT ANG= 0

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
54	1122	1117	27.3	1.3564	58.9	0.0409	0.0787
105	2289	2279	27.4	1.3605	59.7	0.0340	0.0793
146	2123	2114	27.5	1.3623	61.6	0.0391	0.0816

FILE= BEXG - MAXIMUM SAMPLE PAIR DIFFERENCE = 2.0
ANGLE= 45
VERT ANG= 0

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
67	1103	1099	27.7	1.3612	59.4	0.0363	0.0771
106	1827	1820	26.3	1.3410	59.1	0.0387	0.0857
145	2098	2088	27.5	1.3603	61.1	0.0401	0.0806

FILE= BEXG - MAXIMUM SAMPLE PAIR DIFFERENCE = 2.0
ANGLE= 0
VERT ANG= 0

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
54	1283	1276	28.7	1.3725	57.6	0.0397	0.0699
106	2471	2461	27.1	1.3507	59.2	0.0403	0.0806
148	1992	1984	28.3	1.3724	58.1	0.0351	0.0727

FILE= BEXG - MAXIMUM SAMPLE PAIR DIFFERENCE = 2.0
ANGLE= 135
VERT ANG= 0

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
66	1216	1209	27.6	1.3581	60.8	0.0399	0.0798
108	1768	1762	27.7	1.3584	60.3	0.0396	0.0785
145	2104	2099	28.7	1.3769	60.3	0.0362	0.0734

FILE= BEXG - MAXIMUM SAMPLE PAIR DIFFERENCE = 2.0
ANGLE= 0
VERT ANG= 90

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
20	457	456	28.8	1.3597	50.7	0.0276	0.0612
40	285	284	28.0	1.3606	54.5	0.0312	0.0693
60	148	147	25.1	1.3057	49.6	0.0363	0.0790

FILE= BEXG - MAXIMUM SAMPLE PAIR DIFFERENCE = 3.5
ANGLE= 90
VERT ANG= 0

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
55	1564	1558	29.4	1.3783	147.2	0.0694	0.1700
105	3173	3158	29.9	1.3846	150.0	0.0641	0.1683
147	3013	2994	29.7	1.3839	155.2	0.0706	0.1761

FILE= BEXG - MAXIMUM SAMPLE PAIR DIFFERENCE = 3.5
ANGLE= 45
VERT ANG= 0

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
67	1495	1485	30.2	1.3872	143.8	0.0610	0.1575
106	2497	2489	28.6	1.3678	146.0	0.0665	0.1778
145	3007	2989	30.1	1.3848	158.4	0.0705	0.1753

FILE= BEXG - MAXIMUM SAMPLE PAIR DIFFERENCE = 3.5
ANGLE= 0
VERT ANG= 0

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
54	1751	1743	30.8	1.3901	141.5	0.0707	0.1490
106	3353	3336	29.5	1.3786	143.2	0.0633	0.1640
148	2831	2819	30.6	1.3926	154.2	0.0670	0.1652

FILE= BEXG - MAXIMUM SAMPLE PAIR DIFFERENCE = 3.5
ANGLE= 135
VERT ANG= 0

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
66	1706	1698	30.1	1.3810	155.0	0.0743	0.1714
107	2451	2437	29.9	1.3828	149.8	0.0674	0.1674
145	2997	2982	30.7	1.3971	156.9	0.0674	0.1663

FILE= BEXG - MAXIMUM SAMPLE PAIR DIFFERENCE = 3.5
ANGLE= 0
VERT ANG= 90

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
20	593	591	32.8	1.4055	124.2	0.0407	0.1157
40	372	370	30.7	1.3934	134.5	0.0492	0.1423
60	222	220	30.0	1.3736	166.9	0.0552	0.1857

FILE= BEXG - MAXIMUM SAMPLE PAIR DIFFERENCE = 5.0
ANGLE= 90
VERT ANG= 0

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
55	1758	1751	31.4	1.3978	231.0	0.0814	0.2347
105	3717	3695	32.0	1.4034	258.3	0.0854	0.2525
146	3569	3548	31.9	1.4037	269.7	0.0920	0.2647

FILE= BEXG - MAXIMUM SAMPLE PAIR DIFFERENCE = 5.0
ANGLE= 45
VERT ANG= 0

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
67	1710	1697	32.2	1.4062	239.4	0.0767	0.2316
106	2891	2881	30.7	1.3871	246.2	0.0866	0.2610
145	3530	3507	32.1	1.4026	267.0	0.0920	0.2598

FILE= BEXG - MAXIMUM SAMPLE PAIR DIFFERENCE = 5.0
ANGLE= 0
VERT ANG= 0

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
54	2029	2020	33.2	1.4124	243.0	0.0872	0.2206
106	3889	3866	31.6	1.3976	245.1	0.0832	0.2460
148	3336	3317	32.4	1.4087	266.3	0.0911	0.2532

FILE= BEXG - MAXIMUM SAMPLE PAIR DIFFERENCE = 5.0
ANGLE= 135
VERT ANG= 0

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
66	1944	1935	32.3	1.4004	247.1	0.0912	0.2375
107	2852	2832	31.8	1.3997	253.4	0.0878	0.2502
145	3521	3500	32.7	1.4143	267.3	0.0887	0.2499

FILE= BEXG - MAXIMUM SAMPLE PAIR DIFFERENCE = 5.0
ANGLE= 0
VERT ANG= 90

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
20	652	649	34.7	1.4249	195.4	0.0493	0.1626
40	425	422	32.7	1.4141	232.3	0.0614	0.2174
60	260	256	31.5	1.3926	277.9	0.0716	0.2803

FILE= BEXG - MAXIMUM SAMPLE PAIR DIFFERENCE = 8.0
ANGLE= 90
VERT ANG= 0

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
55	1991	1984	34.2	1.4196	441.0	0.1057	0.3770
105	4184	4157	34.5	1.4222	462.8	0.1099	0.3895
146	4099	4077	34.8	1.4248	498.8	0.1199	0.4113

FILE= BEXG - MAXIMUM SAMPLE PAIR DIFFERENCE = 8.0
ANGLE= 45
VERT ANG= 0

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
66	1924	1911	34.9	1.4276	438.5	0.0990	0.3606
106	3306	3294	33.8	1.4121	468.9	0.1117	0.4095
144	3993	3969	34.8	1.4229	463.4	0.1155	0.3836

FILE= BEXG - MAXIMUM SAMPLE PAIR DIFFERENCE = 8.0
ANGLE= 0
VERT ANG= 0

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
55	2294	2278	36.0	1.4340	453.0	0.1095	0.3488
106	4429	4402	34.6	1.4200	459.3	0.1103	0.3837
148	3827	3806	35.3	1.4321	488.1	0.1131	0.3912

FILE= BEXG - MAXIMUM SAMPLE PAIR DIFFERENCE = 8.0
ANGLE= 135
VERT ANG= 0

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
66	2175	2165	34.9	1.4207	435.7	0.1122	0.3584
107	3232	3208	34.5	1.4222	461.4	0.1088	0.3872
145	4014	3990	35.4	1.4350	482.8	0.1125	0.3843

FILE= BEXG - MAXIMUM SAMPLE PAIR DIFFERENCE = 8.0
ANGLE= 0
VERT ANG= 90

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
20	703	700	37.5	1.4460	321.2	0.0587	0.2283
40	475	471	35.8	1.4371	423.4	0.0802	0.3310
60	295	290	35.0	1.4239	478.9	0.0865	0.3900

FILE= BEXG - ALL SAMPLE PAIRS
ANGLE= 90
VERT ANG= 0

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
56	2278	2269	46.8	1.4751	3665.6	0.1523	1.6755
105	4759	4730	44.8	1.4678	2984.2	0.1606	1.4886
137	2215	2210	46.2	1.4765	3105.2	0.1819	1.4520

FILE= BEXG - ALL SAMPLE PAIRS
ANGLE= 45
VERT ANG= 0

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
67	2172	2159	45.4	1.4727	3070.3	0.1475	1.4878
106	3781	3769	45.3	1.4629	3344.6	0.1646	1.6322
137	2586	2576	45.5	1.4742	2985.6	0.1631	1.4431

FILE= BEXG - ALL SAMPLE PAIRS
ANGLE= 0
VERT ANG= 0

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
55	2575	2559	46.7	1.4829	2991.9	0.1445	1.3695
106	5067	5038	45.9	1.4704	3198.2	0.1608	1.5196
140	1923	1914	49.1	1.4947	3686.8	0.1752	1.5318

FILE= BEXG - ALL SAMPLE PAIRS
ANGLE= 135
VERT ANG= 0

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
66	2408	2395	43.9	1.4626	2401.2	0.1425	1.2486
108	3704	3676	46.2	1.4725	3449.1	0.1627	1.6171
138	2681	2671	45.7	1.4799	2899.3	0.1732	1.3868

FILE= BEXG - ALL SAMPLE PAIRS
ANGLE= 0
VERT ANG= 90

LAG	N	LN	AR MEAN	LG MEAN	VG	LOG VG	REL VG
41	530	526	45.7	1.4856	2779.5	0.1068	1.3308
61	337	332	44.3	1.4741	2481.4	0.1203	1.2622
81	179	174	43.3	1.4663	1915.6	0.1115	1.0237

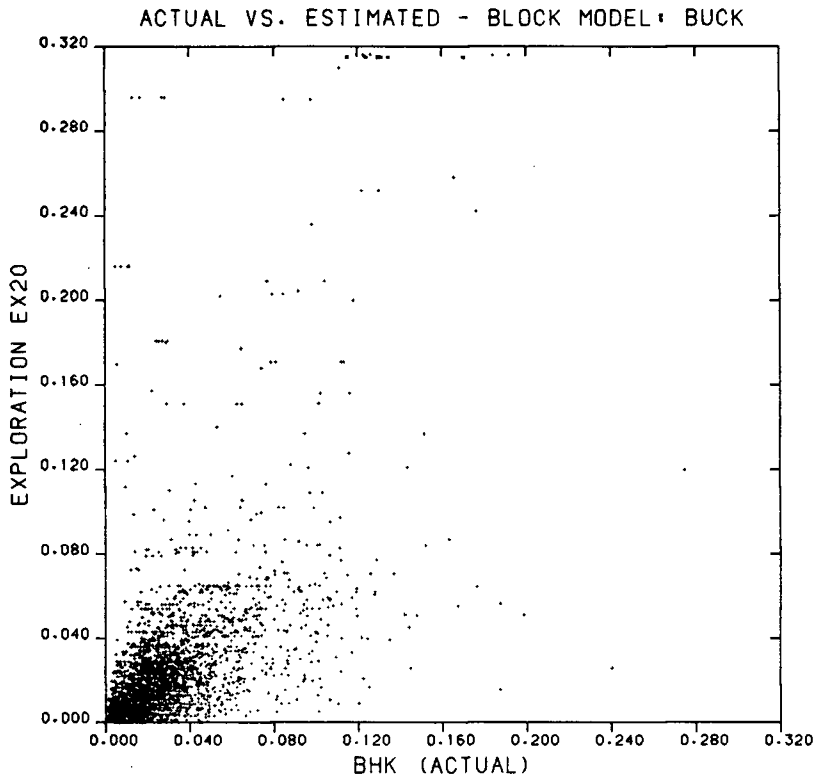
APPENDIX F

SCATTERGRAMS

LEGEND:

	Block Models			Method
BUCK	20' Blocks, no outline.		BHK	Blasthole Kriging -- "Actual".
BUCKG	20' Blocks, with "ore zone" outline.	or	EX20 EX60	Exploration Polygon Weighted (20' & 60')
BUCK60	60' Blocks, no outline.		ID10 ID5 ID3	Inverse Distance to the indicated power.
BUCK60G	60' Blocks, with "ore zone" outline.		ID2 ID1 ID0	
			KRIG	Exploration Kriged Estimate.

note: results from conditional probability cannot be compared on a block by block basis using scattergrams.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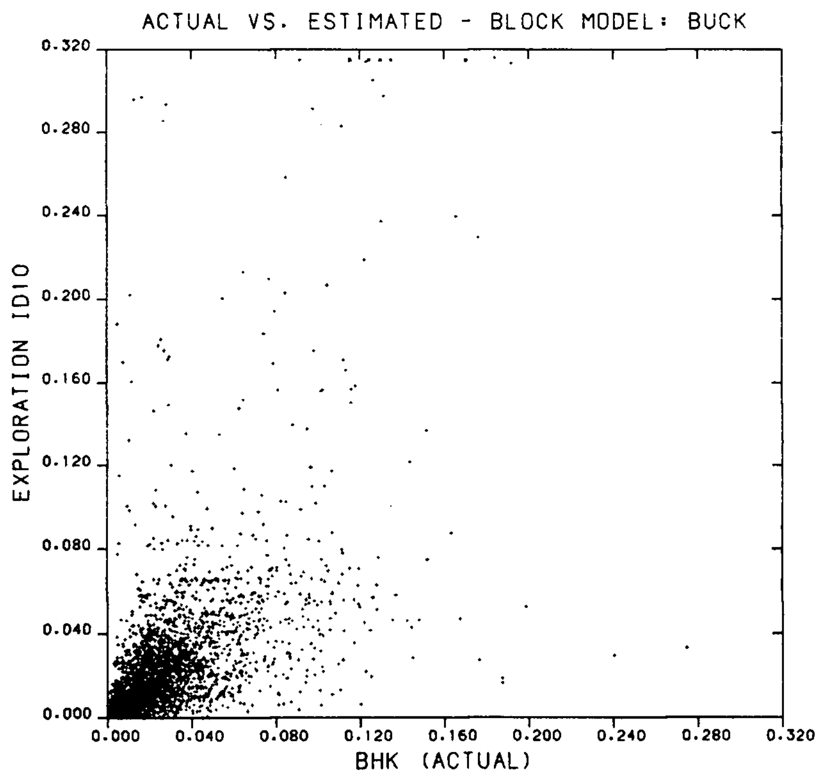
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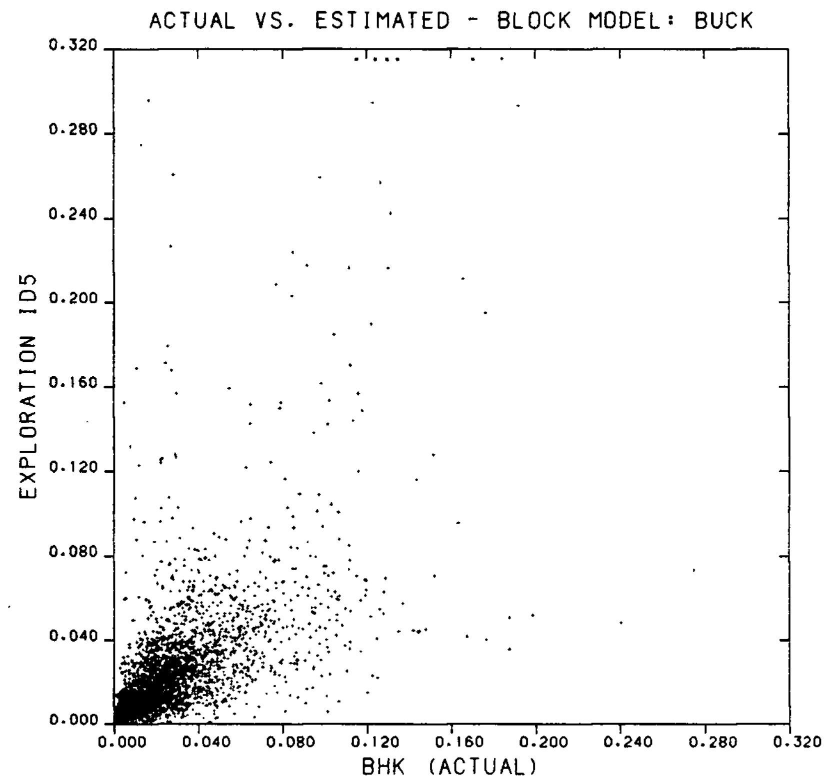
ACTUAL VS. ESTIMATED - BLOCK MODEL: BUCK
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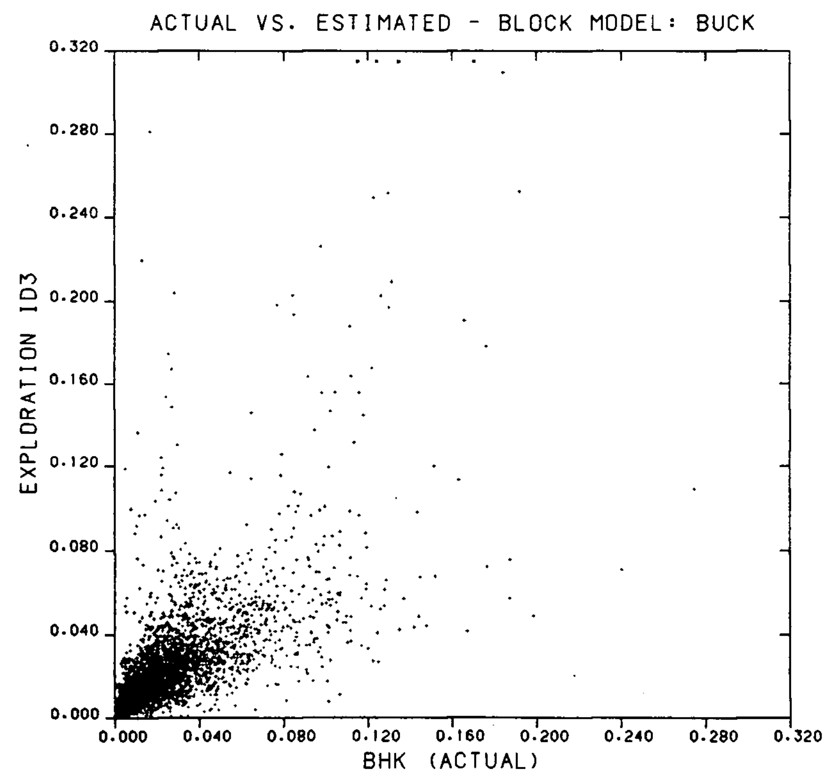
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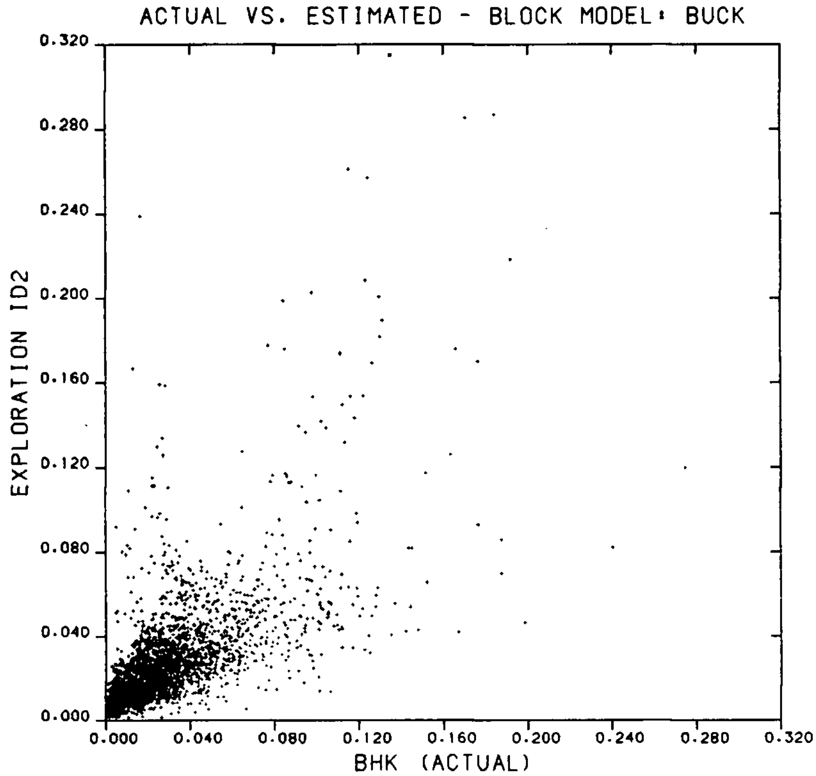

ACTUAL VS. ESTIMATED - BLOCK MODEL: BUCK
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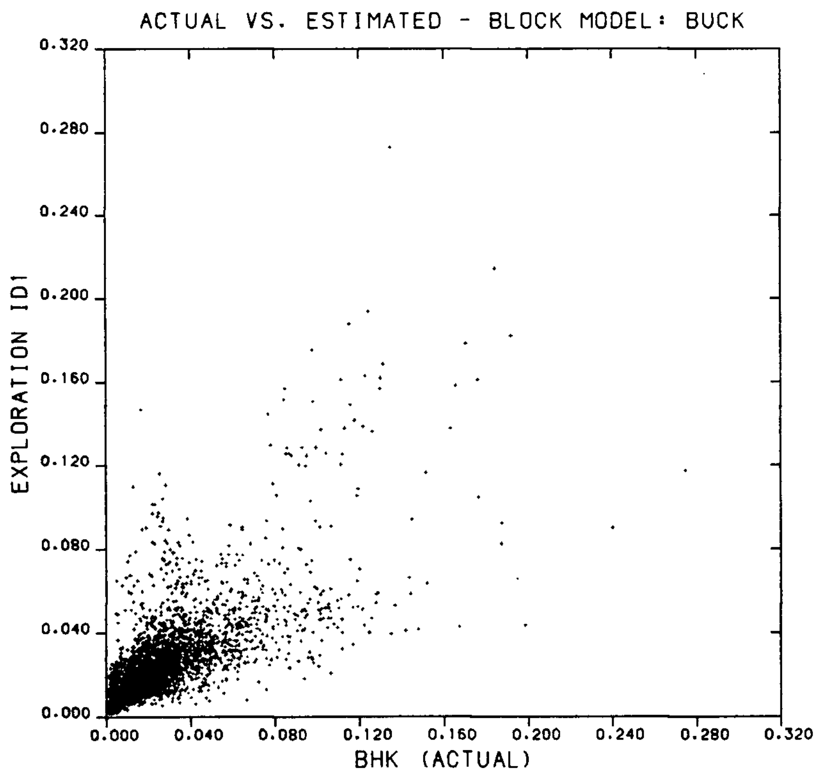

ACTUAL VS. ESTIMATED - BLOCK MODEL: BUCK
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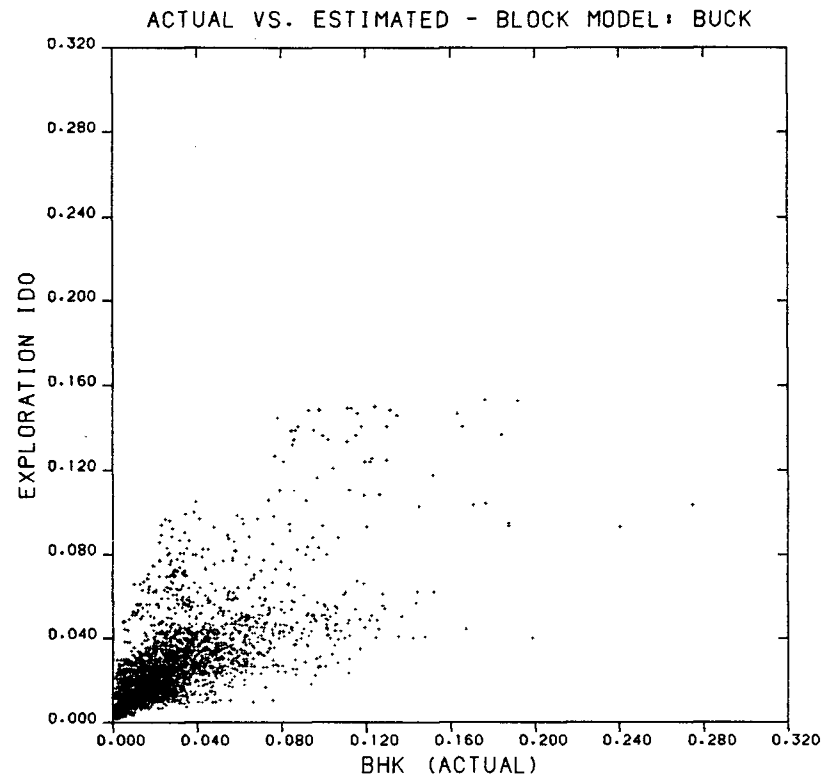
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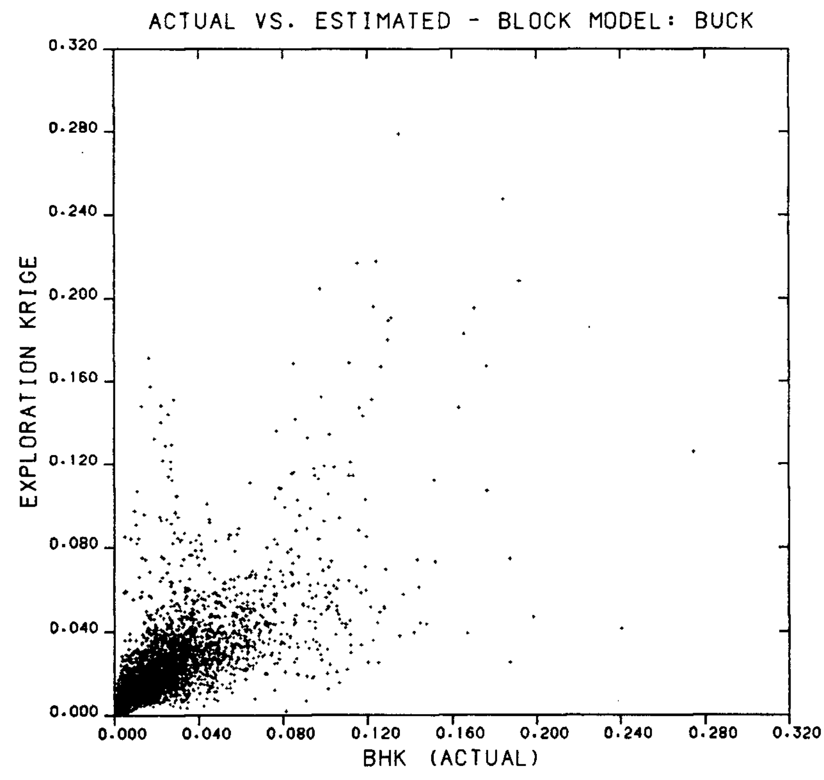
ACTUAL VS. ESTIMATED - BLOCK MODEL: BUCK
EXPLORATION KRIGE
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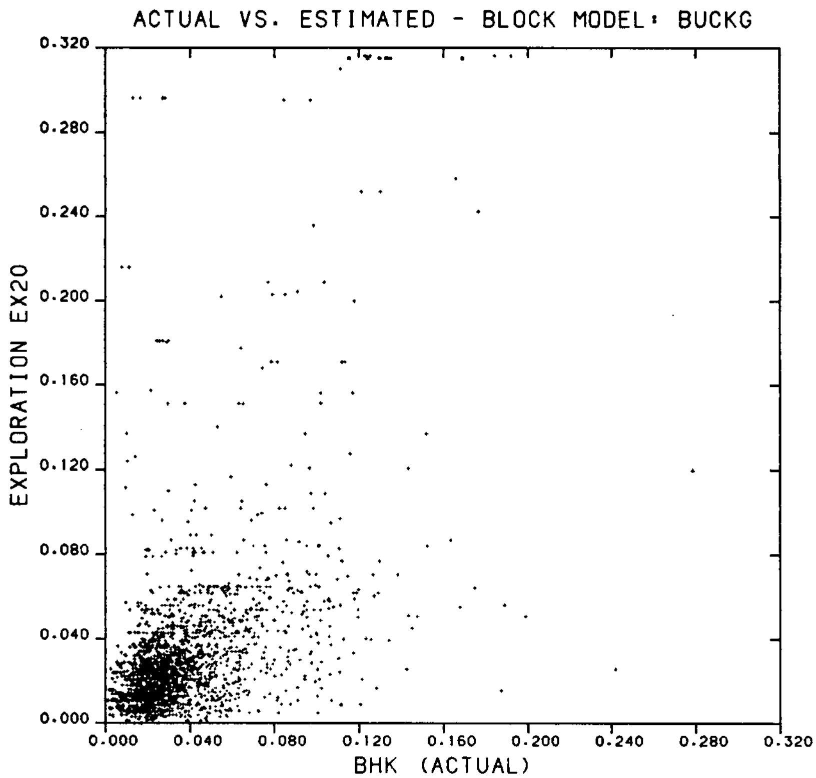
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EXPLORATION EX20
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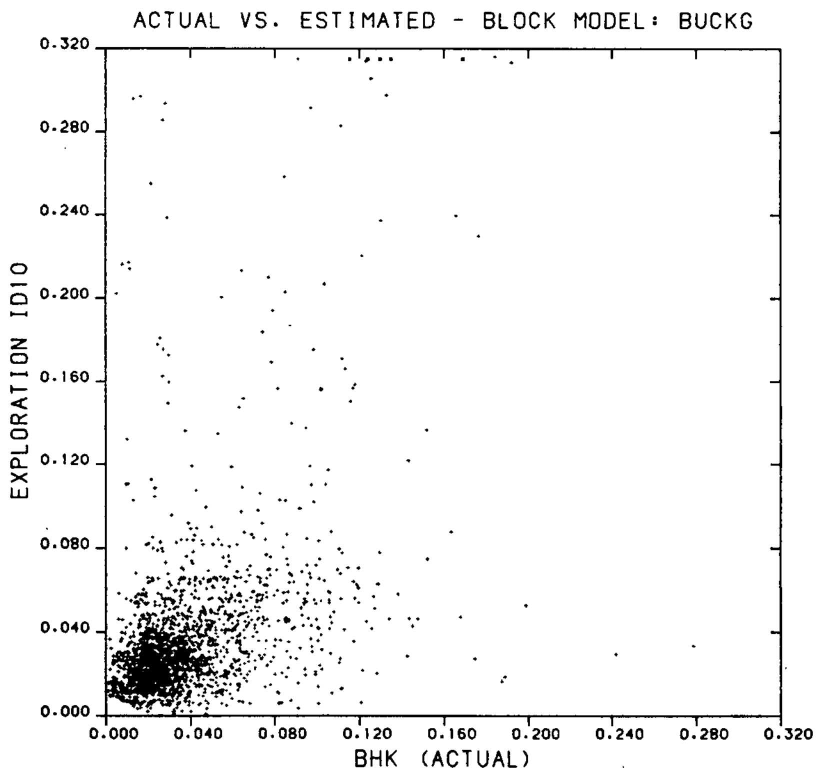
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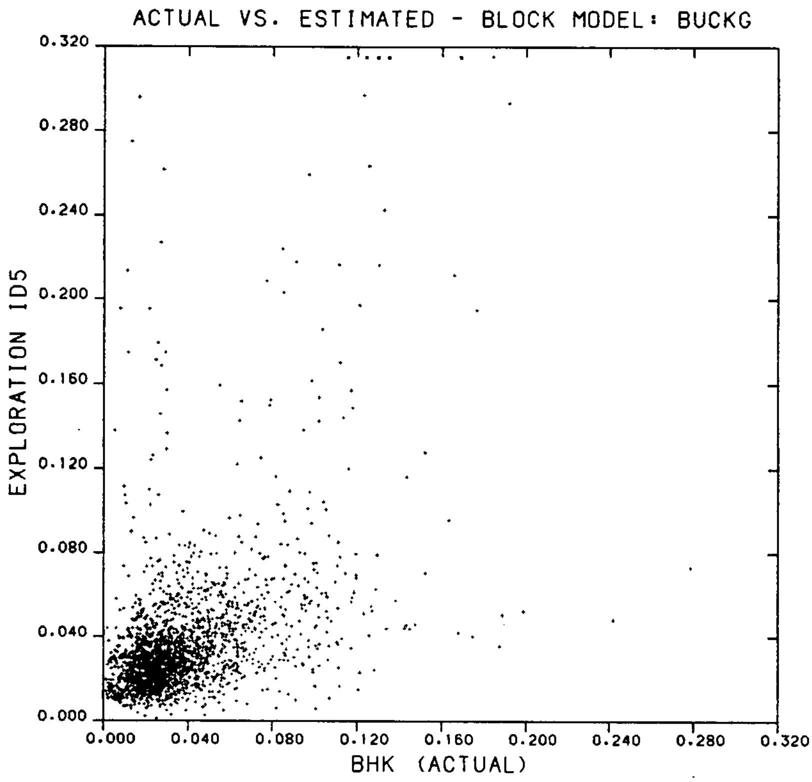
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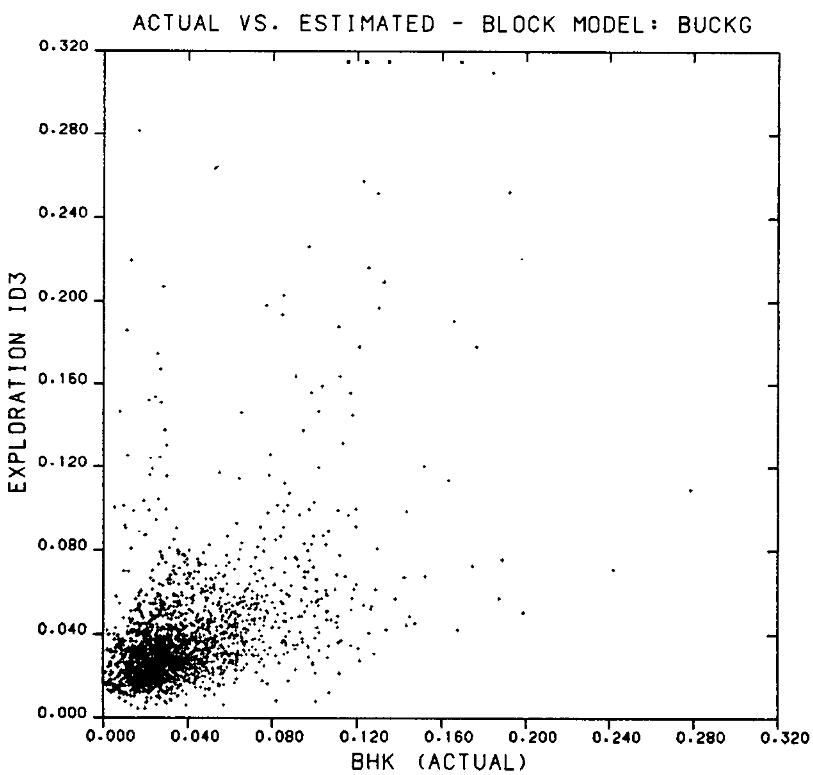
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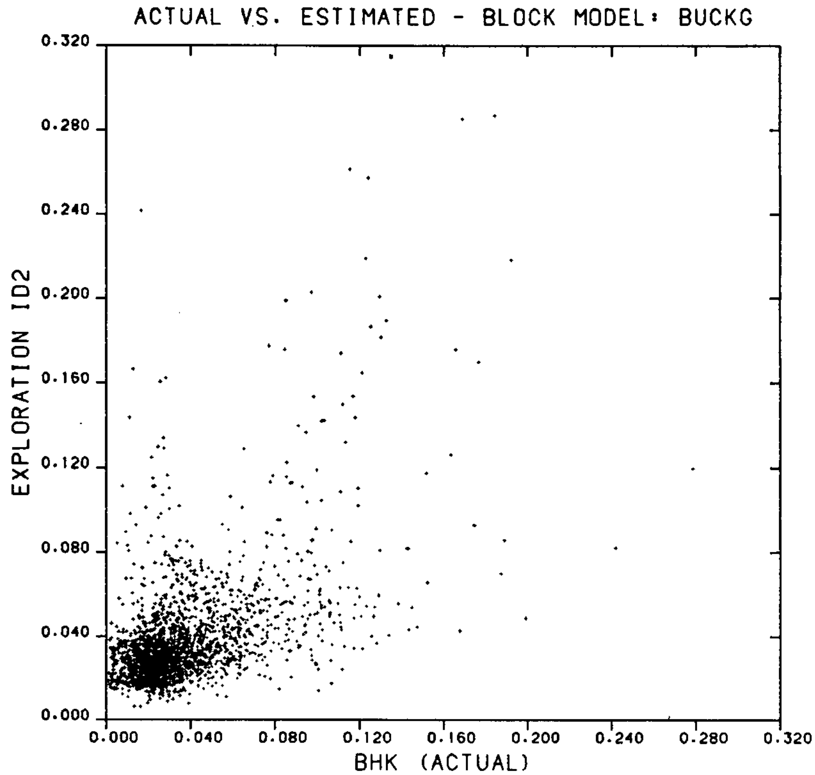
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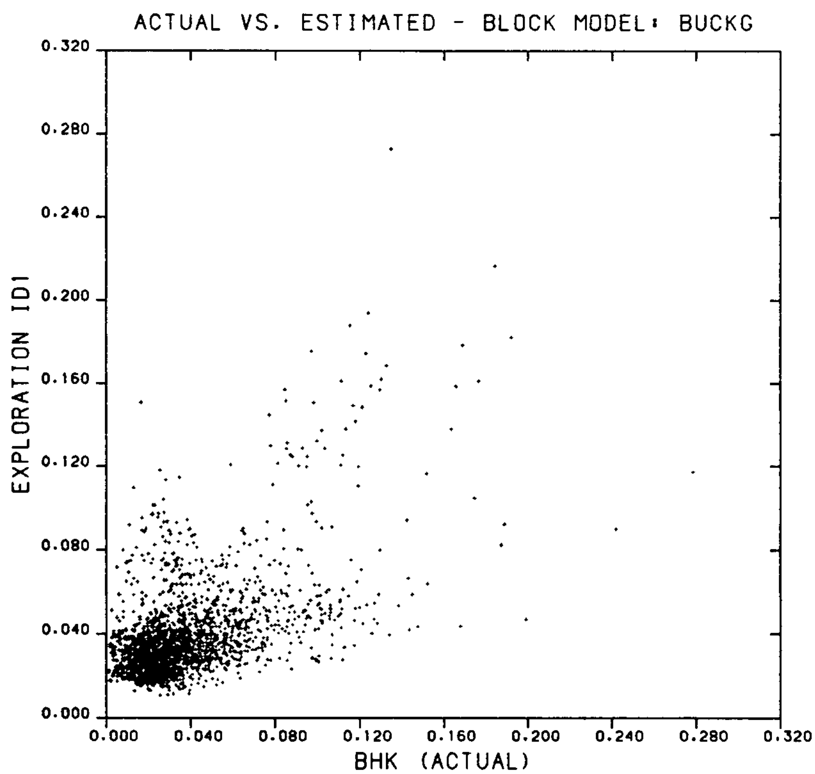
0.320
0.000 0.040 0.080 0.120 0.160 0.200 0.240 0.280 0.320
BHK (ACTUAL)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0.320
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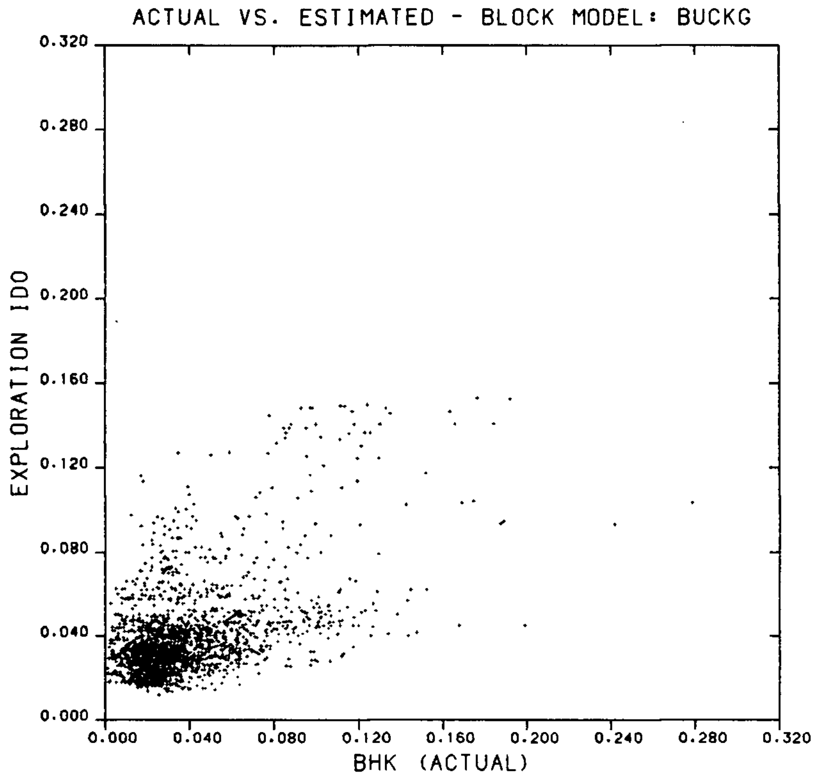
BHK (ACTUAL)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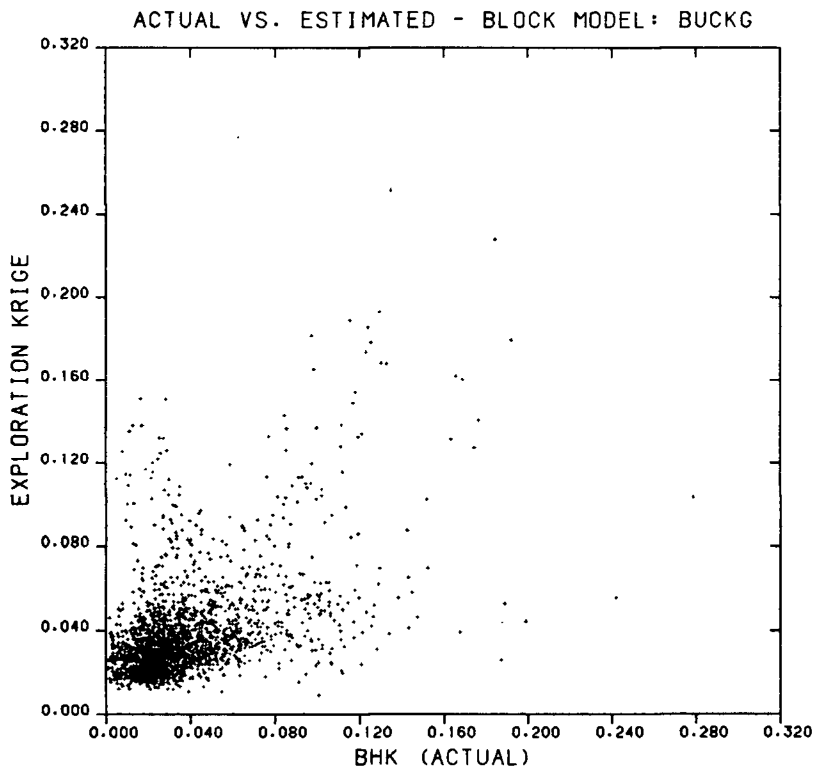
ACTUAL VS. ESTIMATED - BLOCK MODEL: BUCKG
EXPLORATION KRIGE
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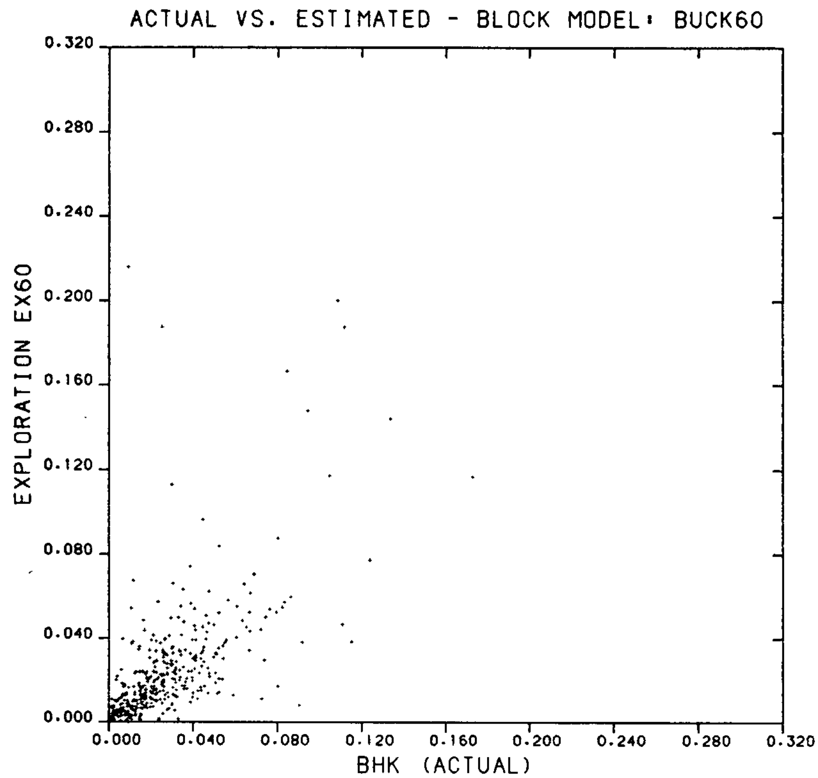
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EXPLORATION EX60
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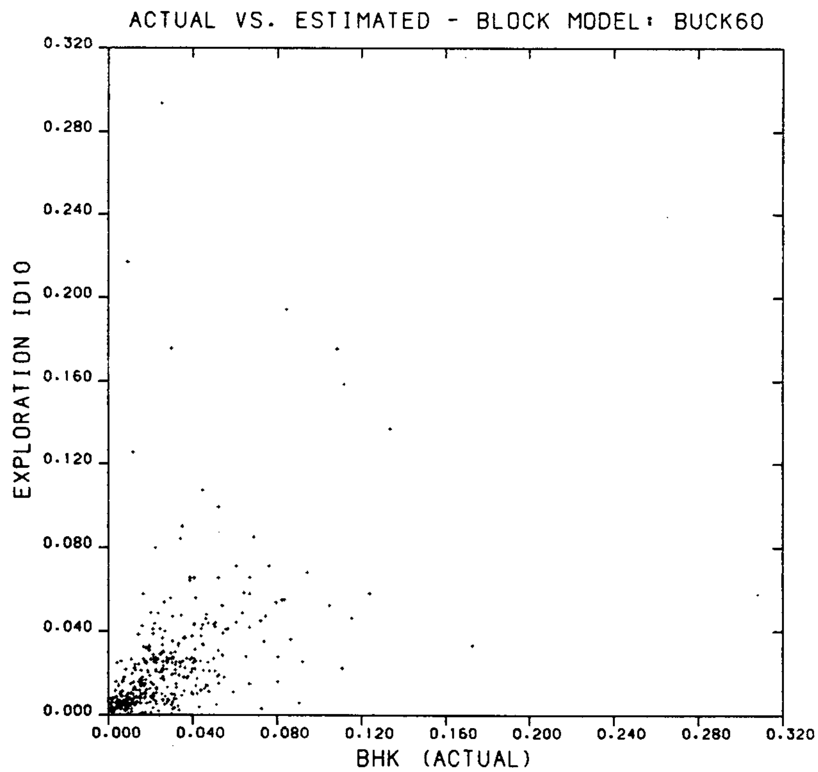
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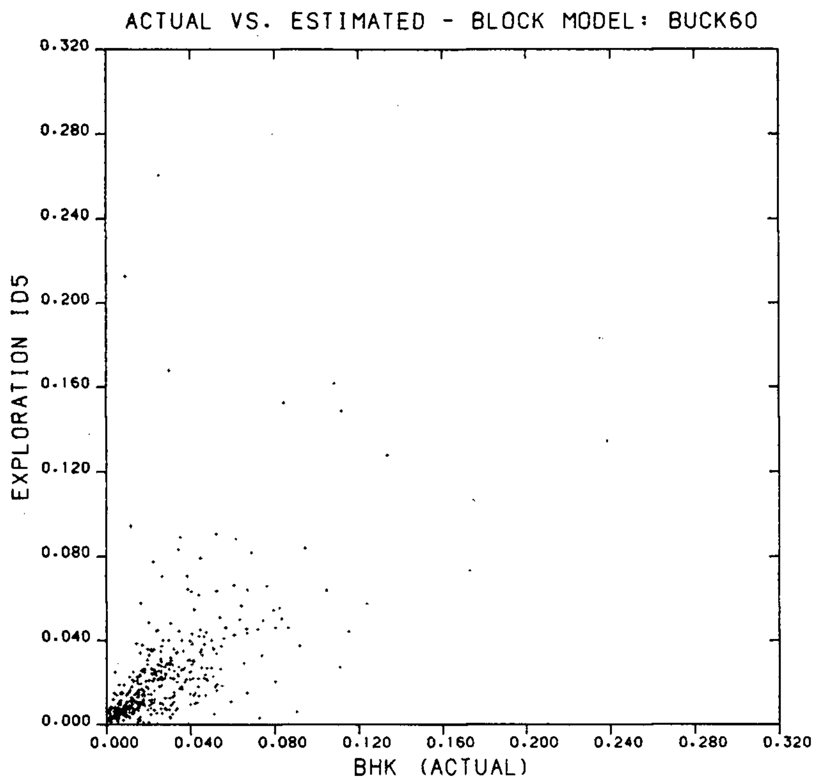
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0.040
0.000
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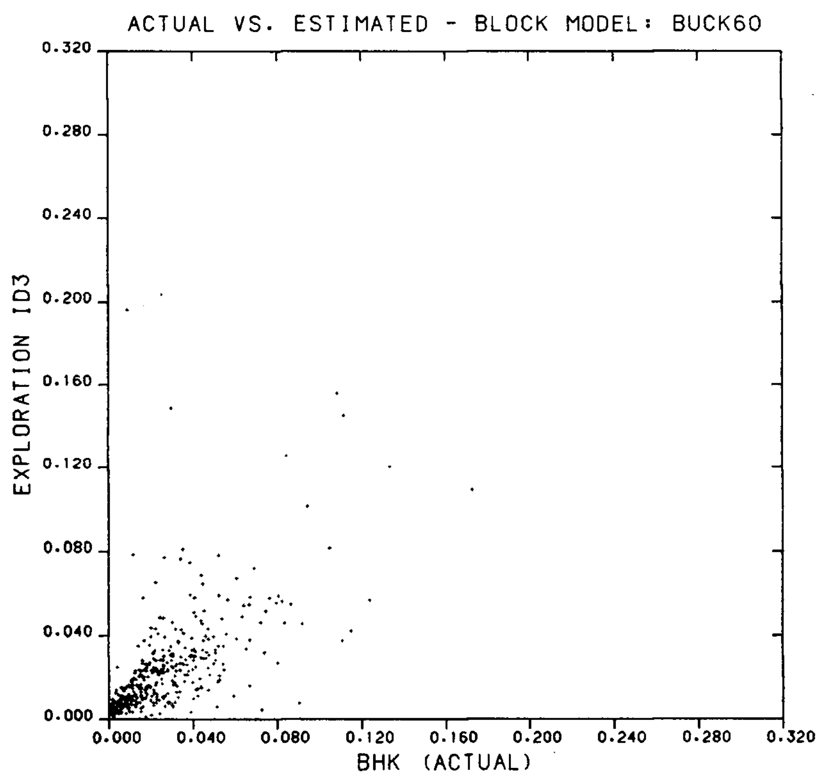
BHK (ACTUAL)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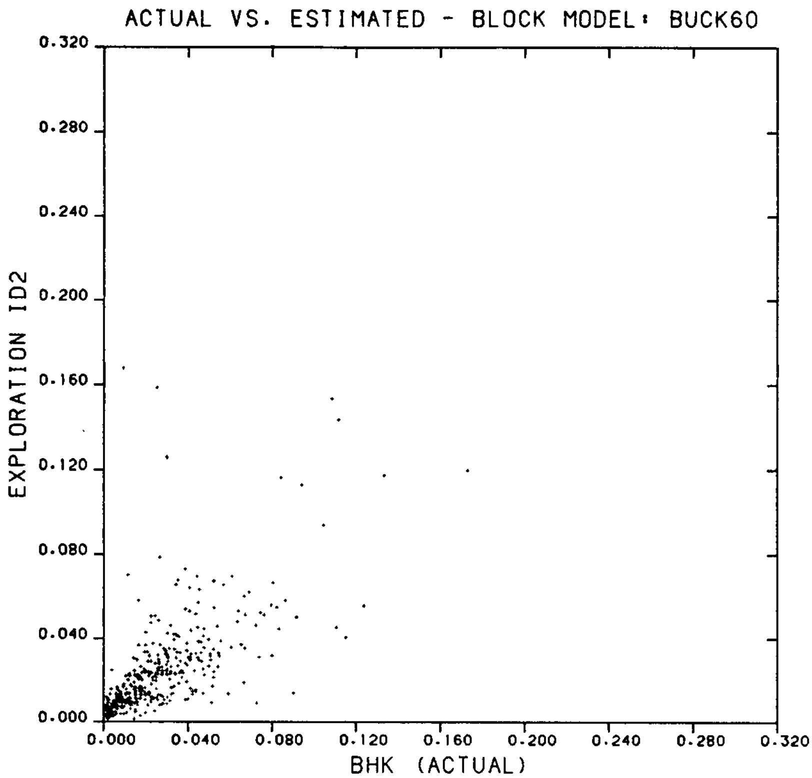
BHK (ACTUAL)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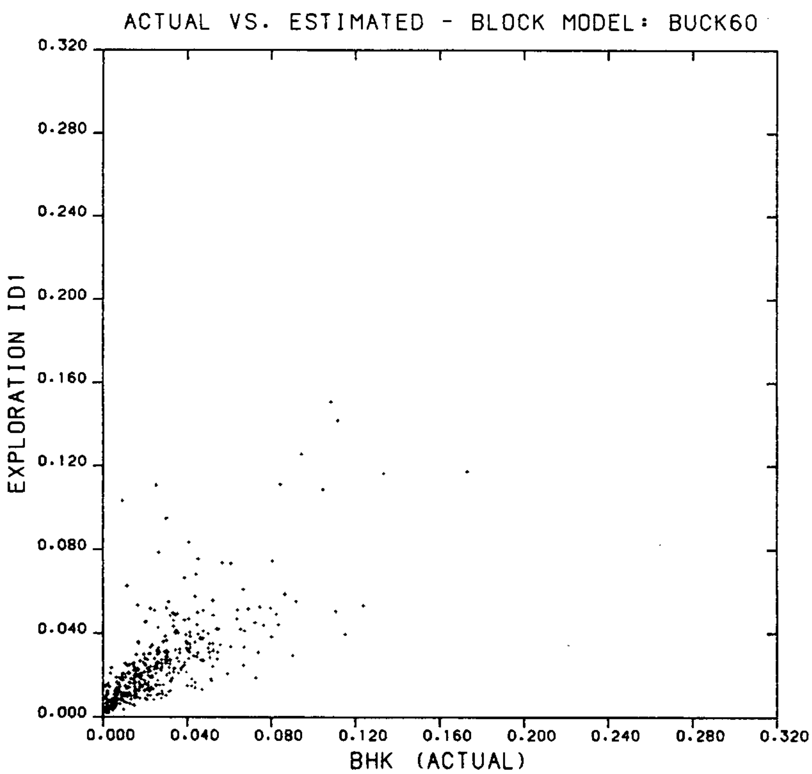
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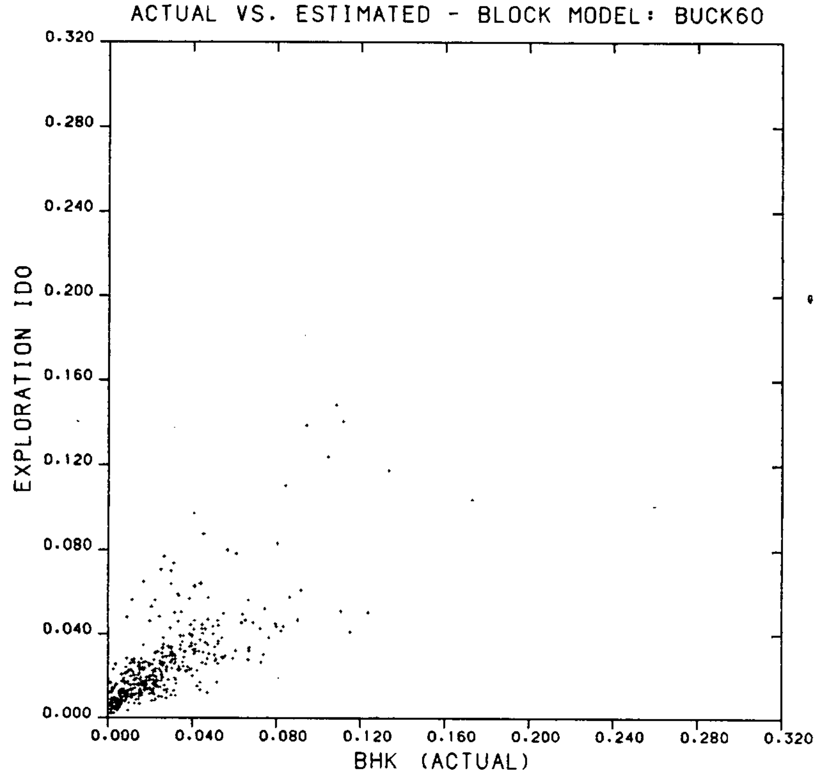
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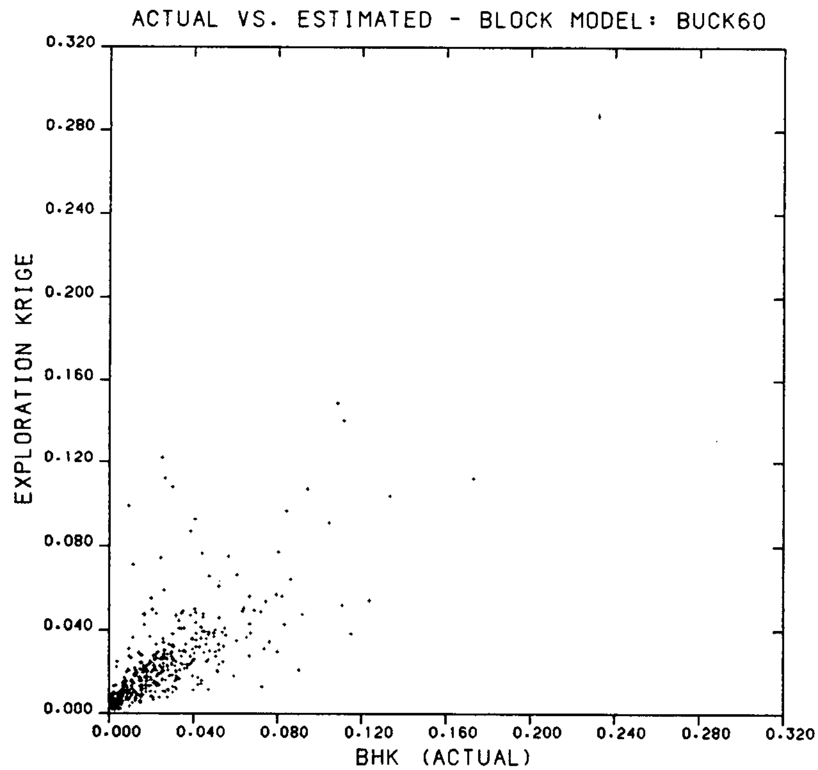
ACTUAL VS. ESTIMATED - BLOCK MODEL: BUCK60
EXPLORATION KRIGE
BHK (ACTUAL)
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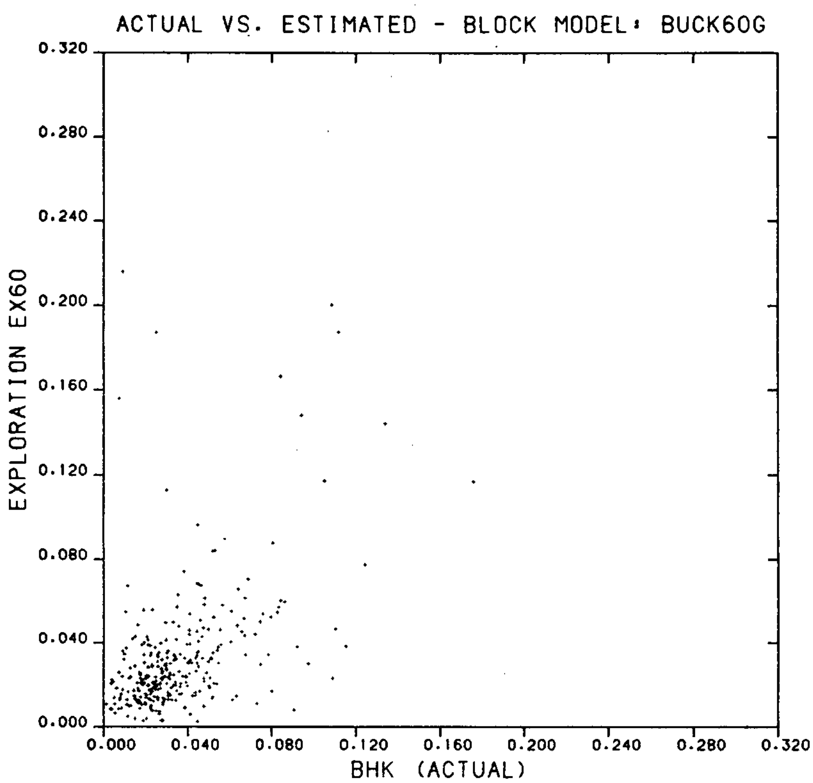
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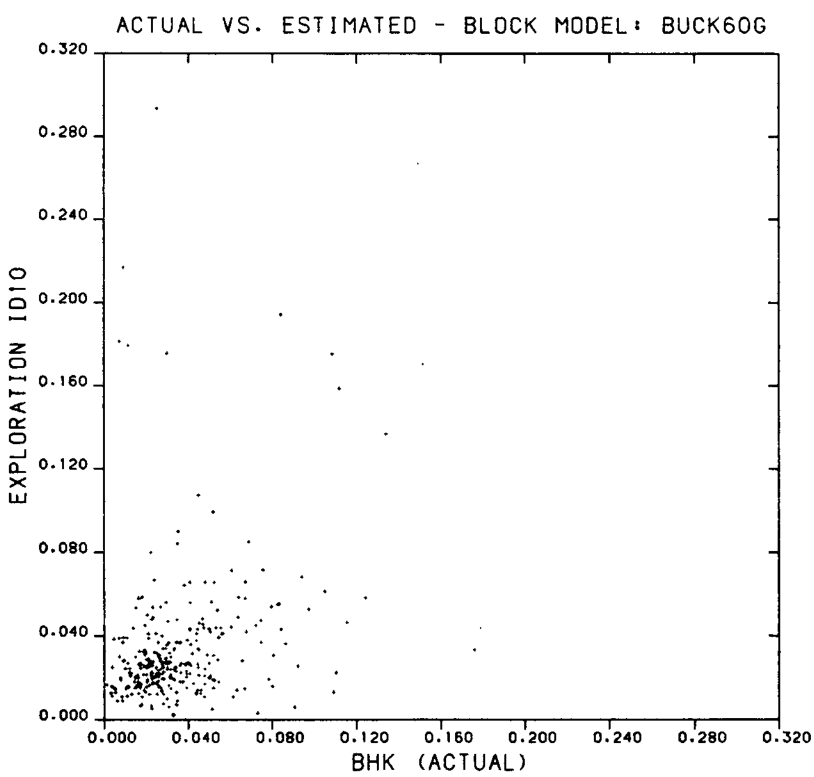
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EXPLORATION ID10
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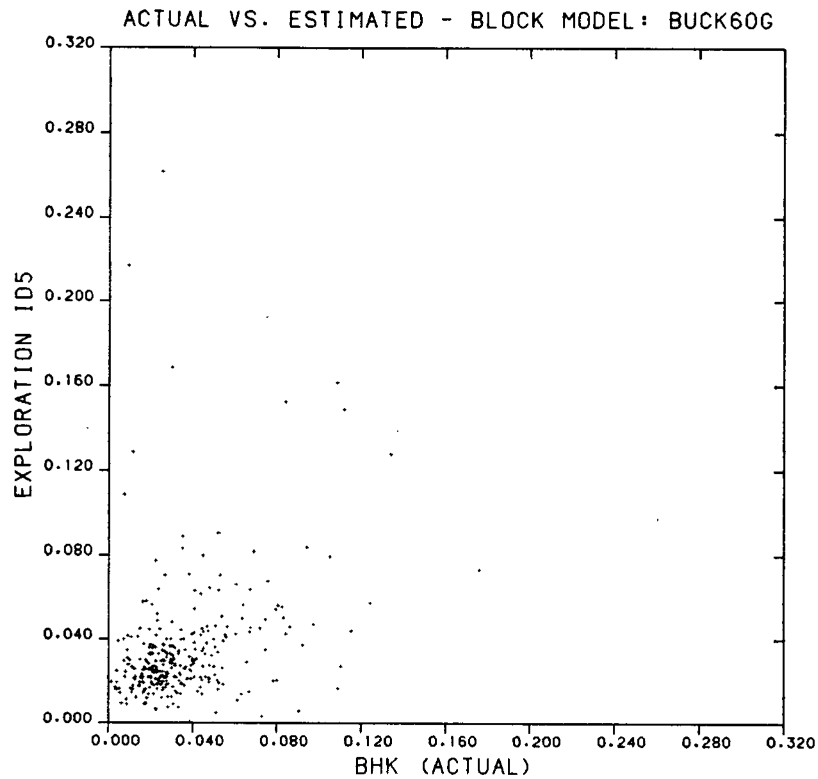
0.320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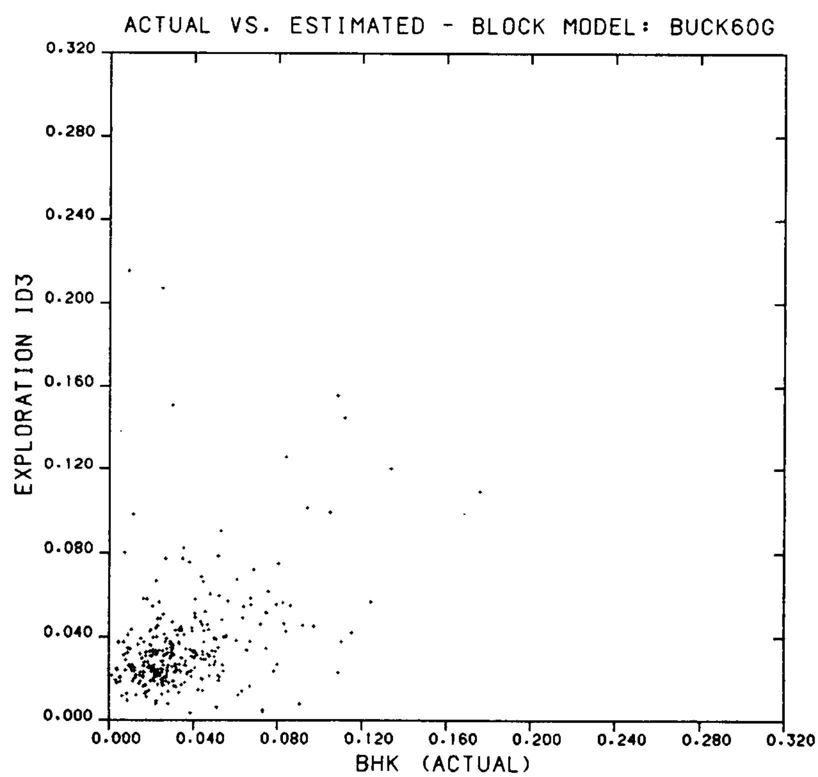
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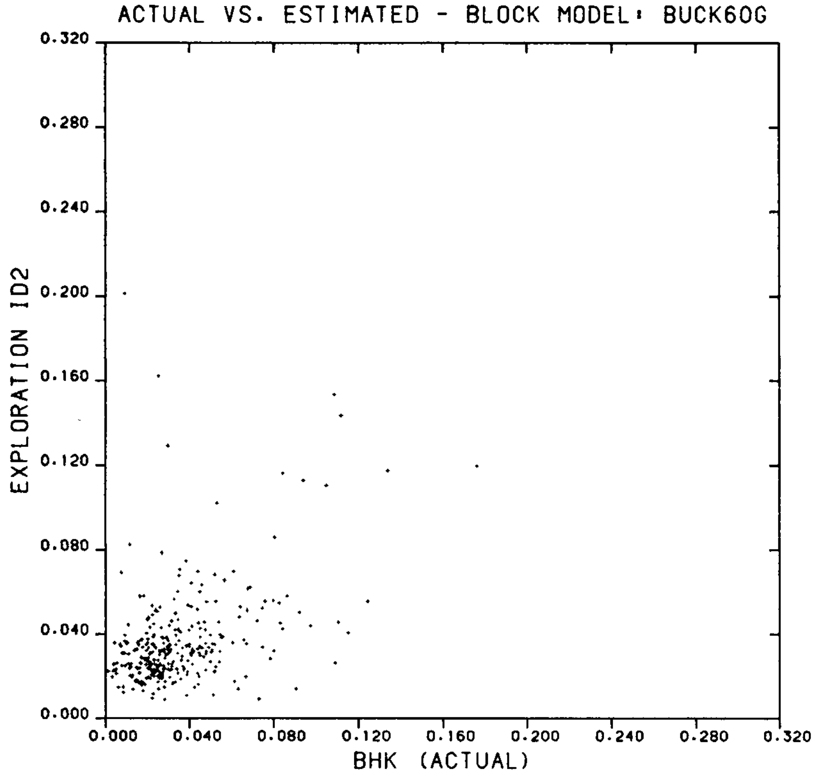
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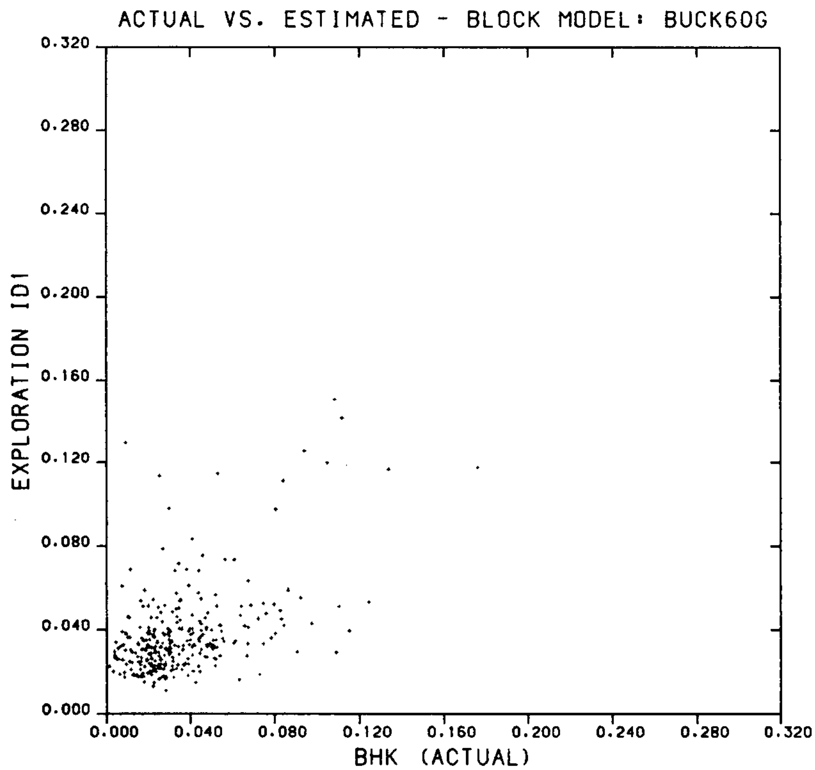
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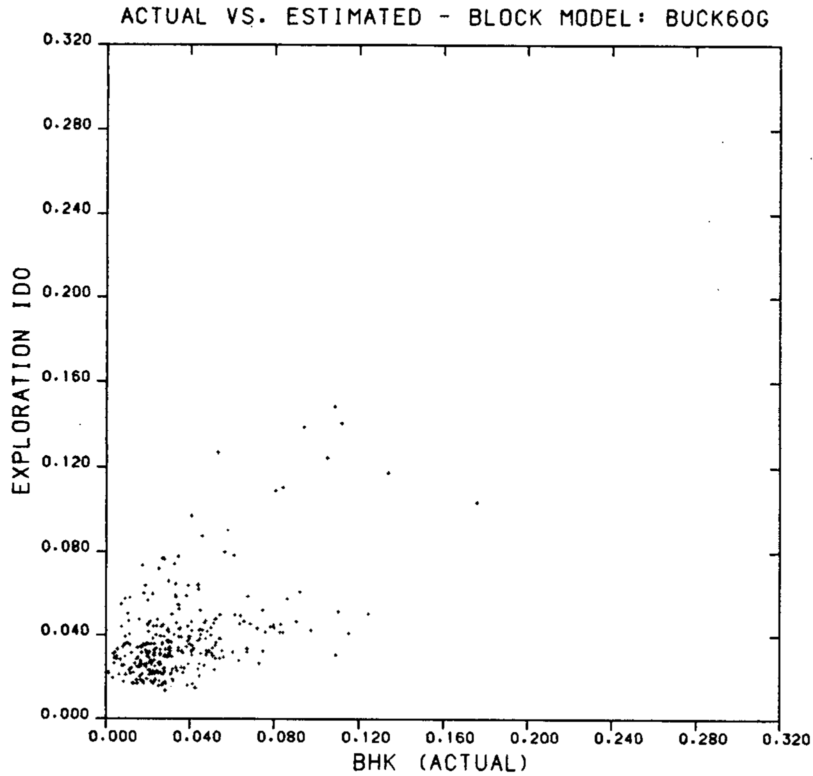
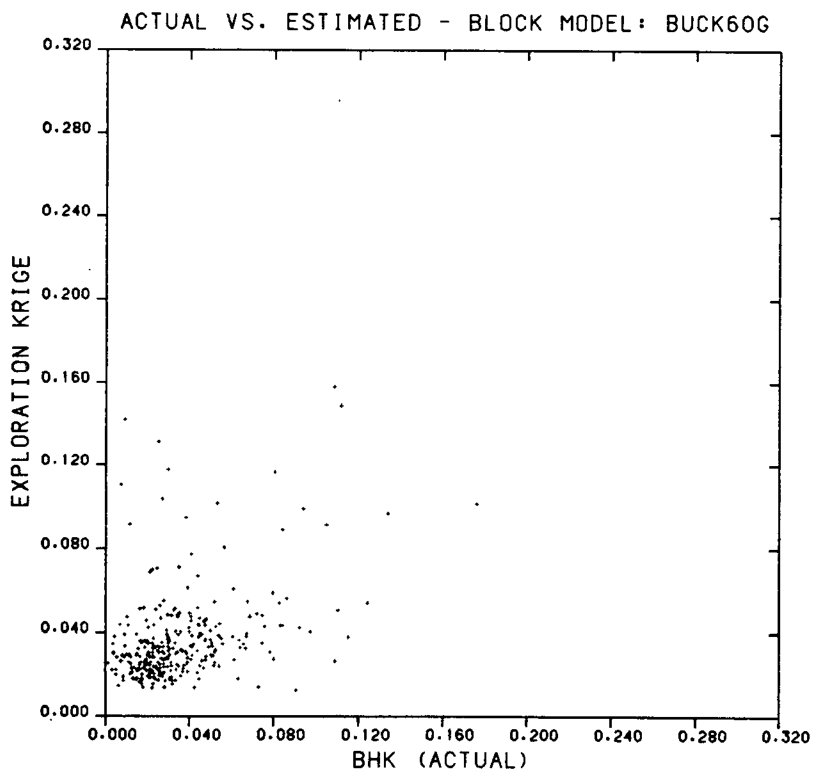
0.320


ACTUAL VS. ESTIMATED - BLOCK MODEL: BUCK60G
EXPLORATION IDO
BHK (ACTUAL)
0.000
0.040
0.080
0.120
0.160
0.200
0.240
0.280
0.320


ACTUAL VS. ESTIMATED - BLOCK MODEL: BUCK60G
EXPLORATION KRIGE
BHK (ACTUAL)
0.000
0.040
0.080
0.120
0.160
0.200
0.240
0.280
0.320