OVERVIEW OF STREAM CHANNEL CONDITIONS

NORTH FORK GARCIA RIVER

by Jack Monschke
16 May 1996

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OVERVIEW OF STREAM CHANNEL CONDITIONS IN THE NORTH FORK GARCIA FROM PRE-1953 TO PRESENT:

Sediment, Large Woody Debris, Riparian Cover/Stream Temp

Submitted by
Jack Monschke
for Coastal Forestlands, Ltd.

16 May, 1996

The purpose of this report is to assess the changes in the North Fork Garcia Watershed, Mendocino County, California, over the span of the past 50 years, specifically focusing on how land use and flood events have affected the following stream channel conditions:

A. Sediment

B. Large Woody Debris

C. Riparian Cover/Stream Temperatures (Because there is such a strong correlation between riparian canopy cover and stream temperatures, these are combined as one condition.)

The North Fork Garcia is about 7 miles long with 7 major tributaries and a total drainage of about 12 square miles. With the exception of a few acres of grassland at Jack's Opening, the entire drainage is forestland; the lower reaches are predominantly redwood with alder directly adjacent to streams; and the upper slopes are a mixture of redwood, Douglas fir, sugar pine and hardwoods.

Data will be presented in the following format:

PART I: Historical Conditions in the Watershed before 1953
PART II: Watershed Conditions from 1953-1988
PART III: Watershed Conditions from 1988 to Present

These dates were chosen because 1954 and 1988 marked specific changes in land use in the watershed, as will be described.

Following the presentation of data is PART IV: Evaluation and Conclusion.

Finally, there are 4 Appendices which contain 4 reports, from which considerable information has been drawn in the preparation of this Overview:

APPENDIX I: Analysis of Stream Channel Recovery of the North Fork Garcia River Using a Modified RAPID Methodology, by Patrick Higgins, Consulting Fisheries Biologist, and D.K. Hagans, Geomorphologist, April 1996.

APPENDIX II: Cumulative Effects Analysis of Sediment on the North Fork Garcia River, submitted to CDF by Jack Monschke, Watershed Management Consultant for Coastal Forestlands, Ltd., May 1995, and revised in May 1996.

APPENDIX III: 1995 Update of Analysis of Cross-Section Data by Jan Derksen, Ph.D.

APPENDIX IV: McNeil Substrate Scores Collected on the North Fork Garcia River by Jan Derksen, Ph.D.

PART I: HISTORICAL CONDITIONS IN THE WATERSHED BEFORE 1953

Slopes adjacent to the North Fork were logged before the turn of the century, first for lumber logs and later for railroad ties. Some land use practices of that time (splash dams and repeated burning for conversion) must have had adverse effects on stream channel conditions, but due to lack of records of all types, it is impossible to quantify the effects of this early land use on the watershed. Information sources for this period were limited to interviews with local citizens, a few historical documents, maps and photos. There is no flow data for the Garcia until 1952, when the United States Geological Survey (USGS) began operation of a stream-gaging station just below the mouth of the North Fork. (MCRCD, 1992.) 1952 aerial photo review shows no evidence of management activities occurring in the lower North Fork immediately preceding that date. (See Appendix I.) Even with limited source material, it is possible to piece together a picture of the general conditions of the watershed prior to 1952.

A. Sediment - before 1953

It is certain from interviews with old-timers in the watershed that fish were plentiful in the North Fork Garcia in the early days, indicating that sediment was most likely not a limiting factor for spawning. (MCRCD, 1992.)

> "Back then there were so many fish and so few people that whatever fishing, no matter where or how they did it, it didn't really matter ... ." (GRV Enterprises, 1991.)

It was also reported that there were many deep pools (8'-10') under large woody debris (LWD), which is another indication that channels were not plugged with sediment.

The 1952 aerial photograph of the North Fork Garcia revealed a stream canopy of older age conifers and hardwoods with several short open canopy lengths adjacent and immediately downstream from natural streamside landslides. (See Appendix I.) There were few signs of large source points of mass wasting or of openings in riparian cover at storage reaches where sediment would have deposited. Because no clear data exists regarding flood events prior to 1953, it is not possible to definitively conclude whether this was due to an absence of major flooding, or whether floods did occur but, because of low impact land use before 1953, little disturbance occurred. It does, however, appear clear that sediment was not a limiting factor in the North Fork Garcia Watershed before 1953.

B. Large Woody Debris (LWD) - before 1953

Interviews provided some background information about pre-1953 LWD (MCRCD, 1992.) A forester for the Hollow Tree Timber Company (the property owner of much of the North Fork Garcia Watershed in the 1950's and 60's) remembers the North Fork channel as overgrown and almost impassable, with cold pools as deep as 10' filled with fish hiding unseen under layers of fallen trees and debris. (McKenzie, personal communication, 1991.)

C. Riparian Cover/Stream Temperature -- before 1953

As stated above, analysis of 1952 air photos confirms information from interviews regarding canopy cover. Contiguous reaches (those reaches that exhibit open canopies to some degree along the stream channel corridor [Grant, 1988]) were 3,722 feet in length in 1952 and averaged only 35' wide. Discontiguous openings (those reaches that show either completely closed canopies or alternating short intervals of closed and open areas [Grant, 1988]) composed over 65% of the stream analyzed (7,188 feet) and were primarily those where the canopy was completely closed and the stream channel almost indiscernible. Average width of the canopy opening in the discontinuous reaches was only 4 feet. (See Appendix I.) With virtually no direct exposure to the sun, it can be assumed that stream temperatures were quite low. Fish were apparently abundant in the North Fork during this period, as noted under Sections A and B above.

PART II: WATERSHED CONDITIONS FROM 1953 TO 1988

Information from numerous sources clearly shows that after 1953, a drastic change occurred. Between 1954 and 1965 almost all of the forested land in the watershed was roaded and logged. At first only the best trees were taken, mostly using tractors; later the same areas were re-entered taking the remaining merchantable trees. There were few regulations and fewer people to enforce the regulations that did exist. Most of the larger streams and many of the smaller ones were used as roads, landings, and/or skid trails. Roads and skid trails that were neither maintained nor properly drained, diverted water from many smaller watercourses onto unchanneled hillslopes, often causing extensive gullies. There were numerous landslides, many caused by fill failures and resulting debris slides and torrents. The land was often burned after logging operations, creating even more unprotected soil subject to erosion. Slash was left in streams (or slid into streams), often creating impassible fish barriers and massive sediment traps. (MCRCD, 1992.)

In December 1955, a large flood occurred that caused extensive damage to the area. There were 3 more floods with similar peak discharges (between 26,000 and 29,000 cfs) between 1964 and 1970 according to the USGS stream-gaging station records. These floods were rated as 10-year floods on a Flood Frequency Analysis Table. A flood occurred in 1974 (at just over 30,000 cfs) which is rated as a 20-year event on the same table. (Ott Water Engineers, 1979.) The storms that produced these floods, combined with extensive soil disturbances described above on upslope forestlands, caused massive aggradation and extensive damage (or total destruction of) riparian vegetation in the North Fork stream channel. (MCRCD, 1992.)

It was not unusual for 50,000 or more board feet/acre to be harvested during this period. Exposed unprotected soil from skid trails, roads, landings, slides and gullies sometimes exceeded 50% of the total surface area in the winter following logging operations, as indicated on 1965 air photos.

After the initial heavy cuts of the 1950's and 60's, there was very little, if any, logging on the North Fork until 1988. Longview Fiber, the major North Fork property owner during this time, apparently cut just enough to cover taxes and minor road upgrade and maintenance. All timber harvest after 1974 had to comply with the Forest Practice Rules mandated by the Forest Practice Act, which outlawed many of the most damaging practices of earlier logging.

A. <u>Sediment -- 1953 to 1988</u>

A report entitled "Illustrations of Logging Operations and Practices Which Protect Northcoast Salmon and Spawning Streams — And Those That Don't," issued by the California Department of Fish and Game (CDFG), contains photos taken November 22, 1955, of North Fork Garcia channels filled with slash and mud from logging that occurred the previous summer. These photos, and others in CDFG files, also show piles of slash perched on steep stream banks. (CDFG, 1955.) (See attached photos at pages 12-15.) A later CDFG report dated 1966 listed all of the North Fork Garcia and the lower reaches of its main tributaries as "severely damaged." (Fish, et al., 1966.)

Review of 1965 aerial photos support this finding. The upstream photographs covering the lower North Fork Garcia River showed major watershed disturbance from logging. Tributary channels appeared to be choked with sediment. It seems that the 1964 flood had caused sediment discharges into North Fork tributaries but that flows were not sufficient to transport large quantities of sediment into the lower mainstem by 1965. There was an overall increase in average channel width on the whole lower 2.25 miles of the North Fork from 14 feet in 1952 to 39 feet in 1965, and to 106 in 1979. (See Appendix I.)

A comparison of 1965 and 1979 aerial photos shows that high flows probably moved sediment from tributary channels into the lower mainstem North Fork during this period, causing stream widening. Logging of older age conifers, which took place between 1965 and 1979 in the riparian zone and on the adjacent hillslopes of the study reach, appeared to be linked to a substantial increase in the number and size of stream side landslides.

Some of those features may also have been caused by channel aggradation, which often contributes to bank failures. (Nawa et al., 1990.) Several meander bends exhibited new high flow channels through the floodplain and many channel reaches exhibited braiding, both of which indicate severe channel aggradation. (See Appendix I.)

Direct observation (field truthing) of the potential sediment delivery sites identified from aerial photos by Coastal Forestlands Ltd. (CFL) as part of a sediment inventory field review supported this finding. Many storage reaches of Class I, II and III watercourses still contain 10' to 20' of instream stored sediment depth, and old flood terraces are evidence that much of the channel reach had 10' to 20' of instream stored sediment in the recent past. (See Appendix II for discussion of *STAR* Worksheet System of Sediment Inventory.)

B. <u>Large Woody Debris (LWD) - 1953 to 1988</u>

The 1955 CDFG report and photographs noted above show huge quantities of logs and rubble pushed into streambeds. Sidecast from roads and fill pushed into crossing sites also included large quantities of LWD. (See attached photos at pages 12-15.) Much of this photo-documented LWD, which occurred as a direct result of 1950's logging, as well as the interview-documented LWD, which was instream before logging, was apparently buried by the 10' to 20' deep layer of sediment described in Section A above. There was also a large quantity of LWD in the stream channels which occurred as an indirect result of logging. This LWD came from road-related debris slides and torrents, as well as from stream bank slides caused by aggradation. Rather than creating functional structure for diverse fish habitat, the LWD was mostly concentrated in debris jams, which blocked fish passage and often destroyed fish rearing habitat. The destruction of riparian vegetation by tree removal and the channel widening caused by the aggradation virtually eliminated the potential for long term recruitment of LWD in the form of growing trees during this period.

C. <u>Riparian Canopy/Stream Temperature -- 1953 to 1988</u>

Analysis of 1965 air photos reveals that riparian cover was greatly diminished by 1965 on all of the upper North Fork Garcia, although there was a 1-1/2 mile reach just above the confluence of the North Fork with the mainstem Garcia where logging had not yet occurred, and old growth conifers provided significant cover as late as 1965. In this lower section, which was the reach covered in the Higgins and Hagans analysis, contiguous open reaches of the stream had increased to 5599 feet (almost 50% of the total stream length) and average channel width in these reaches had expanded to 64 feet. Discontiguous reaches had diminished to 6,703 feet, and the trend toward increased width was also exhibited with an average width of 18 feet. (See Appendix I.)

The most open canopy conditions were observed in the 1979 aerial photo series. The entire length of the study reach had become one long contiguous open reach with an average channel width of 106 feet. (See Appendix I.) Riparian cover in the lower reach was eliminated sometime between 1965 and 1978, apparently caused by three factors: (1) logging of conifers in the riparian zone, which also resulted in much of the hardwood being knocked down; (2) sediment deposition, which widened channels and destroyed riparian vegetation; and (3) entrainment of LWD during floods which knocked down any remaining riparian vegetation.

Although there is no quantitative data available on the water temperatures for the North Fork for this time period, it can be assumed that overall stream temperatures had risen significantly since overstory protection from the heating effects of sunlight on the wider and shallower low flow channel had been eliminated.

In many reaches stream temperature was a moot point in terms of fish because aggradation resulted in flows going subsurface. Debris jam migration barriers and the virtual elimination of quality fish rearing habitat combined with higher stream temperature must have had significant adverse effects on the fisheries resource. This is supported by anecdotal comments from interviews. (MCRCD, 1992.)

PART III: WATERSHED CONDITIONS FROM 1988 TO PRESENT

Field and air photo review of the North Fork Garcia shows that regrowth after the extensive logging of the 1950's and 60's occurred in the watershed through the 1970's and 80's. By 1988 most roads and skid trails were not visible from the air, and many stream corridors were recognizable by a ribbon of alder. (See Appendix II.) However, although air photo review shows major vegetative recovery, field review reveals many erosion and sediment problems related to past logging practices which could not be detected on air photos. (North Fork Garcia THPs, 1988-90.)

Coastal Forestland Ltd.'s predecessor, R AND J Timber, Co., purchased 90% of the land in the North Fork Garcia from Longview Fiber and began extensive land management and timber harvest in 1988. Since 1988, approximately 90% of the North Fork drainage has been under timber harvest plan, with harvest taking residual old growth and commercial thinning of second growth. The cut has been relatively light compared to harvests in the 1950's and 60's with an average of less than 5,000 board feet/acre. This "selective cut" as compared with earlier harvests results in much less soil disturbance and a higher canopy retention on harvest areas. By including extensive areas in THP's, a relatively large proportion of the land base has benefited by upgrading to modern Forest Practice Rules. Road drainage has been improved as well as road surfaces, which have been intermittently rocked to reduce surface erosion. Also, CFL and its predecessor in title, R AND J Lumber Co., initiated management practices that go beyond Forest Practice Rules. (See Appendix II, Section IV, for a listing of these practices.)

The years 1988 to 1994 have been characterized as low rainfall and/or drought years, although there was a flood event with a reoccurrence interval of five years in 1993, according to stream-gaging station records. The winter of 1994-95 broke with this earlier trend. In January the largest flood of record occurred. (FrOG, 1995.) Another flood occurred in March, and the rainfall total for the year was one of the highest on record. (Piper and King, personal communication, 1995.)

A. Sediment -- 1988 to Present

The quantitative analysis contained in Appendix IV and annual observations of the condition of the North Fork conducted by representatives of the North Coast Regional Water Quality Control Board (NCRWQCB), CDF and CFL indicate that the North Fork Garcia Watershed has been either static or in recovery from 1988 to 1995 in terms of sediment transport (i.e., the river system is competently transporting the sediment load delivered without significant changes to the channel geomorphology, both in drought and major flood event years). However, the quantity (volume) and quality (texture) of sediment continues to have a negative impact on the spawning and rearing habitat of salmonids. (See Appendix IV.)

Field review shows that instream sediment from past flood events on the North Fork and its tributaries are still obvious in many places. Although watercourses have downcut into sediment deposits left from past flood events establishing quasi-stable channels, in many reaches there are still 5' to 10' of instream stored sediment below the recently incised stream channel. (See Appendix II.) This was verified by excavations in stream channels during the summer of 1995 at restoration sites: 5' to 10' of sediment (much of it silt) did indeed fill channels. There was no surface water at the start of excavation, and less than 1,000 bd. ft., on average, of exposed LWD per 300 linear feet of stream channel. After excavation there was a flowing stream with 10,000 bd. ft., on average of exposed LWD per 300' of stream channel.

In an attempt to develop ongoing qualitative information about stream channel conditions, the Mainstem North Fork Garcia was walked by representatives from CFL, NCRWQCB and other agencies during the summer of 1995, as in the summers of 1989, 1990, 1991, 1992, and 1993. Additionally, in an effort to quantify sediment conditions, CFL and the NCRWQCB established Monitoring and Reporting Program 89-128, which has recorded cross-section data and McNeil substrate scores from 6 stations along the North Fork in 1989, 1990, 1991, and 1995. Jan Derksen, Ph.D., has prepared a statistical analysis and comparison of these data. (See Appendices III and IV.) A summary of the results follows:

Specific sites that were sampled in the NCRWQCB Monitoring Program show the following:

> Data from the channel cross-section profiles on 6 stations on the North Fork of the Garcia River show that the profiles are equal or better in 1995 than in previous years (1989, 1990, and 1991). The data shows that no significant adverse impact occurred on the Garcia Watershed in terms of channel cross-section profile. All pools deepened and/or became larger, except one pool (Pool 2) that stayed the same. (Derksen, 1995, Appendix III.)
>
> CFL and NCRWQCB crews measured McNeil substrate scores at 6 stations along the North Fork of the Garcia during the summer of 1995. This report compares the 1995 scores with those of 1989, 1990, and 1991. At a 95%

> confidence level, the levels of "fines" in 1995 were found to be equal or lower than those of previous years. (Derksen, 1995, Appendix IV.)

In their Aerial Photo Analysis of Stream Channel Recovery of the North Fork Garcia River Using a Modified RAPID Methodology (Higgins and Hagans, 1996) note that by 1995 the visible portions of the lower North Fork Garcia River channel had diminished substantially in width, dropping from 106 feet in 1979 to 46 feet in 1995. Despite extremely high flows and intense rainfall in 1995, riparian zone widths did not indicate a substantial pulse of sediment deposition in the study reach.

B. <u>Large Woody Debris -- 1988 to Present</u>

Field reconnaissance shows relatively low levels of LWD in the North Fork Garcia channels at this time. It is obvious from observing old debris jam sites that many were removed by past CDFG projects, and there are records detailing this activity. (CDFG, 1980.) Much LWD at jam sites was cut up to eliminate the jam and allow fish passage. The largest quantity of surface LWD exists at old untreated debris jams, most of which are above the limits of anadromous fish runs.

Some LWD is being uncovered as downcutting occurs along certain reaches. The restoration projects mentioned above uncovered and returned large quantities of LWD to channels. Approximately 50,000 board feet of high quality old growth redwood was uncovered during channel excavation in one 200 yard reach.

The most significant input of LWD during this time period is from debris torrents that occurred during the 1995 storm event.

Protection of a 25' riparian vegetation buffer by CFL management practices insures the long term recruitment of LWD in the form of growing trees. At this time, however, the riparian canopy is mostly alder, which limits its benefit as LWD.

C. <u>Riparian - 1988 to Present</u>

1995 aerial photo analysis shows a good riparian canopy recovery. The contiguous open reaches had fallen to 6245 feet and the average width of these sections was down to 71 feet. Canopy closure had been helped substantially by growth of alder trees and the 5,639' of discontiguous reaches averaged only 18' wide. Substantial riparian overstory from large conifers was still largely lacking in the study reach in 1995. (See Appendix I.)

For technical reasons, the upper reaches of the North Fork were not included in the Higgins and Hagans Rapid Analysis. However, a review of the 1965 and 1995 aerial photos was done by the author of this summary report. It shows that the recovery, in terms of canopy closure for the upper reaches of the North Fork Garcia (i.e., those reaches not included in the Higgins and Hagans Analysis), is even more extensive than that occurring on the lower reach.

Limited stream temperature data that is available indicates that the temperatures are currently compatible for Coho Salmon (Peterson, MCRCD, 1992). Qualitative observations indicate that there have been significant increases in the young of the year Steelhead population in the North Fork over the last two years. (Bell, personal communication, 1995, 1996.)

PART IV: EVALUATION AND CONCLUSION

This section includes an evaluation of the effects of recent land use on sediment LWD and riparian cover in the North Fork Garcia Watershed based on the data above, as well as a brief conclusion. The evaluation is based on a comparison of the response of watershed, and specifically the stream channel's response to the 1995 flood event of record with earlier flood events.

A. Sediment Evaluation

The evidence from sources cited in this report is consistent in showing that during the 1995 flood event, sediment was transported competently by the North Fork Garcia and its tributaries, with an overall increase in pool volume and widespread downcutting. Aggradation was observed only sporadically, while degradation was observed along many reaches. This is in direct contrast to the watershed's response to the earlier floods of the 1950's, 60's, and 70's, during which major aggradation occurred in most stream channels.

Higgins and Hagans state, "Flows in 1995 were the largest floods on record in the Garcia River Basin. If sediment yield from CFL property were high, it is likely that stream channel widths following the 1995 storms would be much wider . . .. Despite extremely high flows and intense rainfall in 1995, riparian zone widths did not indicate a substantial pulse of sediment deposition in the study reach." (See Appendix I.)

B. LWD Evaluation

Although a significant volume of LWD was recruited into stream channels by a few debris torrents and high flows during the 1995 flood events, the volume did not compare to that introduced after the logging in the 1950's, 60's, and 70's, when original LWD was buried by sediment. New LWD, which was recruited during these floods from prior logging operations, so overwhelmed stream channels that massive debris jams occurred which formed barriers to anadromous fish passage, buried fish habitat, and diverted stream flow, causing slides.

C. Riparian Canopy Evaluation

Very little riparian canopy cover and/or vegetation was lost in 1995. In contrast, virtually all riparian canopy and vegetation that remained after tree removal was lost in the flood events of the 1950's, 60's and 70's, as a result of being flattened by entrained LWD and/or buried by sediment. The stream channel and riparian zone conditions after these events (i.e., wide meandering or braided gravel and cobble channels with no cover) resulted in a slow riparian vegetative recovery.

D. <u>Conclusion</u>

It is clear from the information presented in this report that the stream channel conditions in the North Fork Garcia Watershed were not affected negatively by the flood events of 1995. This contrasts dramatically with the extreme negative effects on channel conditions which occurred during flood events in the 1950's, 60's, and 70's. It is also clear, although not as dramatic, that the stream channel conditions have been improving during the past 6 years of extensive timber harvest.

Many studies have shown that land use practices have greatly increased erosion rates in this region and periodic large storm events have caused massive amounts of sediment to be routed through stream channels. It has been shown that reducing erosion related to roads can be effective in preventing sediment yield to streams. (Weaver et al., 1981.) If sediment yields are reduced by upslope erosion control activities and improved land use practices, then stream channels can go into recovery.

One important reason for the watershed's different response in 1995, as compared to the response to similar storms in the 1950's, 60's, and 70's, is the dramatic difference in management practices during recent timber harvest. The harvest has been much lighter, streambeds were not used for transportation networks, road and landing reconstruction was generally planned with problem sites identified and mitigated, and specific problem areas were restored.

Perhaps the most important management practice in terms of stream channel conditions has been the correct care of crossings and drainage facilities. All drainage facilities have been planned to withstand a 50-year flood event. In the 1950's and 60's very few drainage facilities were constructed and hundreds of crossing failures occurred, with many of the failures resulting in diversions. In 1995 only 2 drainage facilities failed. There was some erosion at other crossing sites. This is in contrast with losses in the hundreds of thousands of cubic yards which occurred in the past at crossing and drainage facilities. (See Appendix II.) This is the major success story of current CFL management practices and the modern Forest Practice Rules, which have now been applied to virtually all roads in the basin.

There was a significant reduction in sediment delivered from failures occurring at crossings and other drainage facilities during the 1995 flood events as compared to the earlier events in the 50's 60's and 70's. Sediment delivered from road-related mass wasting (debris slides and torrents) during the 1995 flood events was also significantly reduced, but not as dramatically. Although aerial photo analysis shows that there has been a significant decrease in sediment loss from mass wasting in recent years, this is the one area where there is still more work to be done. The challenge for the future is to develop new management practices that identify, prioritize and treat additional potential sediment delivery sites. The *STAR* Worksheet System was developed to address this objective. (See Appendix II.)

To continue harvesting in the North Fork with similar beneficial results to the stream channels is possible but will require careful adherence to the management practices as outlined in the 1995 North Fork Garcia Report. (Appendix II.) A monitoring system to insure both the implementation and effectiveness of these proposed practices is also a critical component. CFL is considering a proposal by CDF to make the North Fork a "demonstration watershed" that would cooperatively develop further monitoring procedures.

NORTH FORK, GARCIA RIVER, MENDOCINO COUNTY, Nov. 22, 1955. Road from which picture was taken, and skid road at left, virtually obliterated stream here. Water can be seen running out from under logs and rubble. *(Fish and Game photo)*

NORTH FORK, GARCIA RIVER, MENDOCINO COUNTY, intersection of a small tributary, Nov. 22, 1955. Landing and parking area built into confluence. Mud in foreground is shoulder of parking area, looking upstream into tributary. No culvert apparent and water appears to be seeping under logs and rubble. No flow visible into the Garcia. *(Fish and Game photo.)*

NORTH FORK, GARCIA RIVER, MENDOCINO COUNTY, Nov. 22, 1955. Stream bed blocked. Side hill left with skid roads running into stream bed without water checks; covered with debris which will be washed into stream by heavy runoff. Rubble which blocked stream was pushed off road by operator. (*Fish and Game photo.*)

NORTH FORK, GARCIA RIVER, MENDOCINO COUNTY, Nov. 22, 1955. Stream bed and skid road visible at lower left. Road shoulder at right is contributing heavy silt second day after rain. (*Fish and Game photo.*)

APPENDIX I

Stream Channel Recovery Study
North Fork Garcia River

by
Patrick Higgins and D.K. Hagans

Analysis of Stream Channel Recovery of the North Fork Garcia River Using a Modified RAPID Methodology

By

Patrick Higgins
Consulting Fisheries Biologist
791 8th Street, Suite N
Arcata, CA 95521

D. K. Hagans
Pacific Watershed Associates
Post Office Box 4433
Arcata, CA 95521

Abstract:

Aerial photographs from 1952, 1965, 1979 and 1995 were analyzed to determine changes in stream channel width along the lower 2.25 miles of the North Fork Garcia River using a modified RAPID approach (Grant, 1988). Widening stream channel trends were interpreted as a sign of high sediment yield stemming from past land use and flood events. The width of the opening in the stream canopy increased from an average of 14 feet in 1952 to 39 feet in 1965 but the greatest increase was shown in the 1979 photos when the average riparian width expanded to 106 feet. Aerial photos from 1995 showed that the average stream width had dropped to 46 feet. Despite extremely high flows and intense rainfall in 1995, riparian zone widths did not indicate a substantial pulse of sediment deposition in the study reach. It would seem that recent land use activity in the watershed is not resulting in catastrophic sediment yields. This may be in part owing to erosion prevention measures being implemented by the land owner on roads within the basin.

Background:

Changes in stream channel width can be used to monitor sediment pulses as they are routed through streams (Grant, 1988). Northwestern California streams were formerly narrow and tree lined with multi-tiered canopies of deciduous and coniferous trees. The stable stream banks provided complex habitat and the shade kept stream temperatures within optimal ranges for anadromous salmonids. Land use practices have greatly increased erosion rates in this region and periodic large storm events have caused massive amounts of sediment to be routed through stream channels (Hagans and Weaver, 1987). Streamside riparian zones have often been buried, resulting in major increases in channel width. Timber harvest in riparian zones has also contributed to this problem. The now typical wide, open and shallow stream channels of northwestern California are poor habitat for spawning and rearing salmonids (Higgins et al., 1992). If sediment yields arc reduced by upslope erosion control activities and improved land use practices, then stream channels can go into recovery. Deciduous trees, such as alders and willows, can effectively colonize these open gravel bars within one or two decades after flood damage.

Grant (1988) suggested the use of sequential historical aerial photos to judge changes in stream channel width as an index of cumulative watershed effects. Under his Riparian Aerial Photographic Inventory of Disturbance methodology (RAPID), length and width of open and closed riparian canopies, as well as sediment sources, are identified. RAPID tracks sediment pulses as they are routed through stream channels, as indicated by channel widening. Aerial photos of upper watershed areas arc used to note landslides related to logging road and landing failures, clear cuts or natural landslides. While substantial amounts of material may enter low order stream channels during floods, stream power may be insufficient to move the sediment pulse into larger order streams. Sequential historical aerial photos can track sediment pulses downstream as they move with subsequent high flows. As sediment yield decreases, riparian zones begin to show narrowing trends.

Methods:

This study followed a modified RAPID approach to study changes in stream channel width of the lower 2.25 miles of the North Fork Garcia River from 1952 to 1995. Aerial photographs of between 1:7920 and 1:24000 were obtained from Coastal Forestlands staff and a Leitz optical stereoscope at 4X power was used for photo analysis to measure changes in channel width. Use of the 4X power allowed more accurate measurements because of the large scale of some of the photos. Unlike a full RAPID study, sediment sources were not tracked and only the aerial photos from the lower mainstem North Fork Garcia River were analyzed.

Photographs provided for this study were at several different scales. The 1952 aerial photo did not have a stereo pair but was at the smallest scale, with one inch equaling 660 feet (1:7920). The 1965 photography was at a 1:24000 scale, while the 1979 and 1995 images were at a scale of 1:12000. Grant (1988) considers photographs at larger scales than 1:16000 to be less than optimal for RAPID studies. The first step was to determine the actual photo scale. Known points on the Eureka Hill and Point Arena USGS 1:24000 quadrangles were measured on the maps and on photos so that actual distance on the ground in each series of photos could be determined.

Fifteen channel cross sections were established at a fixed map distance interval and riparian widths were measures for each year for which photos were obtained. Grant (1988) also suggests that stream reaches by analyzed as contiguous or discontiguous with regard to areas of canopy closure. Contiguous reaches exhibit open canopies to some degree along the stream channel corridor. Contiguous reaches exhibit open canopies to some degree along the stream channel corridor. Discontiguous reaches show either completely closed canopies or alternating short intervals of closed and open areas. Streamside landslides were also noted. Parameters calculated for discussions below included length and average width of contiguous and discontiguous reaches, average stream channel width for the entire study reach, and average widths at the cross sections.

Results and Discussion:

Aerial photo analysis showed interesting changes in stream channel width from 1952 to 1995 (table 1). The 1952 photograph revealed a stream canopy of older age conifers and hardwoods with several short open canopy lengths adjacent and immediately downstream from natural streamside landslides. The contiguous openings were 3722 feet in length and averaged only 35 feet wide. Discontiguous reaches composed over 65% of the stream analyzed and were primarily those where the canopy was completely closed and the stream channel almost indiscernible. Average width of these latter reaches were only 4 feet wide. The average width at cross sections was 16 feet and the overall average channel width was 14 feet. There is no evidence of any recent management activities occurring in the lower North Fork as of 1952.

Table 1. Aerial photography interpretation results.

Parameter (in feet)	**1952**	**1965**	**1979**	**1995**
Contiguous Reach Lengths	3722	5599	12199	6245
Average Width (Contiguous Reach)	35	64	106	71
Discontiguous Reach Lengths	7188	6703	0	5639
Average Width (Discontiguous Reach)	4	18	0	18
Average Cross Section Width	16	28	94	43
Overall Average Channel Width	14	39	106	46

While large areas of the upper and middle North Fork watershed had been extensively roaded and harvested by 1965, the 1965 aerial photographs show that logging had not yet taken place in riparian zones or on the lower 1000 feet of the hillslope adjacent to the mainstem along the study reach. The contiguous open reaches of the stream had increased to 5599 feet and average channel width in these reaches had expanded to 64 feet. Discontiguous reaches had diminished to 6703 feet and the trend toward increased width was also exhibited with an average width of 18 feet. The average width at cross sections was 28 feet and total overall average channel width grew to 39 feet. The upstream photographs covering the lower North Fork Garcia River showed major watershed disturbance from logging. Tributary channels appeared to be choked with sediment. It seems that the 1964 flood had caused sediment discharges into North Fork tributaries but that flows were not sufficient to transport large quantities of sediment in the study reach by 1965.

The most open canopy conditions prevailed in the 1979 aerial photo series. The entire length of the study reach had become one long contiguous open reach with an average channel width of 106 feet. The average width at cross sections was 94 feet, reflecting the overall changes in channel conditions. Storm flows in 1974 actually exceed those of the 1964 flood in the Garcia River basin (Mendocino RCD, 1992). High flows probably moved sediment from tributary channels into the lower mainstem North Fork causing stream widening. Logging of older age conifers took place between 1965 and 1979 in the riparian zone and on the adjacent hillslopes of the study reach. That activity appeared to be linked to a substantial increase in the number and size of streamside landslides. Some of those features may also have been caused by channel aggradation, which often contributes to bank failures (Nawa et al., 1990). Several meander bends exhibited new high flow channels through the floodplain and many channel reaches contained braided streamflow, both of which indicate severe channel aggradation.

By 1995, the lower North Fork Garcia River channel had diminished substantially in width. The contiguous open reaches had fallen to 6245 and average widths of these sections was down to 71 feet. Canopy closure had been helped substantially by growth of alder trees and the 5639 feet of discontiguous reaches averaged only 18 feet wide. Cross section average widths dropped to 43 feet and the overall average width for the study reach was 46 feet. Substantial riparian overstory from large conifers was still largely lacking in the study reach in 1995.

Conclusion:

Many studies have shown that reducing erosion related to roads can be effective in preventing sediment yield to streams (Weaver et al., 1981). Once sediment levels arc reduced, canopy recovery can begin in streams damaged by past floods (Nawa et al., 1990). The North Fork Garcia River from 1979 to 1995 showed a distinct trend toward decreased channel width and increased canopy. Harr and Nichols (1993) reported reduction in sediment yield to streams following erosion prevention work on roads in northwest Washington state. Storm events in 1990 were particularly severe in that region, yet landslides were infrequent in tributaries of the Nooksack River where erosion risk related to logging roads had been reduced. Coastal Forestlands has worked to reduce erosion risk related to its road networks and it would seem that sediment yield from the basin has decreased.

Flows in 1995 were the largest floods on record in the Garcia River Basin. If sediment yield from Coastal Forestlands property were high, it is likely that stream channel widths following 1995 storms would be much wider. Narrowing stream channels provide increased shade canopy and cooler water temperatures for salmonids. Habitat and fisheries surveys performed for the *Garcia River Watershed Enhancement Plan* (Mendocino RCD, 1992) showed that the North Fork Garcia River has recovered sufficiently to provide suitable year round habitat for juvenile steelhead trout. This study did not include sediment sources, such as upland areas or tributary channels; therefore, it is not possible to conclude definitively that the trend of decreasing riparian widths will necessarily continue in future storms.

References

Grant, G., 1988, The RAPID technique: a new method for evaluating downstream effects of forest practices on riparian zones. USDA Forest Service, Pacific Northwest Forest Research Station, Gen. Tech. Report PNW-GTR-220, Portland, OR. 36 p.

Hagans, D.K. and W.E. Weaver, 1987, Magnitude, cause and basin response to fluvial erosion, Redwood Creek basin, northern California. In: Erosion and Sedimentation in the Pacific Rim, proceedings of the Corvallis Symposium, August 1987. IAHS Publ. no. 165, IAHS Press, Wallingford, UK, pages 419-428.

Harr, R.D. and R.A. Nichols, 1993, Stabilizing forest roads to help restore fish habitats: a northwest Washington example. Fisheries, Vol. 18, No. 4, pages 18-24.

Higgins, P., S. Dobush and D. Fuller, 1992, Factors in northern California threatening stocks with extinction. Prepared for the Humboldt Chapter American Fisheries Society, Arcata, CA 26 p.

Mendocino Resource Conservation District, 1992, Garcia River Watershed Enhancement Plan. Mendocino Resource Conservation District, Ukiah, CA. Prepared for the California Coastal Conservancy.

Nawa, R.K., C.A. Frissell and W.J. Liss, 1990, Life history and persistence of anadromous salmonid stocks in relation to stream habitats and watershed classification, annual progress report (4/18/90). Prepared for Oregon Department of Fish and Wildlife, by Oak Creek Laboratory of Biology, Department of Fisheries and Wildlife, Corvallis, OR.

Weaver, W.E., A.V. Choquette, D.K. Hagans and J. Schlosser, 1981, The effects of intensive forest land use and subsequent landscape rehabilitation on erosion rates and sediment yield in the Copper Creek drainage basin, Redwood National Park. In: Proceedings, symposium on watershed rehabilitation in Redwood National Park and other coastal areas, Arcata, CA, 1980; Center for Natural Resources Studies of the John Muir Institute, Berkeley, CA, 1981, pages 341-360.

APPENDIX II

Revised Cumulative Effects Analysis
North Fork Garcia River

by

Jack Monschke

CUMULATIVE EFFECTS ANALYSIS OF SEDIMENT ON THE NORTH FORK GARCIA RIVER MENDOCINO COUNTY, CALIFORNIA

May 1, 1995
Revised May 15, 1996

Submitted to California Department of Forestry

by Jack Monschke

Watershed Management Consultant for
Coastal Forestlands, Ltd.

The North Fork Garcia Watershed, like other coastal watersheds, supports extensive riparian vegetation and habitats for aquatic and terrestrial wildlife. These environmental resources may be negatively impacted by hydrologic events and the associated geomorphic processes of erosion and sediment transport. Timber harvest has been known to alter the streamflow/sediment balance and induce an adjustment or response that adversely affects the quality of aquatic habitat provided by watercourses within a watershed. Adverse effects in the stream channel and riparian zones from past timber harvest are well documented in both published and unpublished literature.

A cumulative effects analysis is therefore needed at this time to evaluate the potential impacts of proposed timber harvest. This report will:

1. provide a description of the hydrology and geomorphology of the North Fork;

2. identify the measures proposed by management of Coastal Forestlands, Ltd. (CFL) to both reduce possible negative impacts of proposed timber harvest and accelerate recovery of hillslopes and streams; and

3. propose a monitoring plan to evaluate the performance of mitigation measures.

It should be noted here that the actual North Fork Garcia River Watershed, and not the Cal Water North Fork Garcia Watershed Unit, was chosen as the assessment area for this report for a number of reasons:

1. the Mendocino County Resources Conservation District (MCRCD) Garcia Enhancement Report provided specific background information on the actual North Fork Watershed;

2. the North Coast Regional Water Quality Conservation Board (NCRWQCB) monitoring program addressed the actual North Fork Watershed;

3. 90% of the actual North Fork Watershed is in CFL's ownership; and

4. it is smaller and more manageable to assess.

It should also be noted here that, in this report the term "past logging" refers to logging that took place in the Watershed before 1974. The term "recent logging" refers to logging from 1988 to present.

Preparation of this report included the collection and analysis of relevant information from a number of sources. Background information was obtained from the Garcia River Enhancement Plan, prepared for the Mendocino County Resources Conservation District (MCRCD) in 1992. More recent information was obtained from the Garcia River Report prepared by Swanson and Associates for Mendocino County; 1995 flood event data from Friends of the Garcia (FrOG) (stream-gaging station records); rainfall records from the California Department of Forestry (CDF), Billy Piper and Nicholas King; and personal communications with Bill Solinsky, Art Haschak, John Burns, Registered Professional Foresters, and Robert White, technician.

Post-1988 THP's from the area were reviewed, noting all information pertinent to crossings and diversions. Field notes and post-harvest reports from 1989 and 1990, the product of field review of over 70 THP's in the general area, and all THP's in the North Fork Garcia Watershed, were also reviewed. Field review in the watershed from 1991 to 1994 included walks of the mainstem North Fork Garcia with two staff members of the NCRWQCB, field days with representatives of the California Department of Fish and Game (CDFG) and MCRCD, and days spent in the field developing the *STAR* Worksheet System.

Finally, information was collected during several days of recent field review in the North Fork Watershed following the 1995 January and March storm events, using the *STAR* Worksheets to record information at specific sites to obtain specific information aimed at addressing the issues of cumulative effects.

Technical assistance and review was provided by Randy Klein, CPESC, Watershed Hydrologist, and Tim Best, Registered Geologist #5277 and Certified Engineering Geologist.

This report is organized as follows:

I. Brief History of Land Use in the North Fork Garcia

II. Present Conditions in the North Fork Garcia and Effects of Recent Management on Sediment, Large Woody Debris, and Riparian Canopy

   A. Sediment

      1. Mass Wasting

         (a) Debris Slides/Torrents

         (b) Streambank Failures

      2. Surface Erosion

      3. Crossings and Diversions

      4. Machine-Placed Sediment (fill placed in streams)

      5. Remobilization of Instream Stored Sediment

   B. Large Woody Debris (LWD)

   C. Riparian Canopy Cover

III. Evaluation of Impacts of 1995 Floods and Comparison of this Event With Comparable Events in the 1950's and 60's

IV. Identification of Measures Currently Implemented and Additional Measures Proposed for Future Implementation by CFL to Mitigate Adverse Impacts of Timber Harvesting and Sediment Drainage from Erosion Sites Caused by Past Timber Harvesting

V. Identification of Measures Proposed by CFL Management That Will Accelerate Recovery of Hillslopes and Streams in the North Fork Watershed

VI. Monitoring Programs Proposed

VII. Conclusion: Evaluation of the Potential Cumulative Impacts of Proposed Timber Harvest in the North Fork Garcia

I.

BRIEF HISTORY OF LAND USE IN THE NORTH FORK GARCIA WATERSHED

A look at historical land use is critical to understanding current conditions in the North Fork Garcia Watershed. The first logging on the North Fork happened before the turn of the century but, due to lack of records of all types, it is impossible to know how these first timber harvest efforts affected the Watershed. Before 1950, the only roads in the Watershed were jeep trails into old homesteads. Between 1954 and 1965, almost all of the forested land in the Watershed was roaded and logged. At first only the best trees were taken, mostly using tractors; later the same areas were reentered, taking most of the merchantable trees. There were few regulations and fewer people to enforce the regulations that did exist. Most of the larger streams were used as roads, landings, and/or skid trails. Roads and skid trails that were neither maintained nor drained diverted water from many smaller watercourses onto unchanneled hillslopes, often causing extensive gullies. There were numerous landslides, many caused by fill failures and resulting debris torrents and slides. The land was often burned after logging operations, creating even more unprotected soil subject to erosion. Slash was left in streams (or slid into streams), often creating impassable fish barriers and massive sediment traps. (MCRCD, 1992.)

In December 1955, a large flood occurred that caused extensive damage to the area. There were three more floods with similar peak discharges (between 26,000 and 29,000 cfs) according to the United States Geological Survey (USGS) stream-gaging station on the Mainstem Garcia between 1964 and 1970. (USGS stream-gaging station flow data, operated from 1963-1983.) This stream-gaging station is located just below the confluence of the North Fork Garcia. These floods were rated as 10-year floods on a Flood Frequency Analysis Table, and the 1974 storm (at just over 30,000 cfs) is rated as a 20-year event on the same table. (Ott Water Engineers, 1979.) The storms which produced these floods, combined with extensive soil disturbances on upslope forestlands, had major effects on the entire Garcia drainage system. (MCRCD, 1992.)

Although raw data and field notes in agency files from the 1950's and 60's could not be found, a set of photographs was obtained from CDFG files. These photos of the North Fork Garcia, taken on November 22, 1955, show the results of logging practices occurring just prior to the 1955 flood. A CDFG study from 1966 listed the Garcia River Watershed (105 miles total) as 35.2% severely damaged; 14.4% moderately damaged; and 35.2% lightly damaged by "roadbuilding, logging, overgrazing, and poor land management practices, aggravated by the 1964 flood." All of the Mainstem North Fork and the lower reaches of its 7 main tributaries were listed as severely damaged. (Fish, et al., 1966.)

A study of aerial photos of the Garcia Watershed taken in 1966 supports this finding. Most stream beds were filled for use as skid trails, roads, and landings; the riparian canopy was non-existent on most streams. There was a great increase of large woody debris (LWD) in many streams, often concentrating in huge debris jams more than 100 yards in length that were detrimental to the salmonid resource. (CDFG, 1955.) Field review and historical research noted above indicates that in areas that were heavily logged between 1954 and 1964, the flood events of 1955, 1964, and 1966 resulted in extreme erosion which caused major long lasting geomorphological changes on almost every low gradient or "response" reach of every watercourse. The result was widespread, extensive aggradation (5' to 20' deep), loss of most riparian vegetation that remained after logging, and formation of massive log jams, completely changing the character of most streams. Anadromous fisheries resources in the watershed were negatively affected by blocked passages, filled-in pools, increased fine sediment within spawning gravels, etc. (Fish, et al., 1966.)

The 1970's through the 80's was generally a period of lower human impact on the watershed compared to earlier periods. New forest practice rules and tougher enforcement by CDF, CDFG, and the NCRWQCB were initiated. Through the 1970's and 80's, second growth conifers and hardwoods had reoccupied most of the logged sites; by late 1980 most roads and skid trails were not visible from the air, and many stream corridors were recognizable by a ribbon of alder. These changes, which arc apparent from review of recent aerial photography, indicate a trend of watershed recovery from past impacts.

Coastal Forestlands Ltd.'s predecessor, R And J Timber, Inc., purchased 90% of the land in the North Fork Garcia from Longview Fiber and began timber harvest of residual and second growth conifers in 1988.

II.

PRESENT CONDITIONS IN THE NORTH FORK GARCIA AND EFFECTS OF RECENT MANAGEMENT ON SEDIMENT. LARGE WOODY DEBRIS AND RIPARIAN CANOPY

The present conditions of the North Fork Garcia could best be described as a state of recovery from the devastation of the logging and floods described above. There are three areas of critical concern in the riparian zone: sediment, large woody debris (LWD), and riparian canopy cover (stream temperature).

A. Sediment

Although the North Fork Garcia Watershed is in equilibrium at this time in terms of sediment transport (i.e., the river system is competently transporting the sediment load delivered without major changes to the geomorphology of the system, both in drought and major flood event years), the quantity and quality (high percentage of fines) of sediment continues to have a negative impact on the spawning and rearing habitat of salmonids, with more than 25% of the sediment measuring 2.5mm and smaller. (Monschke, 1993.)

The study of sediment in a watershed can be broken into 3 categories: source, transport, and storage.

The **source**, or origin of sediment, is generally the hillslopes, where the journey of sediment created by erosion begins and where drainage gradients are generally 20% or higher. Processes that generate sediment include mass wasting (debris torrents, debris slides, and streambank failures) and surface erosion. Other major sediment source sites include sites where road crossings or other factors cause stream diversions, sites where machine-placed fill falls into streambeds, and sites where sediment long ago deposited in stream channels is remobilized.

Fluvial **transport** of sediment occurs in watercourse reaches with a gradient of 8% to 20%. These reaches can often weather large storm events with little or no damage as they go about their business of transporting sediment from source to storage.

Sediment **storage** (or **response)** reaches are generally those reaches with a gradient under 5%. However, the extreme conditions of flood events after the logging of the 1950's and 60's resulted in storage on low gradient reaches as well as on reaches with gradients from 5% to 8% (cemented cobble runs and cobble/boulder step pools). A storage reach is often called a response reach, because it responds to what is happening upslope at the source. If the erosion rate is very high, the response will be aggradation. If the erosion rate is low, the response will be downcutting.

Following is a detailed description of current sediment sources on the North Fork:

1. Mass Wasting

Debris torrents, debris slides, and small slides resulting from stream bank failure were the major types of mass wasting observed during the 1995 storms. Block and deep-seated slides did not appear to be large sediment contributors at this time.

Erosion resulting from debris torrents and slides constituted the most obvious and quantifiable source of new sediment into the North Fork Garcia Watershed during the 1995 flood events. The effects of three debris torrents and three debris slides were documented. (Other smaller debris slides were observed, but delivered sediment was less than 100 cubic yards, and therefore they are not being addressed individually in this report.)

(a) Debris Slides/Torrents: Seven debris slides were mapped in the North Fork of the Garcia River following the major storm events of 1995, 3 of which torrented. (See map.) Field review of these sites indicated that these slides all originated in fill that was placed at the outboard edge of a road, landing, or skid trail at the time of past road construction or reconstruction (1950's - 60's). In six of the seven sites, the old roads had been reopened and winterized following standard Forest Practice Rules during the past seven years, and changes and/or concentration of runoff onto old fill resulting from reopening the roads could have been a possible contributing factor leading to fill failure. The seventh site, also a fill failure, occurred on a road constructed in the 1950's or 60's where there has been no activity for at least 20 years.

A recent study at Redwood National Park links debris slides/torrents to past road construction techniques. It asserts that the potential for road fill failure may currently be greater than in the recent past due to the fact that woody debris buried in fill, a legacy from past road construction techniques, decays and causes a reduction in basal shear strength over time. (Spreiter, 1993.)

It is interesting to note that more debris torrents occurred during the somewhat smaller storms of March 1995 than in the January 1995 event. Mass wasting tends to occur where high pore-water pressures exist; that is, where soils are saturated over long periods of time. Mass wasting also occurs as a result of ponding and/or piping, which also contribute to high pore-water pressure.

It is estimated that over 5,000 cubic yards of sediment as well as large quantities of LWD, were introduced and/or mobilized as a result of the 2 largest debris torrents that occurred following 1995 storm events. (Sites 1 and 2.) At Site 2, the debris torrent plugged a downslope culvert resulting in stream diversion. The resulting erosion from the plugged culvert accounts for about one-half of the sediment delivered to the stream. However, because of relevant THP drainage work on the road, the diversion was redirected back into its natural watercourse 70 yards down the road. Without this drainage work, the diversion would have continued down the road and caused a much larger problem.

The 4 debris slides that did not torrent (Sites 4-7) delivered a cumulative total of approximately 1,000 cubic yards, with approximately 1,000 cubic yards of additional sediment to be delivered in the near future.

Between 1989 and 1994 only 4 new, relatively small, fill failure debris slides/torrents were observed in the watershed. However, in light of the 1995 high rainfall winter and the resulting sediment delivered by debris torrents and slides, CFL management will place greater emphasis on identifying potential fill failure sites. (Sec Sections III and IV.)

The general conclusion drawn from the evidence at these sites is that the recent slides were a direct result of oversteepened fill placed 25 to 40 years ago, when road and skid trail construction practices were unregulated and generally poor. However, there may be a connection between these failures and construction/reconstruction techniques (i.e., reconstructing and winterizing roads using waterbars following the Forest Practice Rules can concentrate runoff and therefore trigger debris slides or torrents). As early as 1990, CFL's watershed consultant recommended to CFL's predecessor, R AND J Timber Co., that road construction and maintenance practices should include the outsloping of roads and installation of rolling dips in sensitive areas (such as, along streams and on steep slopes). Although at that time CDF staff would only approve these techniques on a very limited basis, it is expected at this time that CDF will accept these practices. Therefore, it is recommended that roads in areas sensitive to debris slides and torrents should be outsloped to eliminate runoff concentration on old road fill. (See Section III.)

(b) Streambank Failures: Numerous small slides caused by streambank failure are also contributing a significant amount of sediment. It is estimated that over 1,000 cubic yards of sediment were delivered during the 1995 storm events from sites observed on the section of the Mainstem North Fork in the areas where field review took place in March. (Sec map.) All of these failures were a result of past practices (debris jams diverting stream flows, past road problems, etc.).

2. Surface Erosion

Field review on CFL property has shown that surface erosion (except for gullies, which were included in Section III), contributes only a small fraction of the sediment delivered to Class I watercourses and is adequately mitigated using current practices. CFL's light harvest (average 5,000/acre) means less ground disturbance and more canopy cover, which results in much lower rates of surface soil erosion than more intrusive harvesting.

3. Crossings and Diversions

The current condition of crossings addressed in recent THP's in the North Fork is very stable. There arc approximately 240 active crossings (those listed in post-1988 THP's) in the North Fork Garcia. Of these, approximately 85 are culverts, with 2 bridges, and 1 multi-plane. Approximately 66% of the total road system and 100% of the roads with culverts were reviewed in March and April 1995 after the 1995 flood event. This field review resulted in the following findings:

One culvert was observed, which was the result of a debris torrent (Site 2), and this site was discussed under subsection (a) above. There were 7 culverts that plugged and overflowed, causing less than 100 cubic yards of delivered sediment total. Other problems at culvert crossings resulted in another 50 to 100 cubic yards of sediment total. These were mostly the result of inadequate energy dissipation at the outlets.

Only one diversion was observed at a culvert crossing, which was the result of the debris torrent at Site 2 described above. Only one other diversion was observed at all the crossings reviewed in the field. The sediment delivered from this diversion was approximately 20 cubic yards.

A review of crossings pulled and/or restored as mitigations during implementation of recent THP's (1988-1994) showed that approximately 3,000 cubic yards of potential sediment had been removed or stabilized as a result of pulling these crossings.

In an attempt to quantify the sediment actually "saved" or "lost" as a result of current logging practices, hypothetical scenarios must be evaluated based on a set of assumptions derived from related studies. An unpublished study conducted by RNP at Garrett Creek, a tributary to Redwood Creek, on land that had been managed for timber production, predicted a high failure rate at crossings during a 20-year or greater storm event, with many of these failures resulting in diversions. The predicted failure rate was based on extensive evidence gathered in the study area documenting the history of failures during past storm events with up to a 20-year magnitude. (Hagans, 1995. The number of crossings that failed, diversions, and total erosion (approximately 600 cubic yards) at the 160 crossings observed during the April 1995 field review of the North Fork Watershed (which is approximately 2/3 of the total crossings in the watershed), is far less than predicted by the RNP study.

THP from 1988 to 1994 identified and treated at least 45 drainage problems. Many of these sites were diversions that were still causing extensive erosion. The treatment of these drainage problem sites significantly reduced the sediment delivery in the watershed.

Therefore, it is my professional opinion, based on my observations in the field, my experience in similar situations, and my knowledge in watershed matters, that there has been a significant decrease in sediment delivery as a result of corrective measures taken at crossings in the North Fork Watershed during CFL's management.

4. Machine-Placed Sediment (Fill Placed in Streams)

During the lower rainfall years of 1989 through 1994, erosion at machine-placed sediment sites (mostly abandoned landings and crossings left from past logging) was the largest quantifiable source of sediment in the North Fork based on field observations. At 4 sites where data was collected during the April 1995 field review, an estimated 1,500 cubic yards of sediment was delivered into streams. This is less than the estimate from observed debris torrents and slides, but still represents a major source of sediment.

However, in an attempt to evaluate sediment "saved" or "lost" as a result of current logging practices, it seems conclusive that this sediment source is directly linked to past and not recent logging practices.

5. Remobilization of Instream Stored Sediment

It is in the storage reaches where the legacy of past practices is most dramatically affecting current conditions. Terraces from past flood events on the North Fork and its tributaries are still obvious in many places, and although the watercourses have downcut into the sediment deposits left from past flood events establishing quasi-stable channels, in many response reaches there are still 5' to 10' of instream stored sediment below the newly incised stream channel. It is these lower gradient response reaches that in the past also provided quality rearing habitat for Coho before they filled in with sediment.

After field research during 1989-91, it was my professional opinion that remobilization of instream stored sediment from Class I, II and III watercourses was the largest sediment source in the North Fork Garcia at that time. (MCRCD, 1992.) The field review during April 1995 leads to the same conclusion about the current condition. It is very difficult to quantify remobilization of instream stored sediment. However, the extensive erosion of old flood terraces and downcutting of stream beds indicates that extensive remobilization is still occurring on the North Fork.

B. Large Woody Debris

A fisheries biologist report in 1992 listed the lack of large quantities of LWD as a limiting factor for the fisheries resource in the North Fork Garcia. (Peterson, 1992) In general, this is still true; however, the downcutting which occurred as a result of the 1995 flooding uncovered a substantial quantity of LWD, especially in reaches higher in the system. There is a great deal of high quality LWD buried under the current streambed, which, as it is uncovered as a result of downcutting, will continue to be an important component of LWD recruitment in the upper reaches.

In reaches lower in the system, however, uncovering of LWD did not occur, and without stream excavation, it is unlikely that it will occur. A significant increase in LWD in these reaches did occur as a result of two major debris torrents upstream.

C. <u>Riparian Canopy Cover</u>

Canopy cover is the main determining factor in stream temperatures. (Payne, 1994.) The canopy cover of the Mainstem North Fork and lower sections of the tributaries is between 70% and 80%. This provides enough stream protection from the heating effects of the sun to keep water temperatures on the North Fork below the lethal or stressful point for rearing salmonids. (Peterson, 1992.) As a result of the current condition and CFL's 25-foot sensitivity zone (see Section III), canopy cover/water temperature is not a major problem to the fisheries resource in the North Fork at this time and should improve in the future.

Because of the critical importance of water temperatures on the fisheries resource, the regulating agencies have requested temperature monitoring on the North Fork. For the above reason, and to help determine the best sites for future salmonid rearing habitat restoration, CFL has agreed to establish water temperature monitoring sites on the North Fork.

III.

EVALUATION OF IMPACTS OF 1955 FLOODS AND COMPARABLE EVENTS IN THE 1950's AND 60's

Rigorous, quantitative evaluation of the effects of major storm events on a watershed is difficult at best. Rainfall records over time for the North Fork Garcia do not exist, although there are records for areas surrounding the North Fork. In addition, it is difficult to extrapolate actual flow levels of a river that occur during specific storm events from the rainfall data, even in those instances where reliable rainfall records in an area are available, because of intensity differences over the 24-hour period.

The best data available for the North Fork Garcia comes from the USGS stream-gaging station located on the mainstem Garcia just below the confluence of the North Fork, which was operated intermittently beginning in 1952. Friends of the Garcia began operation of a stream-gaging station at the same site in 1992. Although operation of a station at this site was not continuous, records do include the winters of 1955-56, 1964-65, 1966, 1974-75, 1993 (which include the major storm events for that time period), and the winter of 1994-95. Peak flows during the 1995 storm events were measured at over 30,000 cfs, which is slightly larger than the previous event of record in 1974. Therefore, according to records from this stream-gaging station, the flood event of 1994-95 was the event of record.

Unofficial rainfall data also indicates 24-hour and 48-hour totals to be records for this 40-year period at the rainfall recording sites closest to the North Fork. Personal communications with local residents also indicate that the river was at its highest level in memory at a number of sites besides the stream-gaging station. (Piper, 1995; King, 1995.)

As a means of assessing the effects of post-1988 timber harvest on the North Fork Garcia Watershed, an effort has been made to compare the effects of the 1995 flooding on the current watershed to the effects of the earlier major flood events, which arc described above under Section I above.

In contrast to the extensive aggradation that occurred as a result of flooding during the 1950's, 60's and 70's (as described above), field reconnaissance conducted to date in the North Fork basin showed only sporadic aggradation. Degradation (or downcutting), on the other hand, was observed along many reaches. There was also only one new log jam observed in the stream reaches observed, and this was not a barrier jam, but rather a "floater" which allows passage for both fish and sediment. This can be seen in contrast to numerous barrier jams resulting from earlier floods.

The differences between the effects of the 1995 flood event on the sediment, LWD, and riparian cover of the North Fork and its tributaries and the effects of earlier comparable flood events in the 1950's and 60's is dramatic. In 1995 the sediment was transported competently, with an overall increase in pool volume and overall downcutting, contrasting to the 5' to 20' of deposition during earlier flood events.

Although large quantities of LWD were mobilized by debris torrents and high flows in 1995, this did not overwhelm or dominate extensive reaches. It did not negatively affect the fisheries resource, but rather improved fisheries habitat. Very little canopy cover was lost in 1995, in comparison to the loss of virtually all riparian vegetation in the 1950's and 60's, as a result of being flattened by entrained LWD.

The main reason for the watershed's different response in 1995 as compared to the response to similar storms in the 1950's and 60's is the dramatic difference in management practices during recent timber harvest. The harvest was much lighter, streambeds were not used for transportation networks, road and landing reconstruction was planned with problem sites identified and mitigated, and specific problem areas were restored.

The most important management practice, however, was the correct care of drainages. All drainage facilities were planned to withstand a 50-year flood event. In the 1950's and 60's very few drainage facilities were constructed and hundreds of failures occurred, with many of the failures resulting in diversions. In 1995 only two drainage facilities failed. There was some erosion as noted above at other drainage facilities, but losses were in the hundreds of cubic yards, not in the hundreds of thousands of cubic yards as in the past. This is the major success story of current management practices.

IV.
IDENTIFICATION OF MEASURES CURRENTLY IMPLEMENTED AND ADDITIONAL MEASURES PROPOSED FOR FUTURE IMPLEMENTATION BY CFL TO MITIGATE ADVERSE IMPACTS OF TIMBER HARVESTING AND SEDIMENT DRAINAGE FROM EROSION SITES CAUSED BY PAST TIMBER HARVESTING

The following are new or recently adopted management practices that must be implemented for the conclusions of this report to be valid:

1. 25 foot buffer zone on Class I watercourses and Class II watercourses that have the potential for a viable anadromous fish habitat, as determined by CFL's watershed consultant.

Areas designated for buffer zone status are those areas excluded from current harvest or entry except on existing roads. CFL will remove these areas from timber harvest for 20 years, after which this designation may be reconsidered. The zone is defined as land extending 25' from the bank on either side of a Class I stream.

The reasons supporting the exclusion of timber harvest from these zones are to decrease water temperature (as affected by canopy); increase food for fish (as affected by canopy); encourage recruitment of large woody debris; promote bank stability; promote an increase in the riparian wildlife; and provide a sediment filer strip between the slopes and the stream.

Other areas that may be protected on a site-specific basis are:

(a) headwalls, or steep headwater swales;

(b) steep inner gorge slopes and slopes adjacent to specific deeply incised tributaries;

(c) other extremely unstable areas noted as a result of the watershed analysis; and

(d) other areas of specific concern (i.e., threatened and endangered species sites, archeological sites, etc.).

Conceptually, these buffer zones will not be just ribbons of resources left untouched along streams; but in those areas where there are unstable slides or steep inner gorge slopes, the exclusion zone will balloon out to include these areas as well. This arrangement will be of particular benefit to wildlife by maintaining habitat connectivity.

Watershed and wildlife consultants will have management authority within the riparian buffer to restore and enhance fisheries, wildlife, and water quality. Flagging will be used to mark the exclusion zones where it exceeds the 25 foot minimum buffer.

2. Road drainage will be improved by outsloping road surfaces and installing rolling dips.

Concentration of runoff from road surfaces can cause erosion, including gullies and perched fill failure, which can cause debris slides and/or debris torrents. In general, RPF's correctly identify areas at risk of failure (usually by observation of past failure) and direct drainage away from these sites. However, many perched fill sites have revegetated and no past failure has occurred, making them difficult to identify. Outsloping roads and installing rolling dips will reduce the risk of future gullying and fill failure by dispersing runoff in areas not identified and treated specifically as problem sites. This docs not preclude insloping and berms at identified potential debris slide/torrent sites.

3. Culverts will not be used on seasonal roads where there is high risk of a debris torrent occurring upstream:

To be assessed on a THP-by-THP basis.

4. Rock fords and rolling dips will be used in place of culverts on seasonal roads that are determined at risk on a THP by THP basis.

5. Rolling dips, outsloping, or other drainage measures will be used at all culvert crossings to eliminate the potential for diversion.

This is to be implemented on all permanent roads by the 1995-96 winter season. This is to be implemented on all seasonal roads in stages as they are reused during the next entry for harvest.

6. Trash racks will be placed at crossings on permanent roads where culverts have plugged in the past or where a high risk of plugging has been identified.

7. All pulled crossings and landings will be excavated to ORIGINAL stream grade (not post-1950's to 60's stream grade), and all stream banks will be excavated to a stable (at least 2:1) grade, taking care to compact all excavated material.

If it is impossible to carry out this proscription at a given site, then a specific description of the work proposed at that site must be included in the THP, describing what work will be implemented to protect the site from eroding.

V.
IDENTIFICATION OF MEASURESPROPOSED BY CFL MANAGEMENTTHAT WILL ACCELERATE RECOVERY OFHILLSLOPES AND STREAMS IN THE NORTH FORK GARCIA WATERSHED

The *STAR* Worksheet System, described in the *STAR* Worksheet Manual submitted as Appendix A to this report, will be used as a tool to accelerate recovery of the North

Fork Watershed. The *STAR* System has the capability of identifying and prioritizing potential sediment delivery sites on a watershed scope and can also be used to inventory roads.

Using the *STAR* Worksheet System, a road inventory will be conducted on all roads on each new THP, as follows:

(1) roads that are used during current THP;

(2) roads not used but which arc part of the current CFL road system and arc within the THP boundaries;

(3) abandoned roads within THP boundaries;

(4) roads designated as "appurtenant" (i.e., roads within CFL property boundaries but outside the THP boundary which are used to access THP).

The road inventory will be carried out by the forester, technician, and/or watershed consultant in a timely manner so that restoration required can be completed before the onset of the first winter season after harvest activity. The inventory will consist of surveying all roads described in items (1) through (4) above, and completing a *STAR* Worksheet for all sites that pose a threat for sediment delivery into the watershed.

All potential sediment delivery sites that occur along CFL roads will be identified and prioritized by the *STAR* System during the road inventory. Restoration work proposed for *STAR* sites will take place during the term of each THP in connection with ongoing operations. The selection of a given *STAR* site for restoration is a function of that site's *STAR* System rating and the availability of funds for restoration. Funding for restoration is dependent on the harvest volume from a given THP.

VI.
MONITORING PROGRAMS PROPOSED

CFL will continue to develop its monitoring program on two levels:

(a) mitigations will be monitored on a THP-by-THP basis as described in the Monitoring Plan (Appendix B); and

(b) CFL is developing a long-term monitoring plan as part of the SYP process.

VII.
CONCLUSION:
EVALUATION OF THE POTENTIAL CUMULATIVE IMPACTS OF PROPOSED TIMBER HARVEST IN THE NORTH FORK GARCIA WATERSHED

It is my professional opinion, based on the information presented above, that the North Fork Garcia Watershed is in better condition at this time than it was 5 years ago. This means that there was not an adverse cumulative effect on the critical riparian issues discussed, despite the high percentage of the Watershed that was harvested in the recent past.

The reason for the improved condition is the management practices implemented during the recent harvest period as outlined in the report -- specifically the treatment of crossings and diversions.

To enter the North Fork again with similar beneficial results is possible but will require new management practices. These are outlined in Sections III and IV of this report. A monitoring system (Section V) has been developed and will be implemented to insure both the compliance and effectiveness of these proposed practices.

APPENDIX A

STAR WORKSHEET AND MANUAL

PRIORITY #:

★ STAR ★ WORKSHEET (2/29/96)

(To be completed for all road sites from which there is a potential of sediment transport to a Class I stream.)

Inspector: ____________ Date: ________ Watershed Name: __________ #: __________

Site #: __________ THP #: ____________ Road Name: __________ #: ____ Mileage: ____

PART I SITE DESCRIPTION

1. **Potential Sediment Source:** This site is a:

☐ Debris Slide ☐ Landing Fill ☐ Crossing

☐ Debris Torrent ☐ Road Fill ☐ Streambank Erosion

☐ Other Slide ☐ Road and/or Landing Drainage ☐ Instream Stored Sediment

☐ Gully ☐ Road Surface ☐ Other __________

2. **Size of Site:** ______ yds (width) x ______ yds (length) x ______ yds (depth) = ______ yds^3

3. **Fill:** Perched? ☐ Yes ☐ No Organic matter in fill? ☐ Yes ☐ No

4. **Is there a Knickpoint?** ☐ Yes ☐ No If yes, what height? ______ ft

5. **Water Source:** ☐ 0, ☐ I, ☐ II, ☐ III, ☐ IV If O (Other), what? __________

6. **If site is Crossing,**

 a. **Is there a:**

 ☐ Culvert ☐ Bridge ☐ Humboldt

 ☐ Fill ☐ Armored Ford ☐ Pulled Crossing

 ☐ Dip ☐ Other __________

 b. **If a Culvert:**

 1) Diameter is ______ inches
 2) Downspout Existing: ☐ Yes ☐ No Needed: ☐ Yes ☐ No
 3) Rock Dissipator Existing: ☐ Yes ☐ No Needed: ☐ Yes ☐ No
 4) Trash Rack Existing: ☐ Yes ☐ No Needed: ☐ Yes ☐ No
 5) Current culvert condition: ☐ OK ☐ Problem If problem, what: __________
 6) Culvert plug potential: ☐ Low ☐ Medium ☐ High
 7) Culvert head water height is: ______ feet.

 c. **Is there potential for a diversion?** ☐ Yes ☐ No

 d. **Drainage area above crossing is:** ______ acres.

 e. **Average gradient of slope above crossing is:** ☐ <30% ☐ 30-60% ☐ >60%

 f. **Stream gradient:** ______%, **Area at crossing:** ______ ft^2.

7. **Cause of Failure / Potential Failure:** ☐ Natural ☐ Past Logging ☐ Current Logging

8. **Was there an erosion control measure at this site?** ☐ Yes ☐ No **Successful?** ☐ Yes ☐ No

 If yes, what: __________

9. **Brief Description/Comments:** __________

CONTINUED OVER →

PART II SEDIMENT EVALUATION

1. **Estimated yds³ of potential failure:**

   ________ yds³ minus ________ yds³ already delivered times ________ delivered %
   equals [ ] yds³ potential delivered sediment

2. **Delivery rate:** [ ] (a number from 1 to 4; low — high)

3. **Erosion Potential of the Site:** [ ] (a number from 1 to 4; low — high)

PART III PROPOSED REHABILITATION

1. **Proposed Rehab work:** ____

   ____

   ____

   ____

2. **Estimated Cost of Rehab:** $ [ ]

3. **Is this site treatable?** [ ] (a number from 0 to 3; not treatable — easily treatable)

4. **Cost Effectiveness** (Estimated cost divided by yds3 removed = Cost per yd³)

   $$\frac{\text{Est. \$\_\_\_\_\_\_ (Part III \#2)}}{\text{\_\_\_\_\_\_ yds}^3\text{ removed (Part II \#1)}} = \$\ \boxed{}\ \text{per yd}^3$$

5. **Priority Index #:**

   $$\frac{\text{(II\#1: \_\_\_\_\_\_ x II\#2: \_\_\_\_\_\_ x II\#3: \_\_\_\_\_\_ x III\#3: \_\_\_\_\_\_)}}{\text{III\#4: \_\_\_\_\_\_}} = \boxed{\text{\_\_\_\_\_\_ = PRIORITY INDEX}}$$

Finally, additional comments and/or sketch:

____

____

____

____

STAR WORKSHEET MANUAL

PURPOSE OF THE *STAR* WORKSHEET

This Worksheet system has been developed by Jack Monschke Watershed Management with assistance from CFL staff and consultants with the objective of improving overall long term watershed management by creating a standardized system for assessing erosion risks and cumulative impact of sediment in a watershed. The system was developed specifically for CFL's property, which was extensively logged during the 1950's and 60's, before the Forest Practice Act of 1974 was implemented. Sedimentation appears to be the major factor adversely affecting the fisheries resource in these watersheds at this time over which timber landowners have some control: this includes potential sediment that will erode into the drainage network and eventually enter Class I streams, as well as in-stream stored sediment in Class I's, II's, and III's, which has already eroded into streams and will continue to move through the system.

This system enables foresters and technicians to conduct road inventories and to identify other potential sediment problem sites in a watershed and to record the information they collect regarding these sites on the *STAR* Worksheet. This information will be keyed into the existing GIS computer mapping program and will provide CFL management with information regarding the nature and frequency of potential sediment problem sites in a watershed, the approximate cost of mitigation of these problems, a rough prioritization of treatable sites, and an overview of the cumulative impact of forest practices in the watershed in relationship to sediment.

This manual is intended to accompany the Worksheets to serve as an introduction to this data collecting method and as a training tool for the forester or technician working in the field to complete the worksheets. Section A will address the determination of a problem or *STAR* Site. Section B will provide specific instructions for completing the Worksheet.

<u>A. Determination of Problem or "*STAR*" Site:</u>

The first step is to review current GIS maps, aerial photos (both recent and past), geological maps, and past timber harvest plans, and, where relevant, to discuss specific issues with forestry or agency staff. This will provide initial mapping of probable problem areas: crossings, WLPZ roads and landings, slides, inner gorges and headwalls, roads or landings with perched fill, instream stored sediment sites, etc.

Next, utilizing maps and notes from office research, the forester or technician does a field review of probable problem sites. This usually includes an inventory of all roads and Class I and II streams in an area, as well as all other potential problem sites identified in the office review. During the course of this field review, it is important to be watching for other active or potential sediment problems that may not have turned up during office research. Some of the most commonly found problems include: slides, debris torrents, landing fill failure, failed crossings, streambank erosion, road fill failure, instream stored sediment, gullies caused by watercourse diversions, potential diversions, etc.

<u>**If the expected volume of sediment that could be delivered to a Class I stream from a given site on the CFL road network exceeds 10 cubic yards, or if the expected volume from a non-road site (including abandoned roads) exceeds 100 cubic yards, the site is designated as a *STAR* Site and requires completion of the *STAR* Worksheet.**</u>

<u>B. Instructions for Completing the *STAR* WORKSHEET</u>

<u>IDENTIFYING INFORMATION FOR *STAR* WORKSHEET:</u>

The spaces at the top left of the form are to be completed by the forester or forestry technician as indicated:

<u>Inspector:</u> Note name of forester or technician doing the field review *(Example: J. Monschke)*

<u>Date:</u> Note date of field review *(Example: 3/16/96*)

<u>Watershed Name</u>: *(Example: NFG or North Fork Garcia)*

<u>Watershed #:</u> *(Example: 113.70025)*

<u>Site #:</u> The site numbers will be listed by the forester or technician in chronological order daily *(Example: #7)*

<u>THP#:</u> *(Example: 1-93-015-MEN)*

<u>Road Name:</u> *(Example: Hollow Tree Road)*

<u>Road #:</u> A road numbering system has not at the time of this writing been r resolved.

<u>Road Mileage:</u> On drivable roads mileage will be noted in this *space.(Example: 4.3)* Locations of sites on non-drivable roads will be noted by mapping.

PRIORITY #: After completion of the all the worksheets in a Watershed Protection Unit, the Priority Number will be tabulated in the office, based on the Priority Index Numbers from page 2 of each form. The Priority number will then be entered on the upper left hand corner of each completed Worksheet. *(Example: Priority #: 17)*

PART I: SITE DESCRIPTION

The first question to ask when arriving at a site in the field is:

COULD EROSION FROM THIS SITE DELIVER SEDIMENT TO A CLASS I WATERCOURSE?

This question will be referred to throughout the following manual as

"THE FIRST QUESTION".

Following are some of the many questions that should be asked to help answer The FIRST Question:

a. What is the slope steepness below the site?

b. What is the hydrologic transport capacity at the site — i.e., is there enough water to move the potential sediment? (Less water is needed where the slope is steeper and the material is smaller.)

c. Is there a bench between the site and a watercourse that could trap some or all of the erosion if a failure occurs?

d. What is the quality of the filter strip between the site and a watercourse? (Filter strip refers to the land surface in the area between the erosion site and a watercourse.) The quality of a filter strip depends on two main factors:

1) Ground cover (both surface, i.e., duff and litter, and growing). Examples of good filter materials are: litter from trees, such as leaves, needles and twigs, and grasses and other dense low-growing vegetation.

2) Slope gradient. Even bare soil can trap a high percentage of eroding material before it enters a watercourse if the gradient is gentle.

e. What type of material is incorporated into a potential erosion site? For example, small tan oak slash will rot quickly and be of little or no structural help after one or two years, whereas, large redwood can be a strong stabilizing influence.

f. What type of soils? Rock, porous, blue goo, clay, etc.?

g. Was this site identified as unstable in geologic or soils maps?

h. Is there evidence of past failure? And if so, did the erosion from this site deliver sediment to a Class I watercourse or a watercourse capable of eventually transporting it to a Class I?

i. Do I need to follow the anticipated erosion course downslope to determine the potential of sediment reaching a Class I watercourse?

j. Taking into account the information gained from asking the questions above, what percentage of a potential failure will reach a Class I watercourse as sediment?

(The answers to some or all of the above could be mentioned in your description or comments on the worksheets if pertinent.)

If this study of the site leads you to answer "YES" to The FIRST Question, then a rough estimate of potential cubic yards of sediment multiplied by a rough estimate of percentage delivered must be made to determine whether to fill out a *STAR* Worksheet. (Use the formulas and diagrams at the back of the manual to help get a rough estimate of cubic yards of potential failure.)

****

Following is a brief explanation of each Worksheet item. Fill out only those items that are applicable to the specific site.

PART I:

1. <u>Potential Sediment Source:</u> Mark the appropriate box. More than one answer may be appropriate. If Other, give brief description.

2. <u>Size of Site:</u> Measure site indicating length, width and depth in yards.

3. <u>Fill:</u> Perched fill refers to a large mass of fill placed by man on a slope steeper than the original gradient. Mark yes or no. Organic matter refers to non-mineral debris buried in the fill, which can include everything from small slash to large sound Redwood logs. Mark yes or no.

4. <u>Knickpoint:</u> Knickpoints are those places where an abrupt change of gradient, and thus an increase in eroding energy, occur in a watercourse. When a knickpoint breaks away, it often causes a gully or streambed to unravel rapidly releasing a large quantity of sediment. Knickpoints can be found at any type of erosion site where there is a surface runoff across the site. Mark yes or no. If yes, note height in feet. This is a vertical drop, not a cascade.

5. Water Source: Mark the appropriate box. If O (Other), describe. Possible others include swale, spring, runoff, bog, etc.

6. If site is a Crossing,

   a. Mark the appropriate box.
   b. If culvert, answer questions 1) through 7):

      1) Indicate diameter of culvert in inches.

      2) through 4) For each of the devices listed, indicate whether or not the device exists on site at the time of the inspection, and whether or not it is needed.

      5) Indicate whether the condition of the culvert at the time of inspection is OK or if there is a problem. If problem, describe briefly. Possible problems include crushed inlet, rusty bottom, etc.

      6) Indicate potential of culvert to plug.

      7) Indicate culvert head water height. This is the elevation difference (in inches) between the bottom of the culvert and the lowest point at which water would escape if the culvert plugs and ponds water behind the road prism. This may be the road surface or an adjacent inboard ditch.

   c. Answer this question for all crossings. If the drainage structure fails, will runoff be diverted down a road, or will it return to its drainage at or very near the structure?

   d. and e. Drainage area and slope gradient can be completed in the office or estimated in the field.

   f. Determine the natural stream gradient by shooting from points where the watercourse is at or near its original grade both above and below the crossing.

   Determine the area (two-year storm event in square feet) of the stream at the crossing by calculating the area of the natural watercourse at an undisturbed site immediately above or below the crossing.

7. Cause of Failure/Potential Failure: Answer based on observation. For example,

if there is old road fill failure and no perched fill placed during current logging (post 1988), then this would be called "Past Logging". If there is a slide with no evidence that roads, skid trails, or diversions contributed to the slide, then this would be called "Natural". If evidence points to logging since 1988, then call it "Current Logging".

8. Was there an Erosion Control Measure at this site ? Was there a management practice or specific erosion control device used to prevent erosion at this site? If yes, describe. Was it successful? Any ideas or thoughts about possible reasons for success or failure, suggestions for how to deal with similar sites in the future?

9. Give a brief description of the site in this space (if more space is needed use the reverse or add additional page). The forester or technician should include any pertinent information not addressed by other questions as well as a general short description that captures the essence of the site.

PART II: SEDIMENT EVALUATION

1. To help estimate the approximate volume of sediment that this site could deliver to a Class I watercourse, please see diagrams and formulas A through E at the end of this manual.

$$\frac{\textbf{width x length x height}}{\textbf{6}} \quad \textbf{minus} \quad \frac{\textbf{eroded width x length x height}}{\textbf{6}}$$

= potential erosion x percentage delivered = potential delivered sediment

Use the information from Part I #2. Remember to subtract the volume that has already eroded and to multiply by the delivered percentage.

2. Estimate the sediment delivery rate of this site using numbers 1 through 4, 1 being the slowest rate of delivery (i.e., 5 years or more) and 4 being the fastest rate of delivery (i.e., one storm).

3. Estimate the erosion potential of this site using the numbers 1 through 4, 1 being the lowest potential and 4 being the highest.

PART III: PROPOSED REHABILITATION

1. Briefly describe rehabilitation work you would propose for this site. Use space below or additional pages if needed.

2. Estimate the cost of rehabilitation, considering costs of design, access, excavation, armoring, materials, supervision, etc.

Some relevant questions that apply to III, 1. and 2. follow:

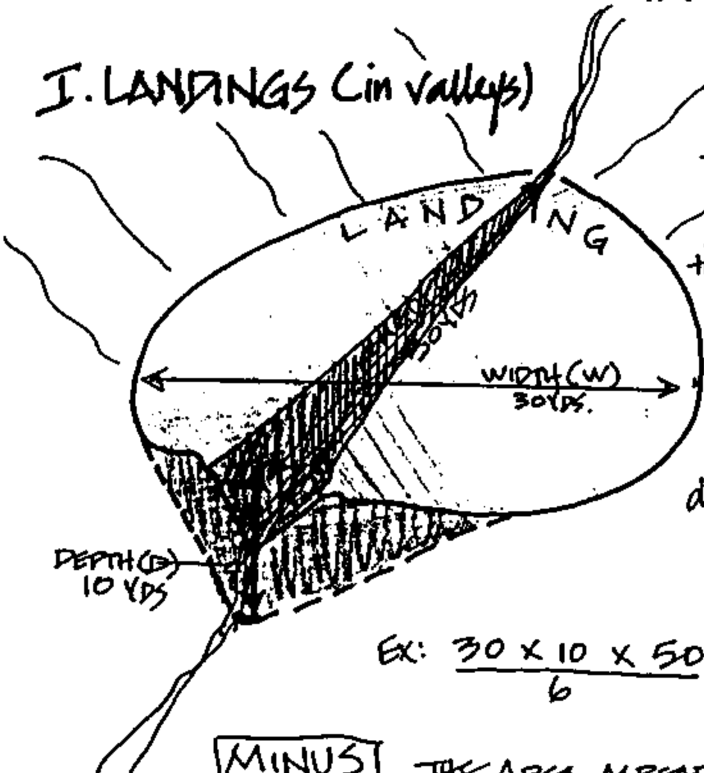
- * What is the travel time to the site?
- * What is the environmental impact of getting heavy equipment to the site (i.e., if access road must be constructed, what is the erosion potential?)
- * Is there rock available at or near the site for armoring?
- * If rock is not at the site, what is the hauling time in hours?
- * Where is the rock quarry, and is the rock easily mined?
- * Is there good quality LWD at the site?
- * Where will the spoils from excavation go? Will it need to be end-hauled? How far?
- * Have similar sites been treated? If so, how and at what cost?

3. Estimate the treatability of this site using numbers 0 through 3, 0 being not treatable, and 3 being easily treatable.

4. and 5. Complete the formulas.
5.
Note: After *STAR* inventory work is completed for a given area, then the sites are prioritized in the office using the Priority Index Number in Part HI, #5. (The highest index # equals the highest priority.) This number is then added on the top left hand corner of page 1 of the Worksheet.

HOW TO ESTIMATE CUBIC YDS. OF POTENTIAL SEDIMENT:

I. LANDINGS (in valleys)



TO GET TOTAL YDS^3 OF LANDING FILL:

WIDTH (AT WIDEST POINT) ~ W

times DEPTH (FROM SURFACE OF LANDING FILL TO ORIGINAL STREAM GRADE AT BOTTOM OF LANDING) ~ D

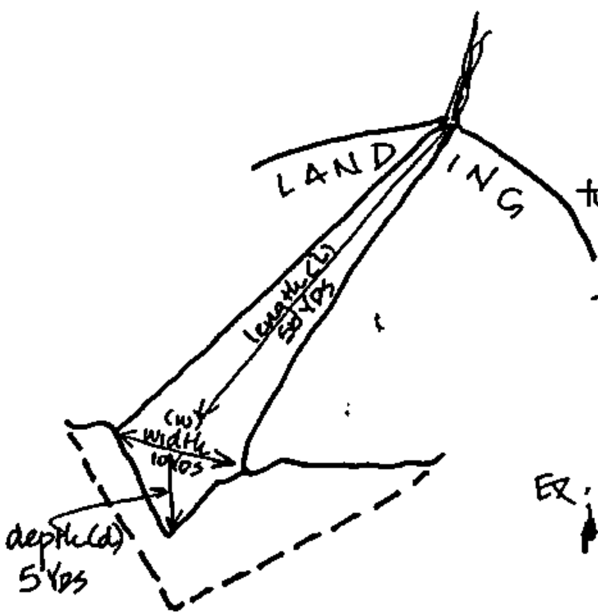
times LENGTH ~ L

divided by 6

$$\boxed{\frac{WDL}{6}}$$

EX: $\frac{30 \times 10 \times 50}{6} = 2500$ YDS^3 (ESTIMATED YDS^3 LANDING FILL)

MINUS THE AREA ALREADY ERODED (SHADED AREA) WHICH CAN BE ESTIMATED AS FOLLOWS:



width (w) OF ERODED AREA AT BOTTOM END OF LANDING

times depth (d) OF ERODED AREA AT BOTTOM OF LANDING

times length (l) OF ERODED AREA

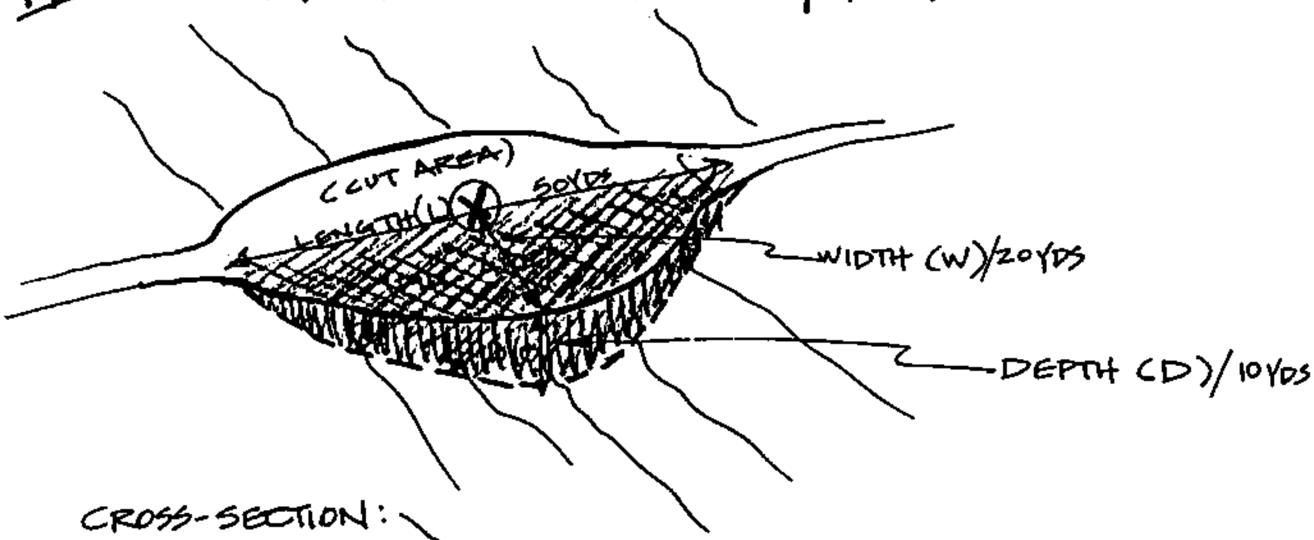
divided by 2

$$\boxed{\frac{wdl}{2}}$$

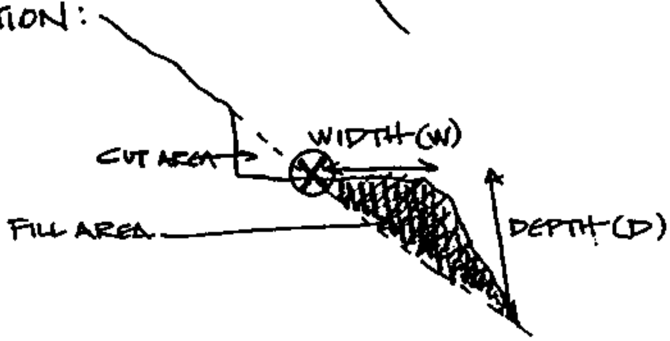
EX: $\frac{10 \times 5 \times 50}{2} = 1250$ YDS^3

$$\therefore \boxed{\frac{WDL}{6} - \frac{wdl}{2}} =$$ ESTIMATED YDS^3 POTENTIAL SEDIMENT FOR LANDINGS IN VALLEYS

II. PERCHED FILL (roads, landings, etc)



CROSS-SECTION:



WIDTH OF FILLED AREA (AT WIDEST POINT) ~ W

times DEPTH OF FILLED AREA (AT DEEPEST POINT) ~ D

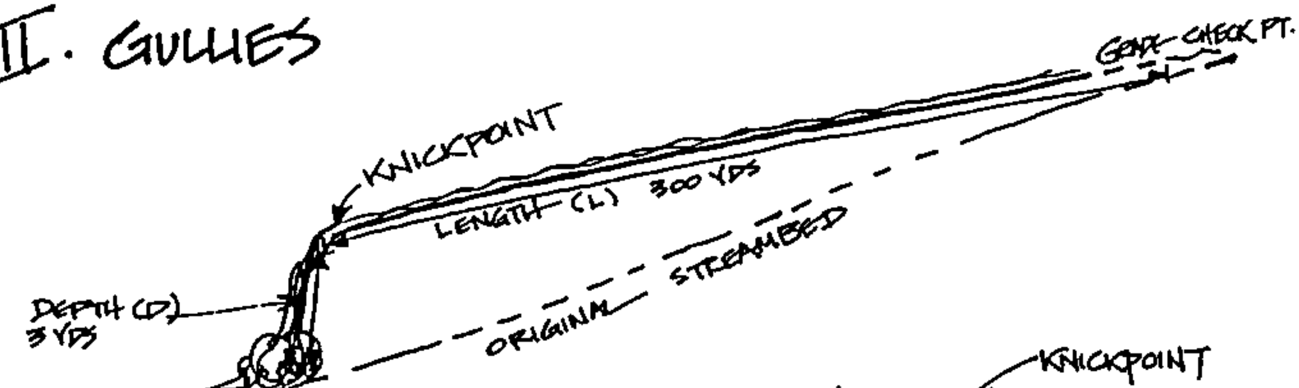
times LENGTH OF FILLED AREA ~ L

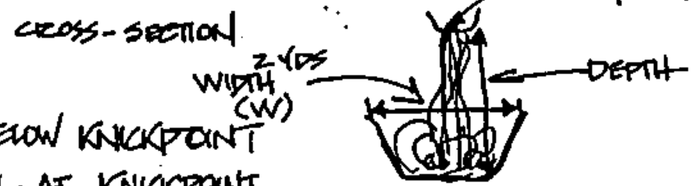
divided by 6

$$\boxed{\frac{WDL}{6}} = \text{ESTIMATED YDS}^3 \text{ POTENTIAL SEDIMENT FOR PERCHED FILL}$$

EX: $\frac{20 \times 10 \times 50}{6} = 1{,}666 \text{ YDS}^3$

III. GULLIES





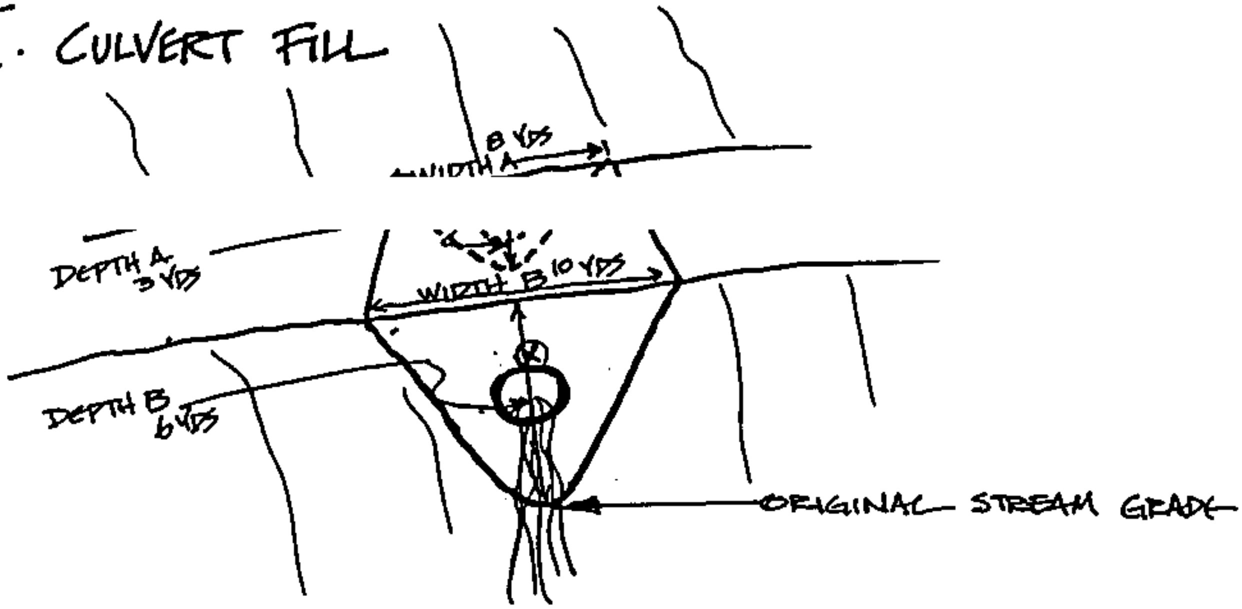
WIDTH OF GULLY BELOW KNICKPOINT
times DEPTH OF WATERFALL AT KNICKPOINT
times LENGTH (FROM KNICKPOINT TO GRADE CHECK UPSTREAM
divided by 6

$$\boxed{\frac{WDL}{6}} = \text{ESTIMATED YDS}^3 \text{ POTENTIAL SEDIMENT IN GULLIES}$$

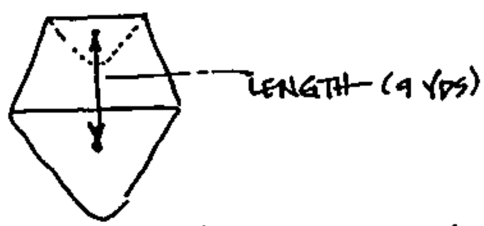
EX:

$$\frac{2 \times 3 \times 300}{6} = 300 \text{ YDS}^3$$

IV. CULVERT FILL



FIND LENGTH BY MEASURING DOWN APPROX. 1/3 OF DISTANCE FROM ROADBED TO ORIGINAL STREAM GRADE (CONNECT TWO POINTS MARKED ⊗.)



WIDTH A times DEPTH A divided by 2 = AREA of A (SMALL END Δ)

plus WIDTH B times DEPTH B divided by 2 = AREA of B (LARGE END Δ)

divided by 2

times LENGTH

$$\boxed{\frac{\frac{W_A \times D_A}{2} + \frac{W_B \times D_B}{2}}{2} \times L} = \text{ESTIMATED YDS}^3 \text{ POTENTIAL SEDIMENT IN CULVERT FILL}$$

EX: $$\frac{\frac{8 \times 3}{2} + \frac{10 \times 6}{2}}{2} \times 9 = \frac{42}{2} \times 9 = 189 \text{ yds}^3$$

APPENDIX B

MONITORING PLAN

1. On-site evaluation by CFL personnel during operations, including:

   A. LTO compliance with the silvicultural requirements of the plan;

   B. LTO compliance with the Forest Practice Rules;

   C. LTO compliance with the specific requirements of the plan; and

   D. LTO compliance with the confidential addenda of the plan.

2. Post-harvest survey of the THP area, including:

   A. Certification of Timber Operations Work Completion;

   B. Certification of Stocking; and

   C. An "in-house" evaluation of the post-harvest stand to determine if silvicultural goals have been met and, if not, to propose appropriate treatment.

3. Watershed/sedimentation control:

   A. All drainage structures shall be installed and/or maintained as stated in the THP.

   B. A short or long form (depending on the amount of fill) *STAR* Worksheet shall be completed for each drainage structure and each "at risk" instream stored sediment site. In following years, annual status reports will be filed during the maintenance period. These reports will be filed in the CFL THP file by November 15 of each year.

   C. Upon THP completion, a status report detailing the condition and the effects of management on all slides and unstable areas shown or described on the plan will be filed in CFL's THP filed by November 15. Where applicable, a short or long form *STAR* Worksheet will be completed and monitoring during the maintenance period will be as in subsection B above.

   D. Other *STAR* areas proposed as part of the THP will be monitored as above.

   E. A brief standardized analysis and summary report of the data from the *STAR* Worksheets will be submitted to the CFL Cal Watershed files and to CDF and the NCRWQCB for submission into their Cal Watershed files by December 31 of each year until the end of the maintenance period.

APPENDIX III

Analysis of Cross-Section Data Collected on the North Fork Garcia River

by
Jan Derksen, Ph.D.

Analysis of Cross-section Data Collected on the North Fork of the Garcia River

Prepared by Jan Derksen
November 1995

Summary: Data from the channel cross-section profiles on six stations on the North Fork of the Garcia River show that the profiles are equal or better in 1995 than in previous years. The data shows that no significant adverse impact occurred on the Garcia watershed in terms of channel cross-section profile.

In 1989 Coastal Forestlands Ltd. (CFL, formerly R&J Timber, Inc.) initiated a monitoring program to determine the impact of its timber operations on the water quality of the North Fork of the Garcia River. One part of the monitoring project required data collection during the summers of 1989, 1990, and 1991. Data was collected, analyzed and discussed in a 1992 CFL report written by Jack Monschke, watershed consultant to CFL. The 1992 report contained chapters that I wrote which presented my statistical analysis of the three years pf data collection.

In the summer of 1995 data was again collected on the North Fork of the Garcia River. In the present report I give my analysis of the 1995 data and compare results with findings from the period 1989-1991.

In 1989 six observation stations were established to measure and compare the depth and profile at various sites of the North Fork of the Garcia. These stations were named L1, U1, 2, 3, 4 and 5. The Garcia's profile was recorded by measuring the depth of the river at many points. A baseline was established parallel with the river, and the river's depth was recorded at points perpendicular to the baseline along "transects". Measurements at the six stations were repeated for the years 1989, 1990, 1991 and 1995.

The following is an excerpt from the 1992 report in which I discussed the data collection and analysis procedures:

> Data collected during a project like the Garcia Monitoring Project are not immediately useful for interpretation. Creek cross section data consist of "meaningless" pages of numbers and only becomes meaningful to human eyes after computer-aided enhancement into three-dimensional pictures of river beds.
>
> Similarly, measurements of sediment levels at various locations and dates are very hard to compare without the help of a computer to tell us which variations in the data are due to chance and which are genuine changes occurring in the river.

Data from Creek Cross-Sections

Measurements of the creek bottom profile were enhanced with special computer programs. Measurements were performed at six river sites in the years 1989, 1990 and 1991.

Several kinds of enhancements were performed:

The performed measurements of the river bed were, by design, irregularly spaced. Smooth parts of the river bed need only a few measurements while steep or irregular parts of the river need many probes.

However, to make maps of the river bed we need regularly spaced points. Special software computed the same number of points throughout the maps in construction. The software filled in the points by taking the average value of neighboring points. This process is called *gridding.* The now evenly spaced *grids* of data points were transformed into the following:

> Topographic maps for each river site and each year, resulting in eighteen topographic maps in all. The topographic maps by means of the contour lines show the depths of the river at various points along the baseline and transect
>
> 3-D maps, eighteen in all. These maps show the same contour lines as the topographic maps. In addition, the 3-D maps are helpful in assessing the overall shape of the river from year to year. The 3-D maps also help in judging whether enough measurements in the right area were made to enable a comparison from year to year.

In 1995 the collection of eighteen maps was enlarged by six topographic and six 3-D maps for the current year. The following pages show the cross-section topographic maps and the 3-D maps for each station for the four years (1989-91 and 1995) in which data was collected. The table below summarizes the information you can see in the maps. (BM means benchmark).

All measurements are in feet.

Station	Year	Baseline Description	Transect Values	BM Elev.	Pool Location	Pool Depth	Comparison of Data from 1989-1995
1Lower	1995	runs from centerpost 0 to 78' downstream	plus (+) on right of baseline as you look downstream from 0 to 78	1.04	BL24-70	8	There is an 8' deep pool that is similar in depth to previous years but that covers a larger area (BL 24 through BL 70) than in previous years.
	1991				BL24	9	
	1990				BL24	9.5	
	1989				BL24.	9	
1Upper	1995	runs from 0 left water edge downstream to 66'	plus (+) on right of baseline when looking downstream	1.14	BL20-80	8	The pool varied in depth and width over the years. 1995 had the deepest and widest pool; 1990 had the most shallow and narrow pool.
	1991				BL20	5.5	
	1990				BL24-44	7.5	
	1989				BL24-60	8	
#2	1995	runs from 0 downstream to 100'	plus (+) on right side of baseline looking downstream	0.36	BL45-80	8	The pool stayed relatively the same size through the years 1989-1995.
	1991				BL24-96	9.5	
	1990				BL30-97	9.5	
	1989				BL24-96	9.5	
#3	1995	runs from 0 (left bank) to 100' downstream on left of stream.	plus (+) on right of baseline as you look downstream from 0 to 100.	0.4	BL50	7.5	One pool (BL 50 to BL 58) increased in depth from 5' in 1989 to 5.5' in 1990 and 1991 and to 7.5' in 1995.
	1991				BL56	5.5	
#3 contd	1990				BL56	5.5	
	1989				BL80	5.5	

Station	Year	Baseline Description	Transect Values	BM Elev.	Pool Location	Pool Depth	Comparison of Data from 1989-1995
					BL58	5	
					BL32	4	
#4	1995	runs from 0 to 60' upstream on left bank	plus (+) on right of baseline as you look upstream from 0 to 60	4.95	BL12	10.35	The pool that was 6' deep in 1989 and 6.5' deep in 1991 was destroyed by a logjam in 1995. In 1995 a new pool appeared downstream from the log jam; the new pool was 10.35' deep.
	1991				BL36	6.5	
	1990						not enough data to make a comparison with other years
	1989				BL36	6	
#5	1995	runs from 0 left water edge to 60' downstream	plus (+) on right of baseline as you look downstream from 0 to 60	1.14	BL32	7.2	One pool next to a boulder (BL 30) increased in depth from 5.5' in 1989, 1990 and 1991 to 7.2' in 1995.
	1991				BL30	5.5	
					BL36	5.5	
	1990				BL40	6	
	1989				BL30-40	6	

Conclusion

Data from the channel cross-section profiles on six stations on the North Fork of the Garcia River show that the profiles are equal or better in 1995 than in previous years. The data shows that no significant adverse impact occurred on the Garcia watershed in terms of channel cross-section profile. All pools deepened and/or became larger except for one pool (pool 2) that stayed the same.

- Lower Pool 1: In 1995 there is an 8' deep pool that is similar in depth to previous years but that covers a larger area (BL 24 through BL 70) than in previous years.

- Upper Pool 1: The pool varied in depth and width over the years. 1995 had the deepest and widest pool; 1990 had the most shallow and narrow pool.

- Pool 2: The pool stayed relatively the same size through the years 1989-1995.

- Pool 3: One pool (BL 50 to BL 58) increased in depth from 5' in 1989 to 5.5' in 1990 and 1991 and to 7.5' in 1995.

- Pool 4: The pool that was 6' deep in 1989 and 6.5' deep in 1991 was destroyed by a log jam in 1995. In 1995 a new pool appeared downstream from the log jam; the new pool was 10.35' deep.

- • Pool 5: One pool next to a boulder (BL 30) increased in depth from 5.5' in 1989, 1990 and 1991 to 7.2' in 1995.

APPENDIX A

STREAM CHANNEL PROFILE MAPS
1995

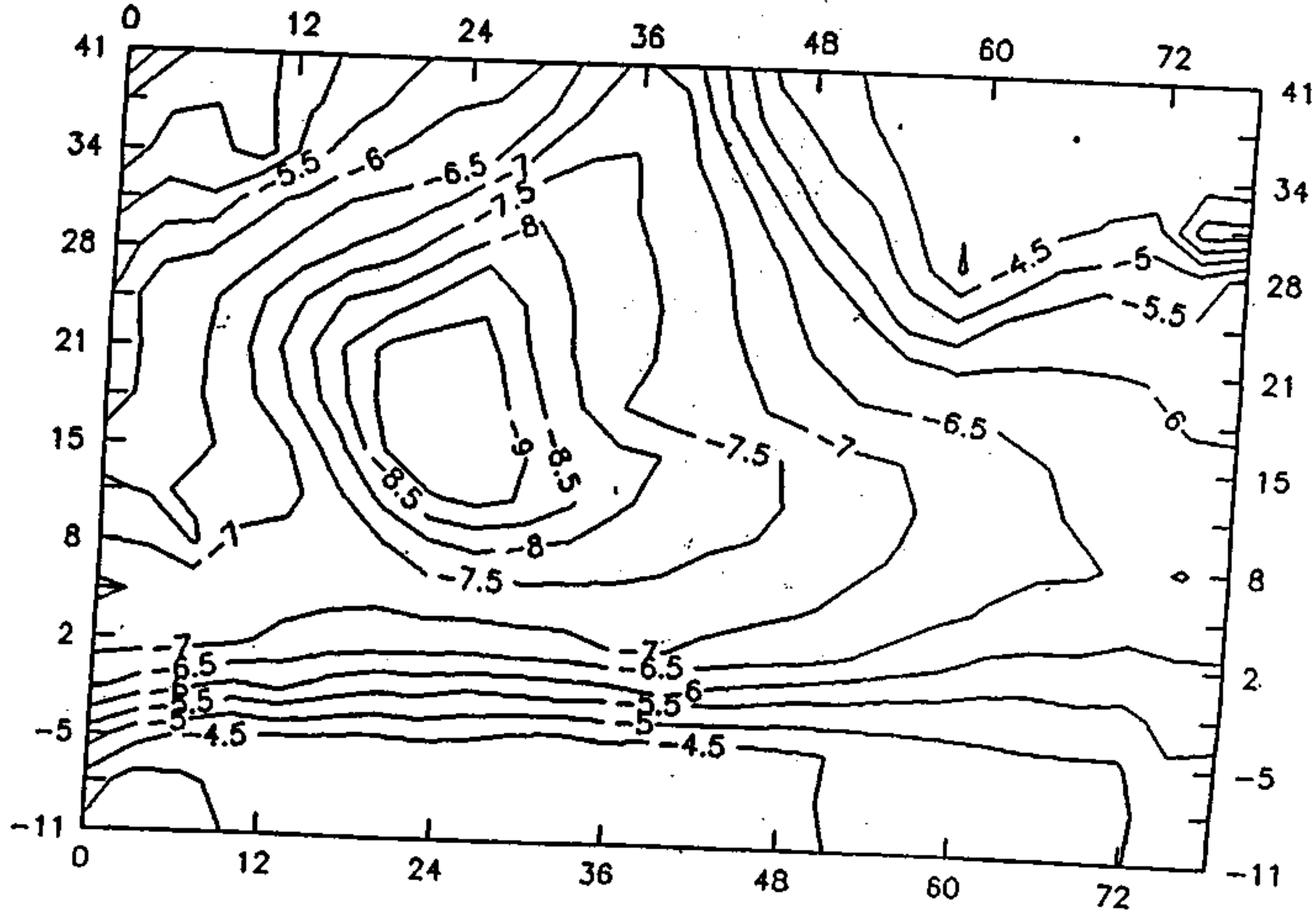
*Stream Channel Profile Maps not included in this KRIS [
edition of this document (due to poor quality of ☐
originals, and file size requirements).*

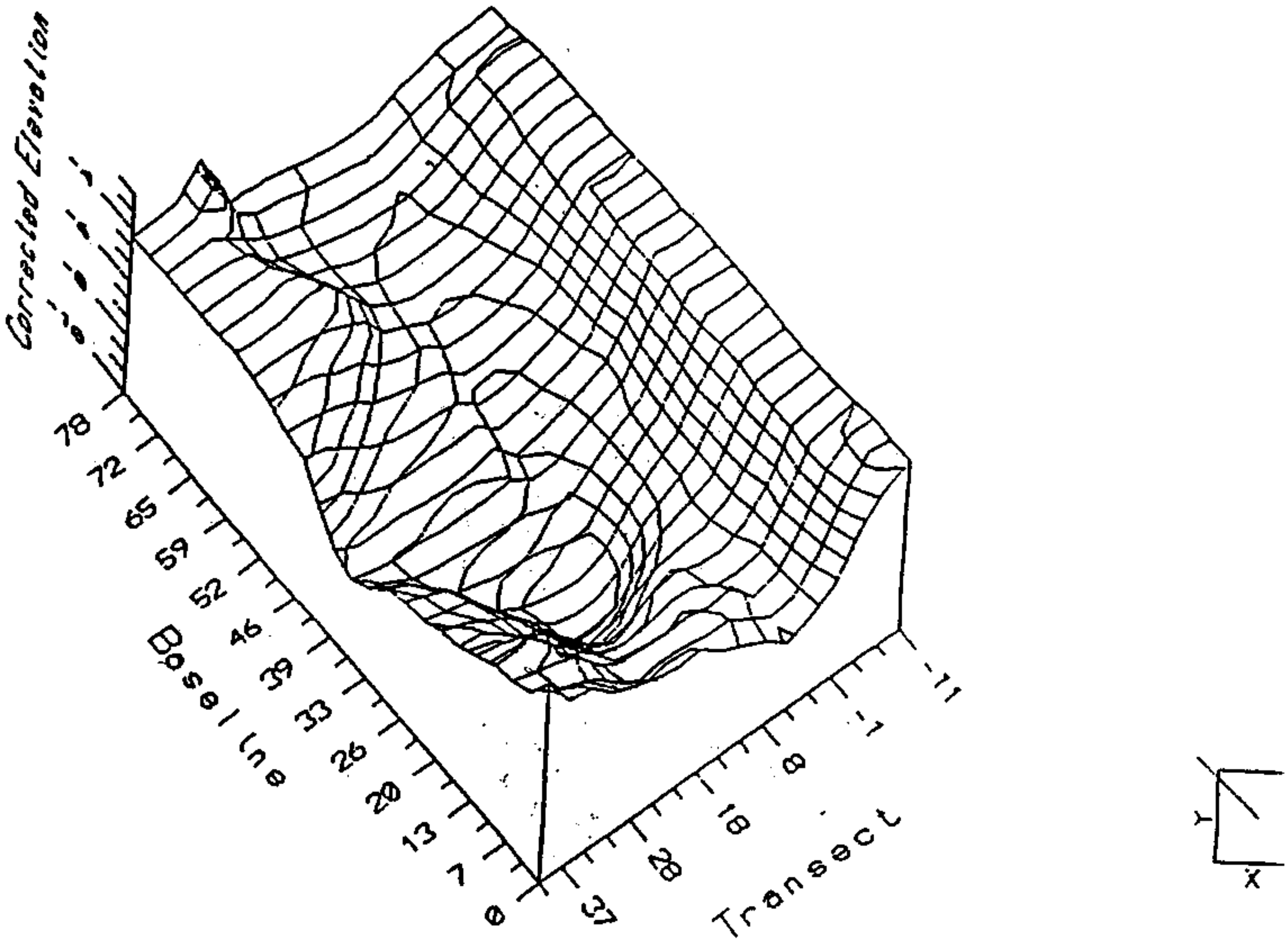
APPENDIX B

STREAM CHANNEL PROFILE MAPS

1989-1991

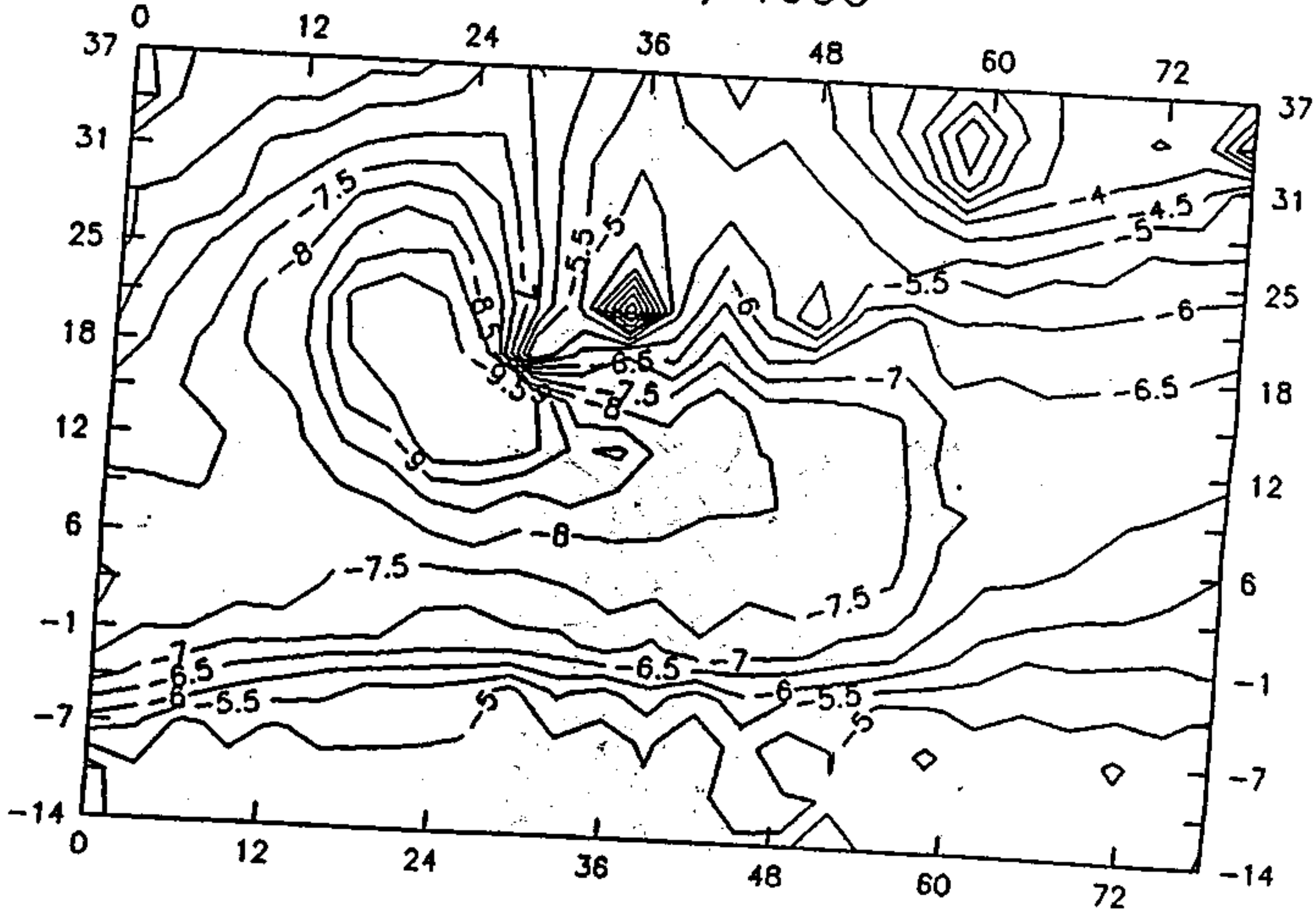
Creek L1, 1989

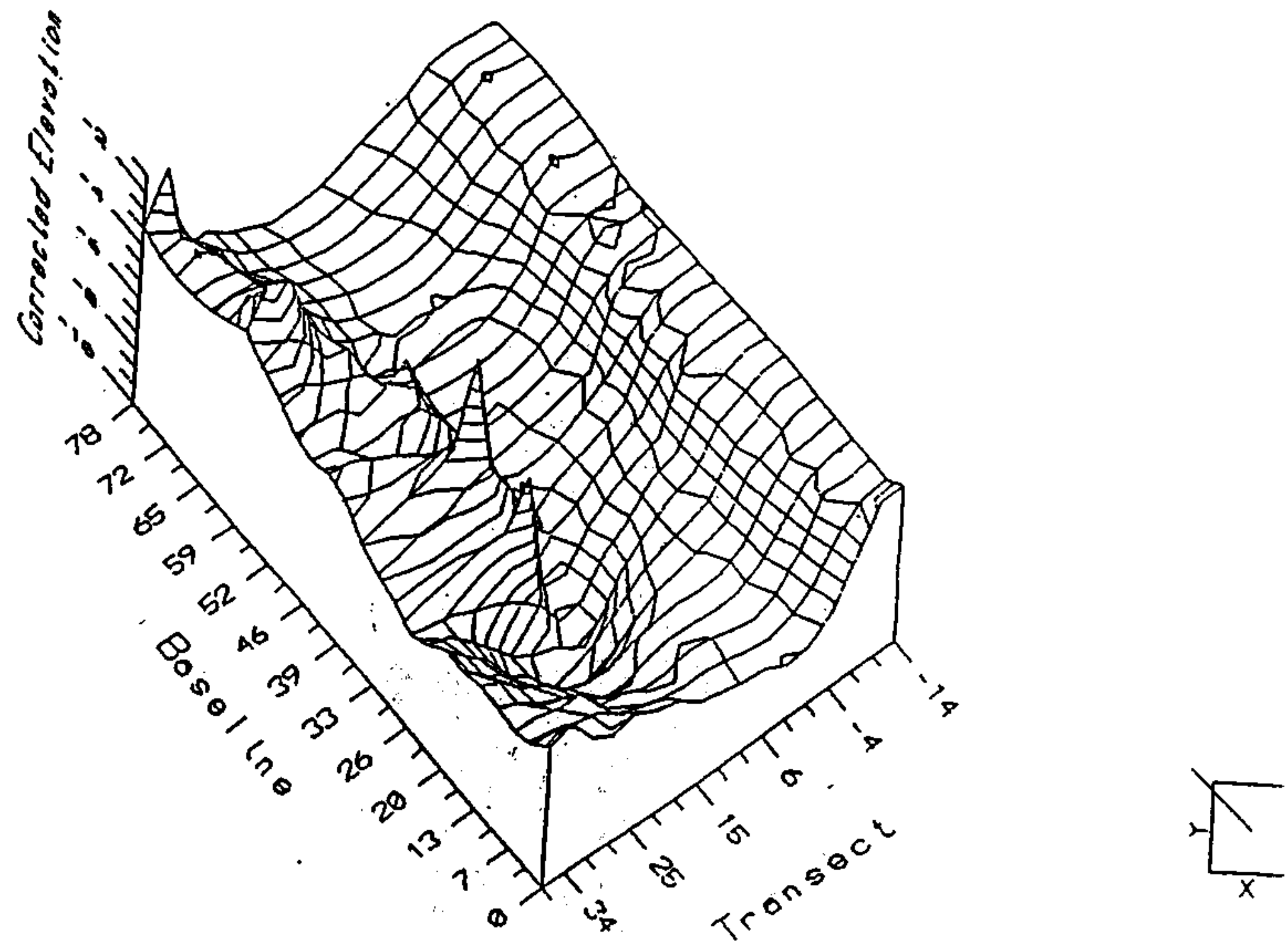




Creek Station L1, 1989

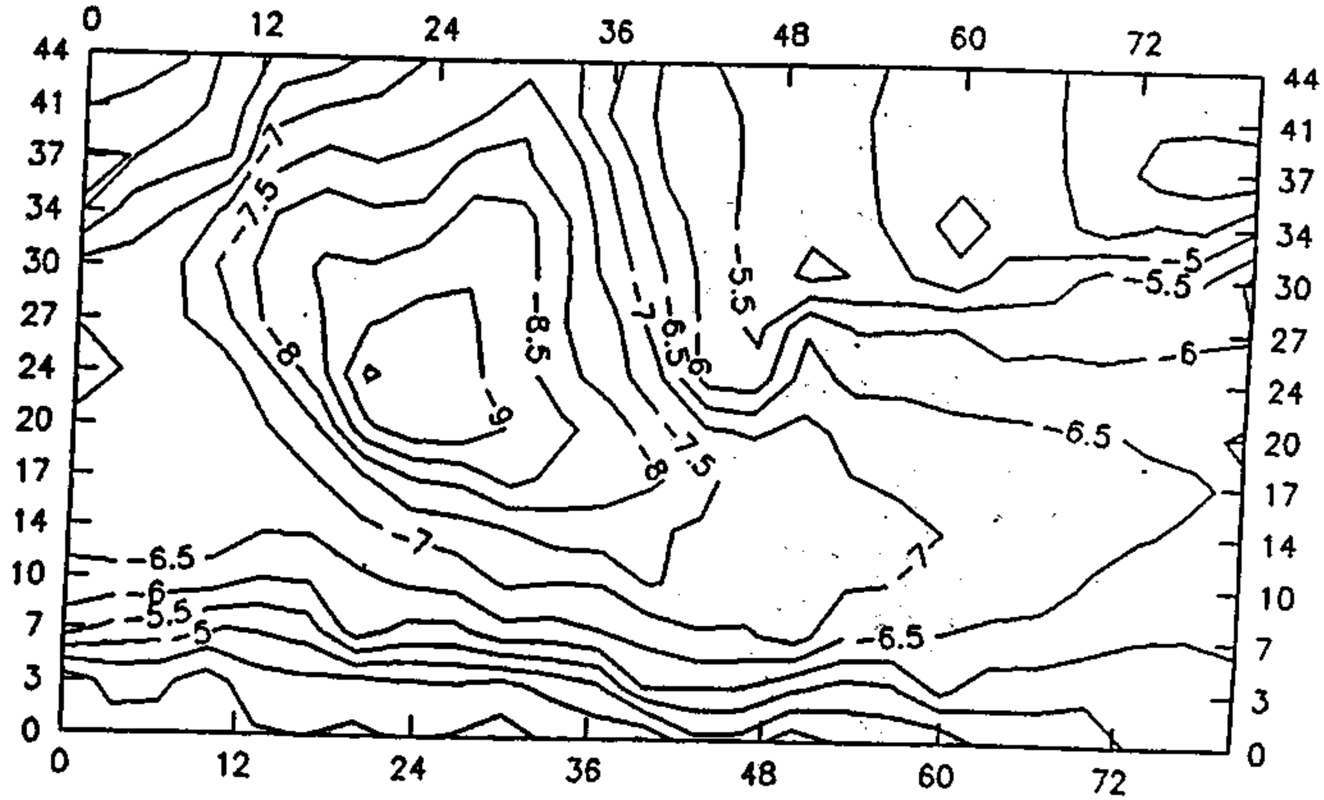
Creek L1, 1990

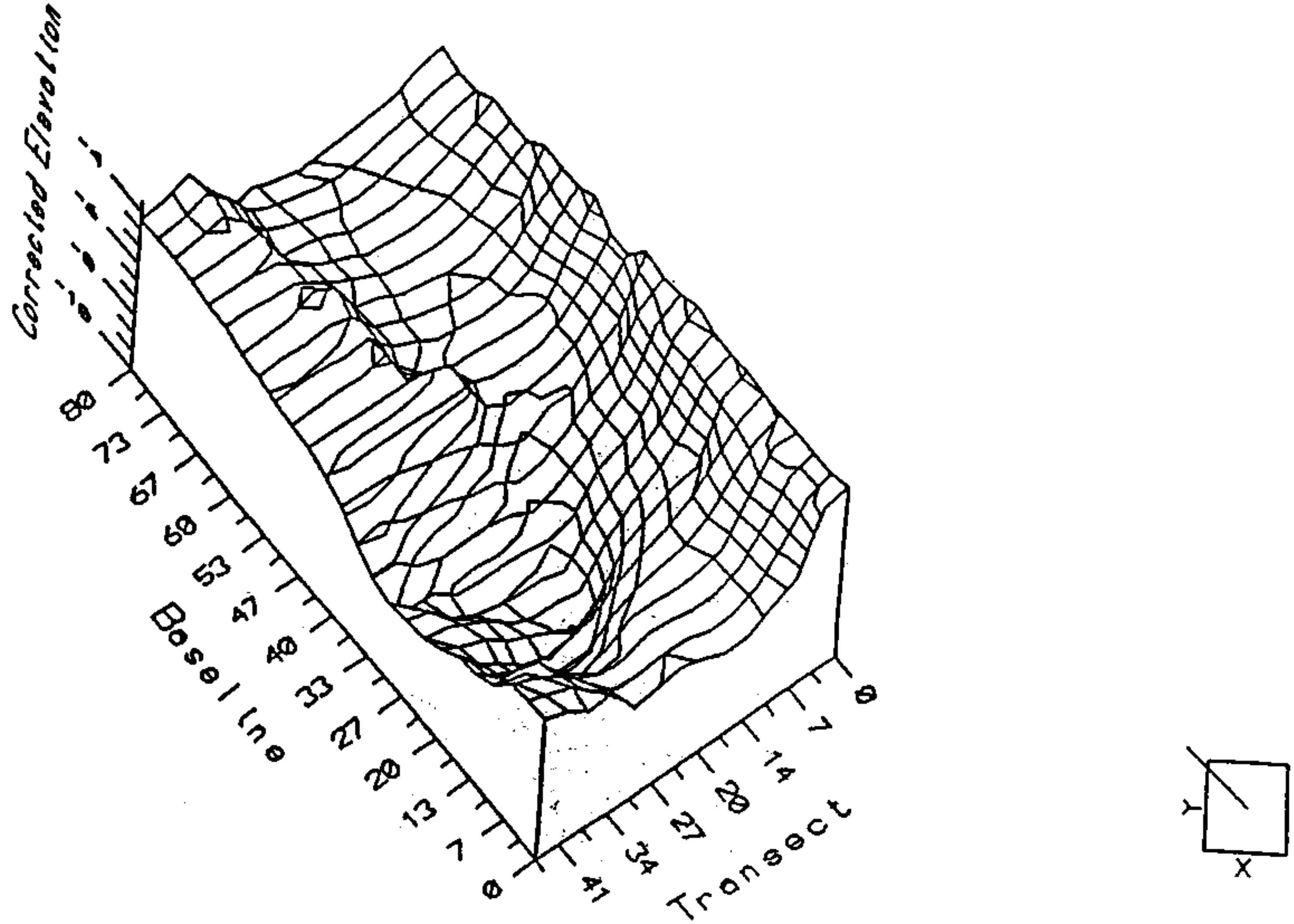




Creek Station L1, 1990

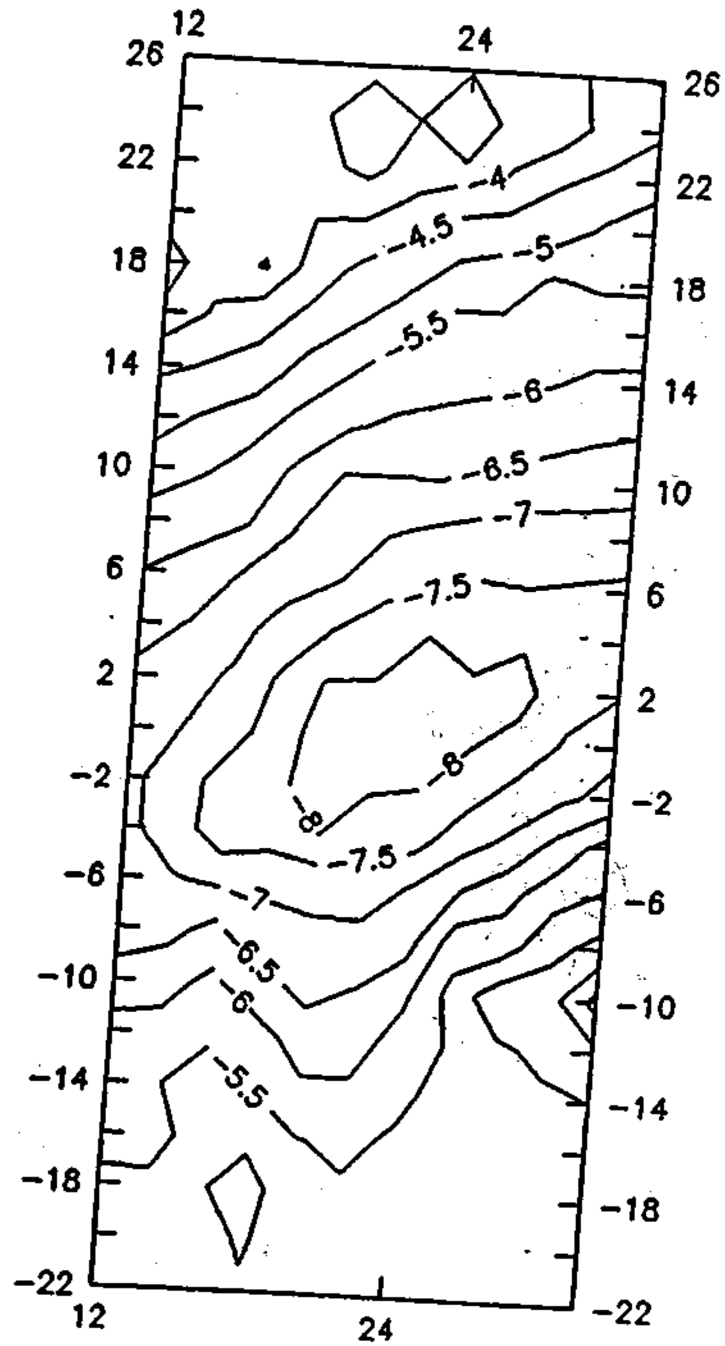
Creek L1, 1991

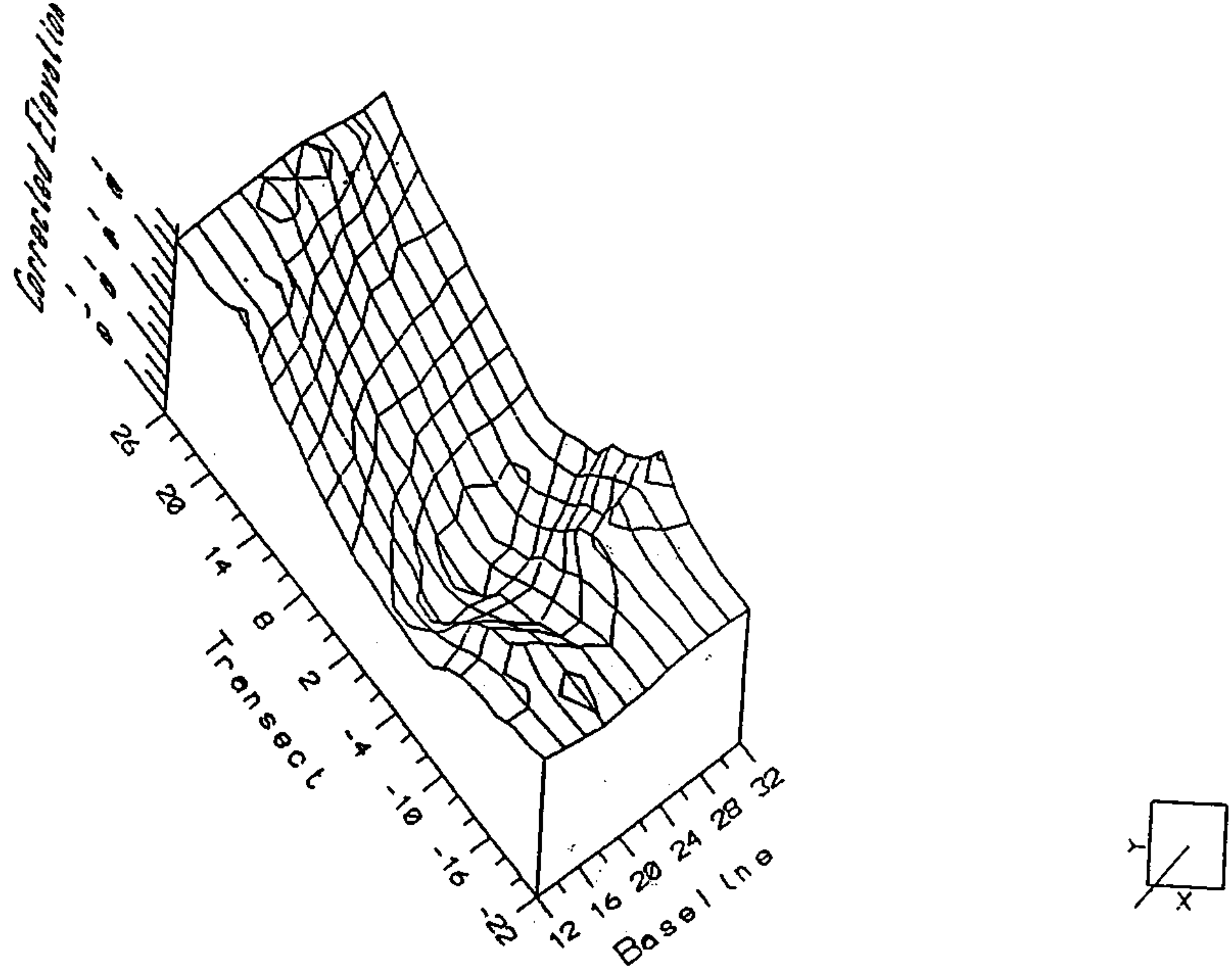




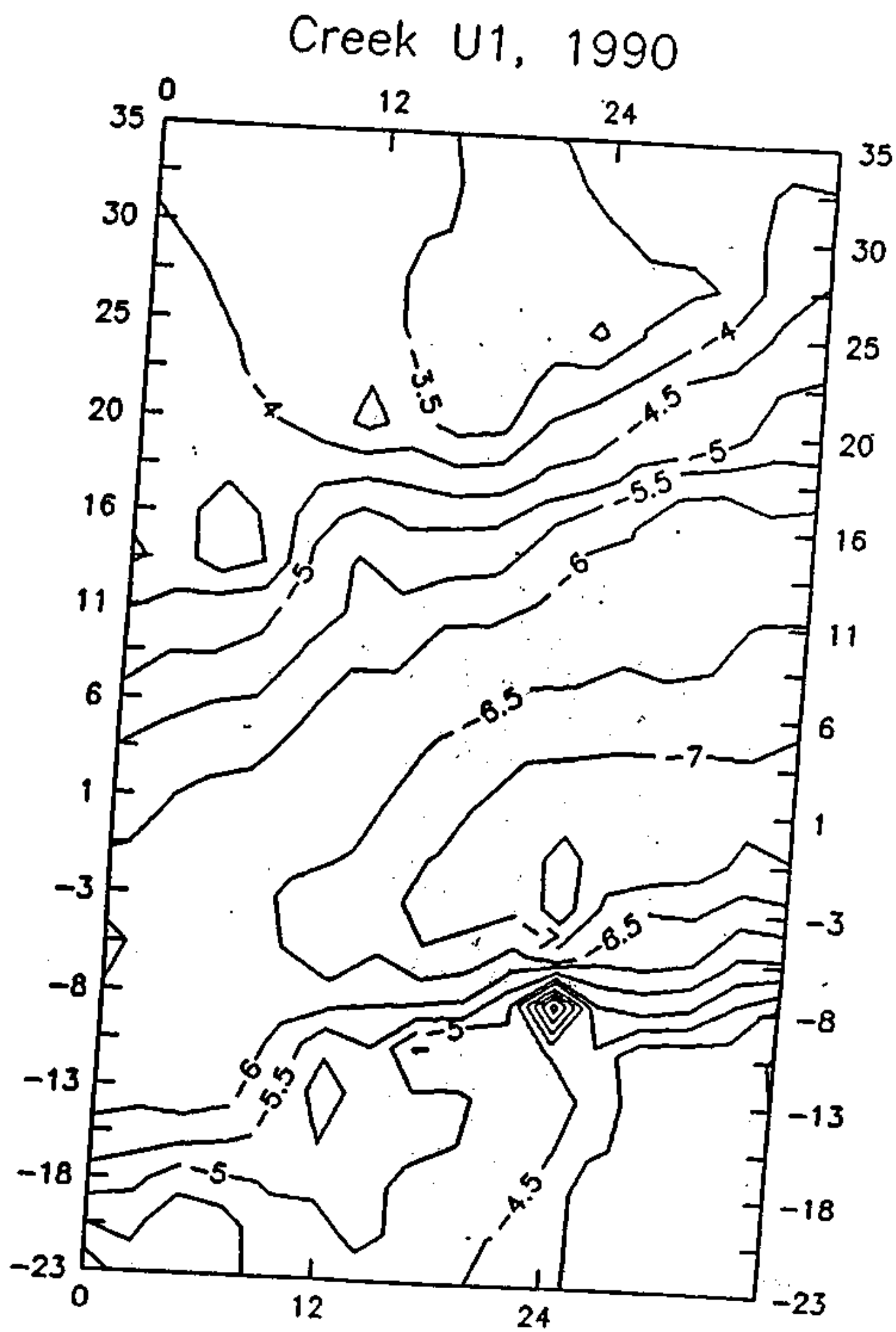
Creek Station L1, 1991

Creek U1, 1989





Creek Station U1, 1989



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0
12
24
35
30
25
20
16
11
6
1
−3
−8
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−18
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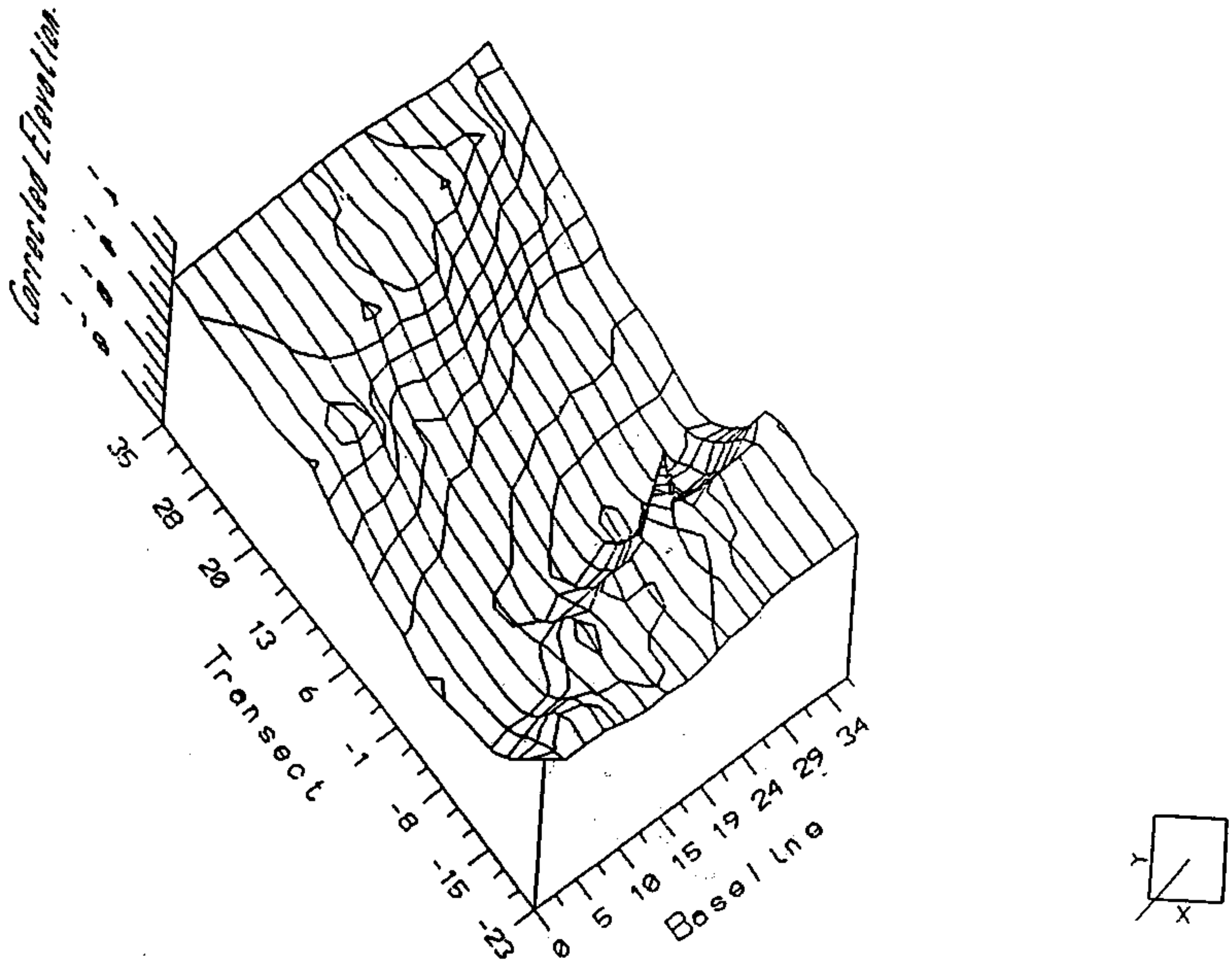
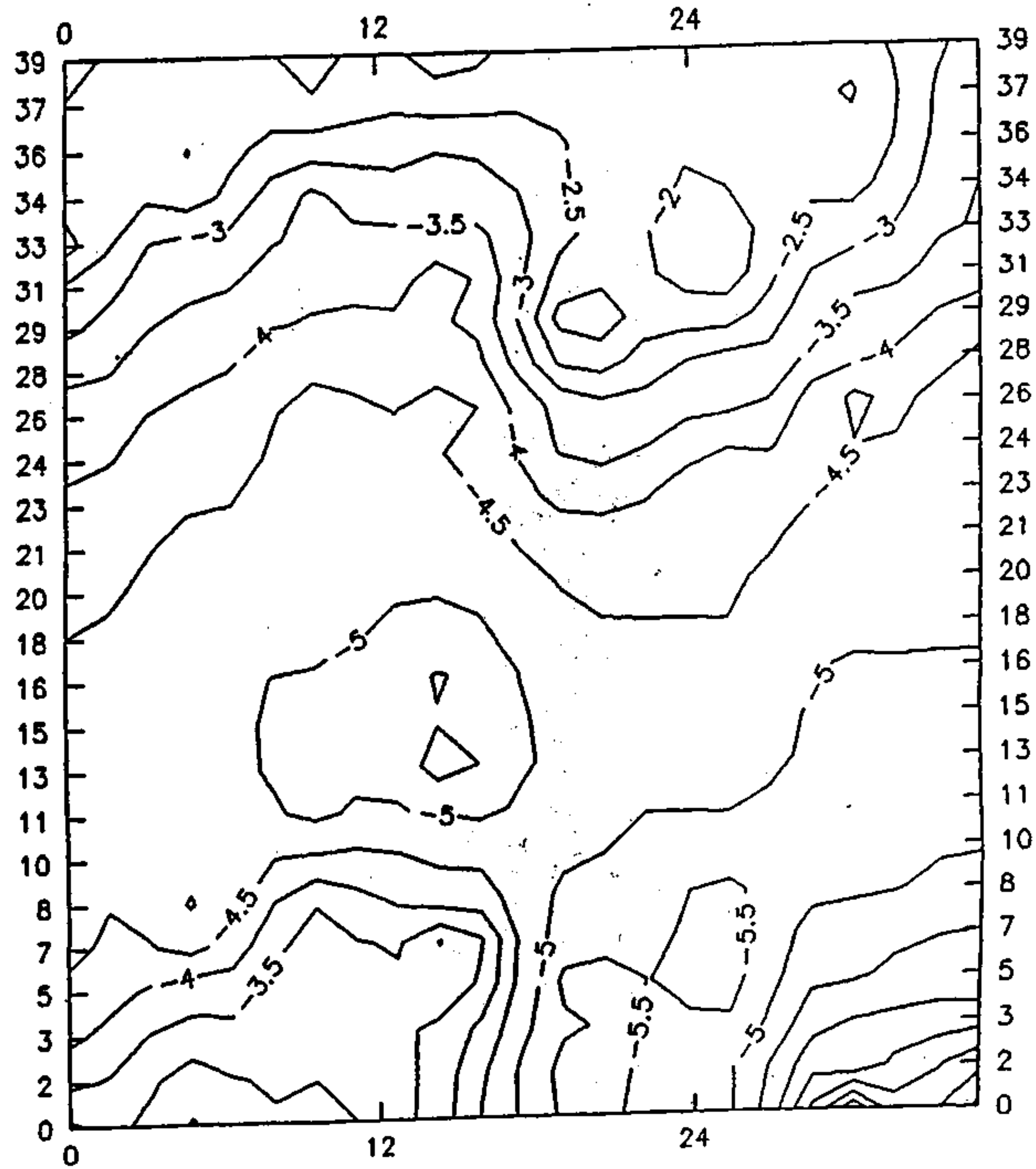
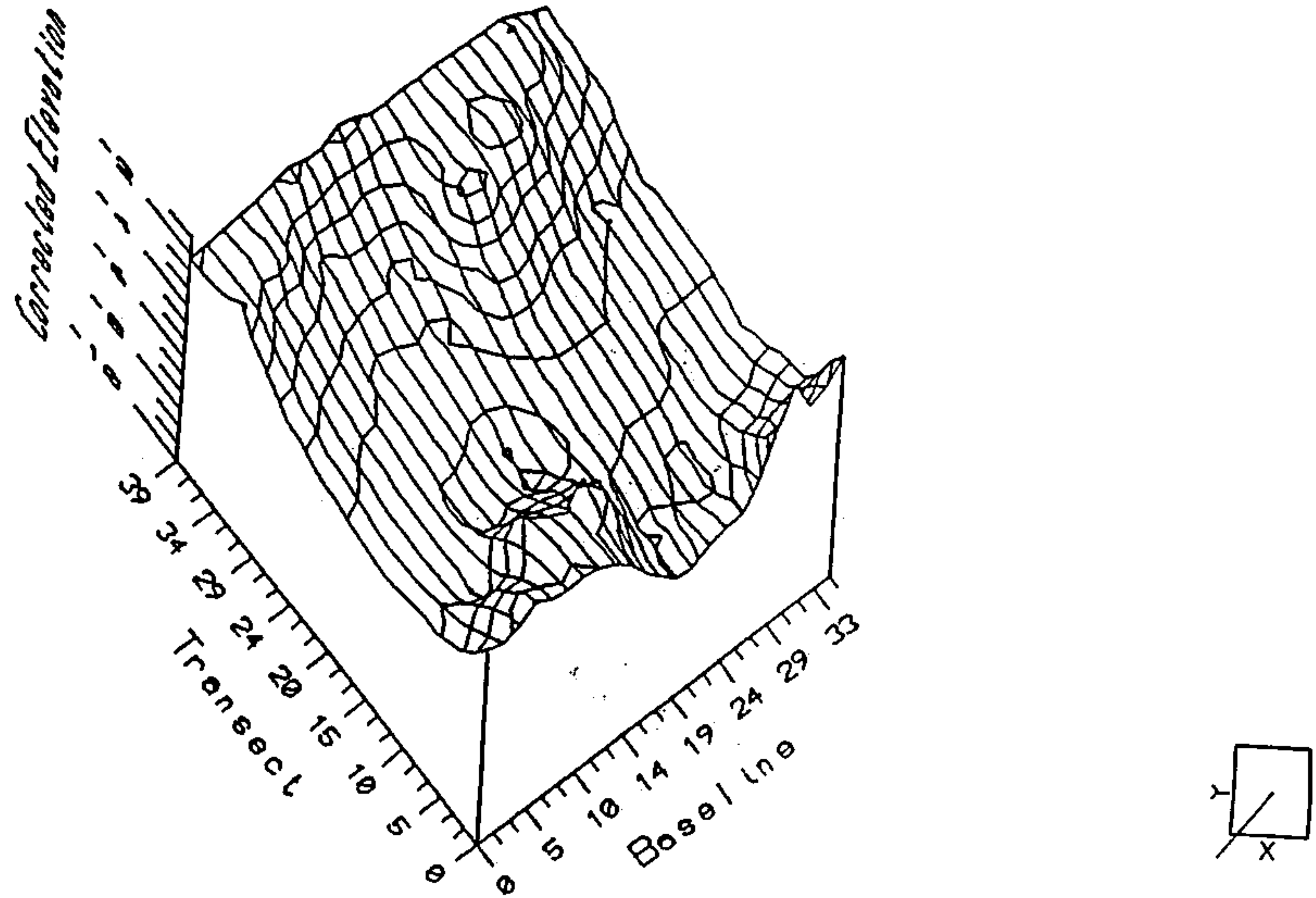
-7



Creek Station U1, 1990

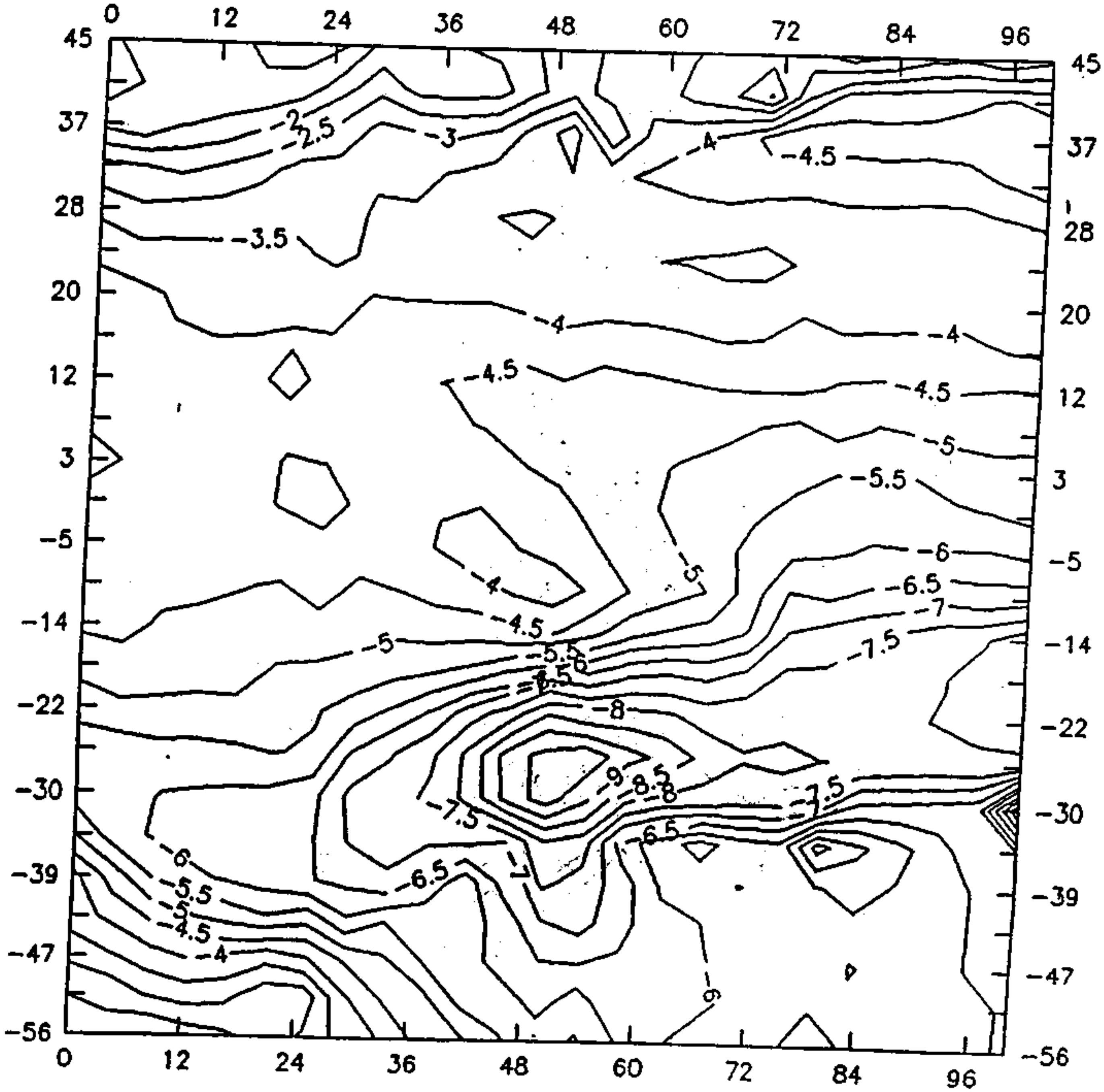
Creek U1, 1991





Creek Station U1, 1991

ᴗreek 2, 1989



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-2.5
-3
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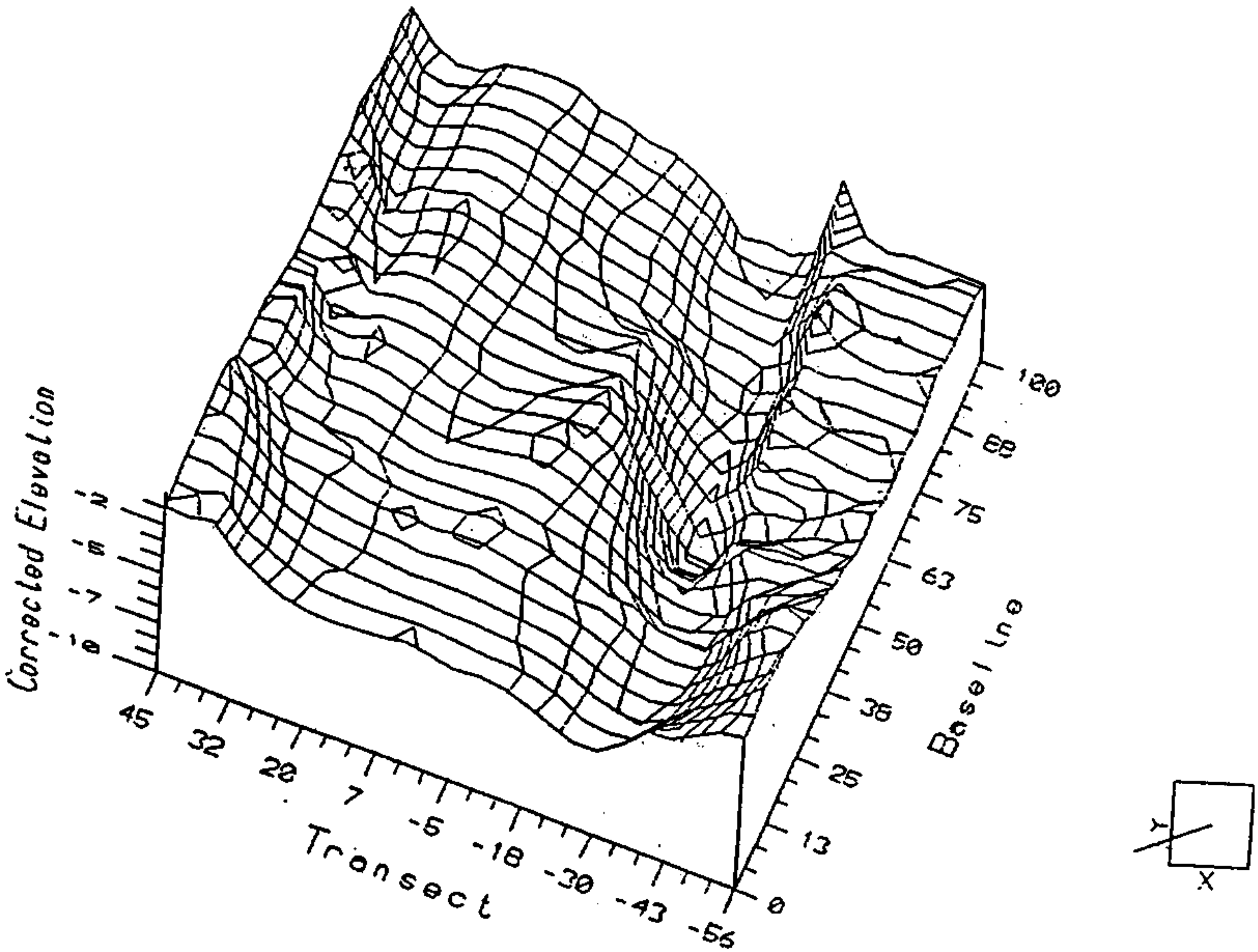
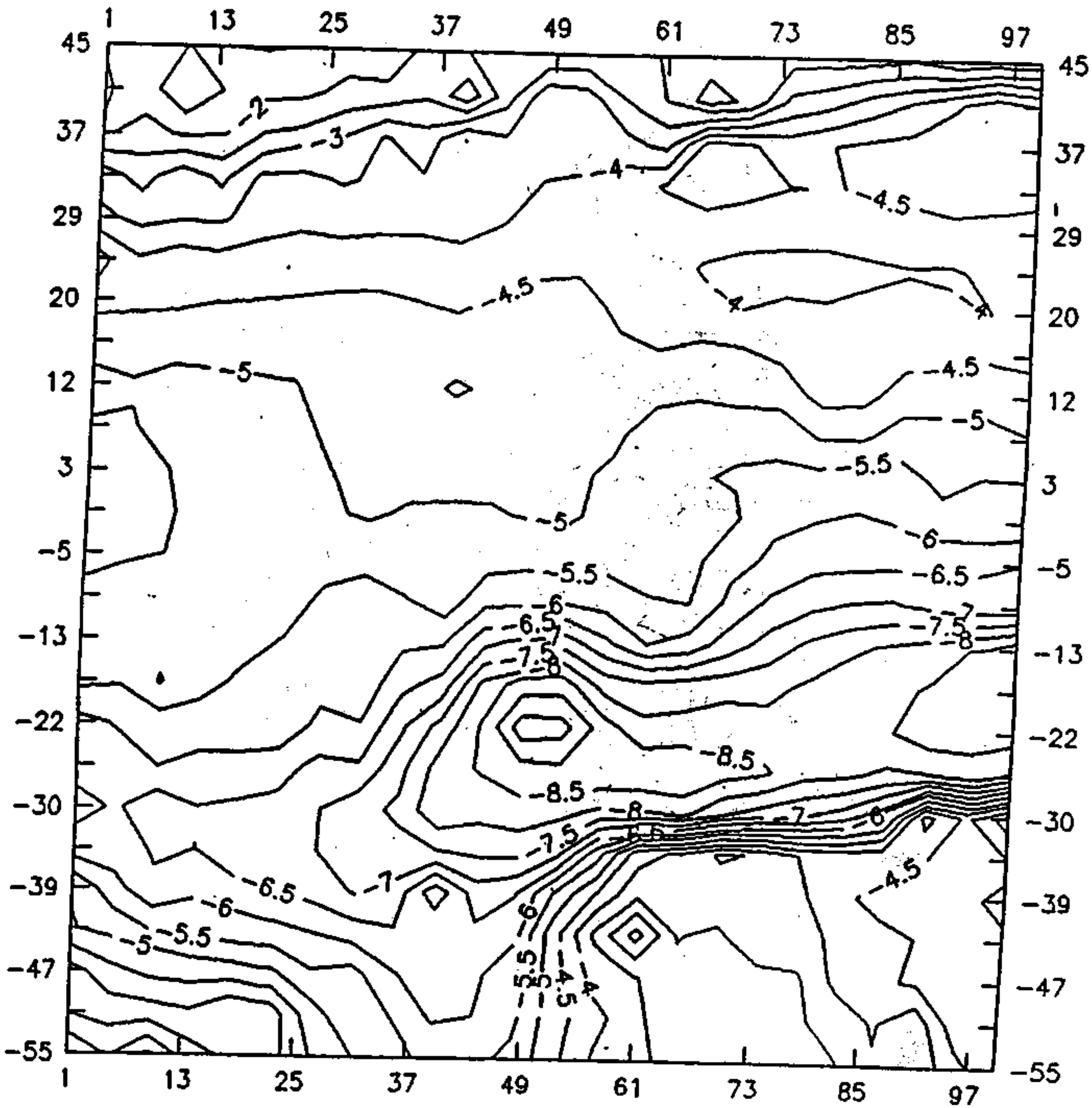


Creek Station 2, 1989

Creek 2, 1990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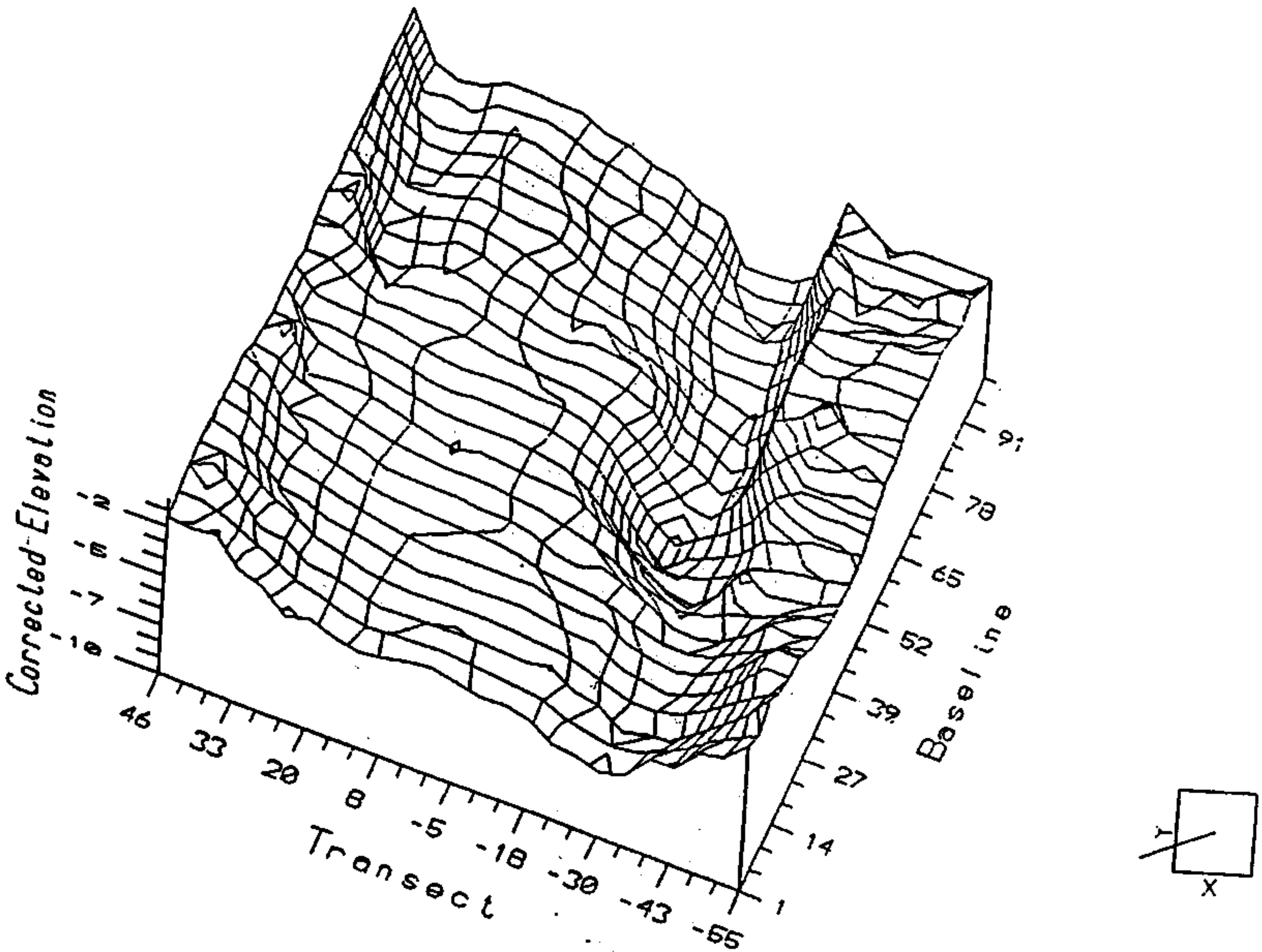
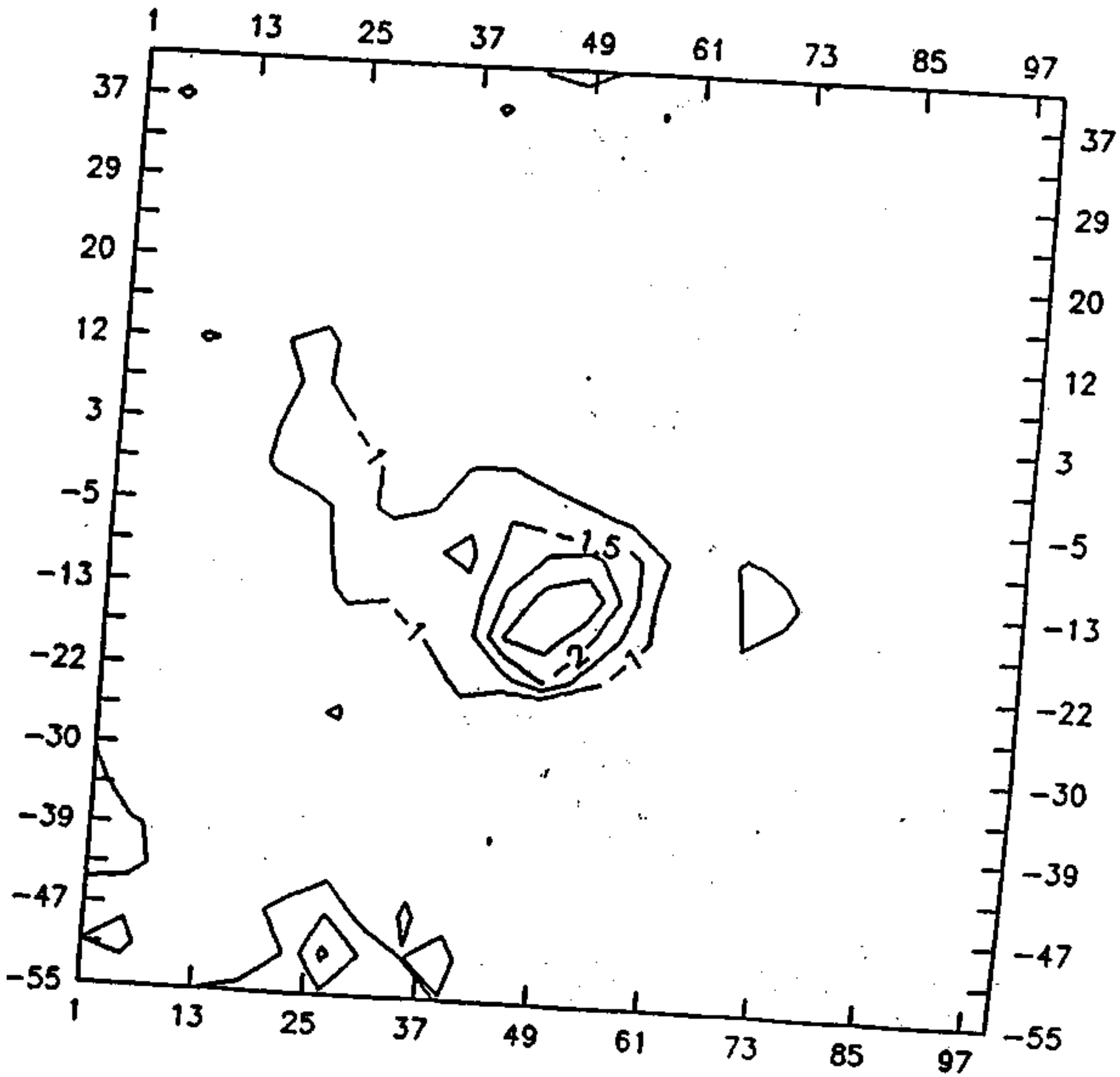
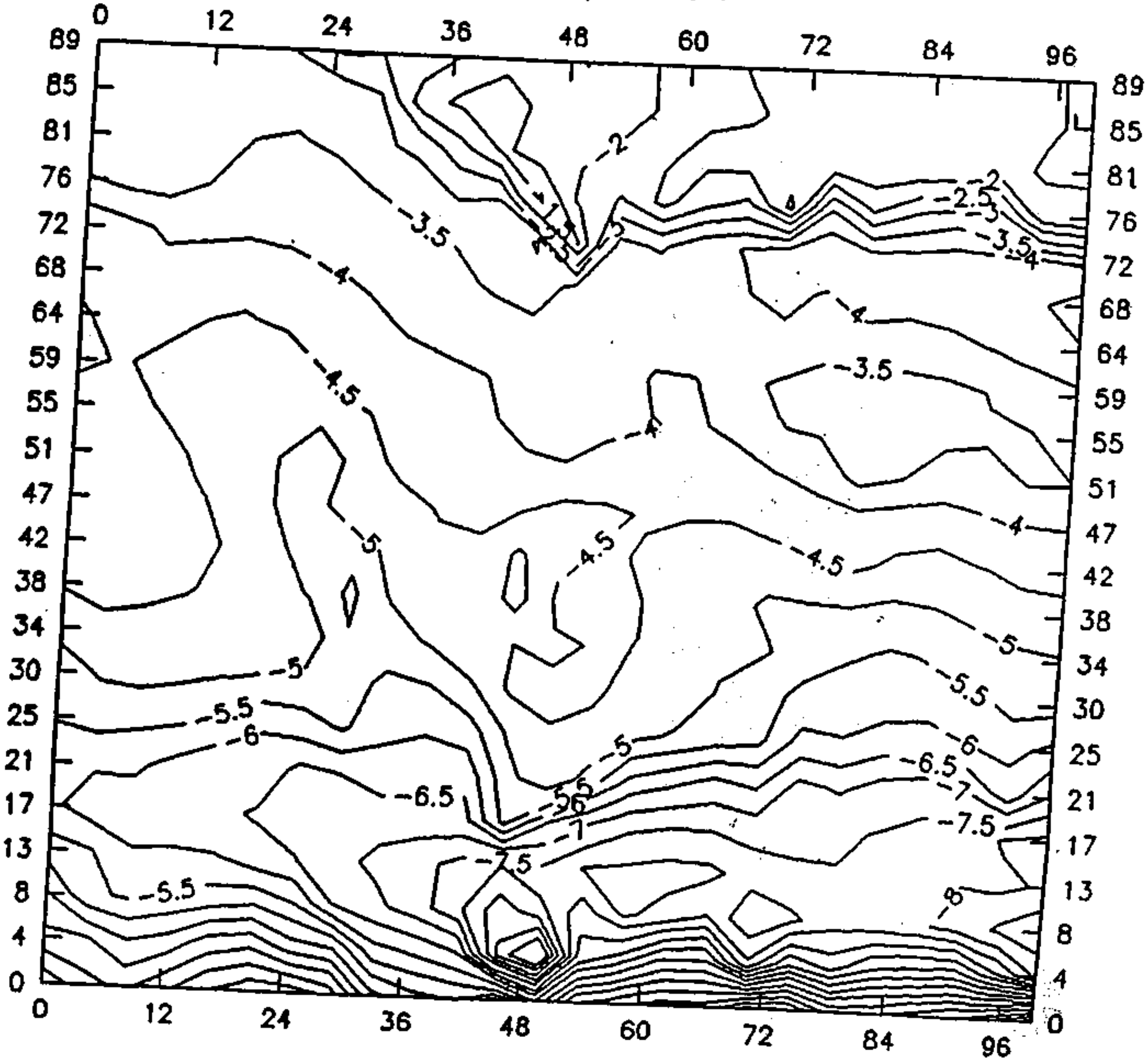


Creek Station 2, 1990

Creek 2, 1990–1989, <0 means 1990 is deeper.



Creek 2, 1991



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38
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30
25
21
17
13
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4
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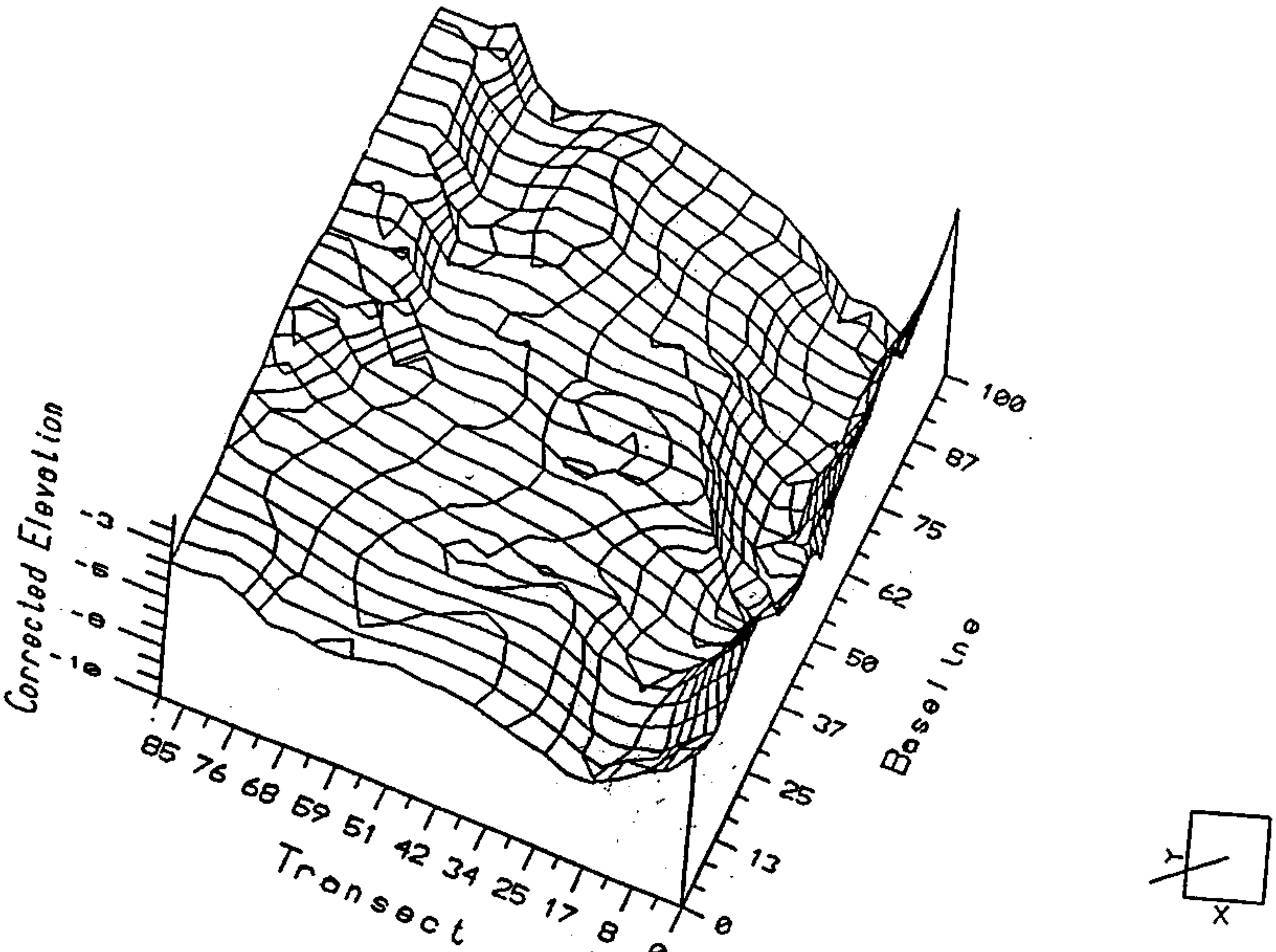
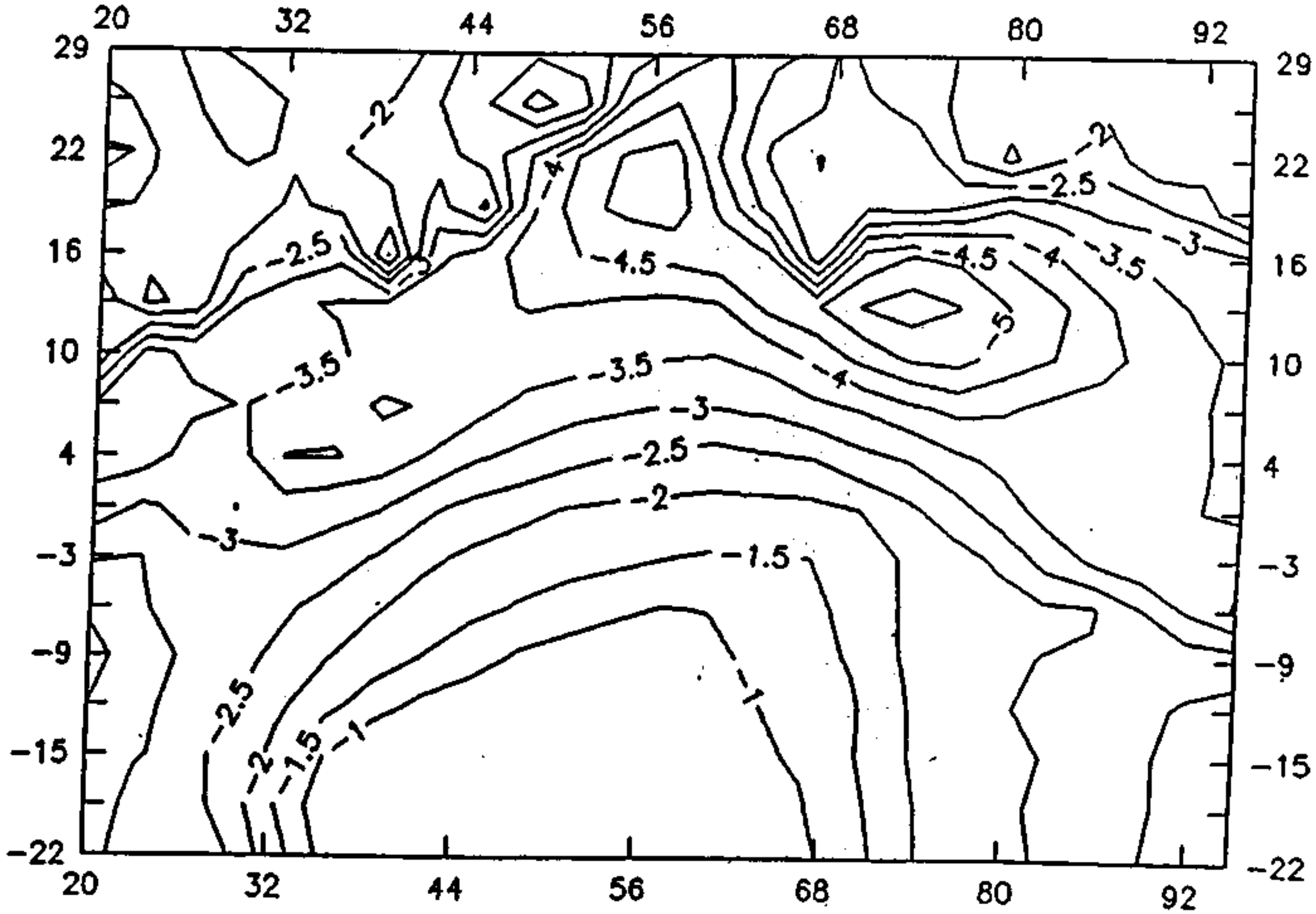
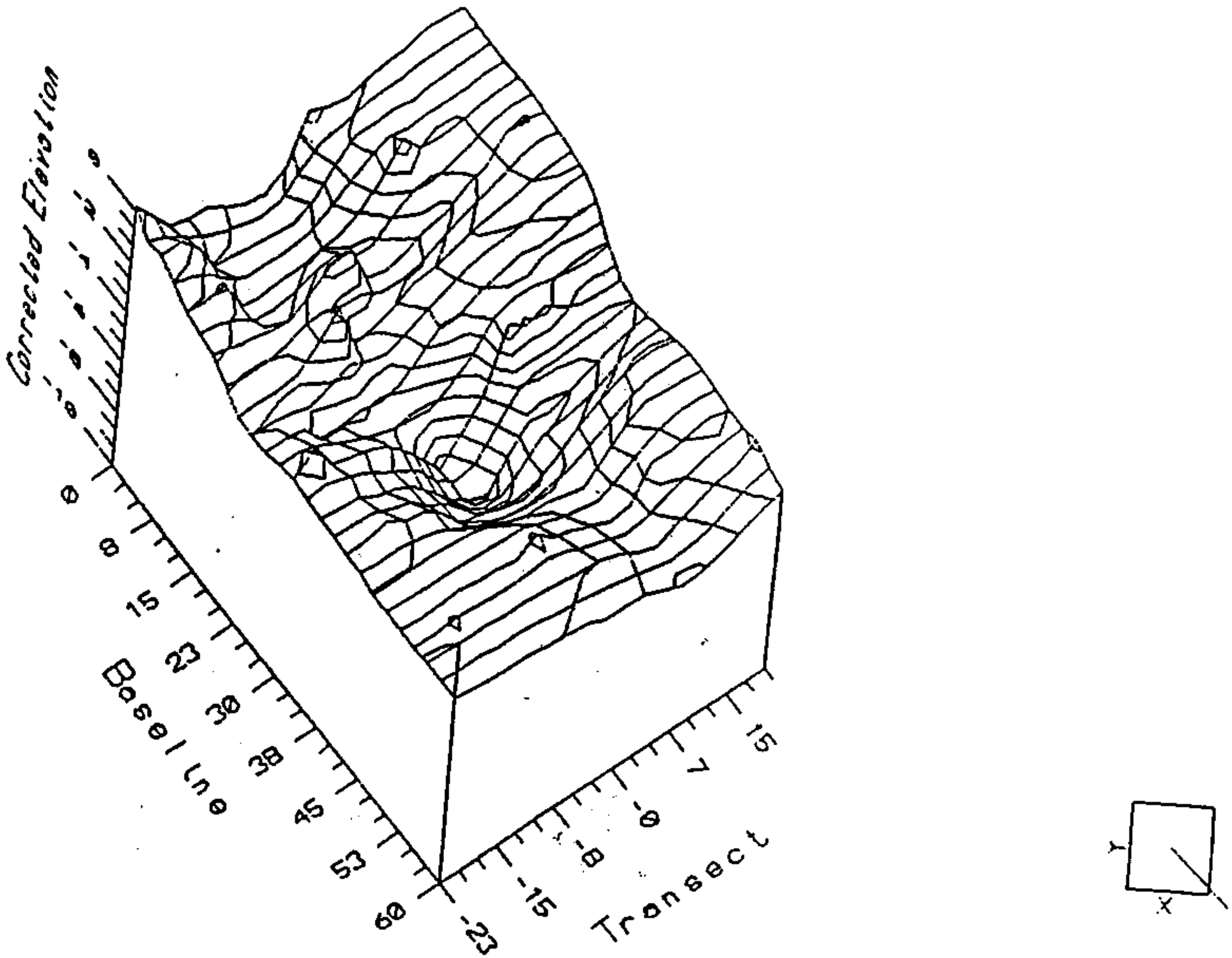


Creek Station 2, 1991

Creek 3, 1989

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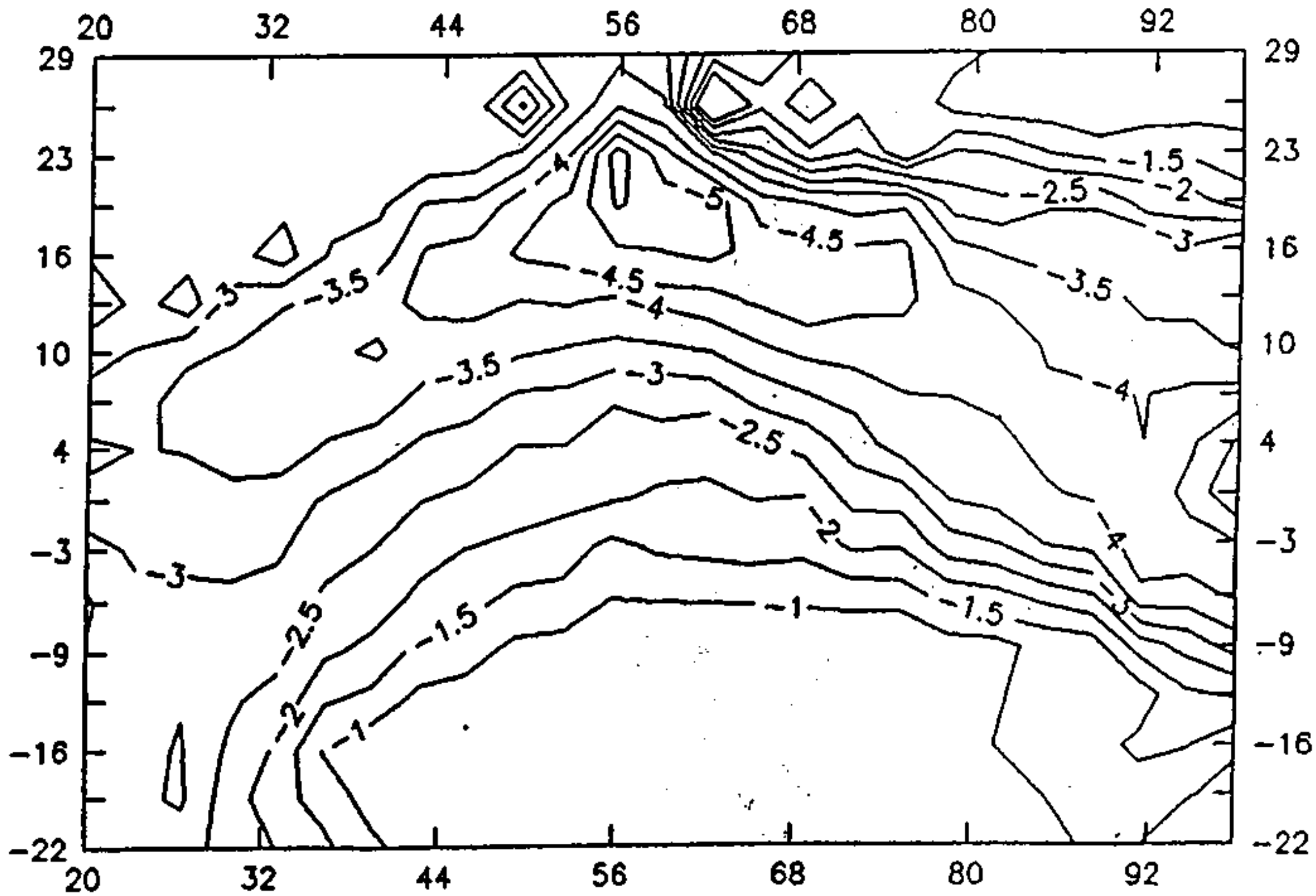
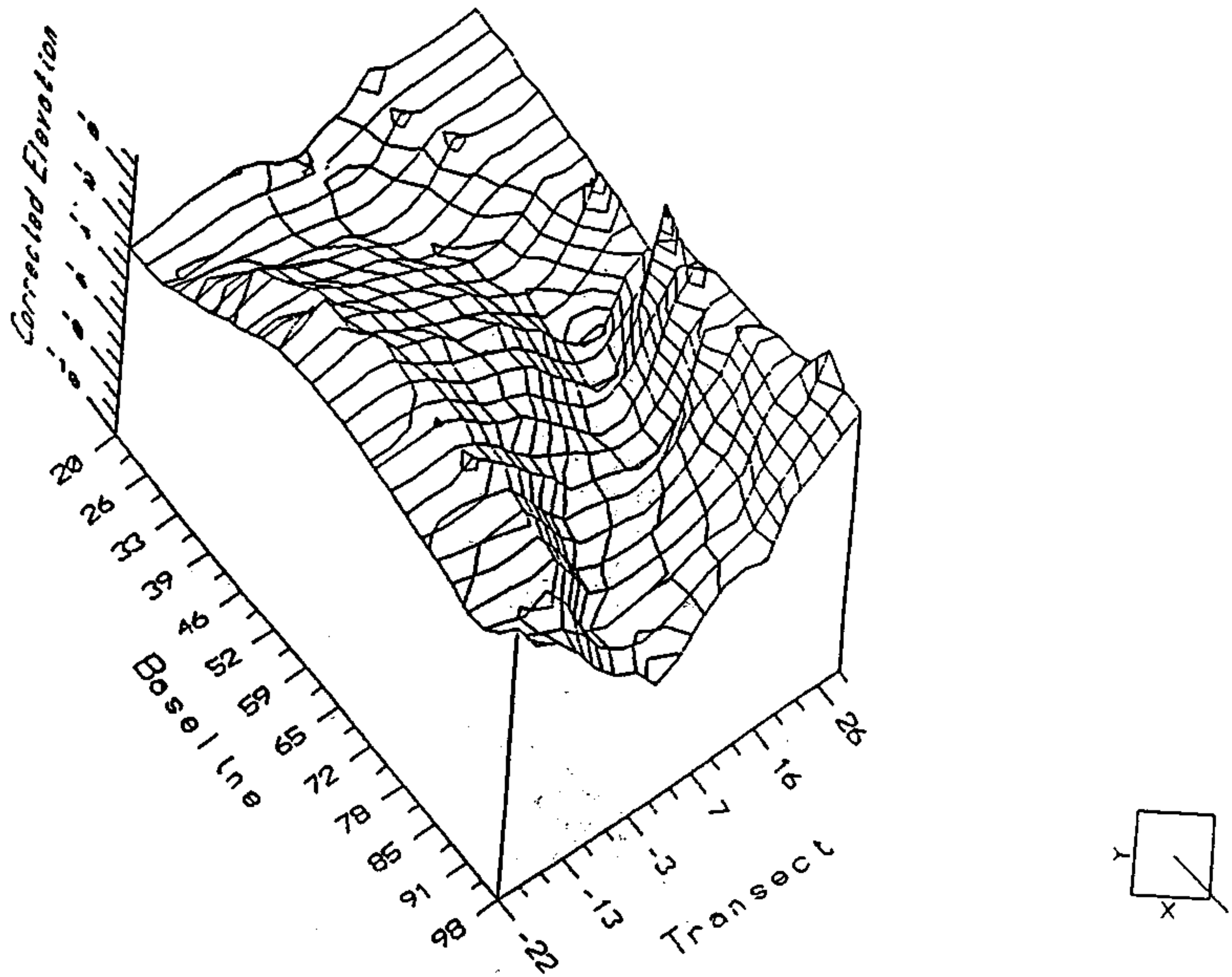
Creek 4, 1989

Creek 3, 1990





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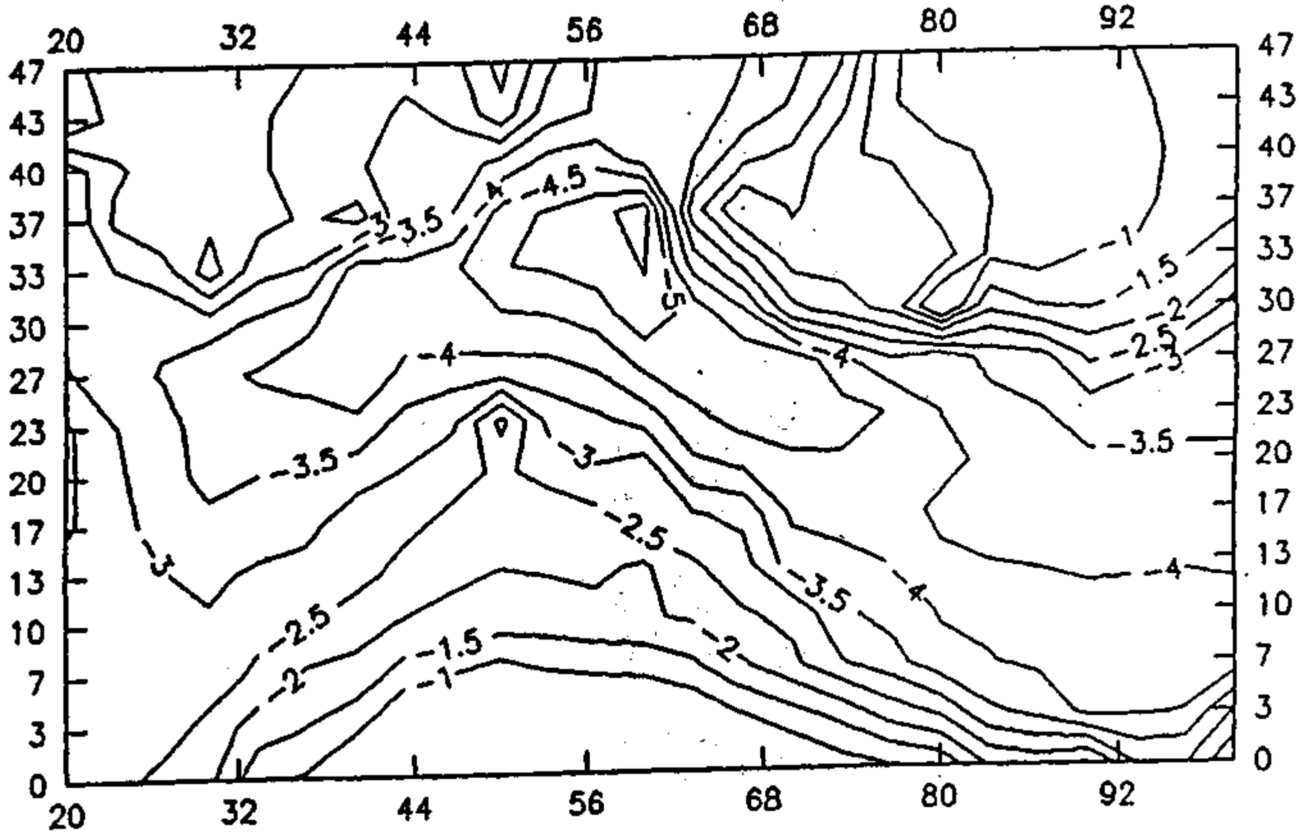
Creek 3, 1991



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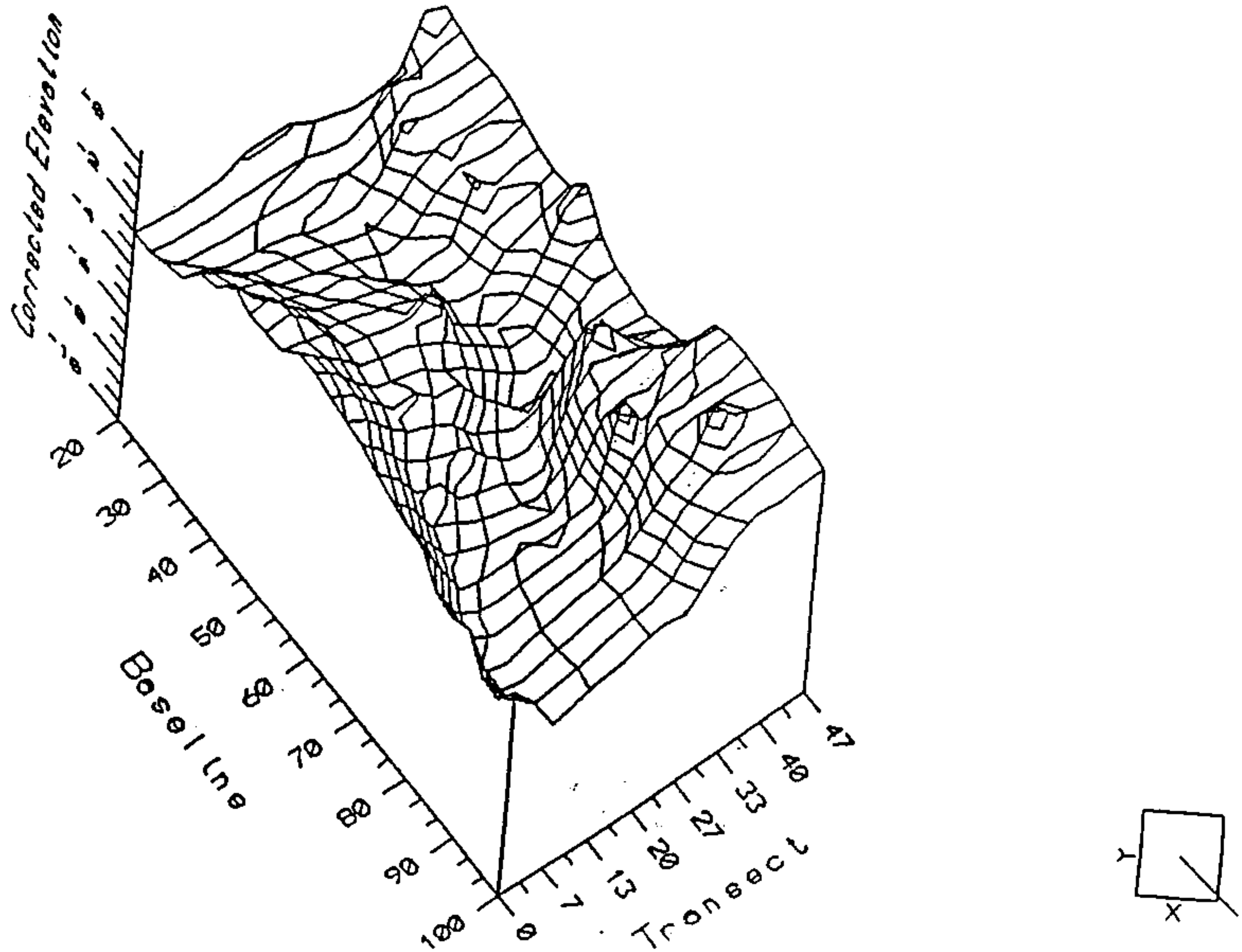

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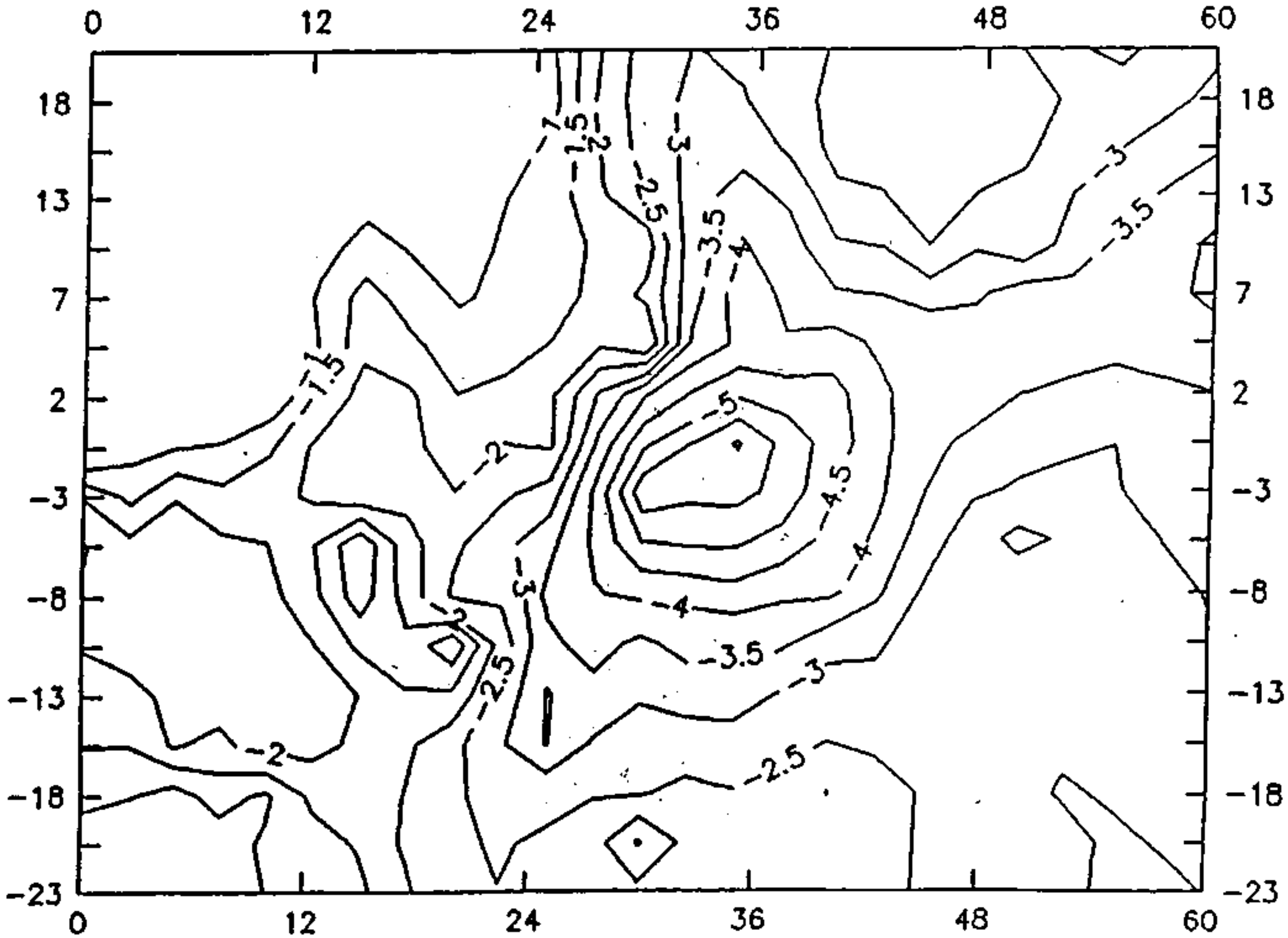

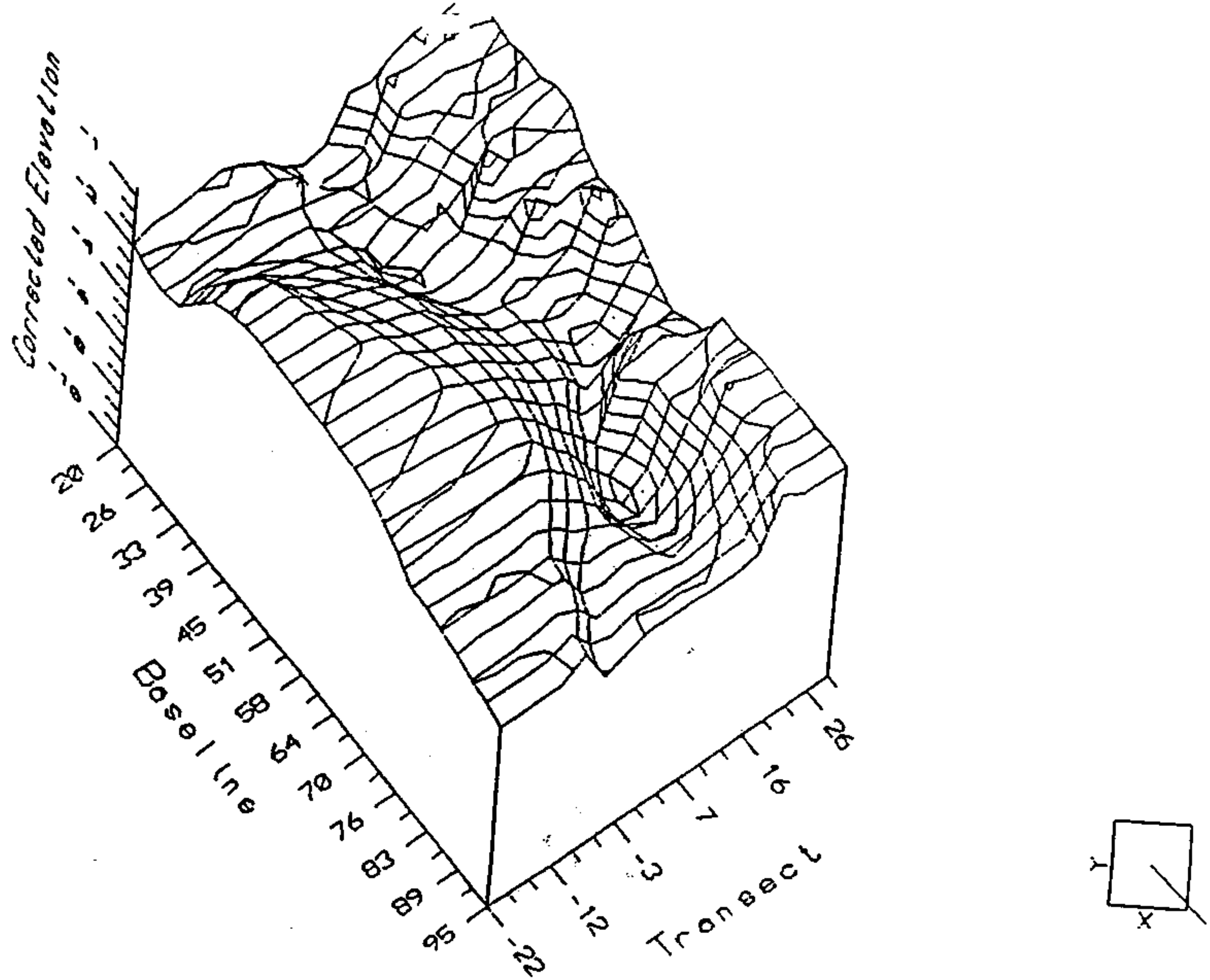

Creek Station 3, 1989

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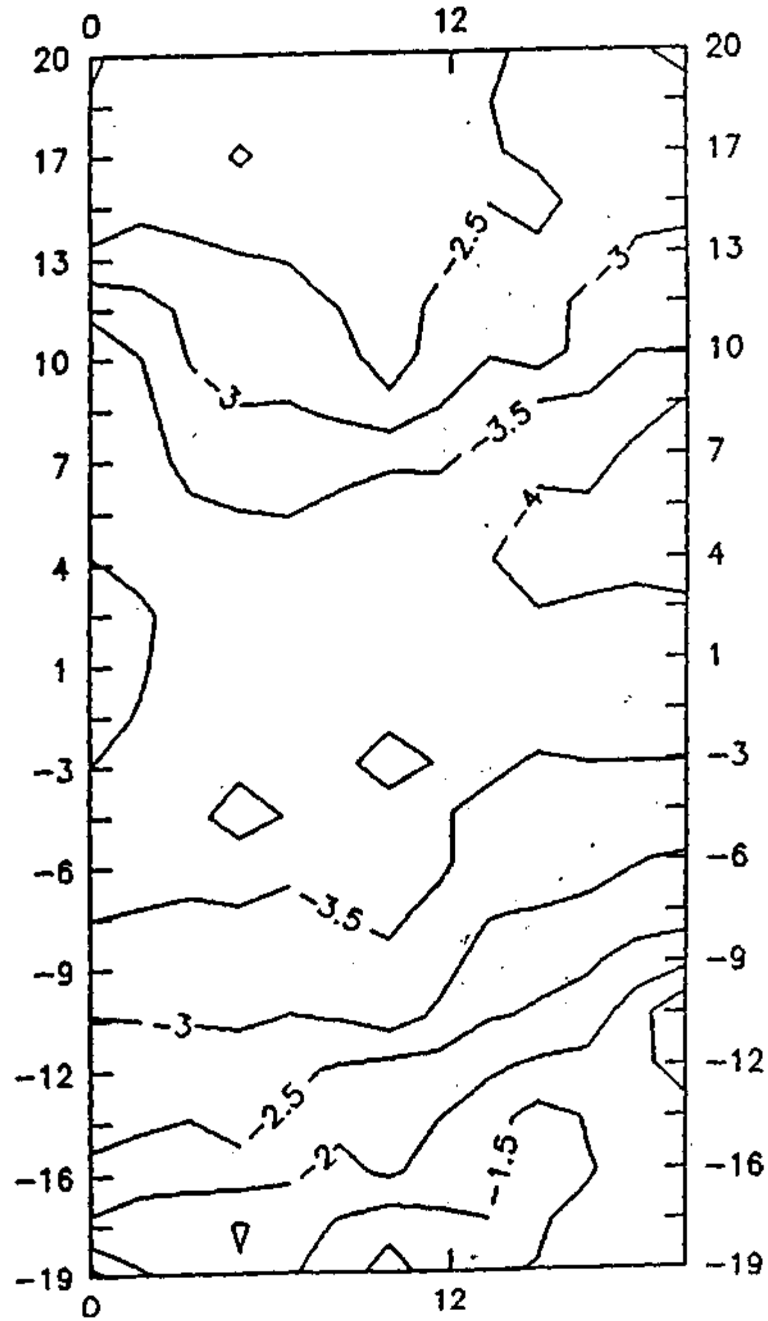

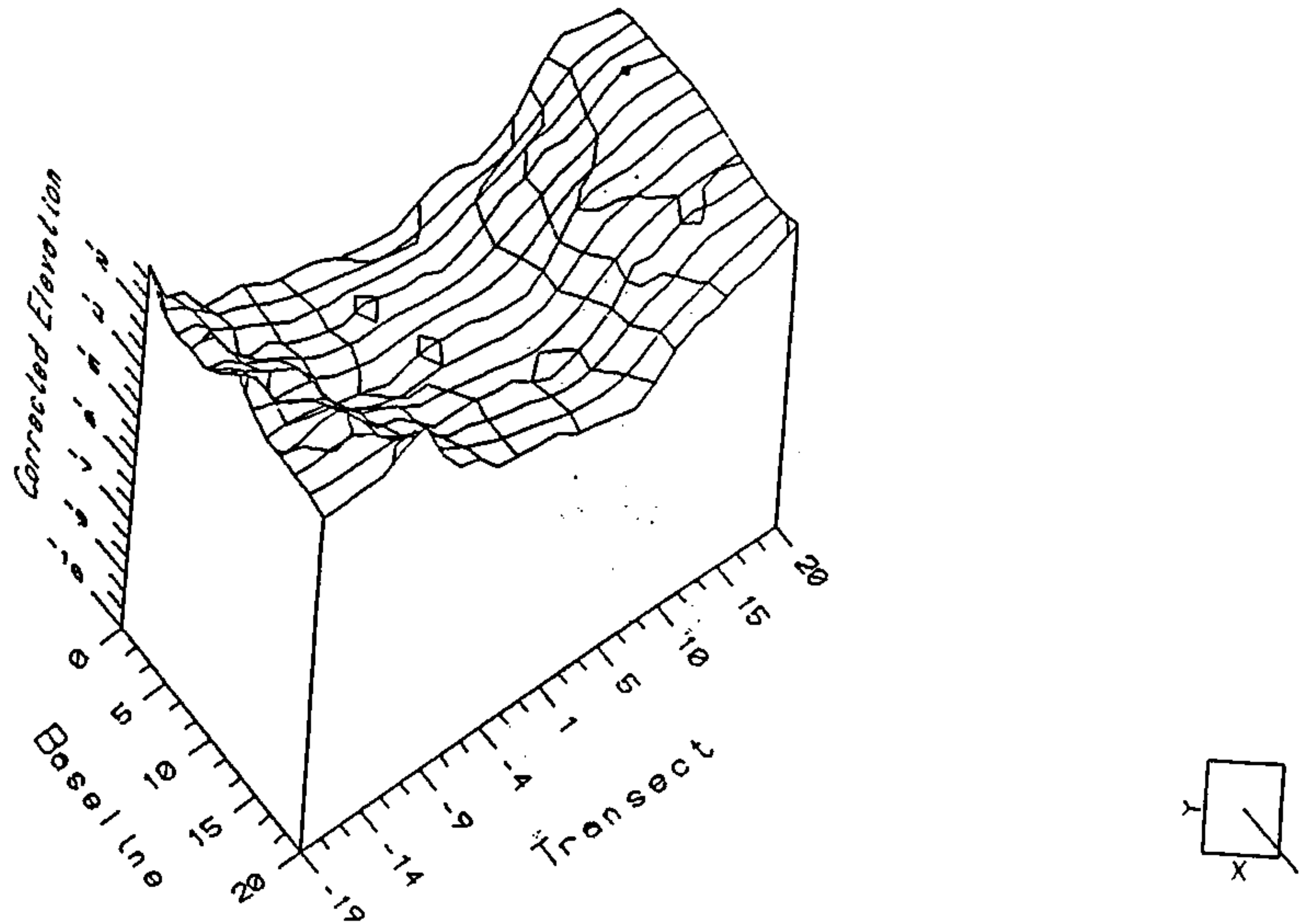
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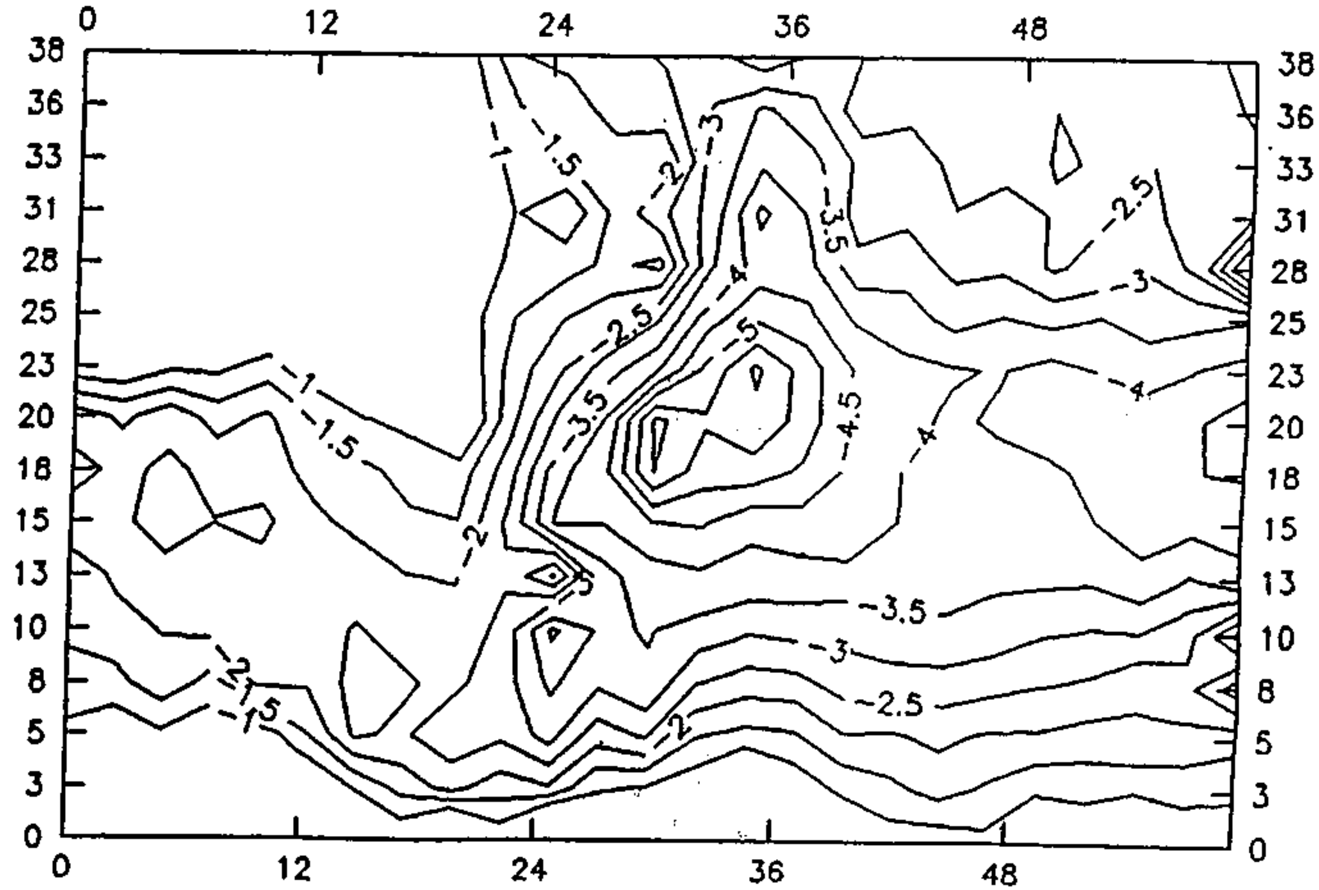
Creek 4, 1990

Creek 4, 1991



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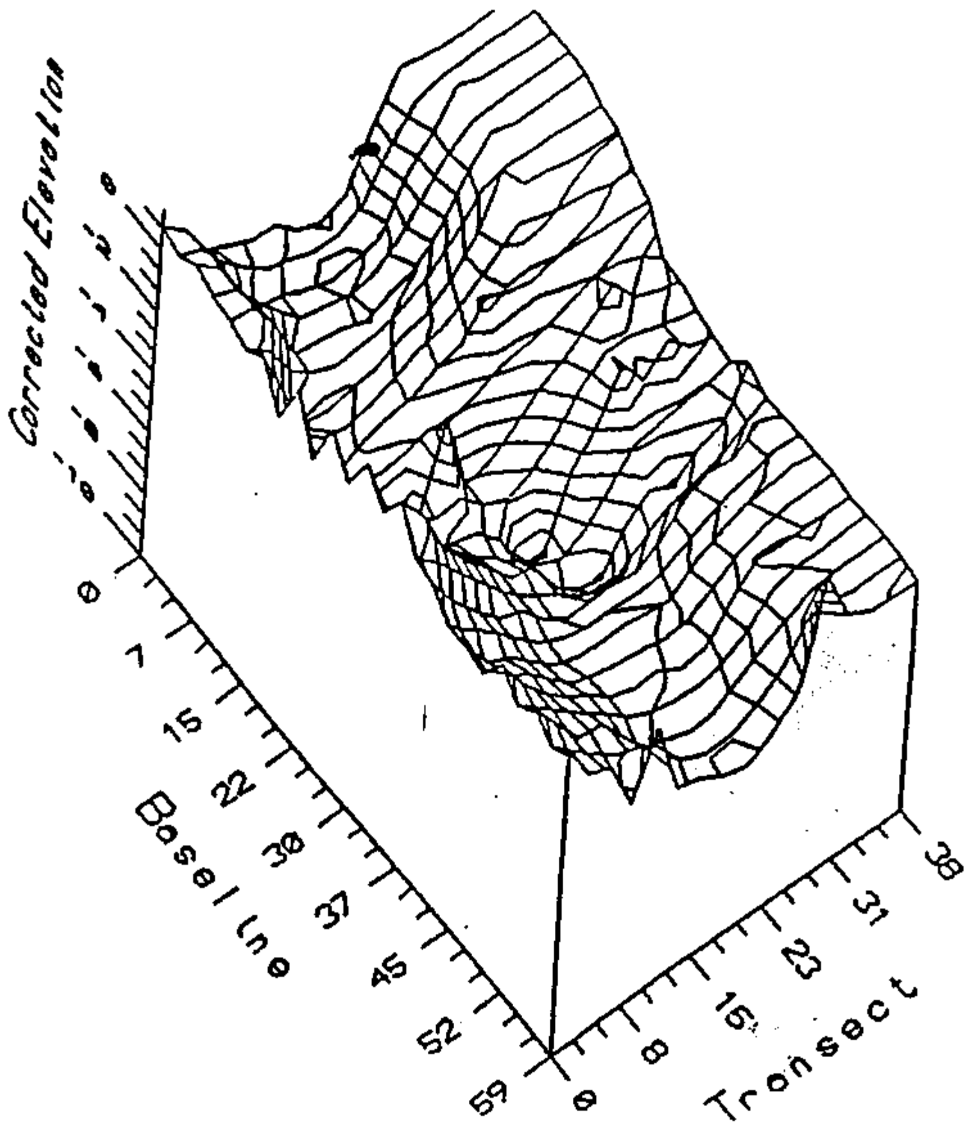
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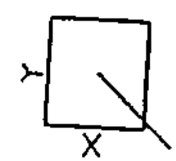
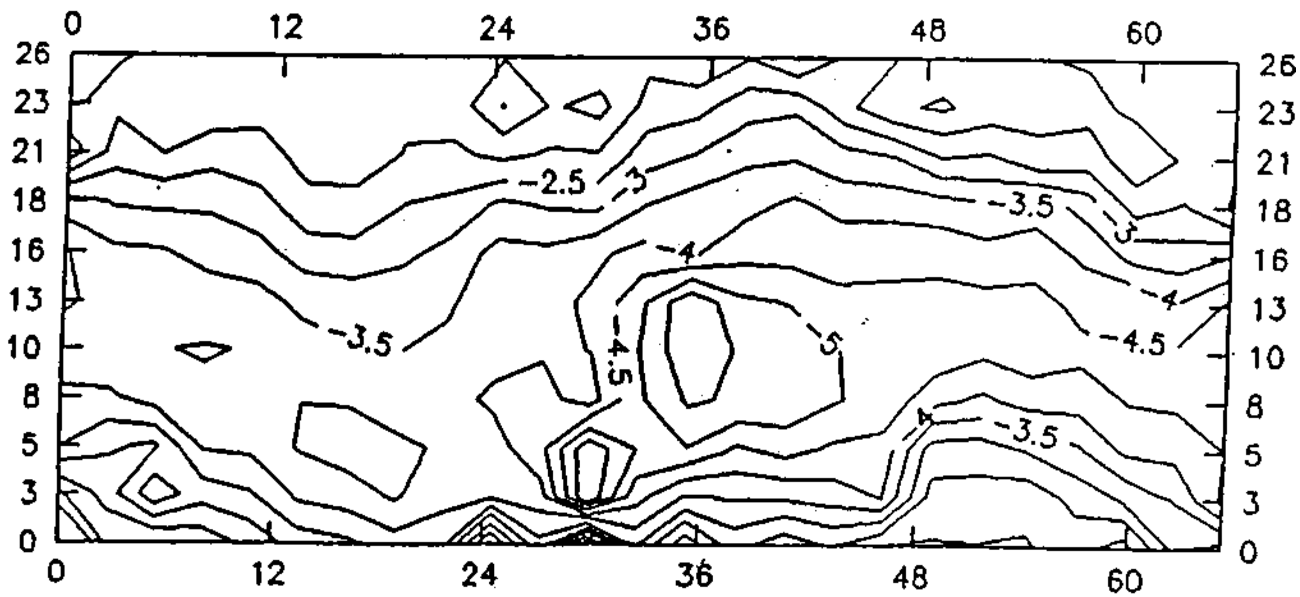
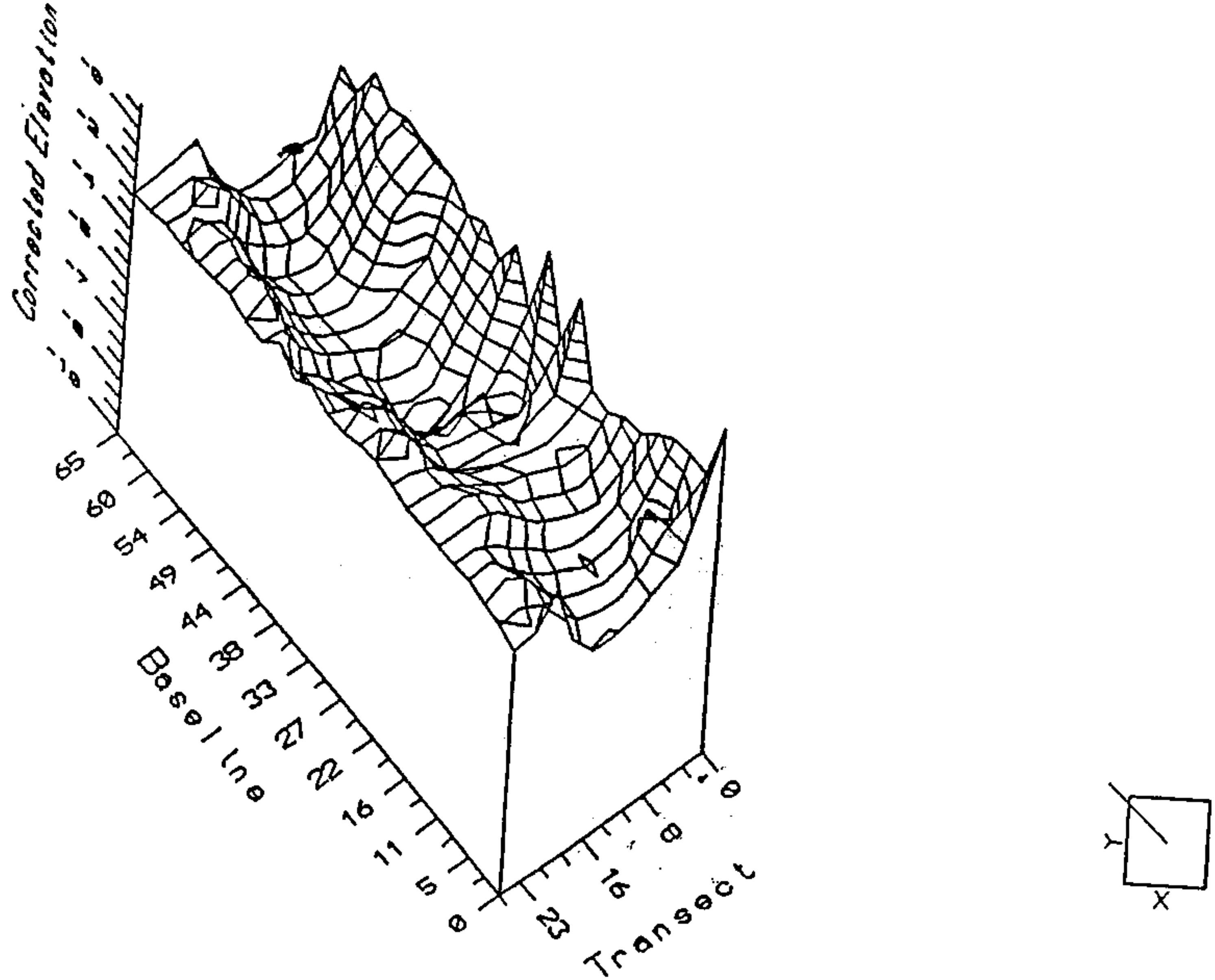

Y
X

Creek 4, 1991

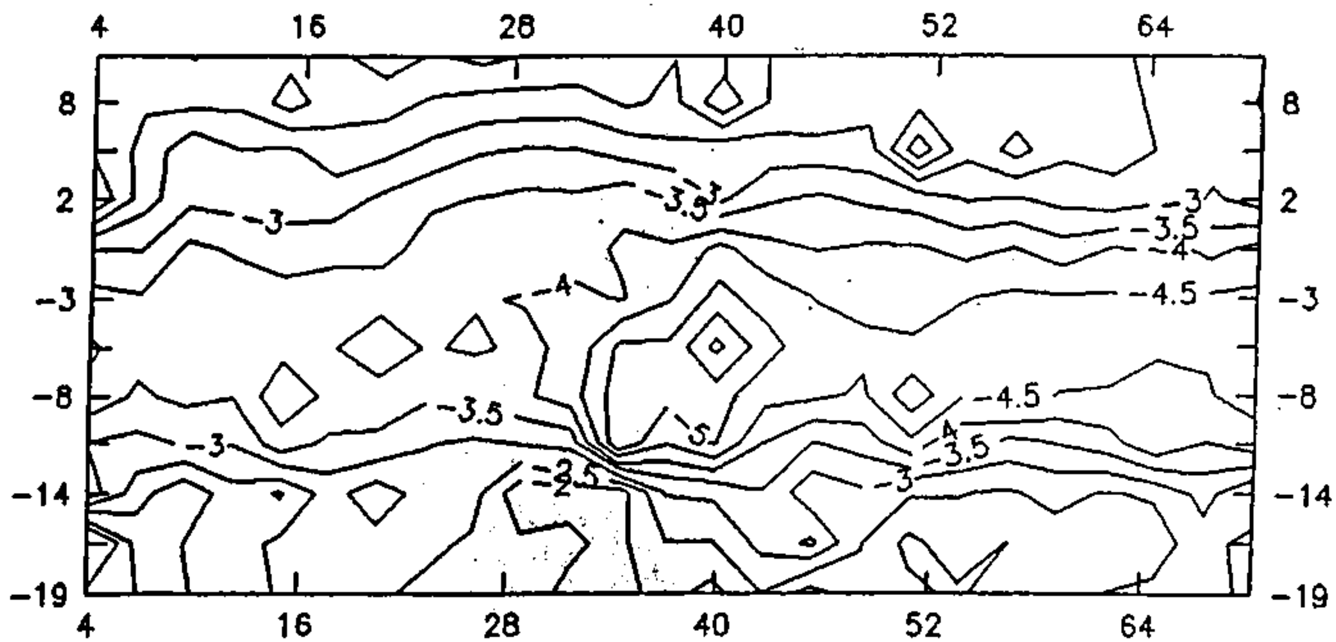
Creek 5, 1991

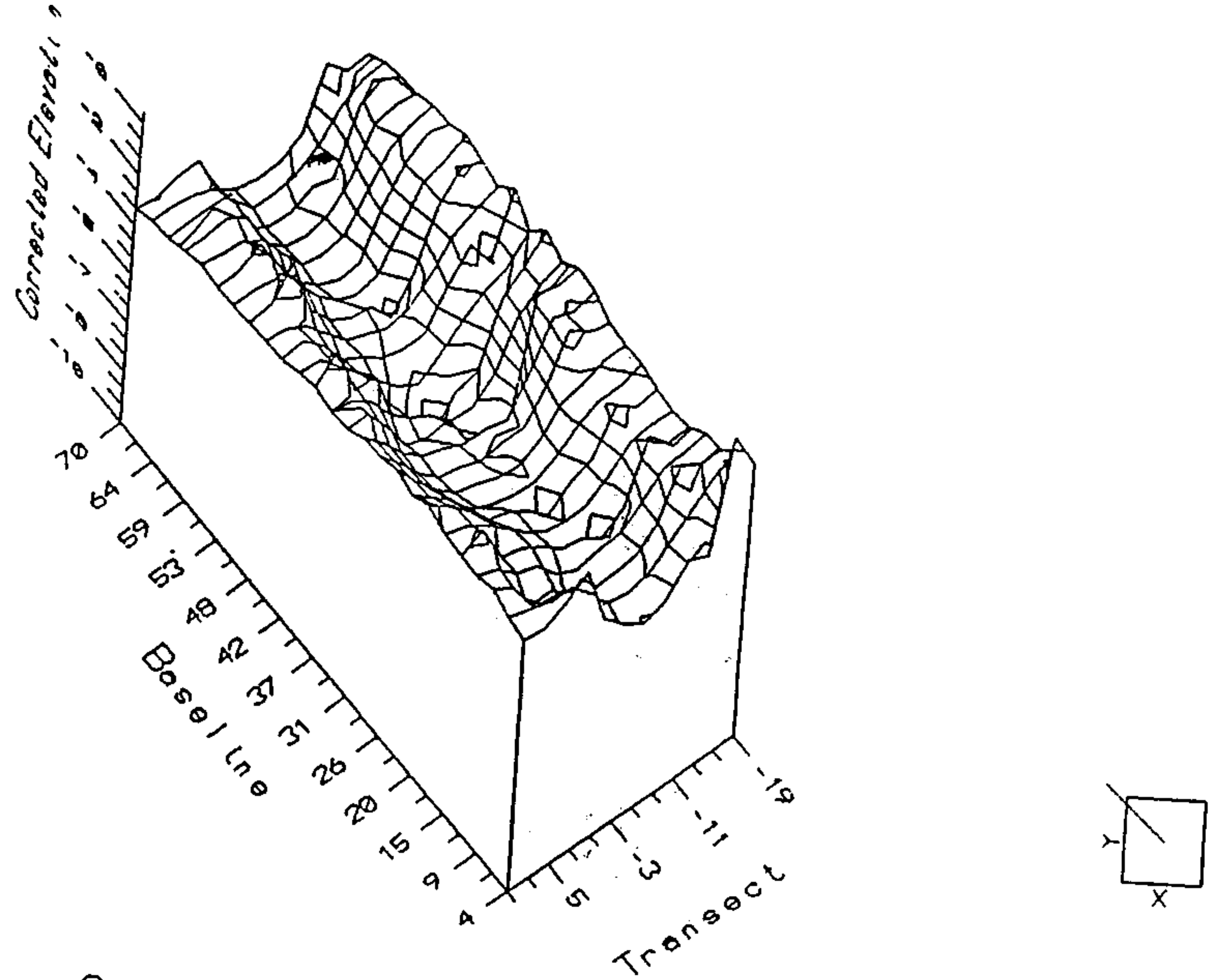




Creek station 5, 1991

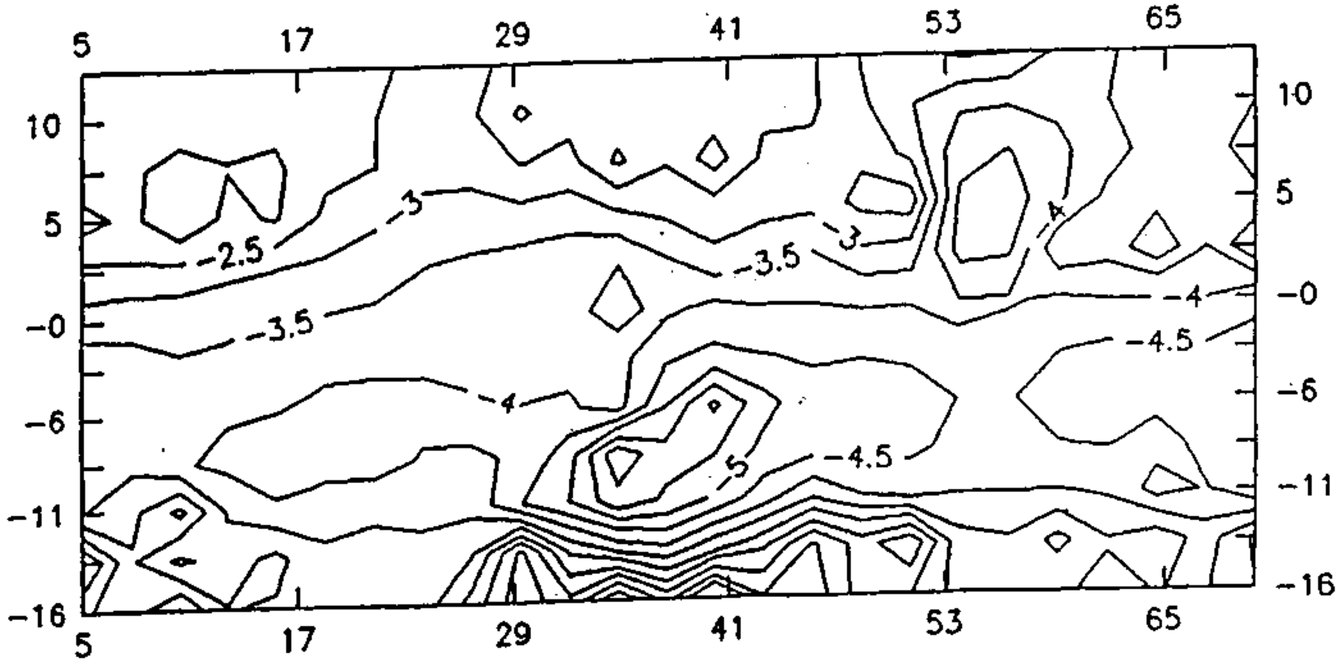
Creek 5, 1990

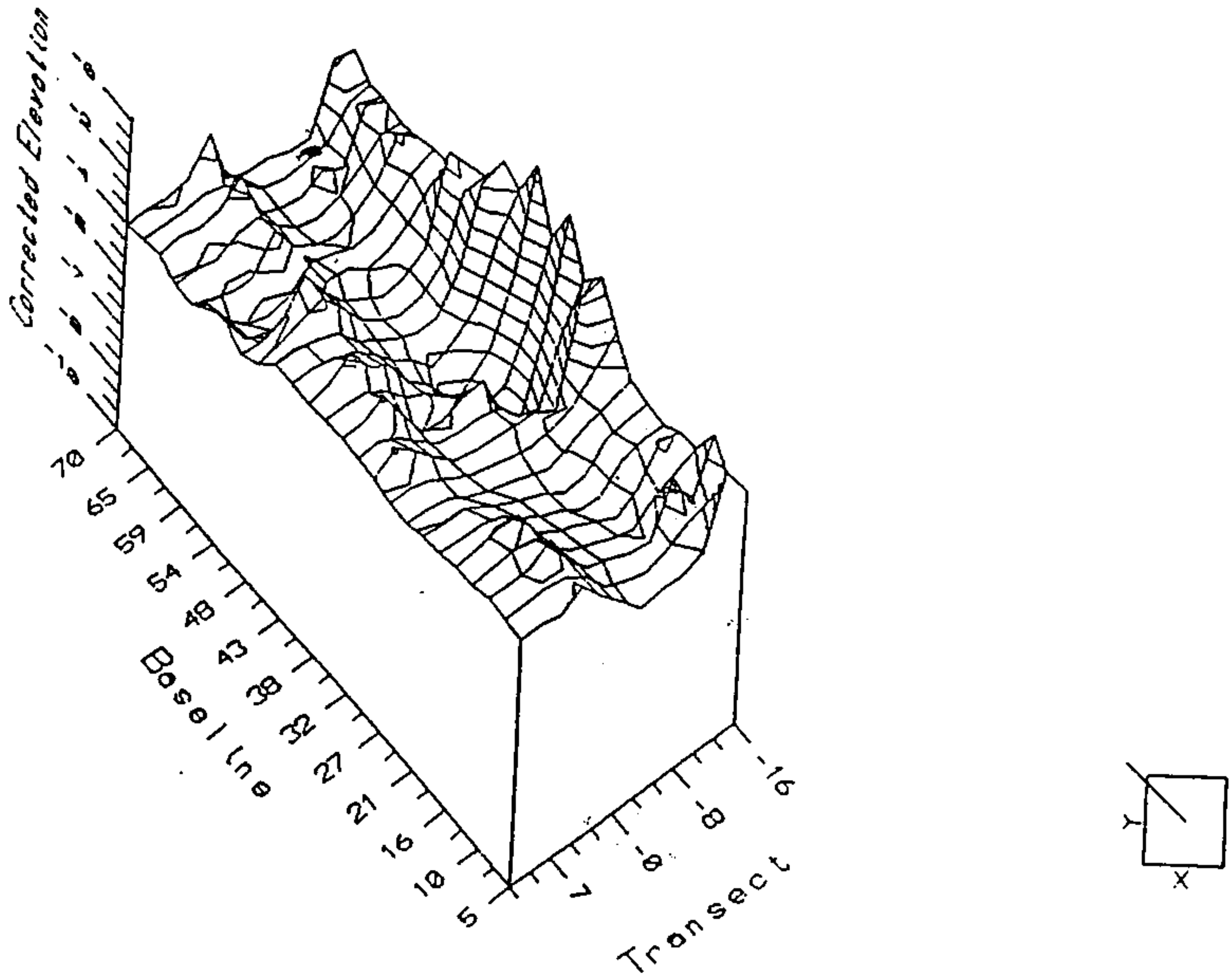




Creek station 5, 1990

Creek 5, 1989





Creek station 5, 1989

APPENDIX IV

Analysis of McNeil Substrate Scores

by Jan Derksen, Ph.D.

Analysis of McNeil Substrate Scores, North Fork Garcia River, 1995

Prepared by
Jan Derksen
November 1995

Summary

CFL crews measured McNeil substrate scores at six stations along the North Fork of the Garcia during the summer of 1995. This report compares the 1995 scores with those of previous years. At a 95% confidence level, the levels of "fines" in 1995 were found to be equal or lower than those of previous years.

During August 1995, a CFL crew measured the amount and size of sediment in the Garcia. At six sites up to six sediment samples were taken so that CFL could judge siltation levels. Each sample was separated into several portions ranging from coarse to fine sediment. Multiple sets of samples were taken at each site to find out the normal variations of the sediment at that site. CFL performed similar measurements in 1989, 1990 and in 1991 and this report compares the current data with the older data.

By using knowledge about the normal variation of each site, the computer-aided statistical analysis can, with confidence, state whether changes in siltation from year to year are due to chance or to real changes in the river's condition (analysis of variance and box plot diagrams).

The analysis concentrated on *fines,* defined for the statistical study as a sediment portion of particles less than 4.75 mm in size. The fines portion is expressed as a percentage of the total sediment volume of a sample. The use of fines percentages more easily allows the comparison of samples from year to year.

The transformation of absolute values to cumulative percent total values allows the comparison of samples from year to year. In addition, benchmark values can be computed. For example, fines should preferably be less than 25-30% (Scott Downy). Our charts and analyses compare the fines portion of the sediment for six stations during four years.

This report uses "notched box-and-whisker" diagrams (McGill, R., Tukey, J. W., and Larsen, W. A. (1978). Variations of box plots. *The American Statistician, 32, 12-16.)* to show graphically the quality of the data and the spread in observations. The diagrams allow visual comparison of changes and the significance of changes in fines from year to year. The diagrams show percentiles. Percentiles can be visualized as cuts in an ordered list of measurements. The 25% percentile divides the lower one-fourth of the data from the upper three-fourths. The 50% percentile is the same as the median: it divides the lower half of the data from the upper half. The 75% percentile separates the lower three-fourths of the data from the upper one-fourth. The percentiles in this report are taken from the values found in a sample. In a given year each station is sampled between 5 and 10 times. These measurements are aggregated into "fines'" and then ordered and separated in the 25%, 50%, and 75% percentiles.

The employed program (Systat for Windows version 5) produces box and whisker diagrams that show the 25^{th} percentile (lower box limit), the 50^{th} percentile (median, middle dividing line), and the 75^{th} percentile (upper box limit). We will call the range of values between the 25^{th} and the 75^{th} percentile, the midrange. The "whiskers", single lines that extend beyond the upper and lower box sides, show the range of measured values that falls between the 25^{th} percentile -1.5 x midrange (interquartile range) and the 75^{th} percentile + 1.5 x midrange. Extreme values that fall outside the whisker range are shown individually as "*" (outside values less than 3 x midrange beyond a box side) or "o" (far outside values more than 3 x midrange beyond a box side).

The box plots in this report have an additional feature: notches. Notches implement 95% confidence intervals around the median of a sample. Boxes are notched at the median and return to full width at the lower and upper confidence interval values. If the notched intervals around the medians in two different boxes do not overlap we can be confident at about the 95% level (strictly speaking one should take into account the "Bonserroni effect" which compounds the error when examing multiple pairs of confidence intervals) that the two population medians are different. The intervals show graphically whether the level of fines in the McNeil samples are significantly different from year to year. Note that confidence intervals may sometimes extend beyond box lines with lines extending back from the notch ends to the box sides (see site 1095 in Figure 1).

An analysis of variance of fines by site by year was performed to confirm the informal box plot assessment of significant changes from year to year. The Tukey post hoc option was used to show which changes in the four year period were statistically significant. Note that the analyses of variance tests the differences between means rather than medians. With the small sample sizes and large variances the results for means and median are not always the same.

In the following charts sites are coded by year and location. Site 1 in 1995 is coded as 1095; site 3 in 1989 is coded as 3089. The captions summarize the findings both for the medians and the means. Most of the time the ANOVA results are more conservative than the median results. In one instance, ANOVA found a significant difference between means where the boxplot test found no significant difference between medians: the station 1 mean in 1995 was found to be significantly different from the 1990 mean (the 1995 sample is lower than the 1990 mean.)

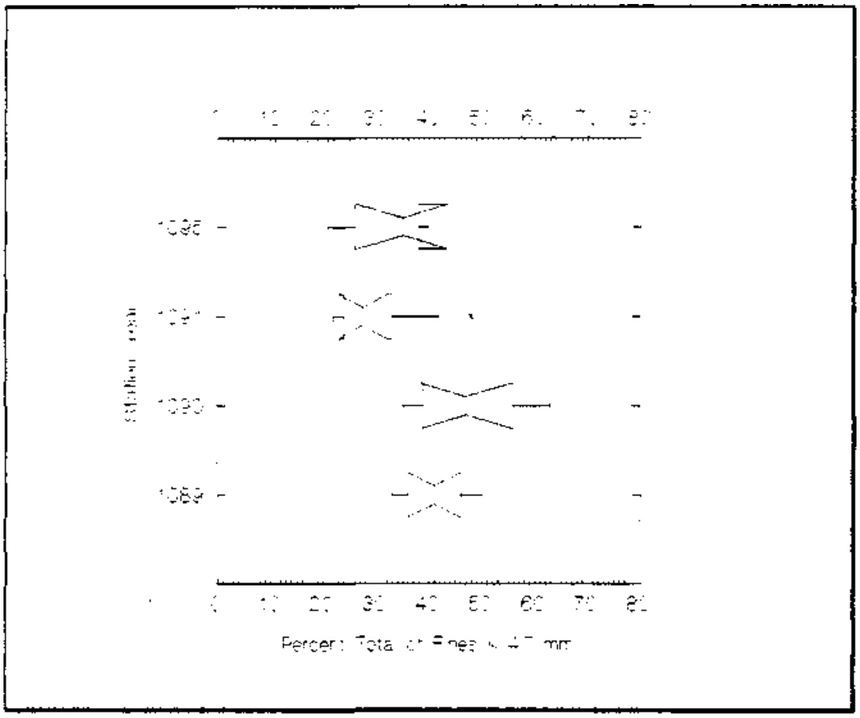


Figure 1. Station 1; 1989, 1990, 1991, 1995. The notches of 1095 overlap those of 1091, 1090, and 1089. Therefore this site shows no significant difference between fines levels in 1995 and earlier years. The notches of 1091 do not overlap those of 1090, and 1089. Therefore, the 1991 median is significantly different from the 1990, and 1989 medians. The 1991 median is lower than the 1990, and 1989 medians. ANOVA finds the 1991 means significantly different from the 1990, and 1989 means. In addition, the 1995 mean is different from the 1990 means. The 1991 means is lower than the 1990, and 1989 means and the 1995 mean is lower than the 1990 means.

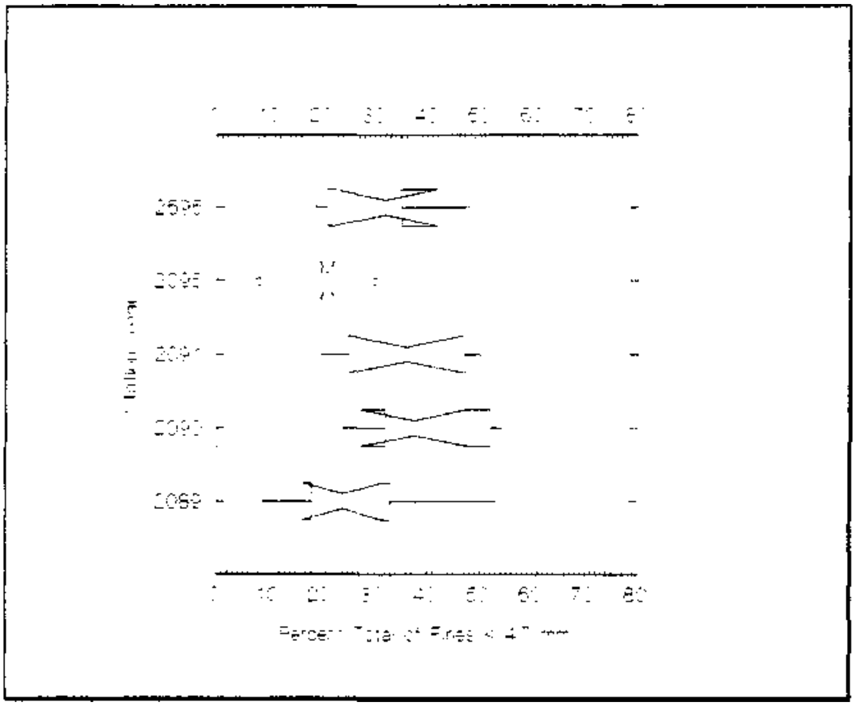


Figure 2. Stations 2.0 and 2.5 (lower and upper); 1989, 1990, 1991, 1995. The 1995 median at site "2 lower" (2095) is significantly different from the 1990 and 1991 medians. The 1995 median at site "2 lower" (2095) is lower than the 1990 and 1991 medians. There are no other significant differences. ANOVA finds the 1995 means significantly different form the 1990 means for the "2 lower" station. The 1995 mean lower than the 1990 means for the "2 lower" station.

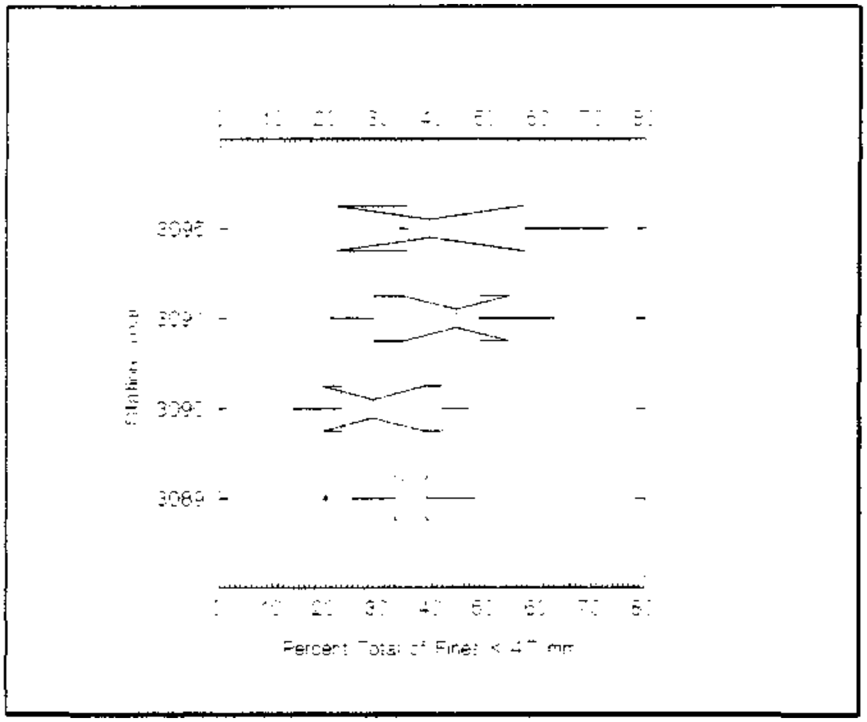


Figure 3. Station 3; 1989, 1990, 1991, 1995. There are no significant differences. Note the wide confidence interval around the 1995 median that signifies that the median is between 22% and 55% at a 95% confidence level. Only 4 observations were usable for station 3 in 1995. ANOVA finds no significant differences between the means.

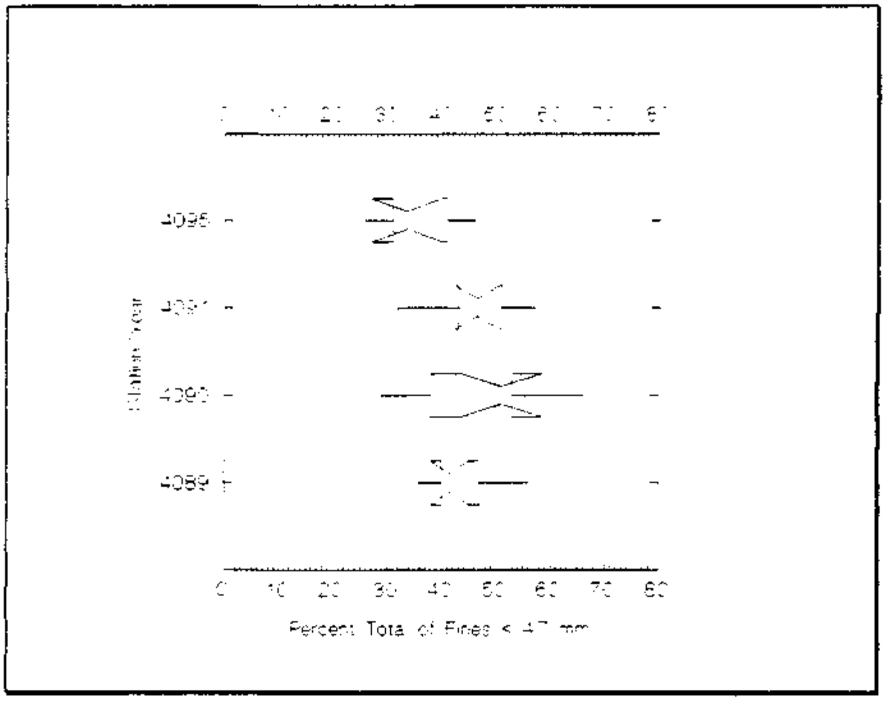


Figure 4. Station 4; 1989, 1990,1991, 1995. The 1995 median is significantly different form the 1991 and 1990 medians. The 1995 median is lower than the 1991 and 1990 medians. ANOVA finds the 1995 means significantly different from the 1990 means. The 1995 means is lower than the 1990 means.

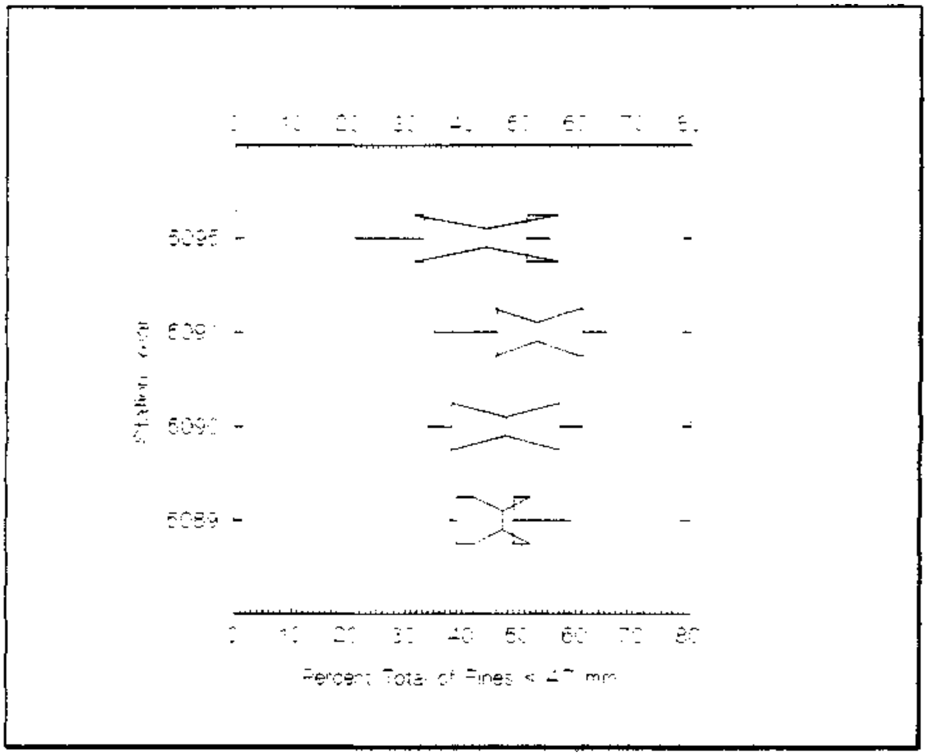


Figure 5. Station 5; 1989, 1990, 1991, 1995. No significant differences between the medians. ANOVA finds no significant differences between the means.

Conclusion

CFL crews measured McNeil substrate scores at six stations along the North Fork of the Garcia River during the summer of 1995. This report compares the 1995 scores with those of 1989, 1990, and 1991. At a 95% confidence level, significant differences were found between the levels of "fines" in 1995 and those of previous years. The levels of "fines" in 1995 were found to be equal to or lower than those of previous years.

- Station 1; the 1995 fines levels were lower than those in 1990.
- Stations 2.0 and 2.5 (lower and upper); the 1995 fines levels at site "2 lower" were lower than those in 1990 and 1991.
- Station 3; no significant differences between 1995 and previous years.
- Station 4; the 1995 fines levels were lower than those in 1991 and 1990.
- Station 5; no significant differences between 1995 and previous years.

Appendix 1.
Analyses of Variance results produced by Systat for Windows version 5.

In ANOVA tests the P-value expresses the presence or absence of group differences. A P-value less than 0.05 signifies that differences in the means for some of the four years have been found at a 95% confidence level. The actual confidence level is (100 - P) %. For station 1, as shown below, the P-value is 0.000. This signifies that

at least some of the means were found to be different from each other with a probability of at least 99.999%.

To find **which** means in a group of samples were different, this report includes a "Tukey post hoc" test. A matrix of pairwise differences and P-values shows the difference in means and the significance of that difference between every pair of values. For example, for station 2 the difference in means between station/year 2 and 4 (2090, station 2 in 1990, and 2095, station 2 in 1995) is -18.9 with a significance of 0.034 or 96.6% confidence.)

Station 1.

MON 10/16/95 5:04:49 PM C:\0\SURFER\MCN1.SYS

LEVELS ENCOUNTERED DURING PROCESSING ARE: STATIONY

1089.000 1090.000 1091.000 1095.000

DEP VAR: FINES N: 35 MULTIPLE R: 0.670 SQUARED MULTIPLE R: .450

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
STATIONY	1774.086	3	591.362	8.438	0.000
ERROR	2172.600	31	70.084		

COL/ ROW	STATIONY
1	1089.000
2	1090.000
3	1091.000
4	1095.000

USING LEAST SQUARES MEANS.
POST HOC TEST OF FINES
USING MODEL MSE OF 70.084 WITH 31. DF.
MATRIX OF PAIRWISE MEAN DIFFERENCES:

	1	2	3	4
1	0.000			
2	7.100	0.000		
3	-10.300	-17.400	0.000	
4	-8.600	-15.700	1.700	0.000

TUKEY HSD MULTIPLE COMPARISONS.
MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

	1	2	3	4
1	1.000			
2	0.250	1.000		
3	0.046	0.000	1.000	
4	0.259	0.009	0.982	1.000

Station 2.

MON 10/16/95 4:59:13 PM C:\0\SURFER\MCN2.SYS

LEVELS ENCOUNTERED DURING PROCESSING ARE:

STATIONY

2089.000 2090.000 2091.000 2095.000 2595.000

DEP VAR: FINES N: 40 MULTIPLE R: 0.510 SQUARED MULTIPLE R: 0.26C

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
STATIONY	1591.300	4	397.825	3.075	0.029
ERROR	4527.800	35	129.366		

COL/ ROW	STATIONY
1	2089.000
2	2090.000
3	2091.000
4	2095.000
5	2595.000

USING LEAST SQUARES MEANS.

POST HOC TEST OF FINES

USING MODEL MSE OF 129.366 WITH 35. DF.

MATRIX OF PAIRWISE MEAN DIFFERENCES:

	1	2	3	4	5
1	0.000				
2	12.100	0.000			
3	8.700	-3.400	0.000		
4	-6.800	-18.900	-15.500	0.000	
5	4.000	-8.100	-4.700	10.800	0.000

TUKEY HSD MULTIPLE COMPARISONS.

MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

	1	2	3	4	5
1	1.000				
2	0.145	1.000			
3	0.441	0.962	1.000		
4	0.810	0.034	0.117	1.000	
5	0.967	0.693	0.942	0.569	1.000

Station 3.

MON 10/16/95 5:00:23 PM C:\0\SURFER\MCN3.SYS

LEVELS ENCOUNTERED DURING PROCESSING ARE:

STATIONY

3089.000 3090.000 3091.000 3095.000

DEP VAR: FINES N: 34 MULTIPLE R: 0.421 SQUARED MULTIPLE R: 0.178

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
STATIONY	959.471	3	319.824	2.159	0.114
ERROR	4445.000	30	148.167		

COL/
ROWSTATIONY

1	3089.000
2	3090.000
3	3091.000
4	3095.000

USING LEAST SQUARES MEANS.
POST HOC TEST OF FINES

USING MODEL MSE OF 148.167 WITH 30. DF.
MATRIX OF PAIRWISE MEAN DIFFERENCES:

	1	2	3	4
1	0.000			
2	-4.400	0.000		
3	6.400	10.800	0.000	
4	10.900	15.300	4.500	0.000

TUKEY HSD MULTIPLE COMPARISONS.
MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

	1	2	3	4
1	1.000			
2	0.850	1.000		
3	0.647	0.217	1.000	
4	0.442	0.169	0.923	1.000

Station 4.

THU 11/23/95 1:20:21 PM C:\0\SURFER\MCN4.SYS
LEVELS ENCOUNTERED DURING PROCESSING ARE:
STATIONY
4089.000 4090.000 4091.000 4095.000

DEP VAR: FINES N: 36 MULTIPLE R: 0.493 SQUARED MULTIPLE R: 0.243

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
STATIONY	709.317	3	236.439	3.424	0.029
ERROR	2209.433	32	69.045		

COL/
ROWSTATIONY

1	4089.000
2	4090.000
3	4091.000
4	4095.000

USING LEAST SQUARES MEANS.

POST HOC TEST OF FINES

USING MODEL MSE OF 69.045 WITH 32. DF.
MATRIX OF PAIRWISE MEAN DIFFERENCES:

	1	2	3	4
1	0.000			
2	4.300	0.000		
3	2.500	-1.800	0.000	
4	-8.833	-13.133	-11.333	0.000

TUKEY HSD MULTIPLE COMPARISONS.
MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

	1	2	3	4
1	1.000			
2	0.658	1.000		
3	0.907	0.962	1.000	
4	0.189	0.022	0.058	1.000

Station 5.
MON 10/16/95 5:02:23 PM C:\0\SURFER\MCN5.SYS
LEVELS ENCOUNTERED DURING PROCESSING ARE:
STATIONY
5089.000 5090.000 5091.000 5095.000

DEP VAR: FINES N: 35 MULTIPLE R: 0.365 SQUARED MULTIPLE R: 0.134

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
STATIONY	470.700	3	156.900	1.593	0.211
ERROR	3053.700	31	98.506		

COL/ ROW	STATIONY
1	5089.000
2	5090.000
3	5091.000
4	5095.000

USING LEAST SQUARES MEANS.

POST HOC TEST OF FINES

USING MODEL MSE OF 98.506 WITH 31. DF.
MATRIX OF PAIRWISE MEAN DIFFERENCES:

	1	2	3	4
1	0.000			
2	0.000	0.000		
3	5.700	5.700	0.000	
4	-5.800	-5.800	-11.500	0.000

TUKEY HSD MULTIPLE COMPARISONS.
MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

	1	2	3	4
1	1.000			
2	1.000	1.000		
3	0.580	0.580	1.000	
4	0.712	0.712	0.171	1.000

Appendix 2. Descriptive statistics and raw data.

For the descriptive statistics, stations are identified in a manner that differs from the one used before. The year (95) is followed by the station (01). The statistics are computed for aggregated data. For example, the field "<4.75%" is computed by adding all measurements for sediment that is less than 4.75 mm in size in a given sample. A total sample value is obtained by adding measurements for sediment of all sizes in the sample. Finally, the sum for sediment less than 4.75 mm in size is divided by the total sum and multiplied by 100 to obtain a "percent total".

For each station/year-sample common descriptive statistics such as the minimum, maximum, mean etc. are computed. In addition, a 95% confidence interval around the mean is computed. Because of the small sample sizes, t-tests are used. For example, at a 95% confidence level we can state that the 1995 population mean of fines (<4.75%) at station 1 is between 21.8% and 42.1%. Finally, the 25%, 50%, and 75% quartiles are reported.

Descriptive statistics.

Id	Field	#	Mean	Min	Max	Var	CfVar	StdDev	Std Err	95% Lower	95% Upper	25%	50%	75%	Mid Range
9501	<0.85%	5	15.4	10.0	22.5	22.6	0.31	4.8	2.1	9.5	21.4	12.6	14.9	17.3	4.6
9501	<2.37%	5	25.3	17.3	33.5	45.1	0.27	6.7	3.0	17.0	33.6	19.6	27.1	29.0	9.4
9501	<4.75%	5	32.0	21.1	39.6	66.9	0.26	8.2	3.7	21.8	42.1	25.7	35.1	38.4	12.6
9501	<6.3%	5	35.5	22.7	43.8	87.0	0.26	9.3	4.2	24.0	47.1	29.1	38.4	43.6	14.5
9501	<12.5%	5	46.7	31.2	57.3	114.7	0.23	10.7	4.8	33.4	60.0	42.3	47.0	56.0	13.7
9501	<25.4%	5	60.8	42.9	70.8	136.4	0.19	11.7	5.2	46.3	75.3	55.8	63.9	70.4	14.6
9501	<75%	5	92.3	76.6	100.0	120.1	0.12	11.0	4.9	78.7	105.9	84.7	100.0	100.0	15.3
9501	Total%	5	100.0	100.0	100.0	0.0	0.00	0.0	0.0	100.0	100.0	100.0	100.0	100.0	0.0
950210	<0.85%	5	10.8	4.6	14.4	14.3	0.35	3.8	1.7	6.1	15.5	10.4	11.7	12.9	2.5
950210	<2.37%	5	15.1	5.6	21.1	32.9	0.38	5.7	2.6	7.9	22.2	15.3	16.6	16.7	1.4
950210	<4.75%	5	20.3	7.6	30.3	67.2	0.40	8.2	3.7	10.1	30.5	20.0	21.5	22.3	2.3
950210	<6.3%	5	23.4	9.2	35.1	86.2	0.40	9.3	4.2	11.8	34.9	22.5	24.5	25.5	3.0
950210	<12.5%	5	31.8	13.5	47.5	148.0	0.38	12.2	5.4	16.7	46.9	30.7	33.1	34.4	3.7
950210	<25.4%	5	41.0	17.1	67.8	327.4	0.44	18.1	8.1	18.5	63.5	36.9	41.0	42.3	5.4

Id	Field	#	Mean	Min	Max	Var	CfVar	StdDev	Std Err	95% Lower	95% Upper	25%	50%	75%	Mid Range
95021o	<75%	5	77.7	52.4	100.0	419.4	0.26	20.5	9.2	52.3	103.1	60.3	84.2	91.7	31.4
950210	Total%	5	100.0	100.0	100.0	0.0	0.00	0.0	0.0	100.0	100.0	100.0	100.0	100.0	0.0
9502up	<0.85%	5	14.6	9.9	22.6	30.2	0.38	5.5	2.5	7.8	21.5	10.6	12.0	18.0	7.4
9502up	<2.37%	5	24.0	14.5	39.2	104.5	0.43	10.2	4.6	11.4	36.7	14.8	24.2	27.5	12.7
9502up	<4.75%	5	31.0	18.9	47.5	136.1	0.38	11.7	5.2	16.5	45.5	20.7	32.2	35.4	14.7
9502up	<6.3%	5	34.5	21.9	51.2	142.6	0.35	11.9	5.3	19.6	49.3	24.0	36.2	38.9	14.9
9502up	<12.5%	5	44.4	30.6	61.6	157.4	0.28	12.5	5.6	28.8	59.9	33.7	46.8	49.1	15.4
9502up	<25.4%	5	58.1	42.9	77.2	169.8	0.22	13.0	5.8	41.9	74.3	49.6	60.0	60.8	11.1
9502up	<75%	5	94.6	72.8	100.0	148.4	0.13	12.2	5.4	79.4	109.7	100.0	100.0	100.0	0.0
9502up	Total%	5	100.0	100.0	100.0	0.0	0.00	0.0	0.0	100.0	100.0	100.0	100.0	100.0	0.0
9503	<0.85%	4	21.8	18.6	23.3	4.6	0.10	2.1	1.1	18.4	25.2	21.6	22.7	22.9	1.3
9503	<2.37%	4	35.2	23.1	57.4	231.7	0.43	15.2	7.6	11.0	59.4	27.0	30.2	38.4	11.4
9503	<4.75%	4	46.6	33.6	73.1	324.7	0.39	18.0	9.0	17.9	75.2	36.4	39.8	49.9	13.5
9503	<6.3%	4	58.3	42.0	89.5	458.7	0.37	21.4	10.7	24.2	92.4	46.1	50.9	63.1	17.0
9503	<12.5%	4	72.6	56.6	98.1	318.4	0.25	17.8	8.9	44.2	101.0	63.6	67.9	76.9	13.3
9503	<25.4%	4	85.3	73.7	99.6	114.4	0.13	10.7	5.3	68.3	102.4	80.8	84.0	88.5	7.7
9503	<75%	4	100.0	100.0	100.0	0.0	0.00	0.0	0.0	100.0	100.0	100.0	100.0	100.0	0.0
9503	Total%	4	100.0	100.0	100.0	0.0	0.00	0.0	0.0	100.0	100.0	100.0	100.0	100.0	0.0
9504	<0.85%	6	15.8	7.4	26.1	43.6	0.42	6.6	2.7	8.9	22.7	12.2	14.9	19.0	6.8
9504	<2.37%	6	26.6	18.5	37.1	54.2	0.28	7.4	3.0	18.8	34.3	21.4	24.6	31.8	10.3
9504	<4.75%	6	35.4	26.3	46.5	52.3	0.20	7.2	3.0	27.8	43.0	31.7	33.7	39.3	7.6
9504	<6.3%	6	42.9	31.2	55.4	82.2	0.21	9.1	3.7	33.4	52.5	37.4	41.9	49.0	11.7
9504	<12.5%	6	58.2	46.2	73.3	102.9	0.17	10.1	4.1	47.6	68.9	50.8	57.8	64.0	13.2
9504	<25.4%	6	78.4	60.2	88.9	123.1	0.14	11.1	4.5	66.8	90.1	73.0	81.9	86.1	13.2
9504	<75%	6	100.0	100.0	100.0	0.0	0.00	0.0	0.0	100.0	100.0	100.0	100.0	100.0	0.0
9504	Total%	6	100.0	100.0	100.0	0.0	0.00	0.0	0.0	100.0	100.0	100.0	100.0	100.0	0.0
9505	<0.85%	5	26.2	16.1	34.6	57.1	0.29	7.6	3.4	16.8	35.5	20.9	27.9	31.2	10.3
9505	<2.37%	5	35.6	19.4	46.4	120.1	0.31	11.0	4.9	22.0	49.2	30.7	37.0	44.3	13.6
9505	<4.75%	5	40.9	21.3	55.0	189.2	0.34	13.8	6.2	23.8	58.0	33.0	44.1	51.0	18.0
9505	<6.3%	5	44.3	22.7	59.3	215.2	0.33	14.7	6.6	26.1	62.5	37.2	47.6	54.7	17.5
9505	<12.5%	5	54.9	30.5	70.7	248.6	0.29	15.8	7.1	35.4	74.5	50.0	57.7	65.7	15.7
9505	<25.4%	5	70.3	51.5	80.2	126.6	0.16	11.3	5.0	56.3	84.3	69.1	74.4	76.4	7.3

Id	Field	#	Mean	Min	Max	Var	CfVar	StdDev	Std Err	95% Lower	95% Upper	25%	50%	75%	Mid Range
9505	<75%	5	100.0	100.0	100.0	0.0	0.00	0.0	0.0	100.0	100.0	100.0	100.0	100.0	0.0
9505	Total%	5	100.0	100.0	100.0	0.0	0.00	0.0	0.0	100.0	100.0	100.0	100.0	100.0	0.0

Raw data.

Id	<4.75%	75	25.4	12.5	6.3	4.75	2.36	0.85	sand	silt	Total	<0.85%	<6.3%	<12.5%	<25.4%	<75%	Total%
9501	38	0	540	240	245	100	170	215	227.5	87.5	1825	17	44	57	70	100	100
9501	21	555	800	280	200	40	90	110	270	30	2375	13	23	31	43	77	100
9501	35	295	560	170	165	65	155	235	151	137	1933	15	38	47	56	85	100
9501	40	0	850	430	360	115	180	320	621	32	2908	22	44	56	71	100	100
9501	26	0	860	515	315	80	145	230	157	81	2383	10	29	42	64	100	100
950210	21	1130	515	225	252	115	175	105	282	50	2849	12	26	34	42	60	100
950210	22	640	1910	250	250	90	230	250	259	161	4040	10	25	31	37	84	100
950210	8	1450	1075	110	130	50	60	30	110	30	3045	5	9	13	17	52	100
950210	30	0	610	385	235	90	175	155	185	60	1895	13	35	47	68	100	100
950210	20	180	1100	170	230	55	70	50	245	68	2168	14	23	33	41	92	100
9502up	21	0	1300	410	250	85	160	120	201	54	2580	10	24	34	50	100	100
9502up	48	0	550	375	250	90	200	400	355	190	2410	23	51	62	77	100	100
9502up	19	820	900	370	260	90	125	125	110	210	3010	11	22	31	43	73	100
9502up	35	0	790	235	205	70	160	190	270	93	2013	18	39	49	61	100	100
9502up	32	0	850	280	225	85	170	260	215	40	2125	12	36	47	60	100	100
9503	37	0	715	465	400	125	247	150	360	260	2722	23	42	57	74	100	100
9503	73	0	10	40	220	425	405	880	370	231	2581	23	90	98	100	100	100
9503	42	0	625	497	580	448	377	355	432	408	3722	23	54	70	83	100	100
9503	34	0	420	525	510	385	290	125	397	119	2771	19	47	66	85	100	100
9504	46	0	550	500	440	110	280	330	550	230	2990	26	50	65	82	100	100
9504	33	0	340	900	440	130	330	370	140	62	2712	7	38	54	87	100	100
9504	34	0	1100	390	250	82	205	330	150	260	2767	15	37	46	60	100	100
9504	31	0	400	470	350	325	195	170	142	193	2245	15	46	61	82	100	100
9504	26	0	600	410	370	98	157	145	150	76	2006	11	31	50	70	100	100
9504	41	0	249	350	400	322	170	295	362	93	2241	20	55	73	89	100	100

Id	<4.75%	75	25.4	12.5	6.3	4.75	2.36	0.85	sand	silt	Total	<0.85%	<6.3%	<12.5%	<25.4%	<75%	Total%
9505	33	0	550	525	275	90	50	210	250	200	2150	21	37	50	74	100	100
9505	55	0	600	285	345	130	260	460	432	513	3025	31	59	71	80	100	100
9505	21	0	1400	605	225	40	55	95	303	163	2886	16	23	31	51	100	100
9505	44	0	950	350	310	105	220	280	413	442	3070	28	48	58	69	100	100
9505	51	0	600	270	280	95	170	245	444	436	2540	35	55	66	76	100	100