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BANGLADESH FLOOD ACTION PLAN

Ministry of Irrigation, Water Development and Flood Control
Flood Plan Coordination Organization (FPCO)

Technical Report

Comparison of Elevation Data from BWDB and FINNMAP

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Prepared by

Geographic Information System (GIS)

FAP 19

ISPAN

IRRIGATION SUPPORT PROJECT FOR ASIA AND THE NEAR EAST

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1. Introduction

Most of Bangladesh is flat with low elevation, and approximately 30 percent of the country is subject to annual flooding. Many of the proposed Flood Action Plan (FAP) investments are aimed at changing both the extent and duration of this flooding. By knowing the changes in the area, depth, and duration of flooding resulting from these interventions, their impact on agricultural production, the environment, and human settlements can be estimated. This will enable the proposal of appropriate schemes that can then be subjected to detailed engineering and economic analysis.

Many FAP projects use the MIKE 11 mathematical model to predict flood levels under different scenarios. The area and depth of the designed flood level is then calculated by determining the difference between water and ground elevations. Because of the low relief of the countryside and rapid changes in river channel morphology, up-to-date, precise elevation data are necessary to obtain accurate flood area estimates. The only available maps of Bangladesh were produced by the Bangladesh Water Development Board (BWDB) in the mid-1960s. Most FAPs are using or have used these dated maps, which have detailed spot heights and contours and are scaled at 4 in. and 8 in. to 1 mi. Because it would take considerable time to survey all of Bangladesh, it is impractical to create up-to-date maps for the Flood Action Plan to fulfill current needs. Therefore, the acceptability of the older maps for flood delimitation and other purposes must be addressed.

2. Approach

To estimate the accuracy of the BWDB maps, FAP 19 compared the historic BWBD maps with more recent maps for three sample areas. Geographical information system (GIS) and digital elevation modelling (DEM) techniques were used to process the data for this study. The spot level elevations for the two dates were compared along with corresponding flooded-area elevation curves. The hypothetical flooded area is the water surface area obtained by filling a flood cell to a certain level. The measurement assumes contiguity of the water surface over the cell, although in reality a single flood source would not likely fill all areas equally.

3. Study Areas

A recent set of elevation data available for comparison with the 1960 BWDB maps was prepared in 1988 by Finnmap for the Gumti Phase I and Phase II area. Three sample areas were identified within the Gumti project: Area 1, in the active floodplain of the Meghna River; Area 2, which has average conditions; and Area 3, which is affected by flash floods. Each study area covers 19.5 square km, and there are approximately 600 to 700 spot elevations within each area. The spot level information on the Finnmap 1:8,000 scale maps is in centimeters and contour lines are in 50 cm intervals. The spot elevations on the older 4 in. to 1 mi. BWDB maps (which were used for this comparison) are in tenths of feet and are on a grid of approximately 100 m by 300 m. The map's contour lines are at one foot intervals. The locations of the study areas, described below, are shown in Figure 1.

Study Area 1, map index number 79I-14/2B, lies between 23°37'30" to 23°40'00" north and 90°47'30" to 90°50'00" east (Figure 2a). There is an earthen road in the western half, and the entire area is in the active floodplain of the Meghna River. More than 75 percent of the area has been partially protected from flooding. Some 715 spot levels are available on the Finnmap sheet, compared with 643 points on the BWDB map. This area was chosen to represent a region of active fluvial processes.

Study Area 2, map index number 79I-13/9D, is relatively flat and therefore has few contour lines. It lies between 23°45'00" to 23°47'30" north and 90°57'30" to 91°00'00" east (Figure 2b). About 622 spot elevation points are available on the Finnmap map, compared to only 513 on the BWDB map. This area represents a typical stable condition.

Study Area 3, map index number 79M-1/9A, lies between 23°47'30" to 23°50'00" north and 91°10'00" to 91°12'30" east (Figure 2c). Some 700 spot heights are available on the Finnmap sheet, compared to some 407 spot heights on the BWDB map. The low number of BWDB points in this area are attributable to the generally lower spot elevation point density of these maps and to the fact that the area has more homesteads for which information was not recorded. Railroad tracks cross the area from south to north. This area, because it is subject to floods from the Tripura hills, was chosen to represent a region exposed to siltation and erosional processes due to active flash flooding.

4. Data Capture

The spot height data from the Finnmap 1988 map was digitized, and the elevation of each point was simultaneously encoded as an attribute. The reference points used to coregister the two map series were selected for easy identification on the BWDB contour maps. The Finnmap spot heights were then plotted on a transparency at 1:16000 scale. As illustrated in Figure 3, this transparency was overlaid on the BWDB maps where corresponding elevations were interpolated from adjacent points and contour intervals. Spot elevations were interpolated in units of feet, encoded as a separate attribute, and digitally converted to metric units for comparison with Finnmap data.

Homestead boundaries from the Finnmap series also were digitized, which permitted the separation of elevation points within cultivated land from those within homesteads. Because people often raise or expand their homestead by cutting land from the surrounding area, a 50 m buffer surrounding each homestead was also classified as homestead land. Both map series use the Survey of Bangladesh (SOB) datum.

5. Processing

5.1 Spot Height Comparison

The digitized elevation data were plotted on hard copy and checked against the source. The elevation data from BWDB contour maps then was converted into meters, and the elevation difference was calculated for each point on the Finnmap and BWDB source maps. The array of points, homestead areas, and spot heights differences for each study area are shown in Figure 2a, 2b, and 2c.

5.2 Flooded-Area Elevation Curves[1]

The digitized spot heights were interpolated onto a regular 40 m grid, and a hypothetical flooded area was then identified as a series of heights corresponding to horizontal water levels at 10 cm intervals. A filter was applied to perform this procedure separately for areas classified as homesteads and cultivated land. The curves for each filtered data set are shown in Figures 4a, b, and c.

6. Results

6.1 Elevation Differences and Frequency Distribution

Table 1 shows the distribution of spot height differences between the Finnmap and BWDB maps, and Figures 2a, 2b, and 2c show the spatial distribution of those differences. Figures 5a, b and c, prepared from the DEM for each data set, illustrate the frequency distributions of spot elevations by location for the cultivated lands. These curves were generated from continuous, raster DEMs of each study area.

Table 1
Spot Height Differences Between Finnmap and BWDB Maps

		Percentage of Points by Difference Range (cm)				
	No. Points	Less	-75	-25	25	More
Area 1						
Cultivated	517	5	17	42	26	10
Homestead	76	5	16	37	23	19
Combined	643	5	18	41	25	11
Area 2						
Cultivated	394	3	7	81	10	0
Homestead	119	4	17	61	7	11
Combined	513	3	9	76	9	3
Area 3						
Cultivated	324	9	19	47	19	16
Homestead	83	11	11	25	16	37
Combined	407	10	17	35	18	20

In the cultivated portion of Area 2 some 80 percent of the spot elevations from the two sources are within ± 25 cm; whereas corresponding values for unstable Areas 1 and 3 are considerably lower. Differences between the two map series for homestead lands is consistently greater for each of the three study areas, possibly because of substantial changes in those areas. Because topography is more complex, comparison

[1]This procedure is described in more detail in Technical Report 5, Computing Area Elevation Curves Using GIS.

between spot elevations is more problematic and possibly not valid for these homestead areas. Also, because the Finnmap series includes substantially more elevation points in the homestead areas than the BWBD, comparisons of frequency distribution curves for these areas were considered invalid and were not prepared as for cultivated lands (Figures 5a, b, c).

For all elevation points in DEM for the cultivated part of Area 1, the Finnmap levels averaged 8.5 cm lower than the BWDB levels (Figure 5a). Greater land elevation differences were found outside embanked areas, which are within the active floodplain of the Meghna River (Figure 2a). In Area 2, Finnmap levels averaged only 1.1 cm higher than the BWDB levels in cultivated areas and the frequency distribution curves are very similar (Figure 5b). This sample is typical of rural areas in Bangladesh; it is neither close to a main river nor does it have many depressions or high elevations. For Area 3, the mean Finnmap level is 4.9 cm higher than BWDB for cultivated land (Figure 5c).

6.2 Regression Analysis

A regression analysis of BWDB heights against Finnmap heights was carried out for each data set. Simple linear regressions were performed: one permitting an intercept, and another forcing the origin to zero. A slope of unity for the latter curve would be expected if the corresponding data sets were the same (Table 2). Figures 6a, b and c show scatter plots for corresponding levels on each map.

Table 2
Regression Analysis

	Correlation With intercept			Correlation W/O intercept		Mean Level	
Study Area	Corr. coef.	Inter-cept	Slope	Corr. coef.	Slope	BWDB	Finnmap
Area 1							
Cultivated	0.225	1.496	0.622	0.124	1.034	2.775	2.690
Homestead	0.460	1.019	0.709	0.365	1.024	3.271	3.768
Area 2							
Cultivated	0.720	0.875	0.796	0.665	1.015	4.023	4.034
Homestead	0.343	1.241	0.712	0.286	1.001	4.378	4.415
Area 3							
Cultivated	0.685	0.954	0.774	0.623	0.998	4.329	4.378
Homestead	0.124	2.191	0.695	0.073	1.134	4.305	7.149

6.3 Area-Elevation Curves

The cumulative area-elevation curves for each study area are shown in Figures 4a, b and c. These curves were computed for considering the impact that the different elevation data may have on predicting flooded areas or flood phase. It can be observed from these curves that there is little difference between the

elevation sources for cultivated land. However, for homestead land there is a significant difference in area elevation curves, except in the stable Area 2. Because the BWDB elevations are lower on average than the Finnmap values, there is a tendency for the BWDB data to indicate a larger flooded area for the same water elevation.

7. Conclusions and Recommendations

This study compared spot elevations of BWDB maps created in the 1960s against maps created by Finnmap in 1988. A digital comparison of the spot heights in the two map series for three study areas found numerous differences. The correlation between elevations at corresponding locations on the two map series is generally poor. In part, this is inevitable given the nature of the terrain and the sampling methods used. These differences in elevations between the two map series may be attributable to a number of other factors, including:

- Land erosion or river siltation.
- Land development to raise or expand homestead areas.
- Changes in river alignment.
- Survey and map production procedures.
- Interpolating and digitizing errors.

Examination of Figures 5a, b, and c together with the observation of mean elevations (Table 2) provides no evidence that the elevation differences are due to a datum shift alone. A datum change would be expected to yield a consistent shift in mean elevation that would result in similar histogram curves but with a shift along the x-axis.

The total range of elevation differences for corresponding points between the two data sets varies from -2.4 m to +1.9 m; overall, about 50 percent of the spot heights are within ± 0.25 m of one another. The correlation between the two map series is poorest for areas near active river systems or close to settlements, suggesting that real changes in the landscape have occurred over time. There are greater variations in elevation for homestead lands than for cultivated areas. These relatively larger differences in elevation may be due to homestead expansion over time since homesteads are commonly created by "borrowing" land from one place to raise it in another.

In the Finnmap series, some 15 to 20 percent more points were surveyed than the BWDB series and the homestead areas are significantly better represented. A limitation of both surveys is that few elevation points were taken for beels or other water bodies. Additionally, to facilitate the preparation of area-elevation curves and elevation-storage curves for the relatively flat terrain of Bangladesh, a 25 cm contour interval would be preferable to the 50 cm contour lines currently on the Finnmap series. With the growing use of GIS processing capability in Bangladesh, it also would be valuable if Finnmap could release its elevation database in a digital format for use by others (e.g., DXF or ASCII with an identifier, latitude, longitude, and elevation). This would save considerable time and labor in carrying out terrain analysis.

When using elevation data from the older BWDB maps, it is important to incorporate current river alignments to update the land level data for spatial analysis. The settlement area also should be separated

if possible. While it is difficult to generalize the findings of this study for the whole of Bangladesh, it can be concluded that if no new maps are available, old maps of stable areas can be more confidently used than those for unstable areas.

Differences between the two map series are significant to the Flood Action Plan if their locations are important, as is the case when a certain drainage pattern is desired or when a structure is to be built. However, despite the differences for specific elevation point data, for most general uses, the older map series appears quite useful. It is the recommended that the BWDB maps be used for regional feasibility studies and for some engineering purposes. Those purposes include flow modelling and evaluation of flooding effects on agriculture. For detailed engineering design involving structure location, flow modification, and environmental impact assessment (EIA) more up-to-date mapping should be sought.

Figure 1: Study Area Location Map

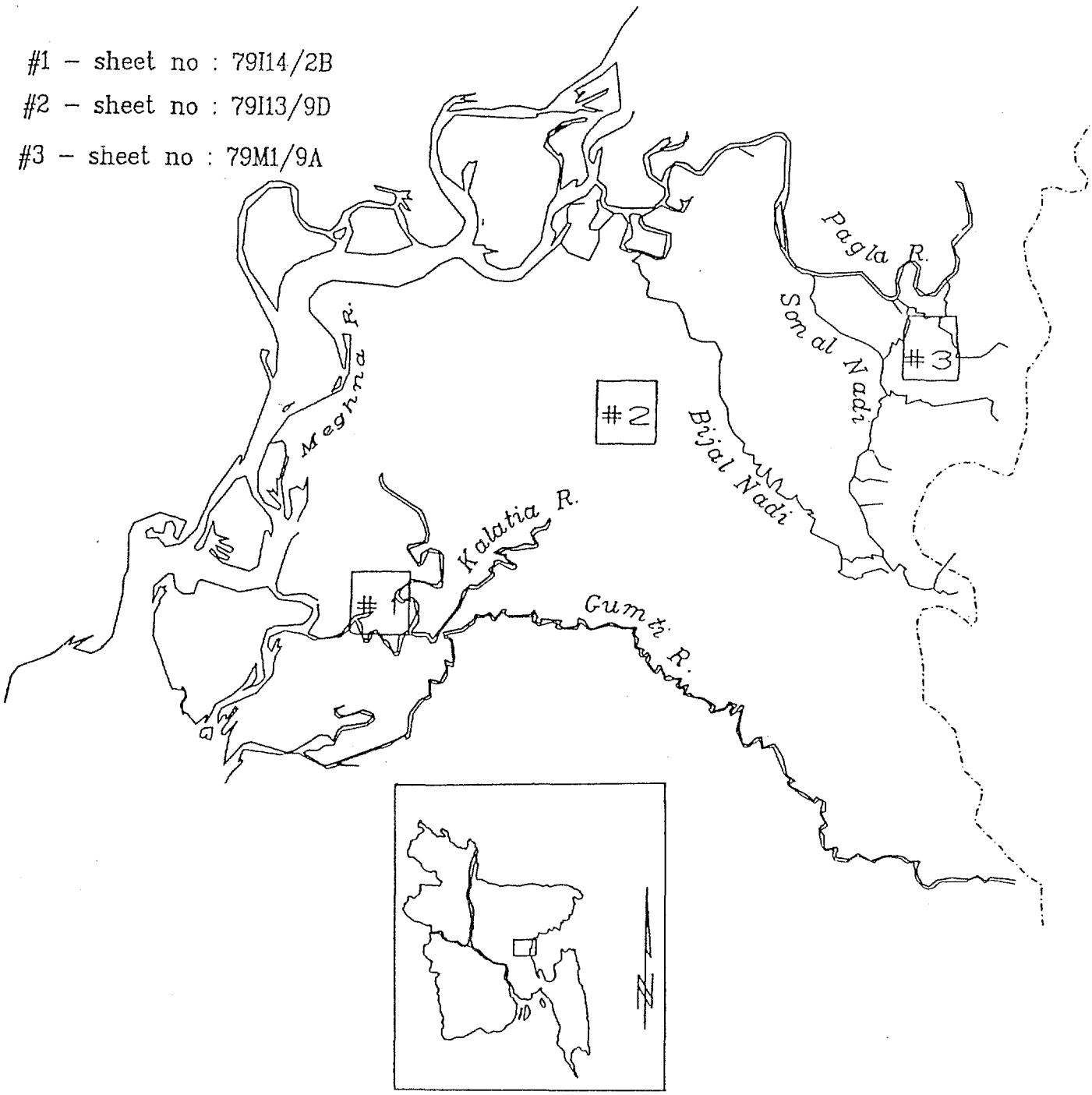


Figure 2a: Elevation Data Comparison Map, Area 1

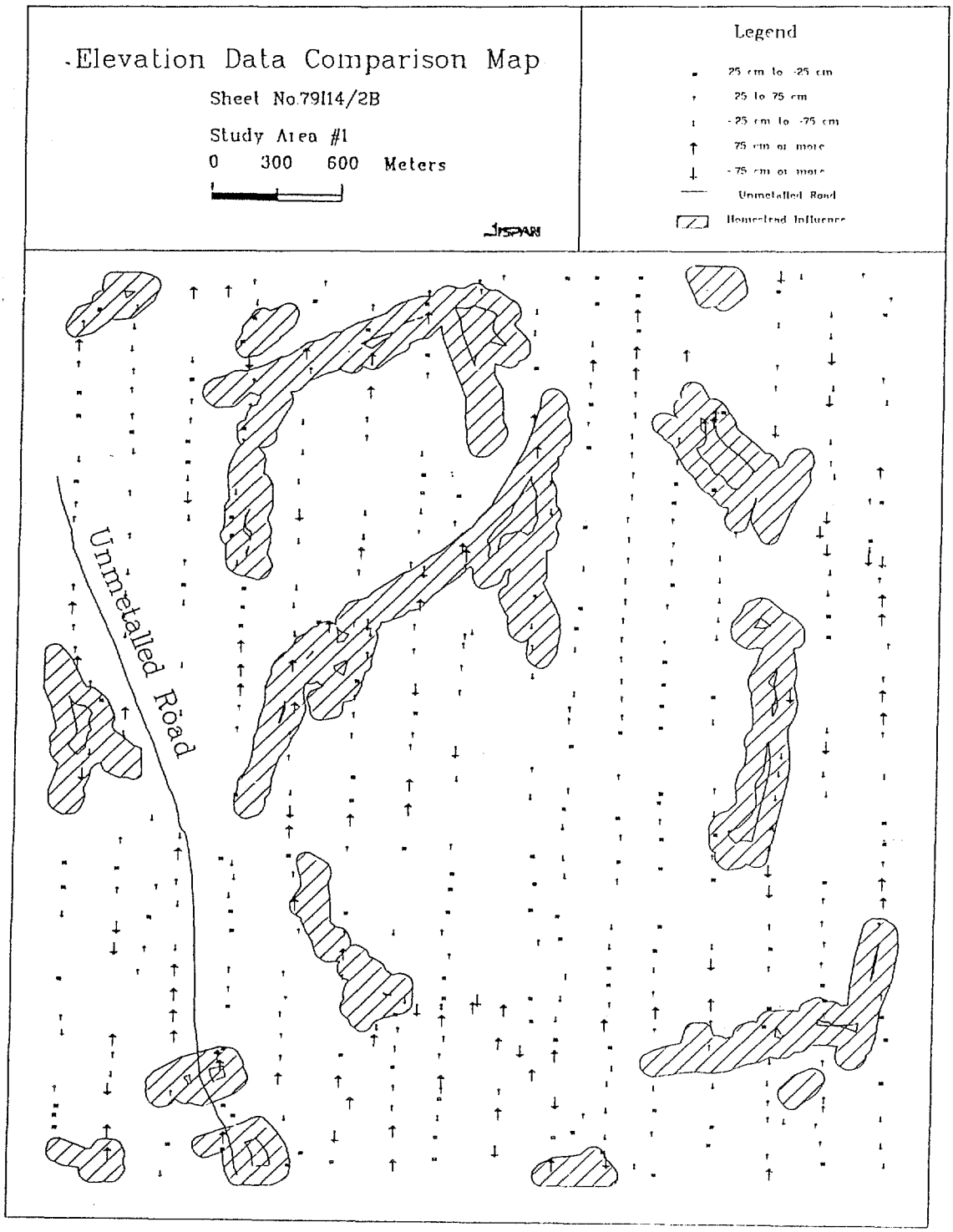


Figure 2b: Elevation Data Comparison Map, Area 2

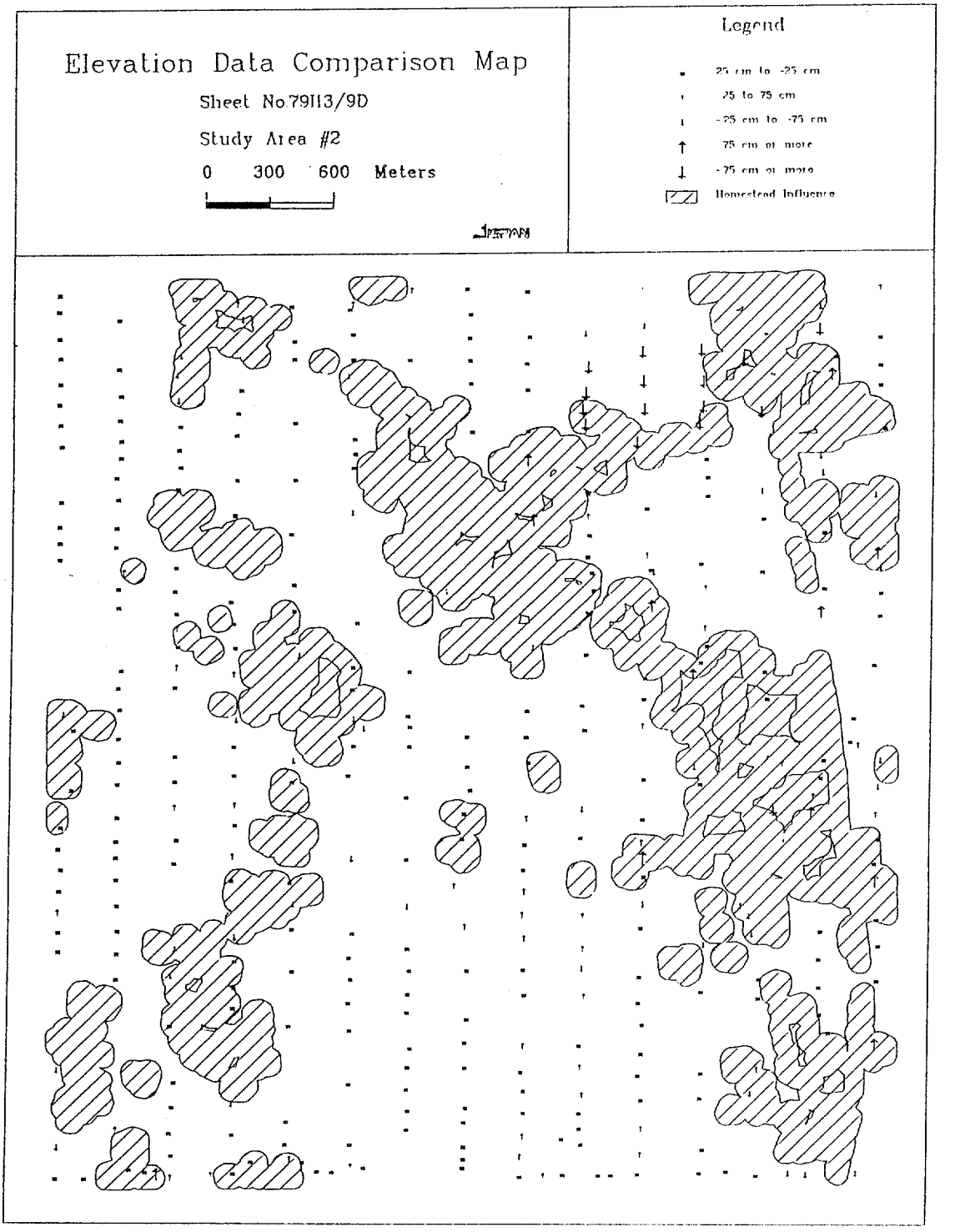


Figure 2c: Elevation Data Comparison Map, Area 3

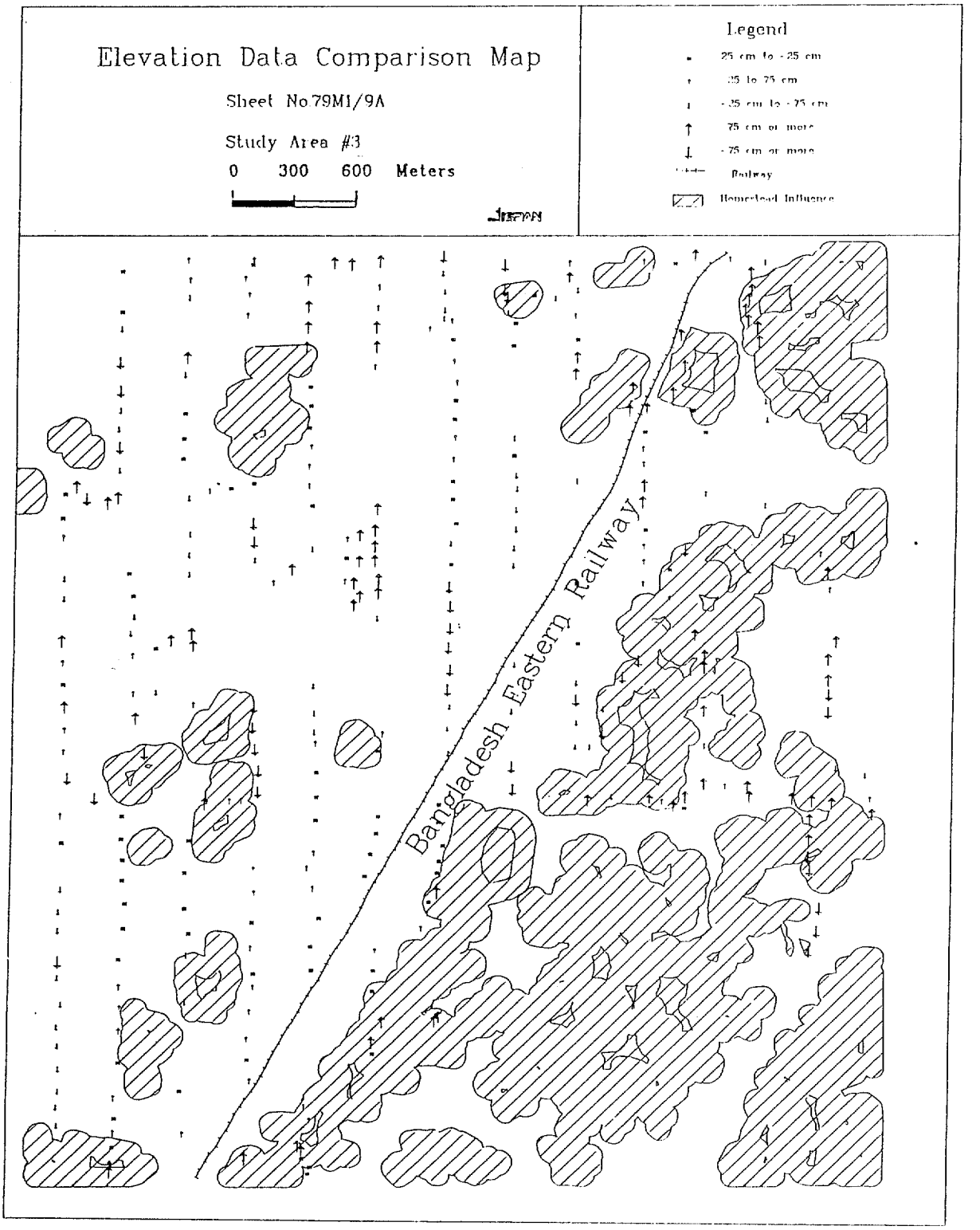


Figure 3: Selecting Spot Elevations From the Two Sources

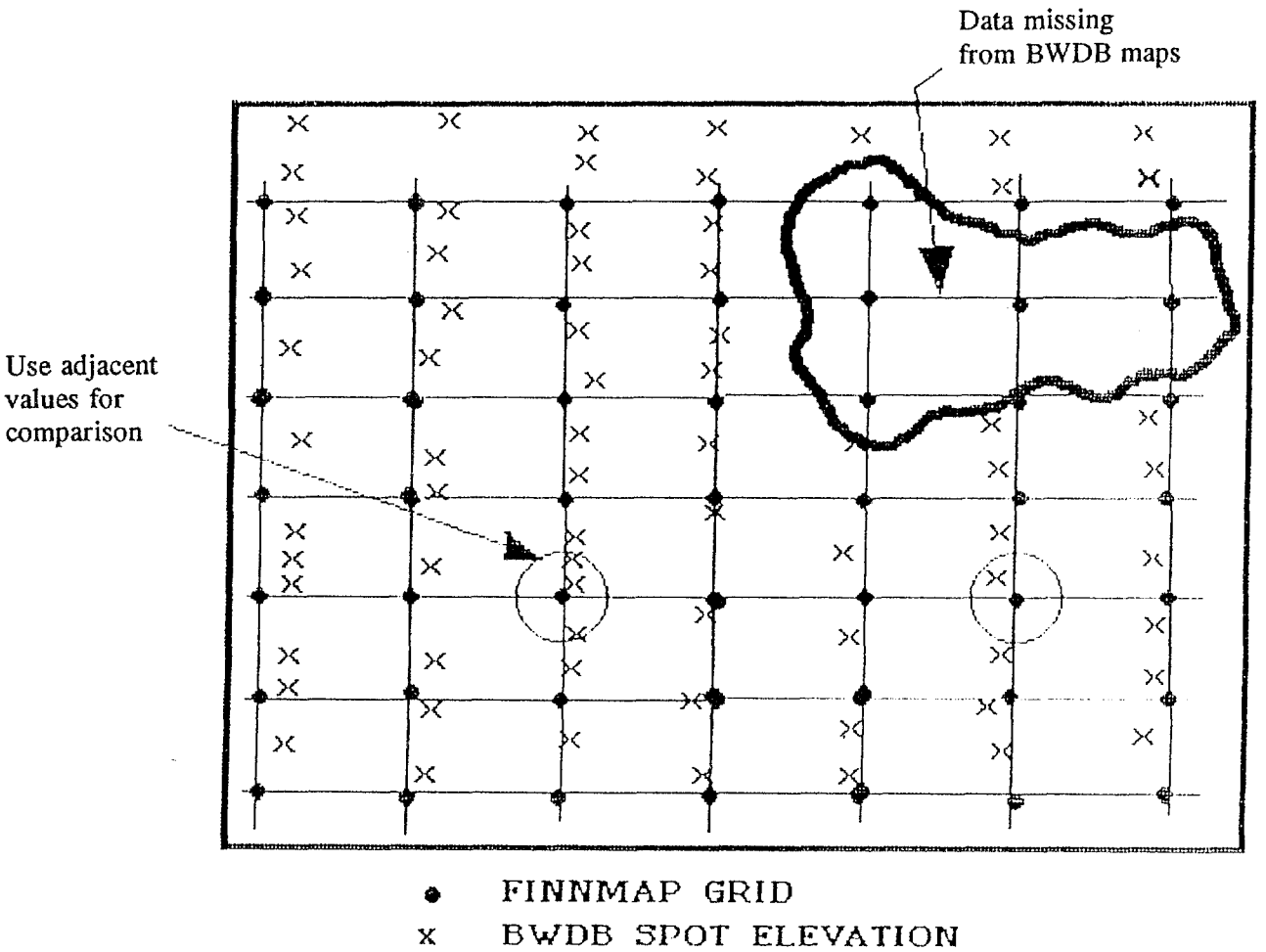
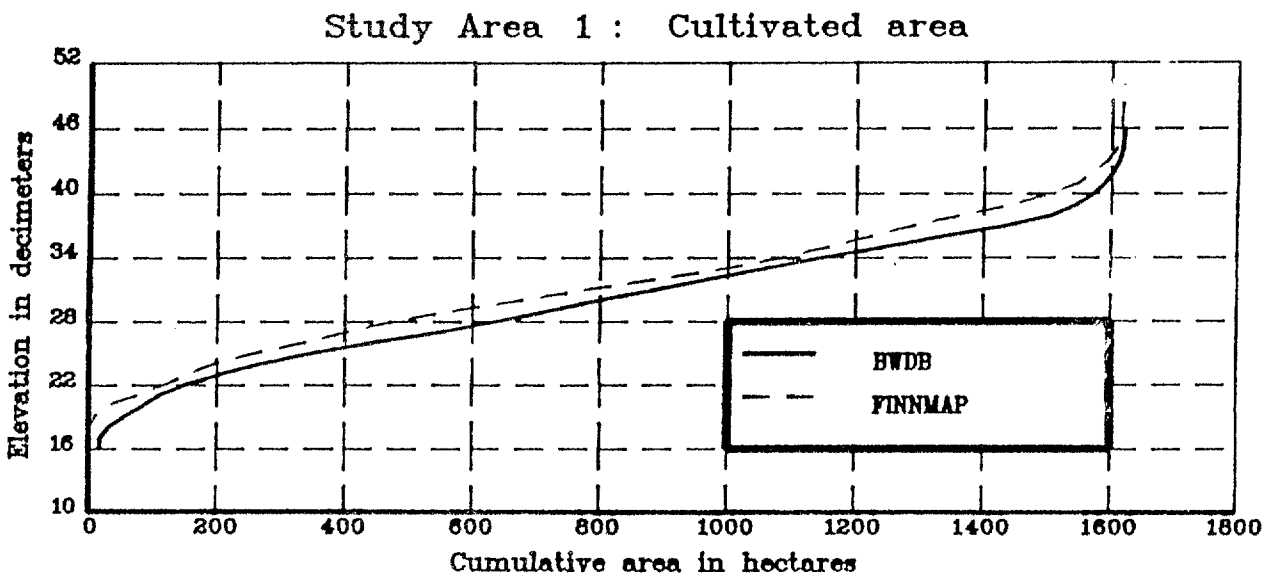


Figure 4a: Cumulative Area Elevation Curves, Area 1



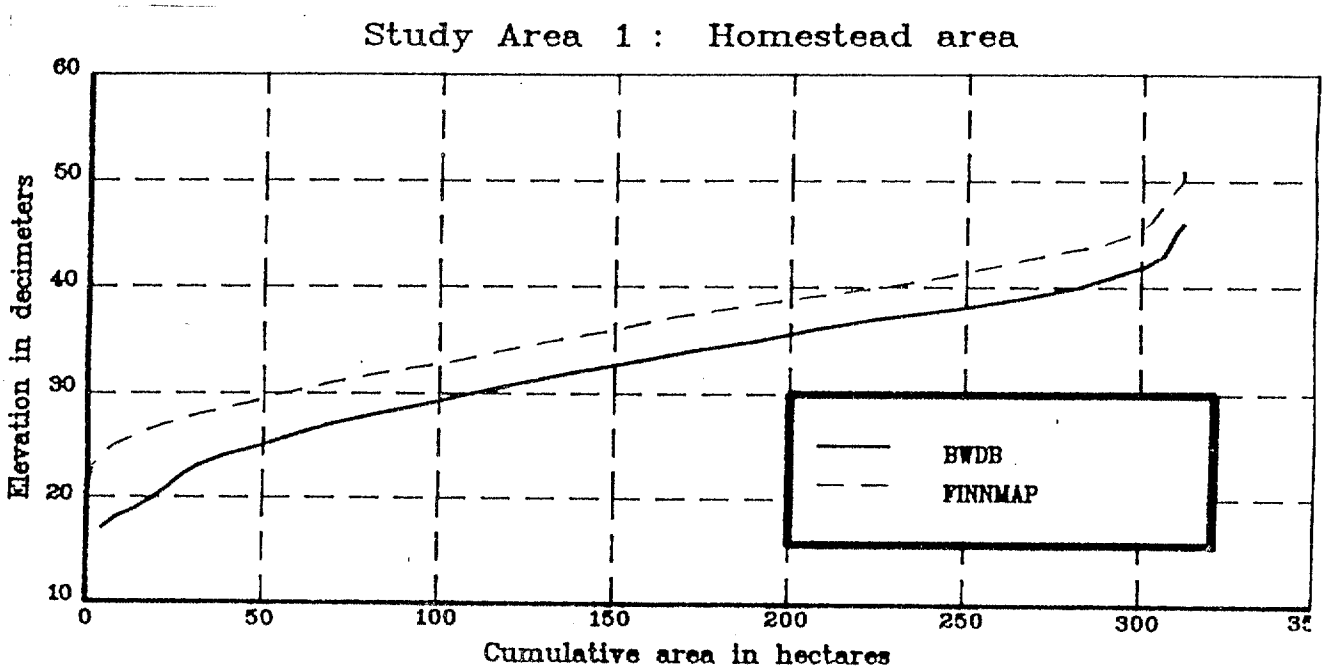
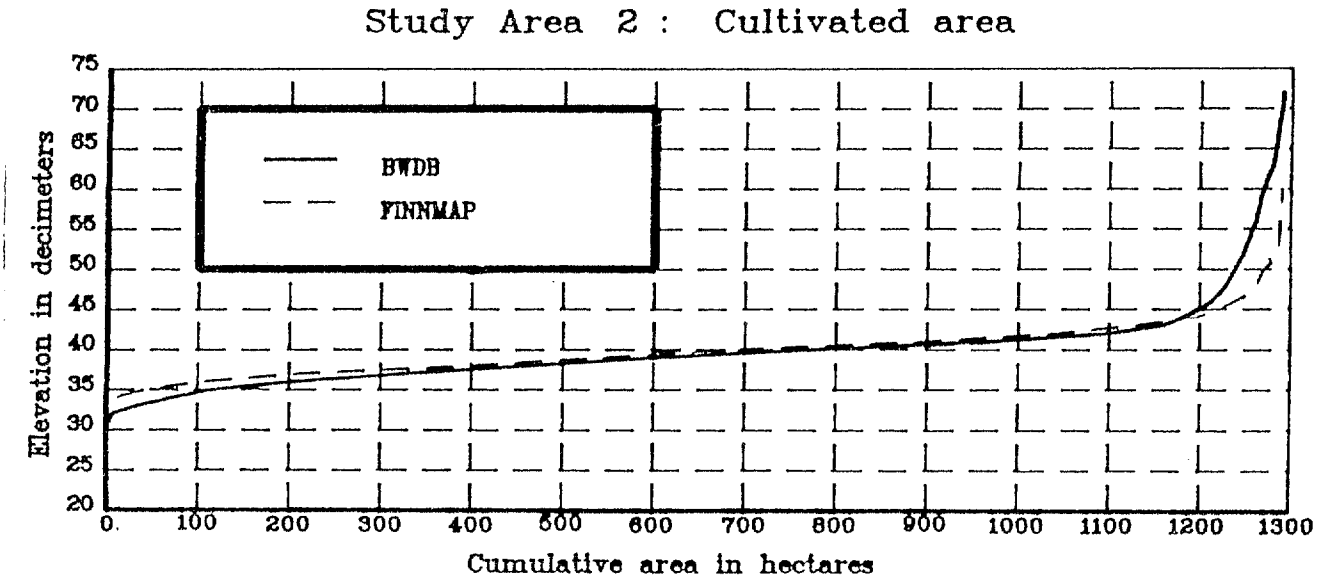


Figure 4b: Cumulative Area Elevation Curves, Area 2



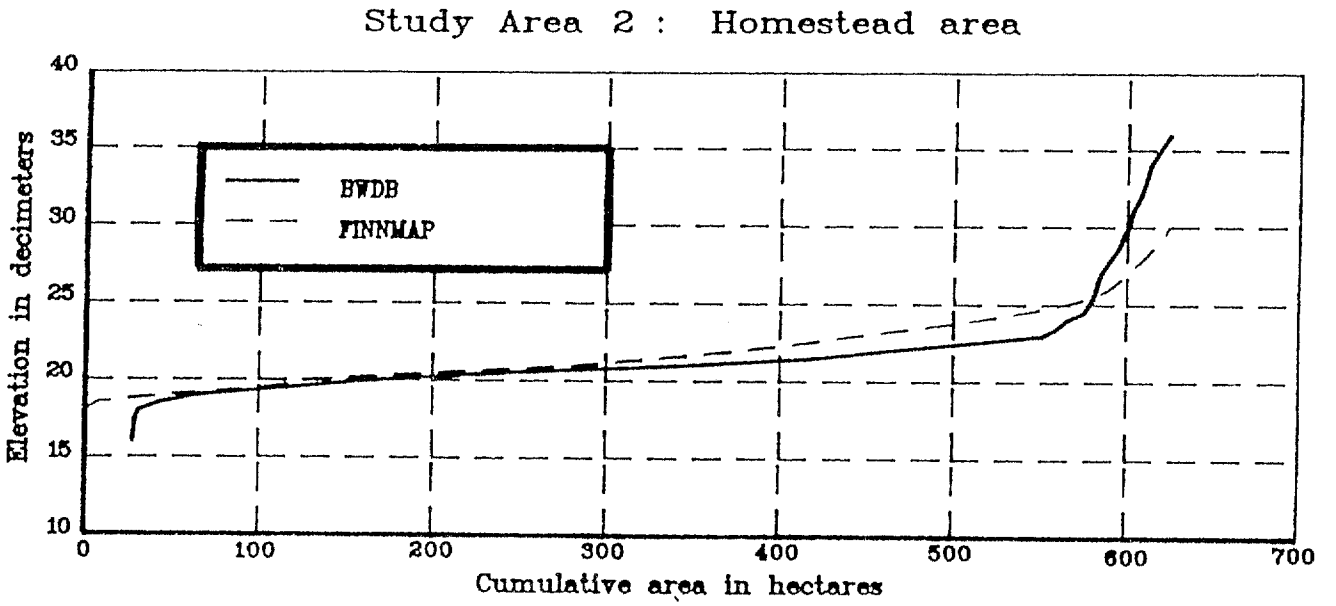
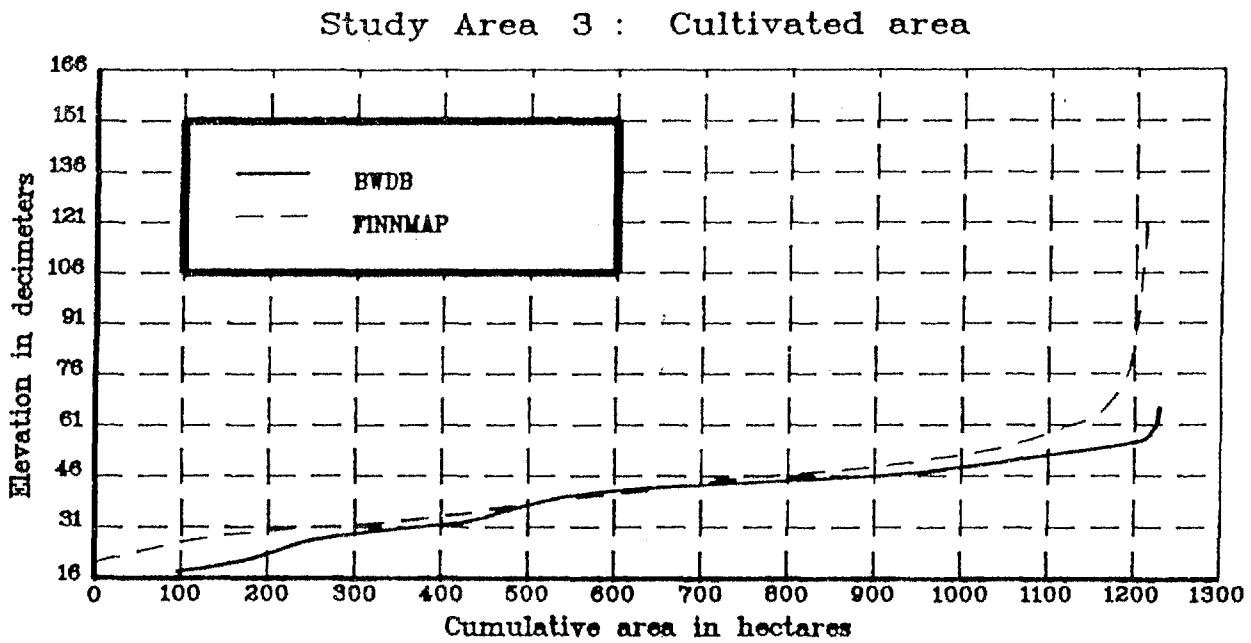


Figure 4c: Cumulative Area Elevation Curves, Area 3



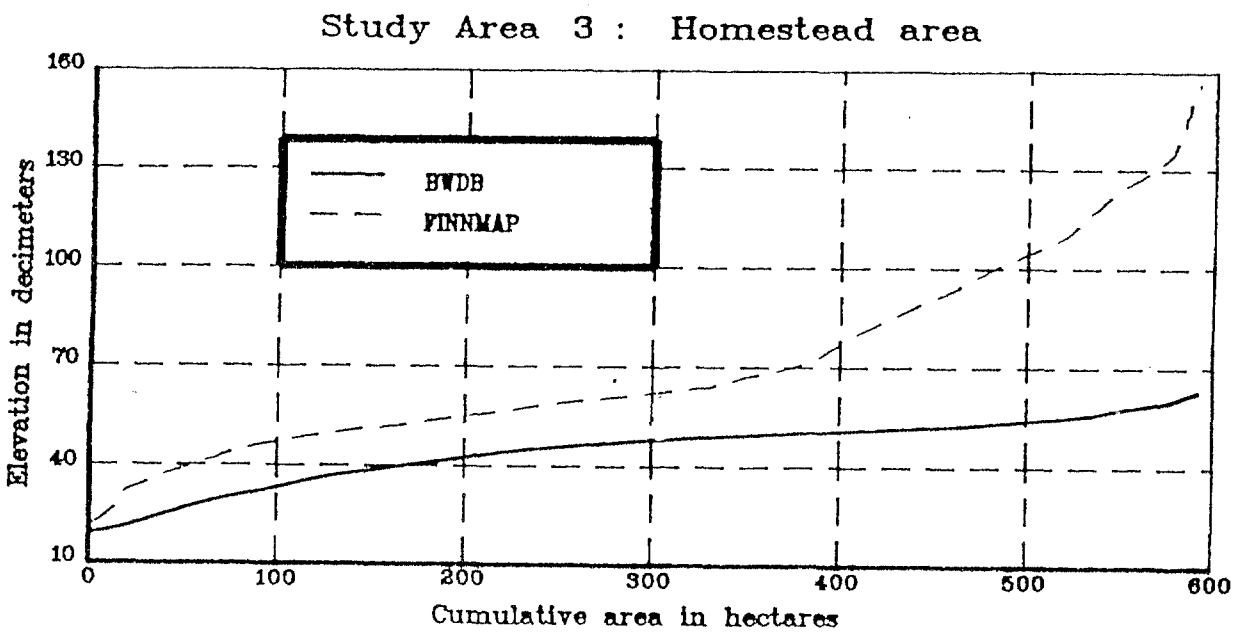
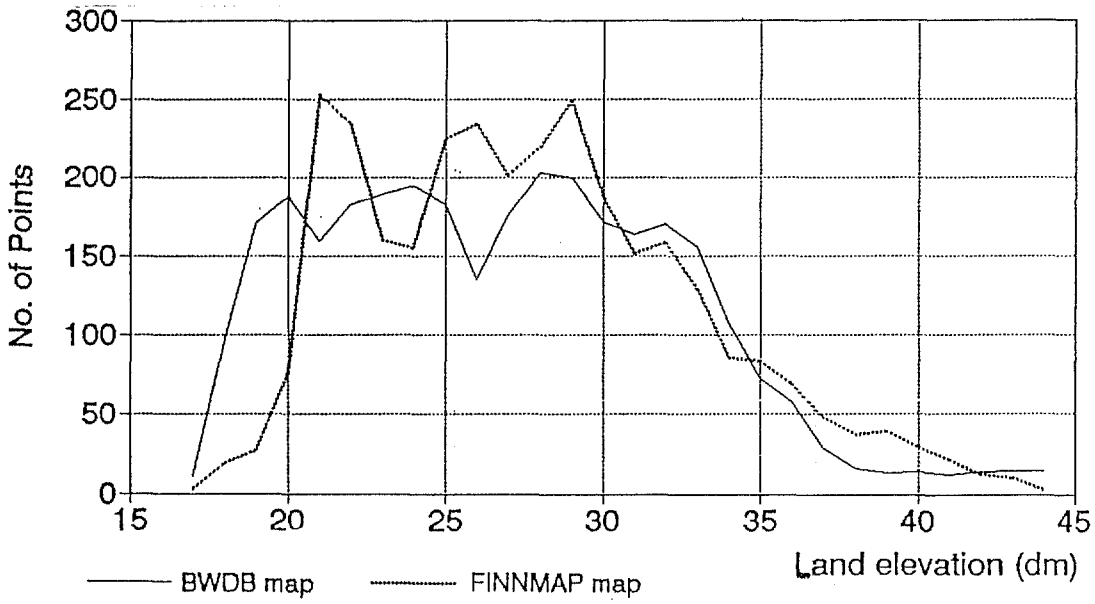
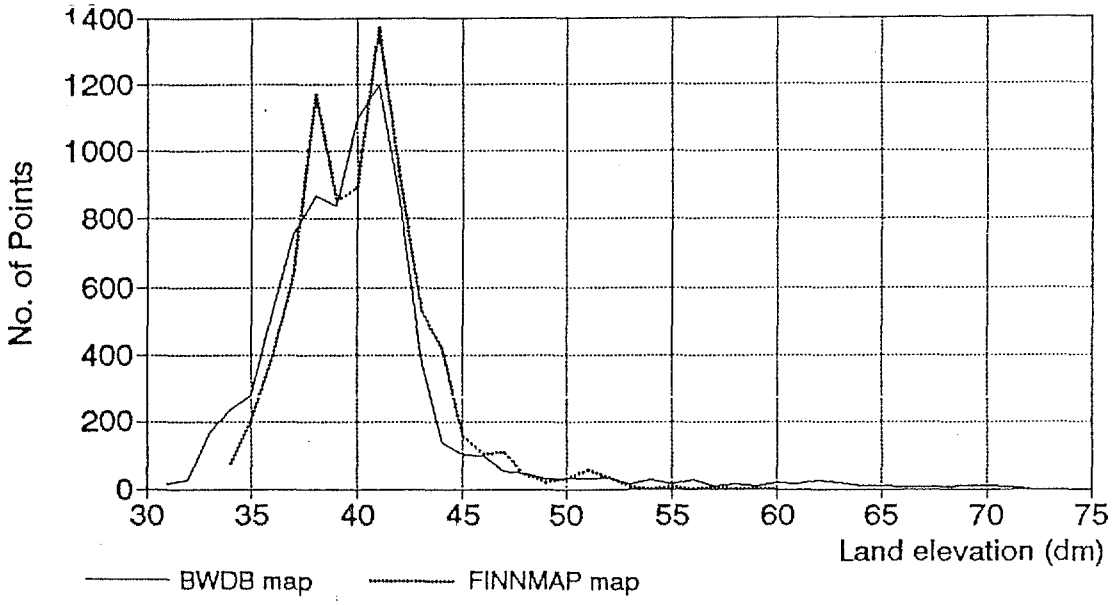


Figure 5a: Histogram of Spot Elevations for Area 1 Cultivated Land



Mean	27.75	Mean	26.90
Std dev.	5.21	Std dev.	5.59

Figure 5b: Histogram of Spot Elevations for Area 2 Cultivated Land



Mean	40.23	Mean	40.34
Std dev.	17.36	Std dev.	11.78

Figure 5c: Histogram of Spot Elevations for Area 3 Cultivated Land

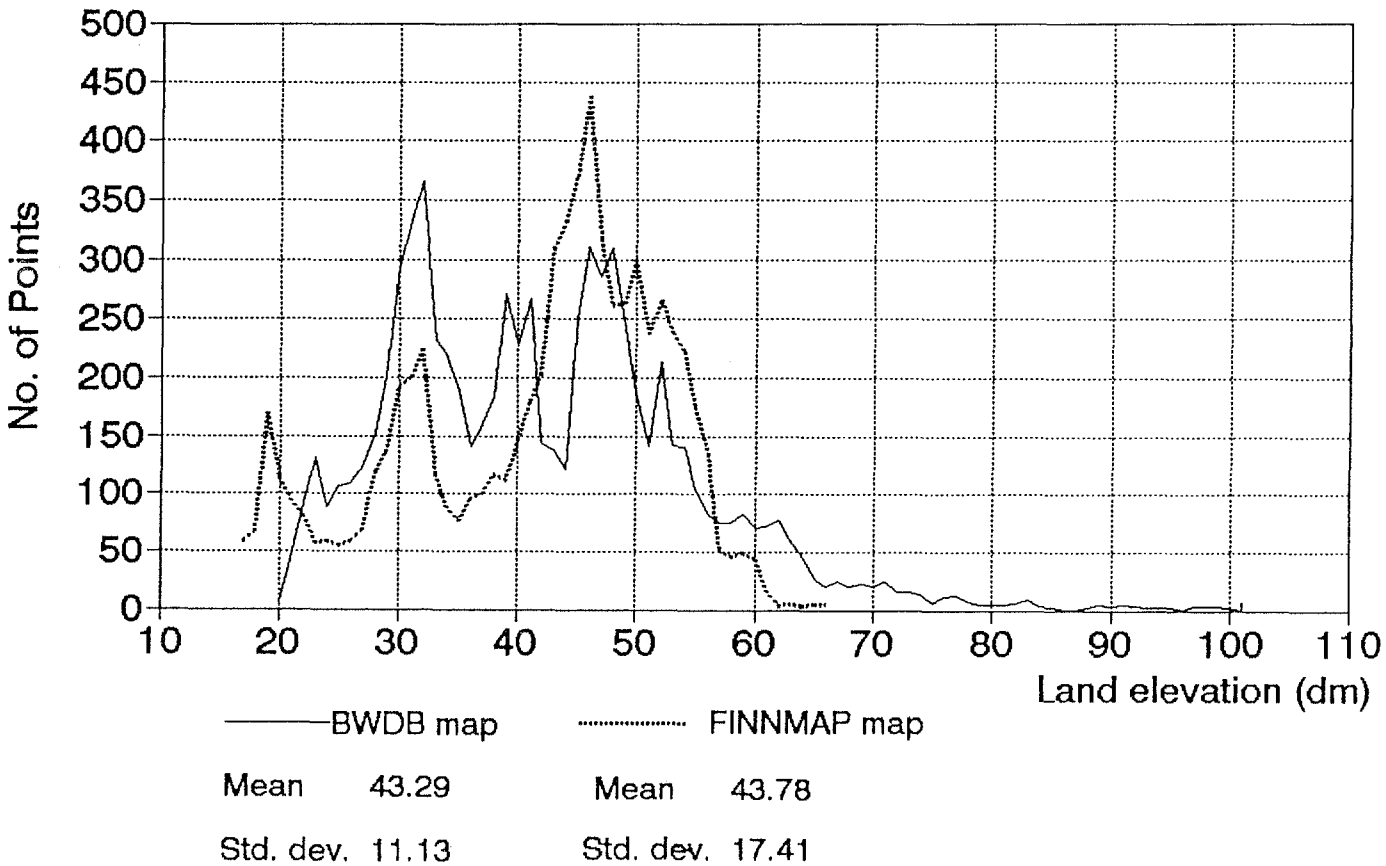
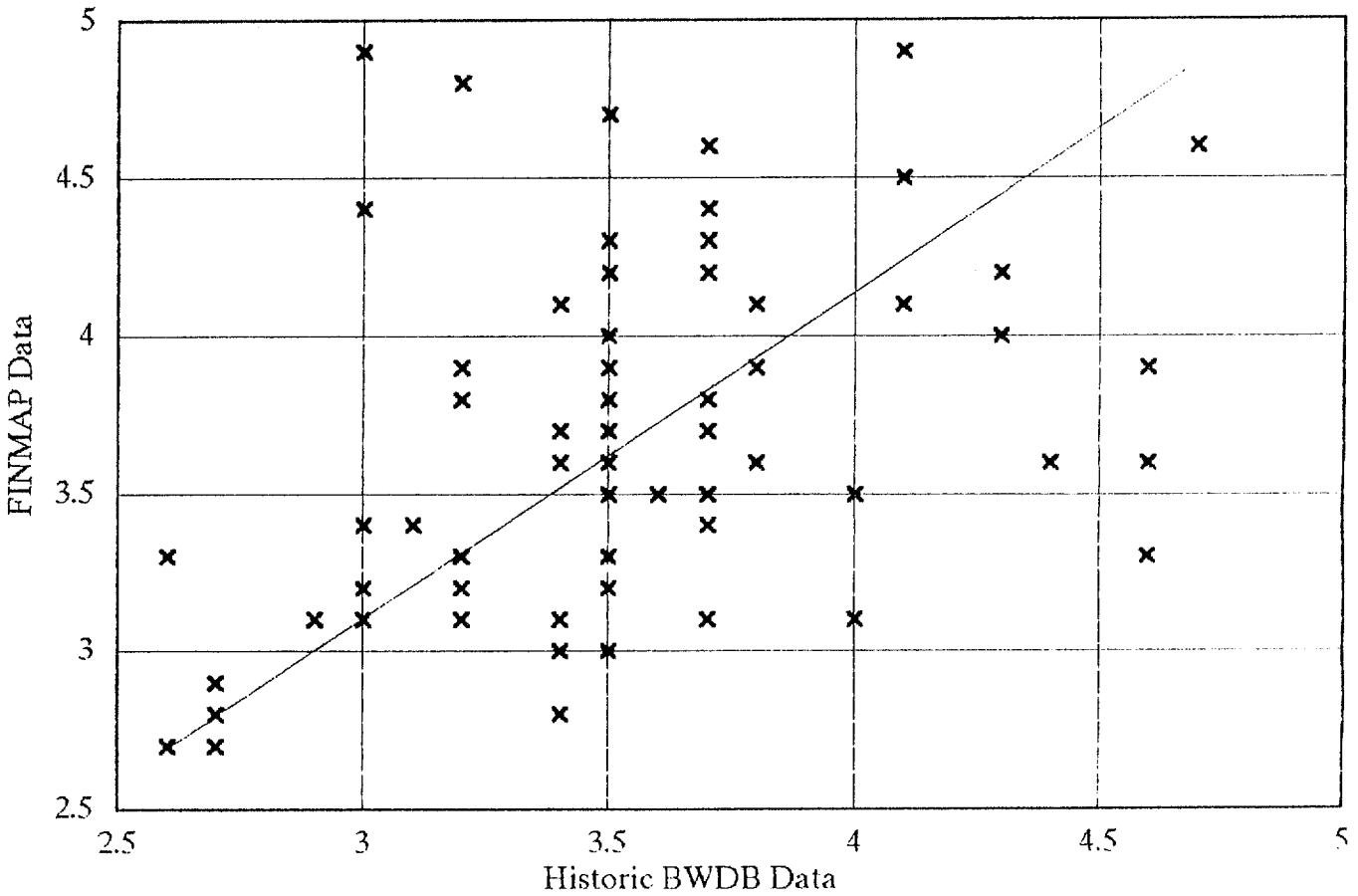
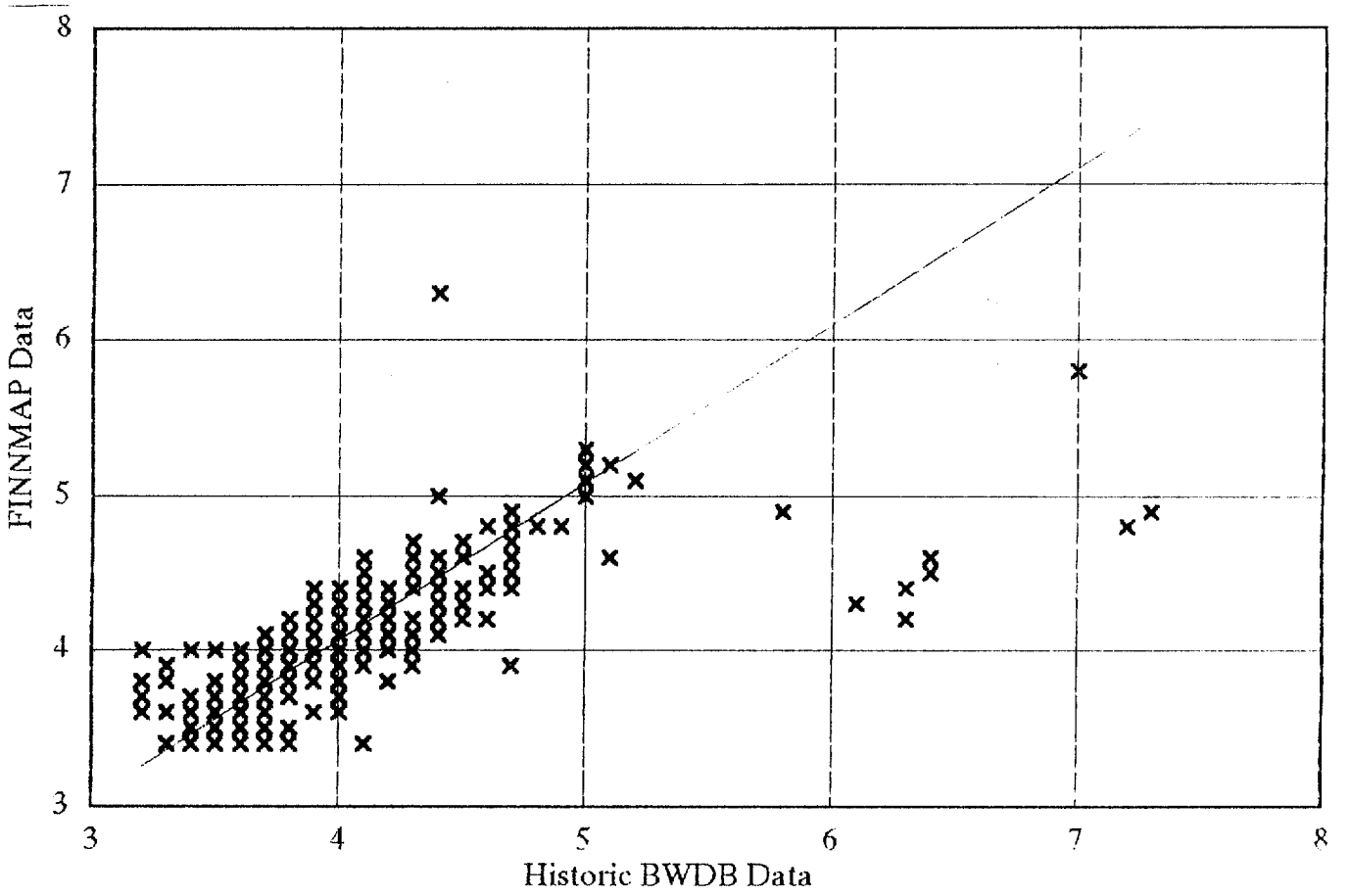


Figure 6a: Correlation of Finnmap and BWDB Elevations for Area 1



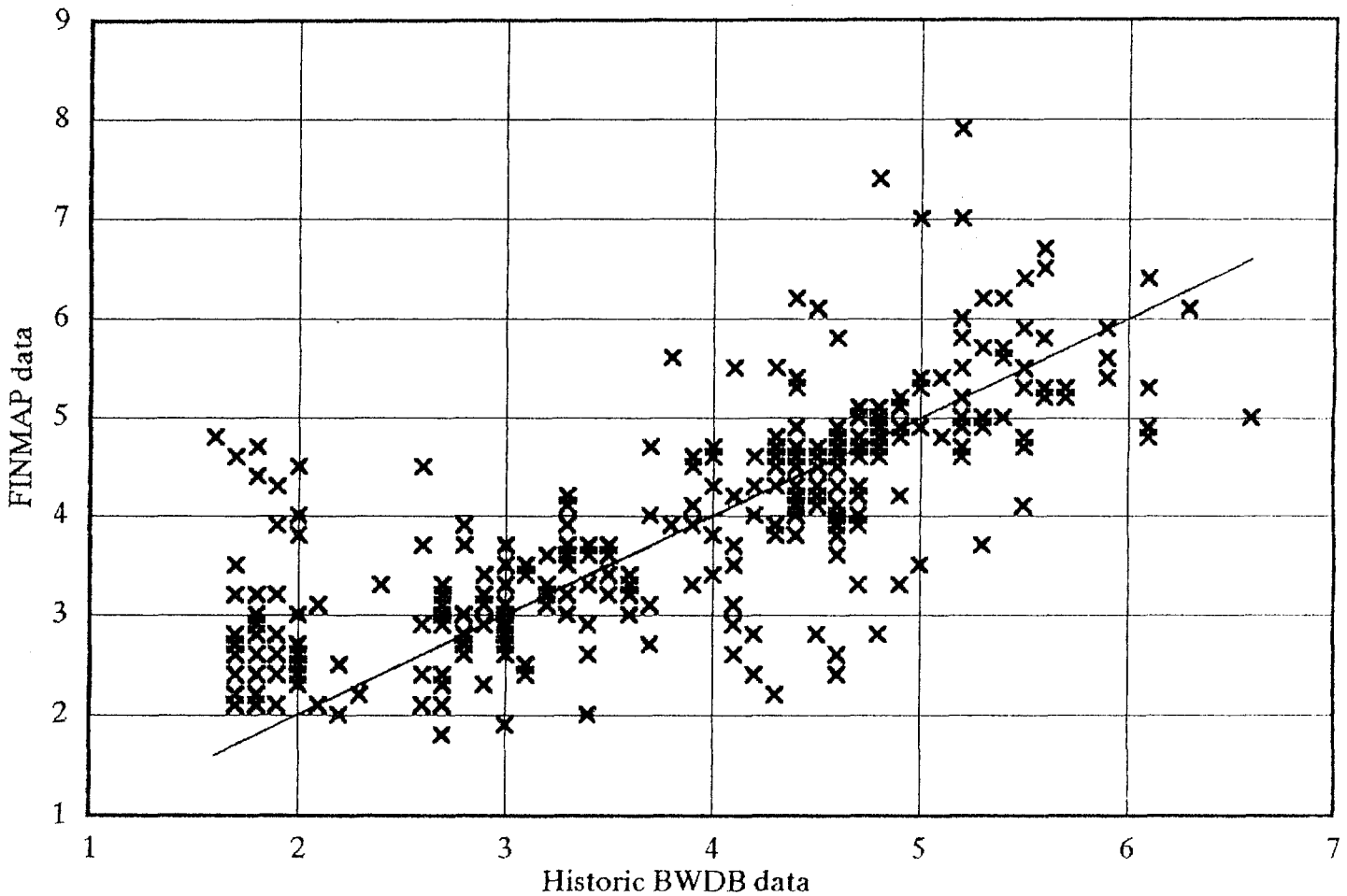
Note : Elevation in meter. SOB

Figure 6b: Correlation of Finnmap and BWDB Elevations for Area 2



Note : Elevation in meter. SOB

Figure 6c: Correlation of Finnmap and BWDB Elevations for Area 3



Note :Elevation in meter, SOB