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Analysis of the Sedimentary Characteristics of the Tees Estuary using Remote Sensing and GIS techniques

Volume Two

Christoph Konrad

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Thesis submitted for the degree of Master of Science.
University of Durham, Department of Geography.

March, 1995



- 8 JAN 1996

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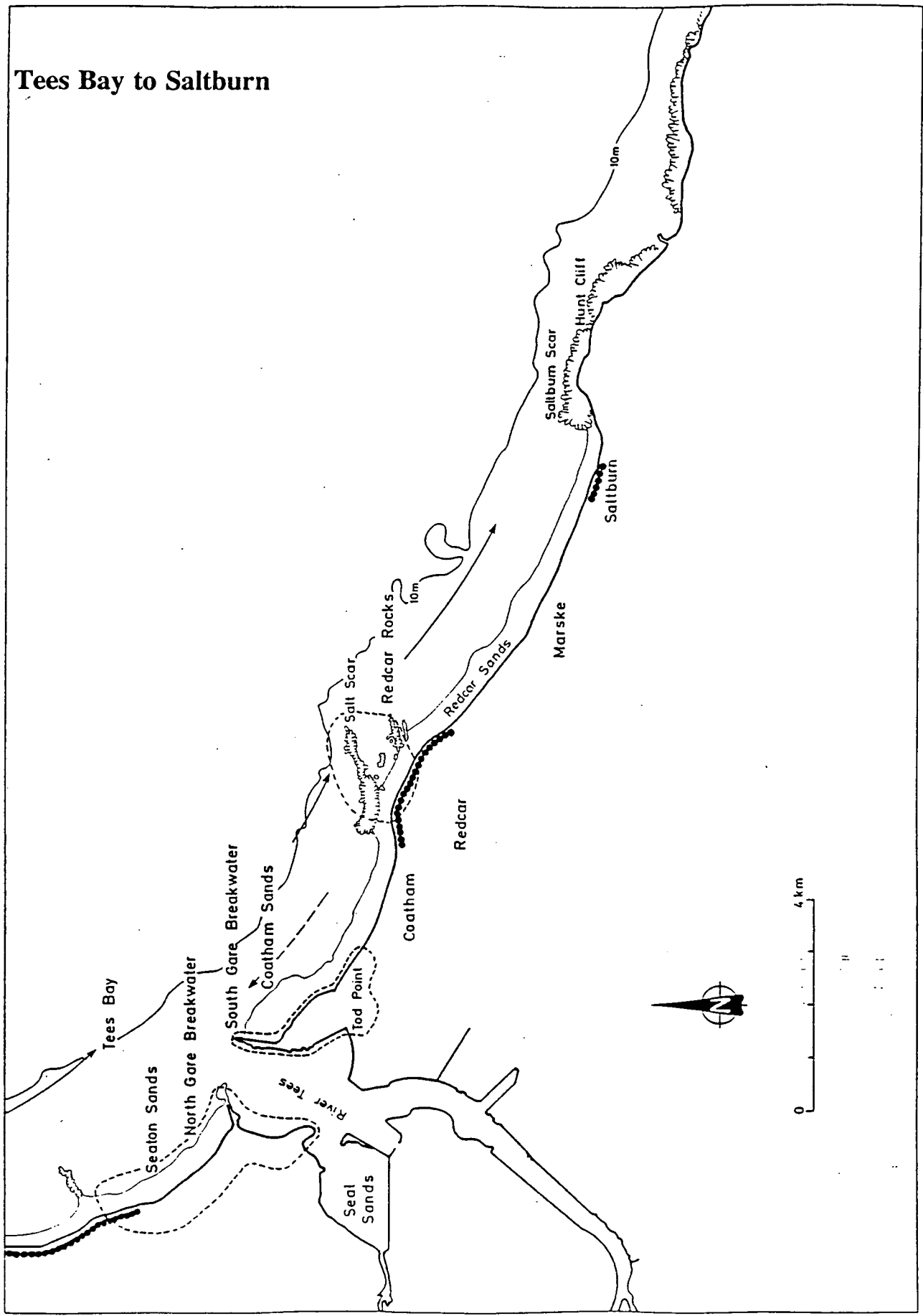
Figure 1.1 a,b,c,d,e The study area: Great Britain, North East Coast of England (Teesbay), Teesmouth, Seal Sands (Teesmouth bird club) and aerial photograph.



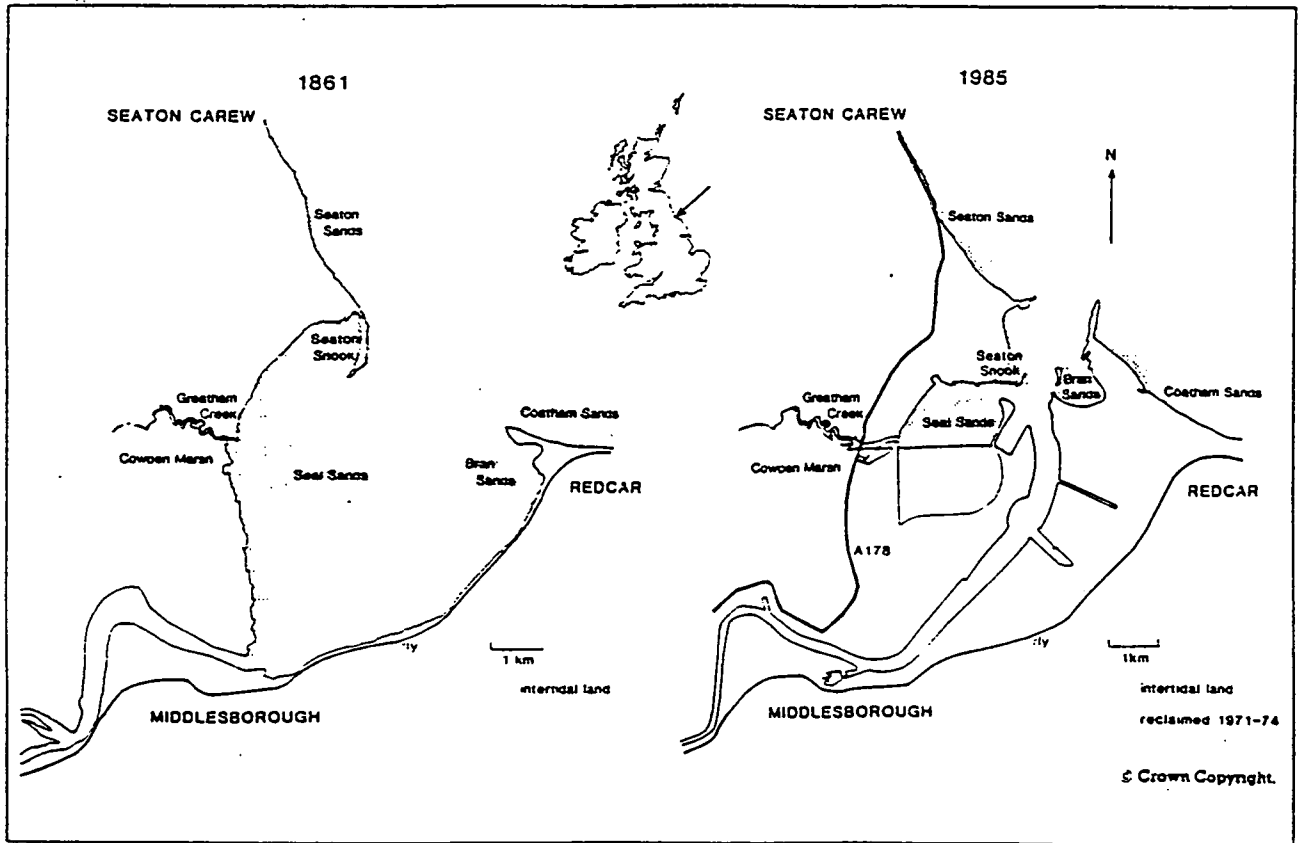
Tees Estuary

Location Map of Study Area

Tees Bay to Saltburn

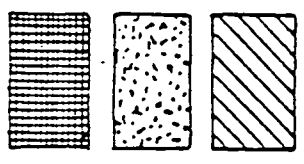


Intertidal area in the Teesmouth 1850 and 1985.

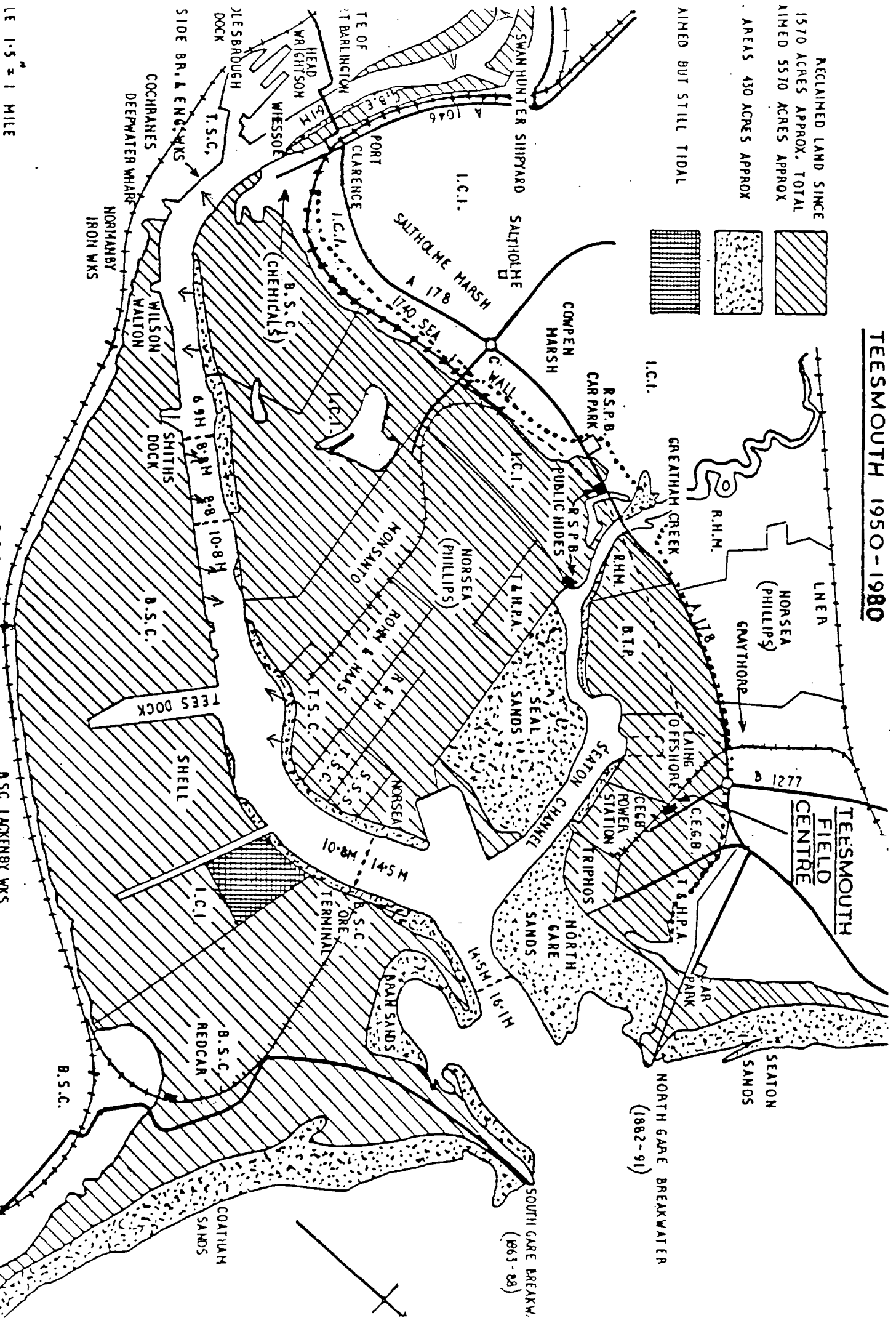


TEESMOUTH 1950-1980

RECLAIMED LAND SINCE 1950 APPROX. TOTAL
 1570 ACRES APPROX. TOTAL
 5570 ACRES APPROX
 AREAS 430 ACRES APPROX



AIMED BUT STILL TIDAL



1.5" = 1 MILE

ASC LACKENBY WKS

SOUTH GARE BREAKW. (1963-69)

NORTH GARE BREAKWATER (1982-91)

SEATON SANDS

TEESMOUTH FIELD CENTRE

NORSESEA (PHILLIPS)

LNRA

R.H.M.

GREATHAH CREEK

I.C.I.

R.S.P.B. CAR PARK

COMPEN MARSH

SALTHOLME

I.C.I.

SALTHOLME MARSH A 178

CLARENCE

PORT

HEAD WRIGHTSON

LESBROUGH DOCK

T.S.C.

SIDE BR. & ENDS WKS

COCHRANES

NORMANBY IRON WKS

WILSON MALTON

SMITHS DOCK

B.S.C.

TEES DOCK

SHELL

I.C.I.

B.S.C.

REDGAR

B.S.C.

COATHAM SANDS

NORSESEA (PHILLIPS)

MONSANTO

ROYN & HMAS

T.S.C.

NORSESEA

BRAH SANDS

B.S.C.

ORE TERMINAL

B.S.C.

ILH.P.A.

SEAL SANDS

SEATON CHANNEL

TRIPHOS

NORTH GARE SANDS

T. & H.P.A.

C.E.G.B. POWER STATION

SEATON SANDS

SEATON SANDS

LAING OFFSHORE

B 1277

B.T.P.

R.H.M.

R.S.P.B. PUBLIC HIDES

R.S.P.B. CAR PARK

R.H.M.

LAING OFFSHORE

C.E.G.B. POWER STATION

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B.T.P.

R.H.M.

R.S.P.B. PUBLIC HIDES

R.S.P.B. CAR PARK

R.H.M.

No. 92/22

TEESMOUTH

17.6.92

2000m

Run 2

086



Figure 1.2 Conceptual diagram of data processing and information flow within the Coastal Monitoring GIS for Seal Sands.

GIS & Remote Sensing

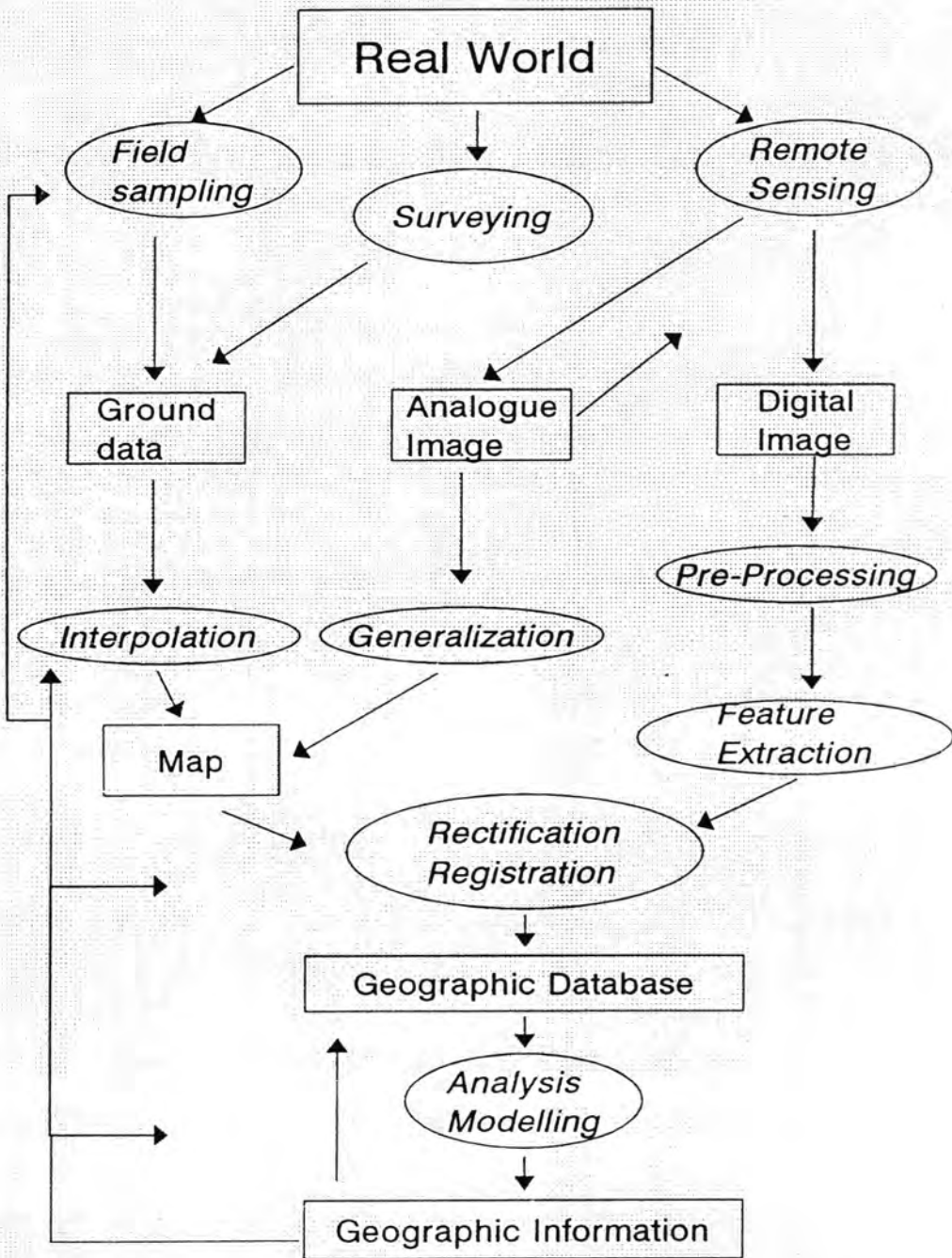


Figure 2.1 View across Seal Sands, from reclaimed land.



Figure 2.2 Mean Spring tide curve of the Tees estuary (Admiralty tide table, Hydrographic Office 1993).

RIVER TEES ENTRANCE

MEAN SPRING AND NEAP CURVES

Springs occur 2 days after New and Full Moon.

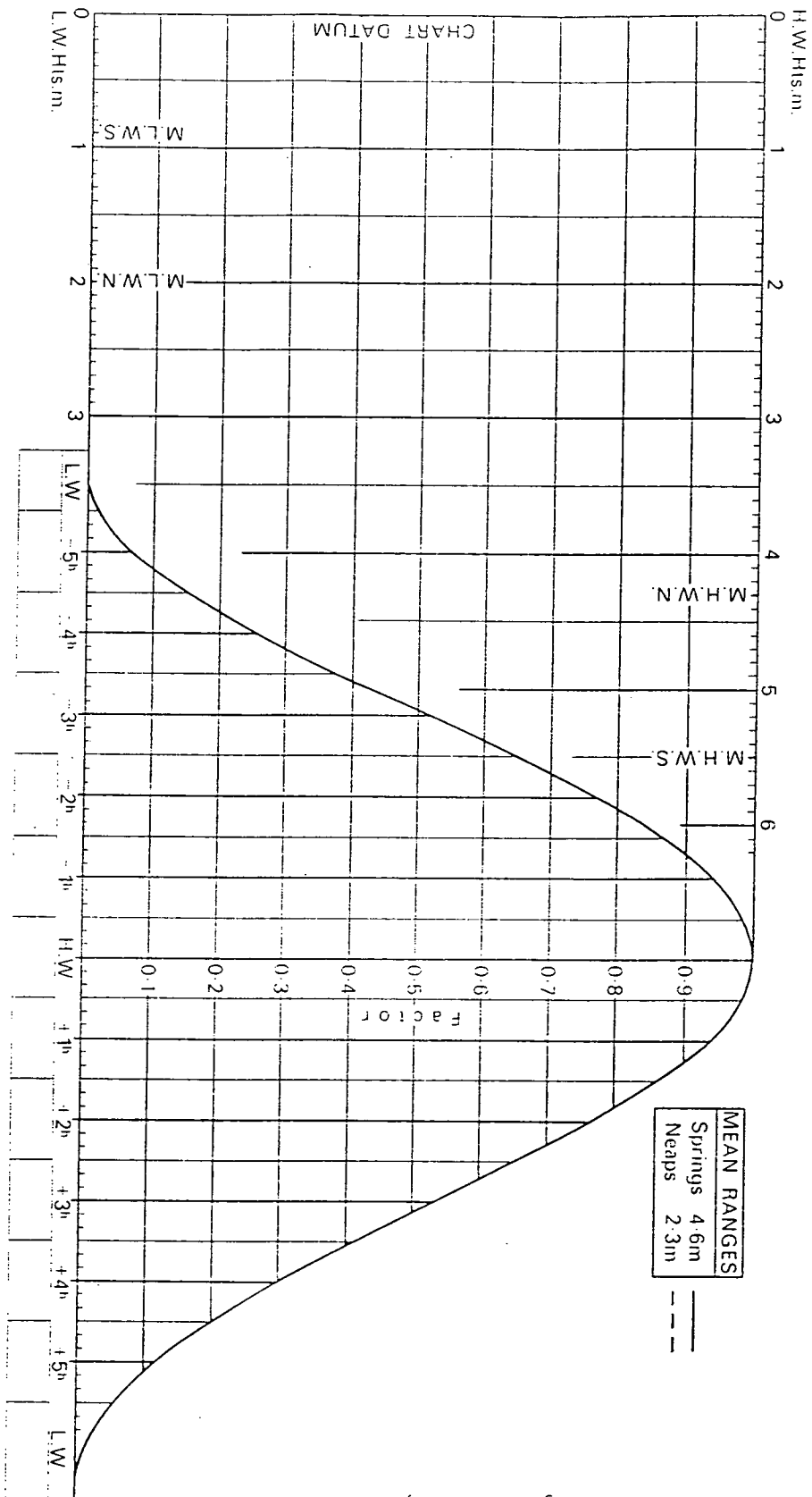


CHART DATUM

L.W./H.S. in m.

H.W./H.S. in m.

Figure 2.3 Predicted heights during March 1989 on the Tees Estuary.

Heavy shading = coverage throughout the daily tidal cycle

**Light shading = coverage for only one part of the cycle (Davidson
et al. 1991).**

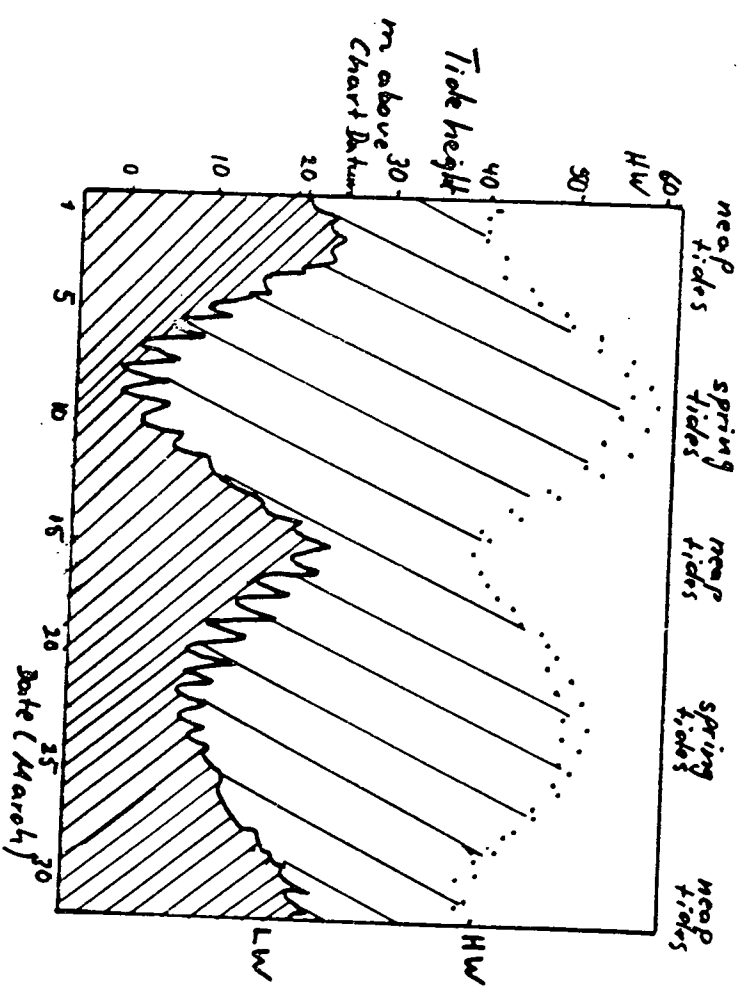
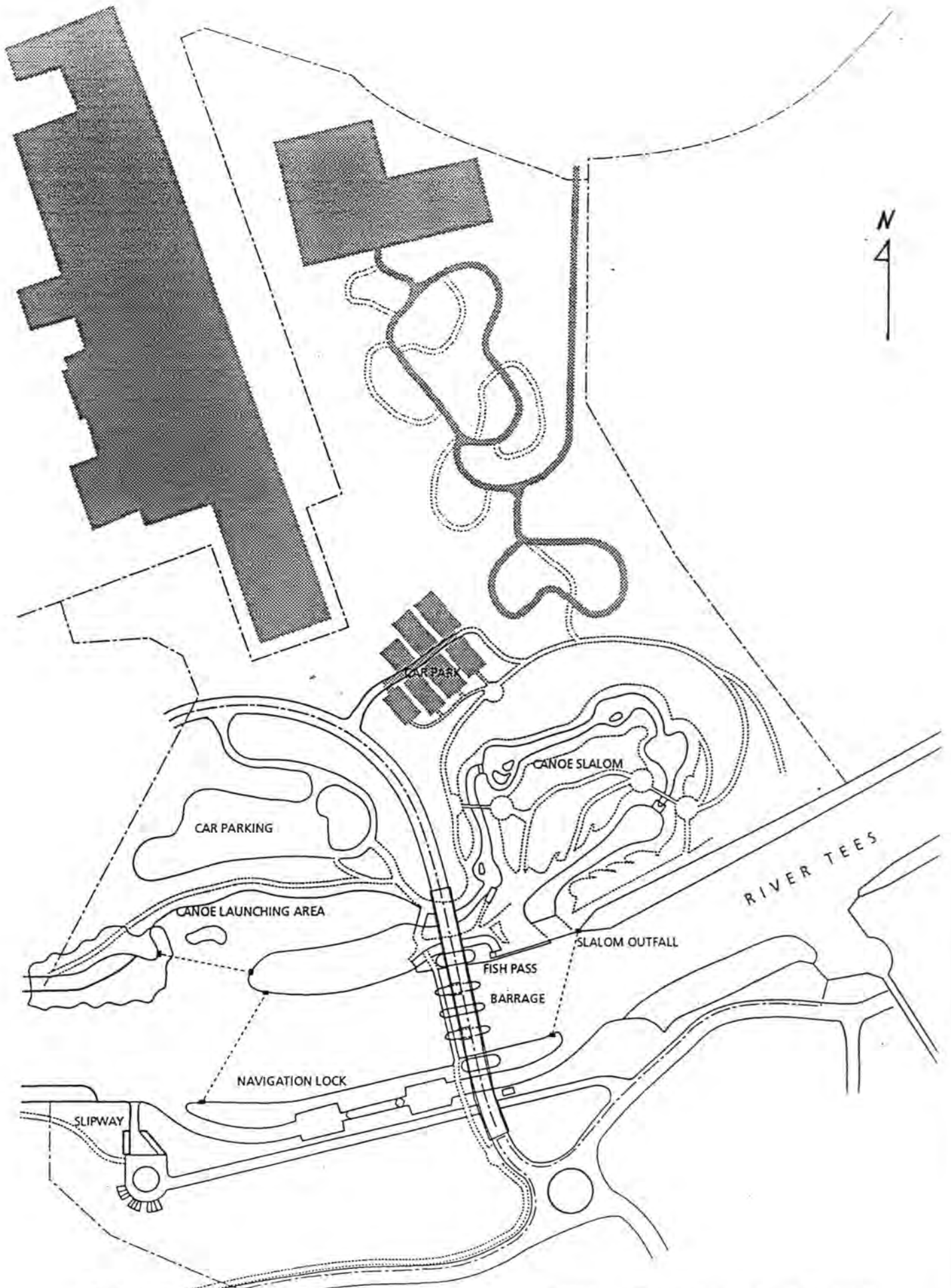


Figure 2.4 Map of the Tees Barrage near Stockton.



Scale: 1: 10560

Source: Teesside Development
Cooperation

Figure 2.7 Cross view over Seal Sands with *Enteromorpha* spp. vegetation, sampling station and tidal creek.



Figure 2.8 Photograph of a tidal creek system in a mudflat at Seal Sands.

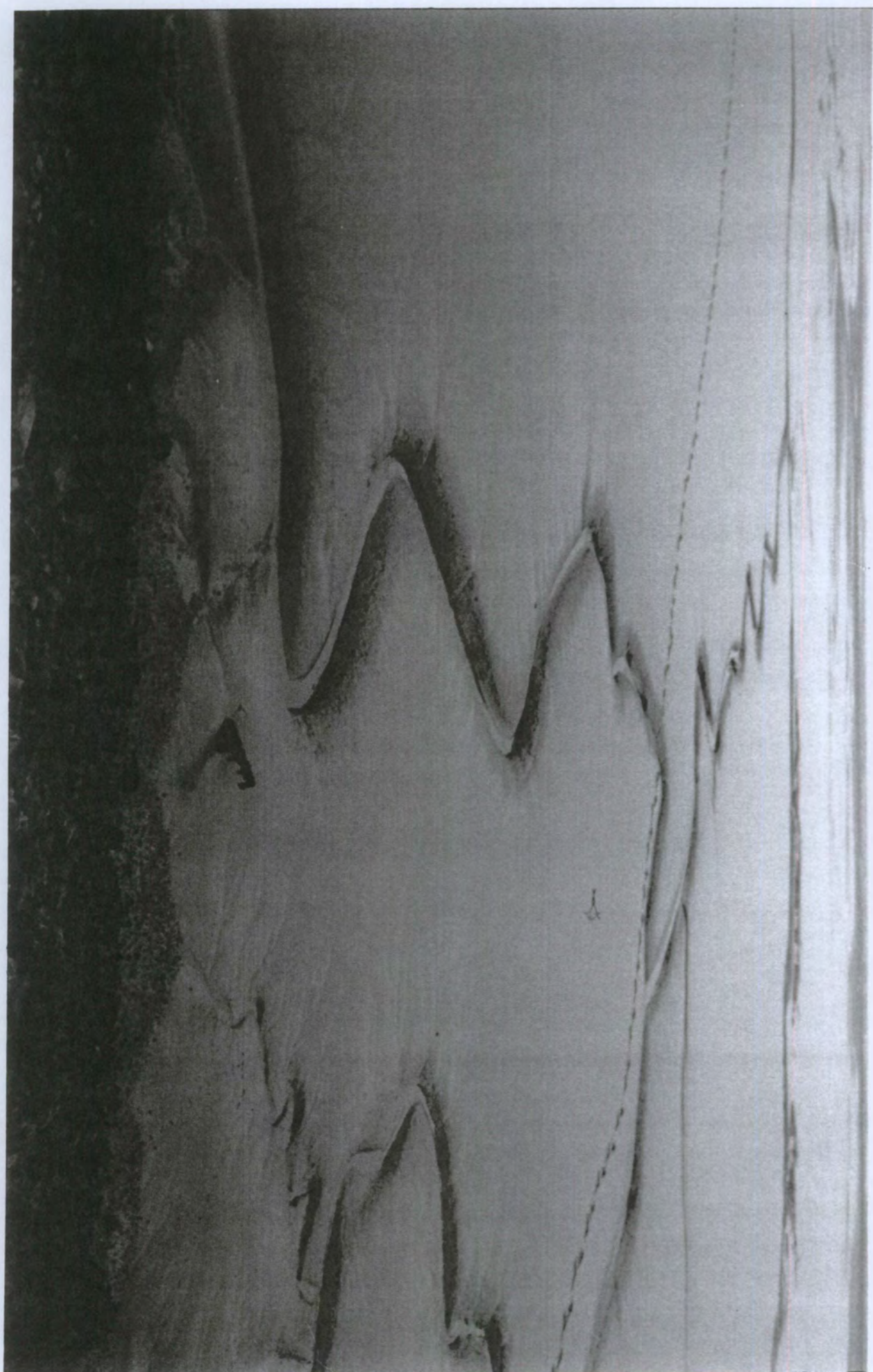
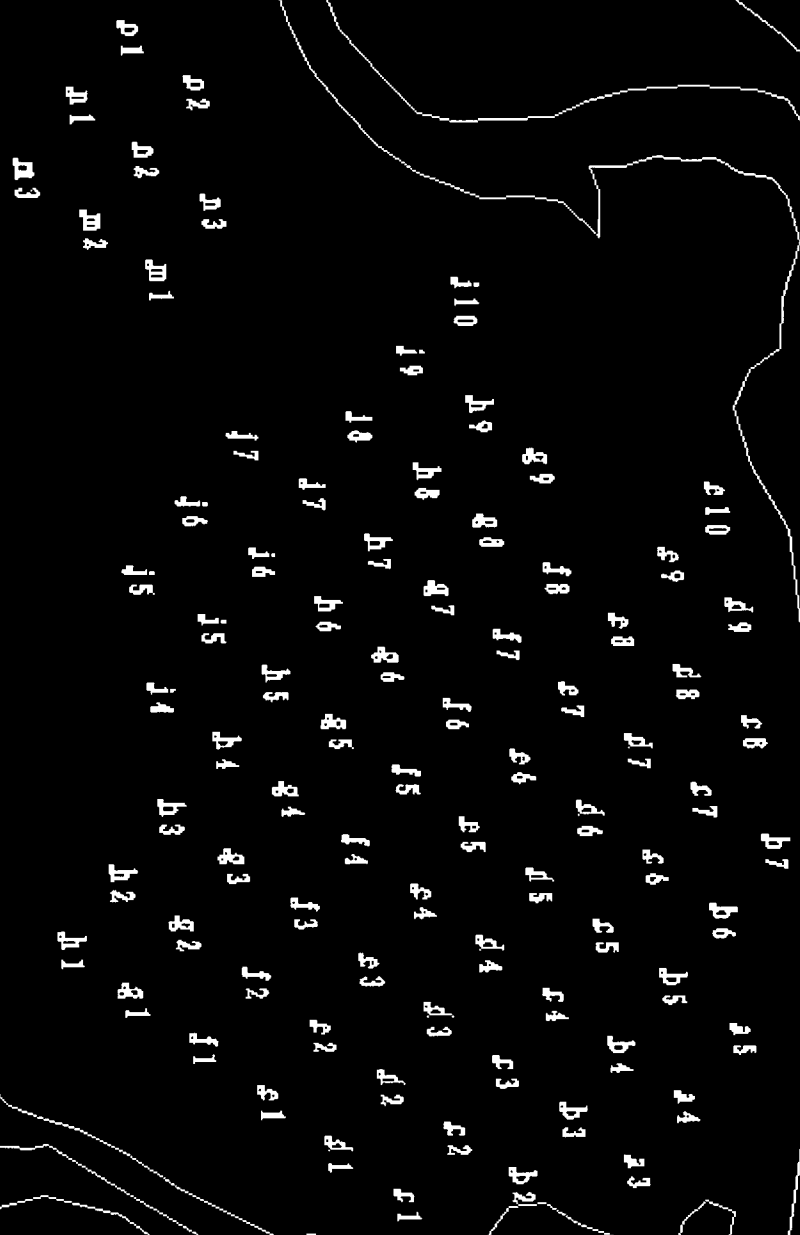


Figure 2.9 Photograph of the drainage pattern in a sandflat at Seal Sands.



**Figure 3.1 Position of sampling stations over Seal Sands;
Scale = 1: 10400.**

Intertidal zone of Seal Sands, including sampling stations



CHRISTOPHER FOREHEAD

Figure 3.2 Photograph of a sampling station at Seal Sands.



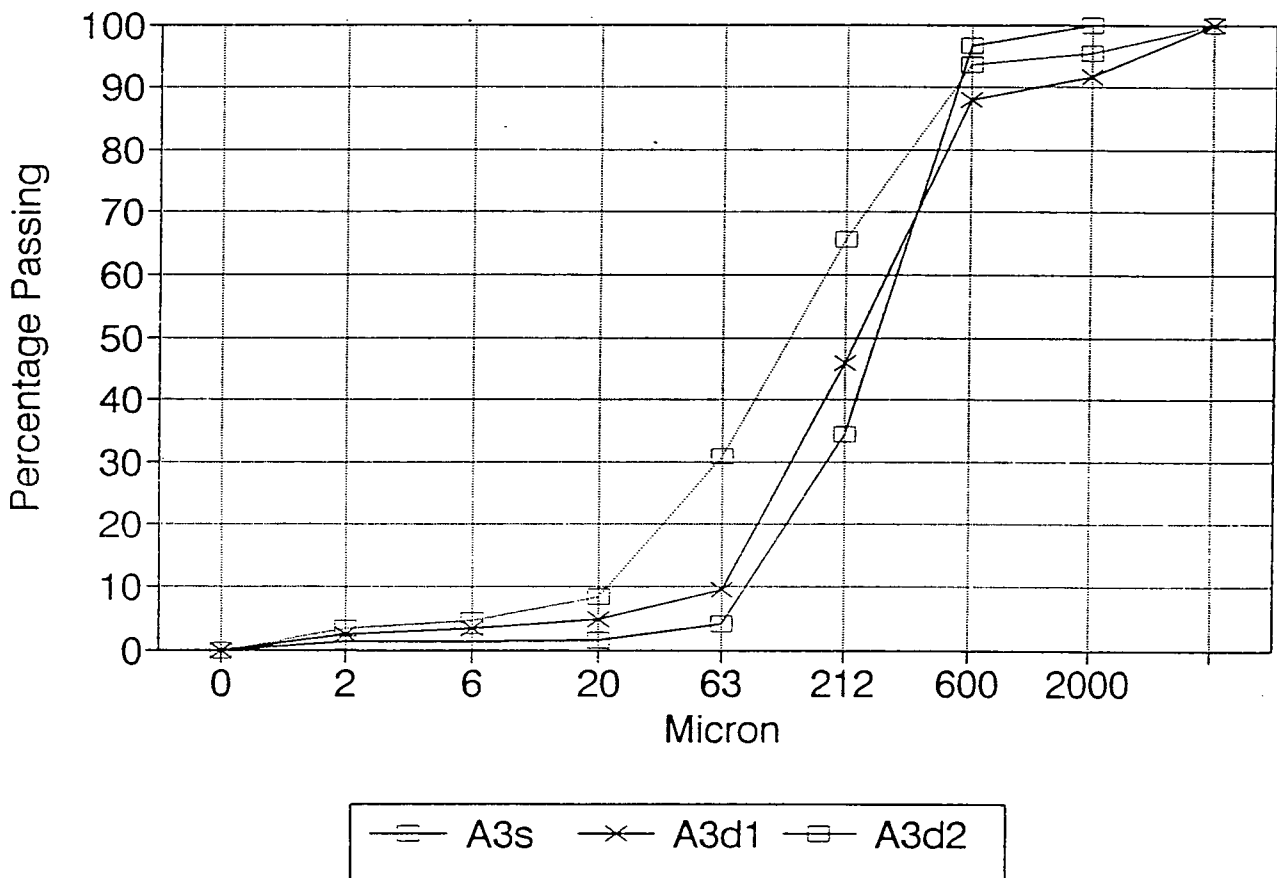
Figure 3.3 a-j **First resampling of tidal sediments over Seal Sands using the Pipette Method.**

s = surface

d = 2 to 3 cm depth

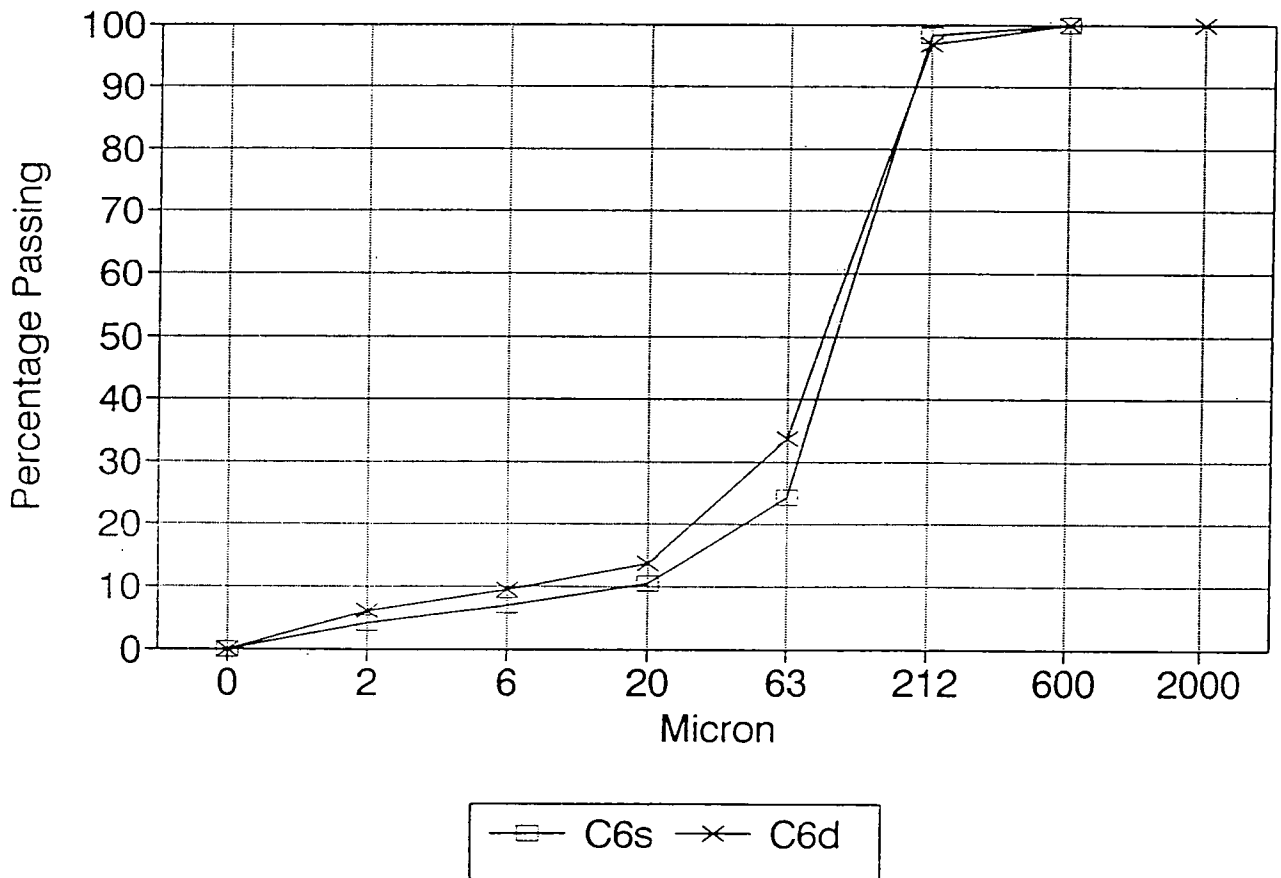
PARTICLE SIZE DISTRIBUTION

Sealsands



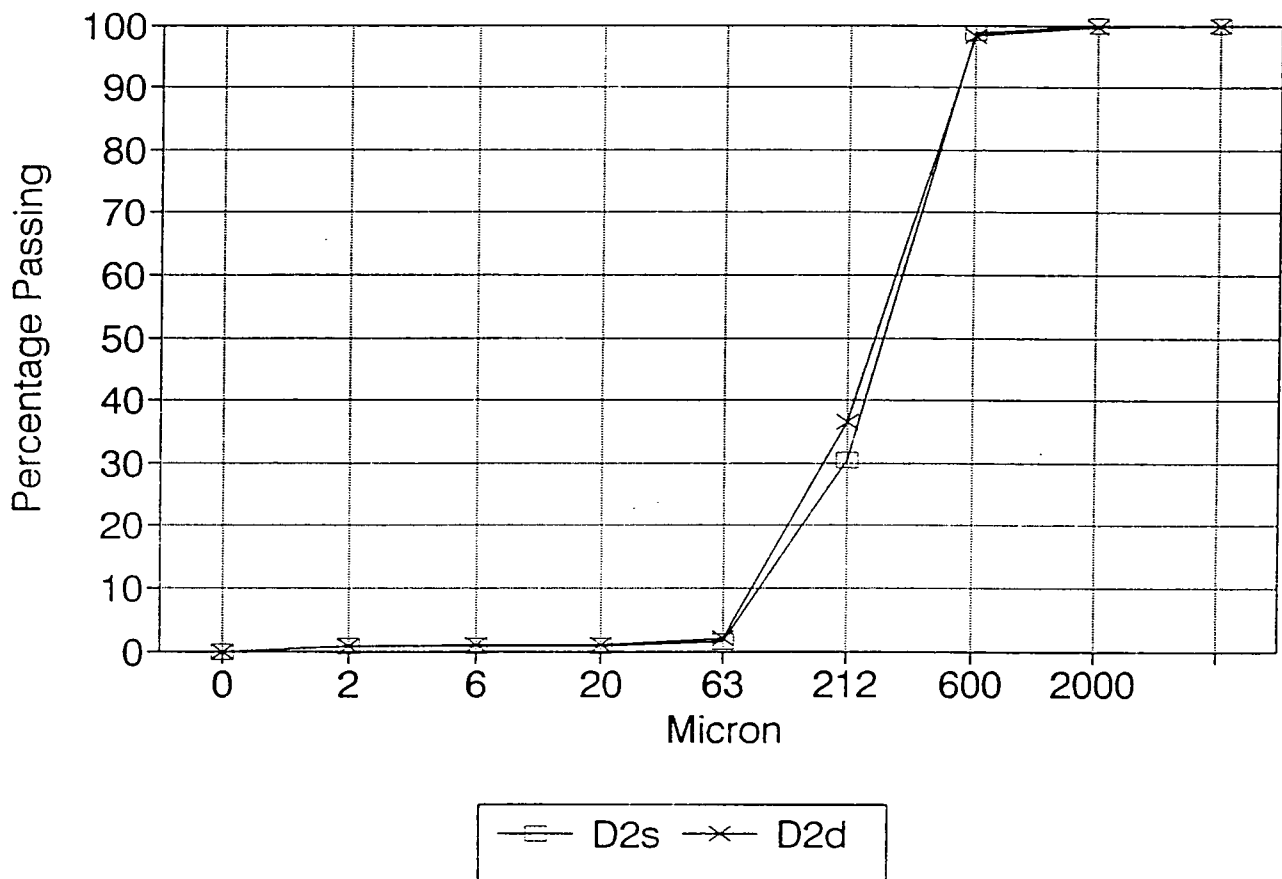
PARTICLE SIZE DISTRIBUTION

Sealsands



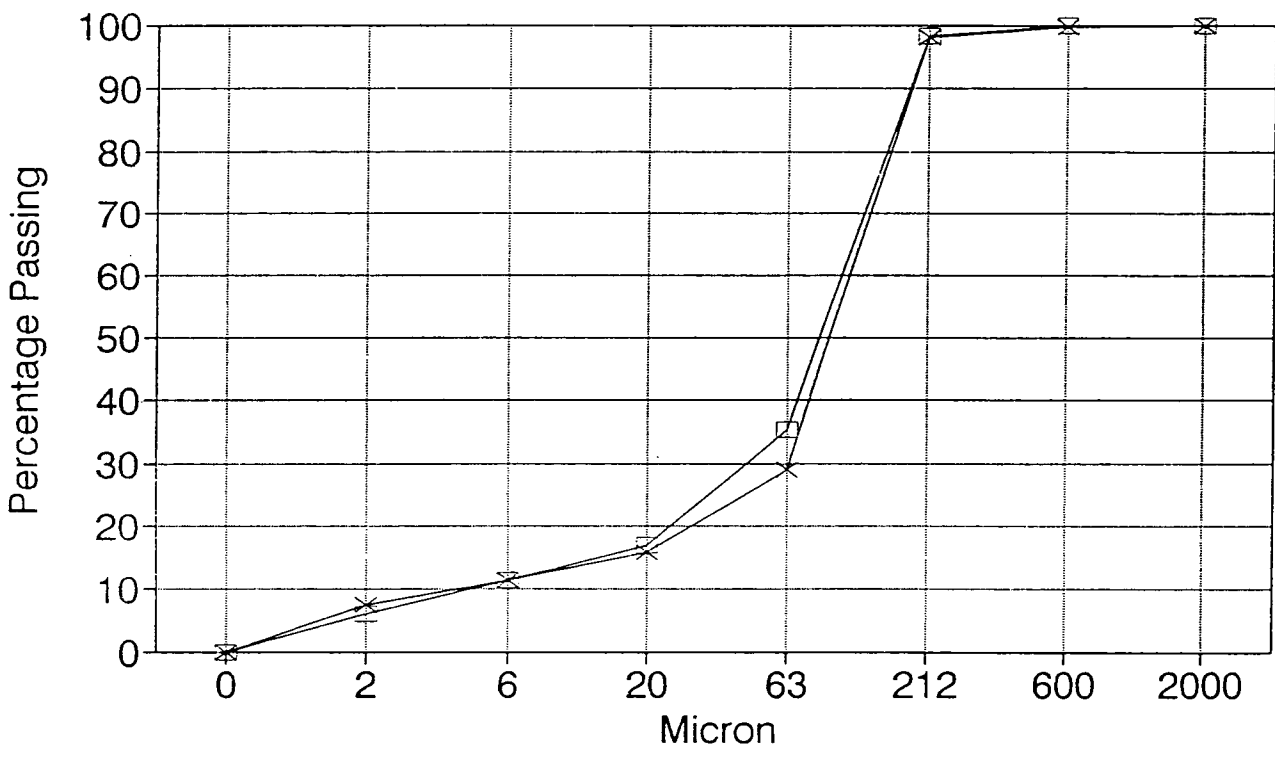
PARTICLE SIZE DISTRIBUTION

Sealsands



PARTICLE SIZE DISTRIBUTION

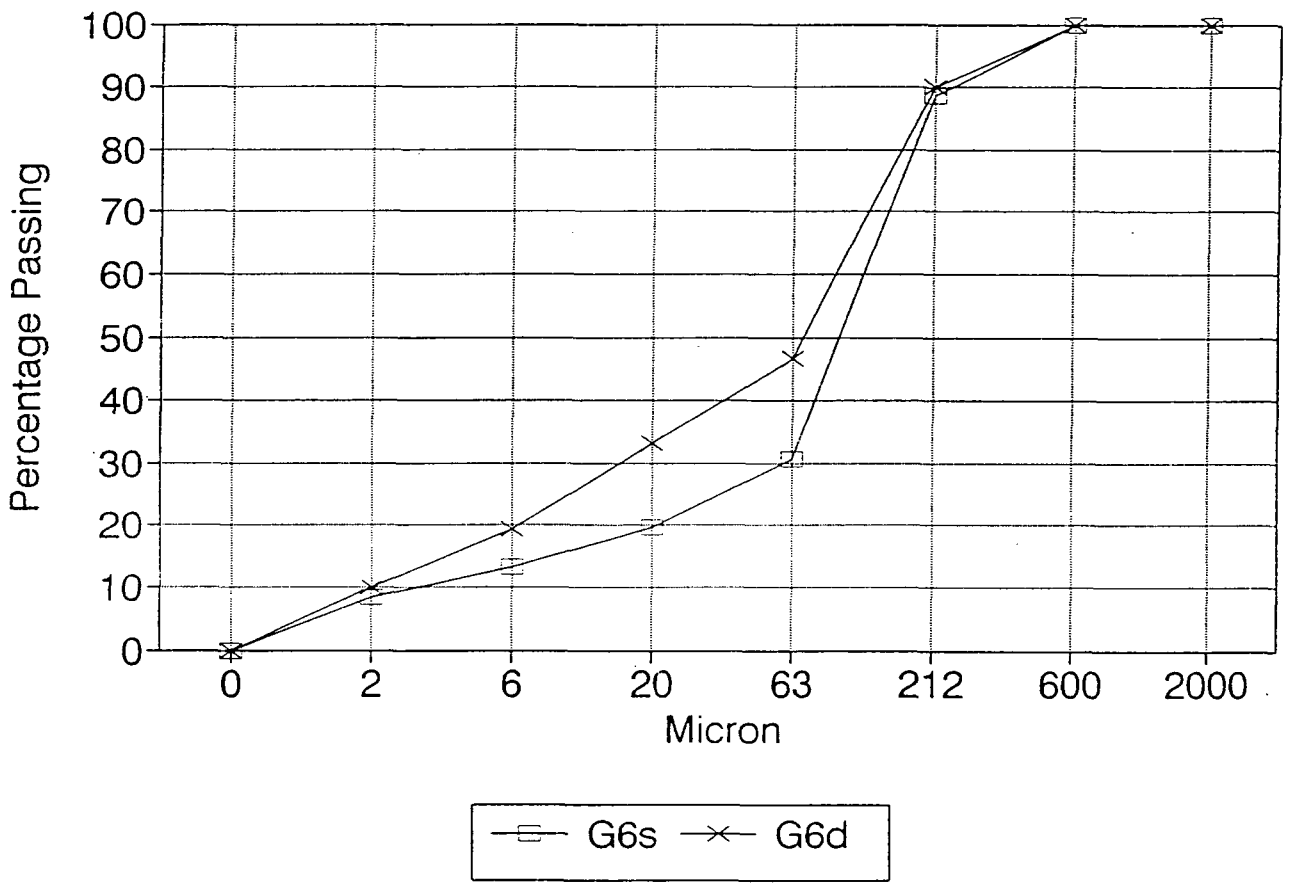
Sealsands



—□— E9s —×— E9d

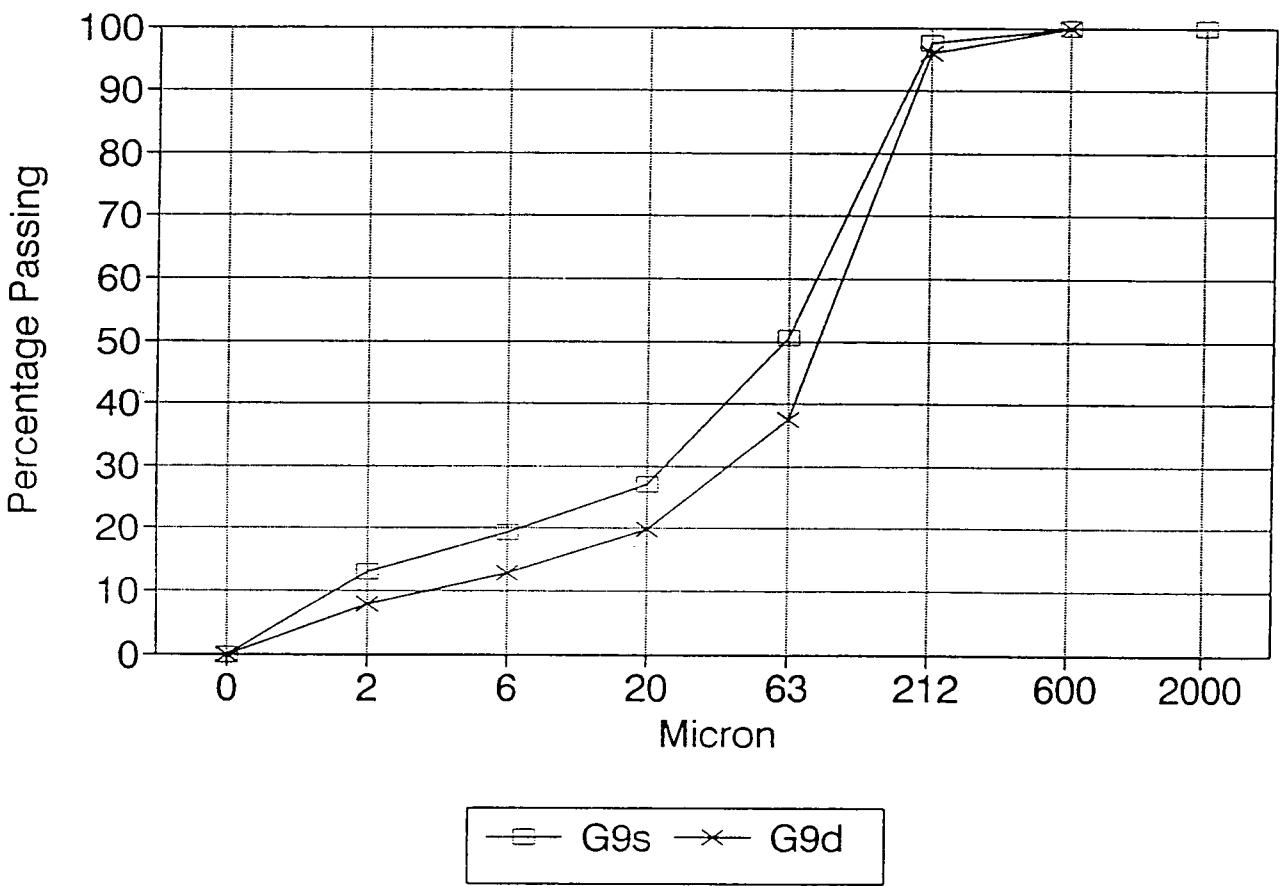
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Sealsands



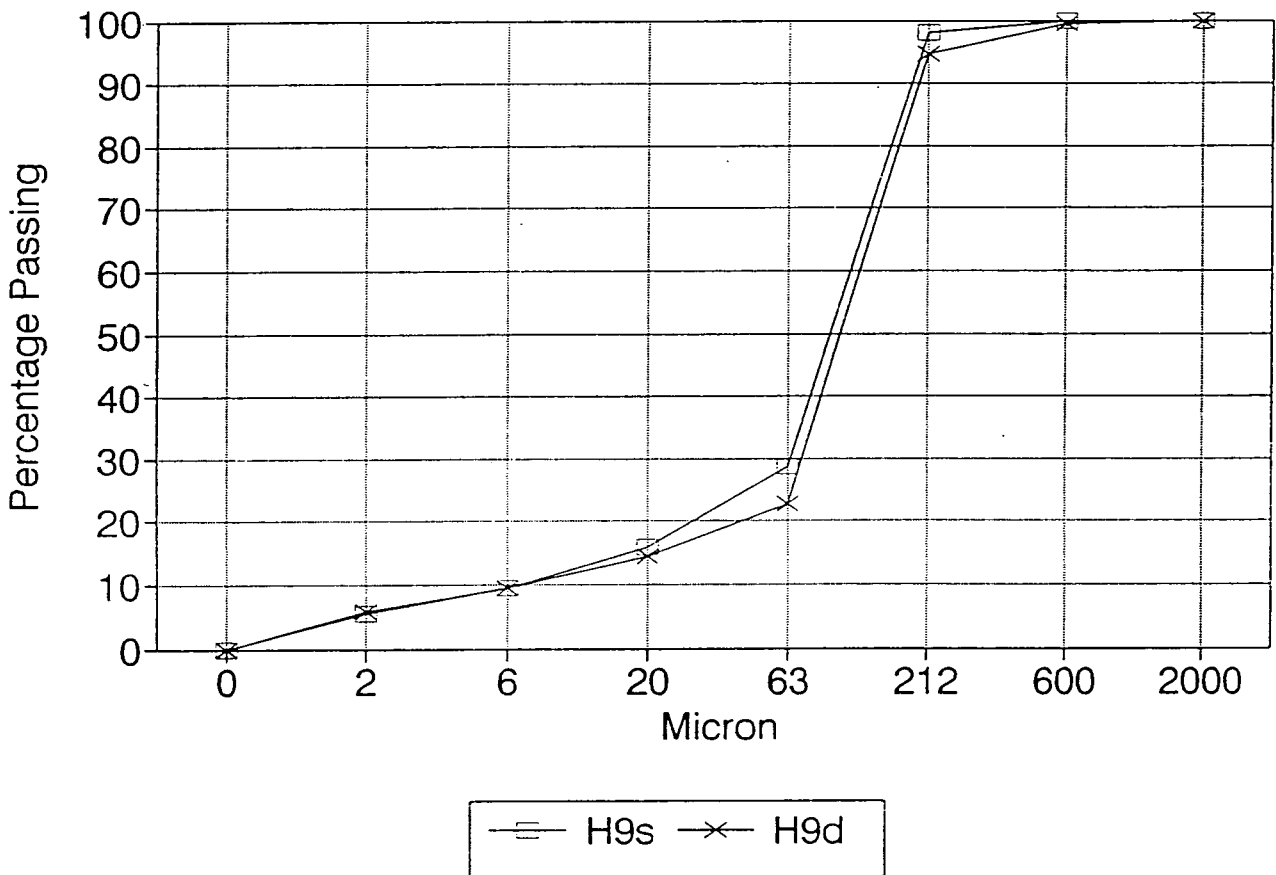
PARTICLE SIZE DISTRIBUTION

Sealsands



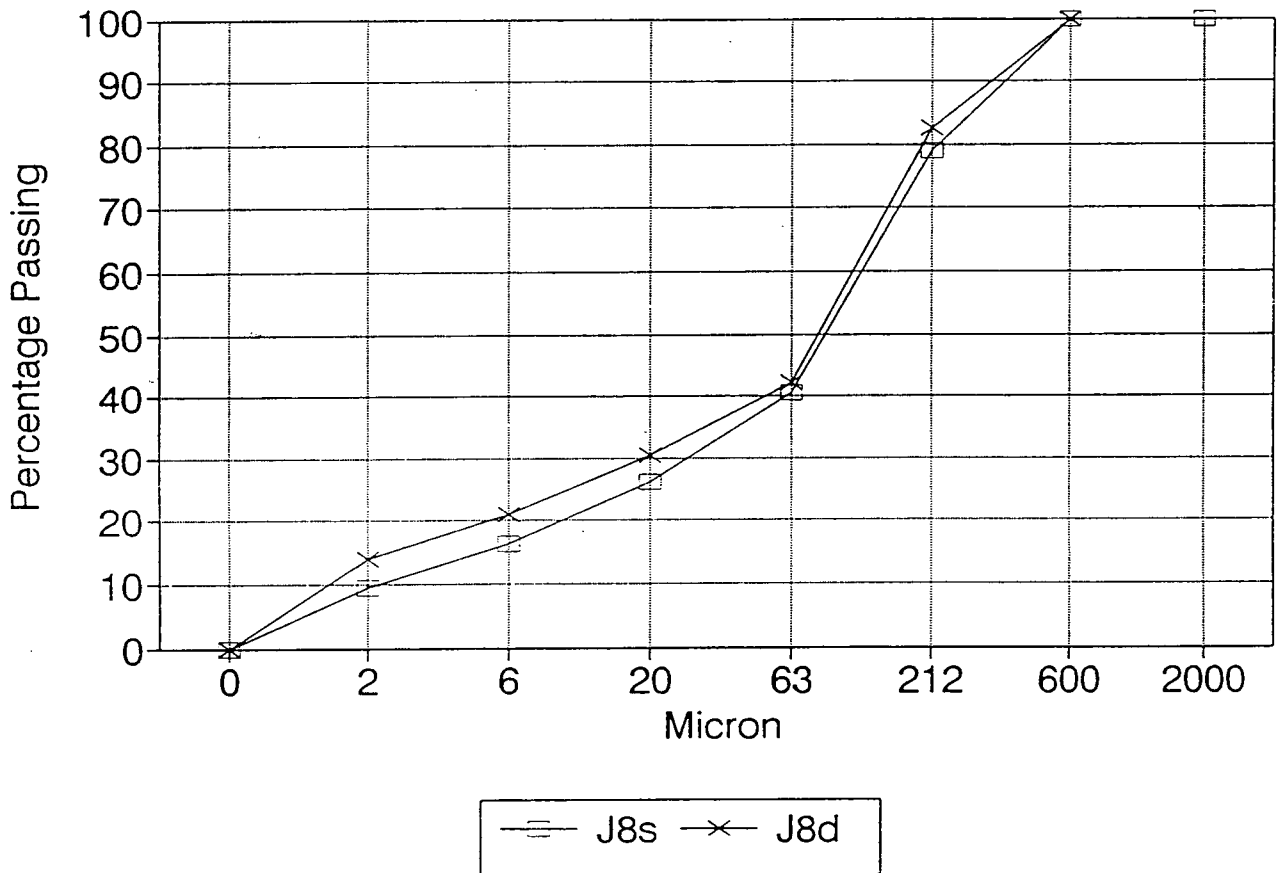
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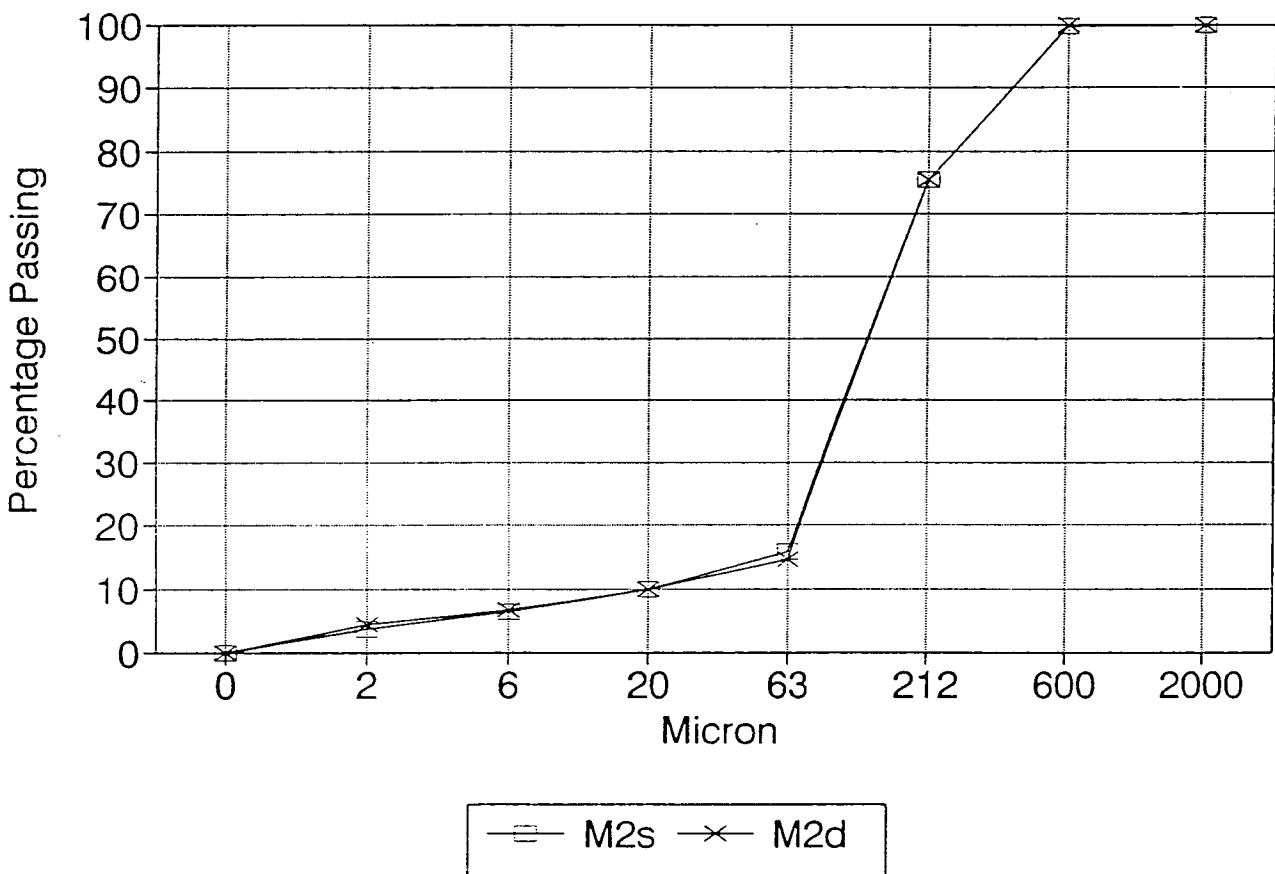
PARTICLE SIZE DISTRIBUTION

Sealsands



PARTICLE SIZE DISTRIBUTION

Sealsands



PARTICLE SIZE DISTRIBUTION

Sealsands

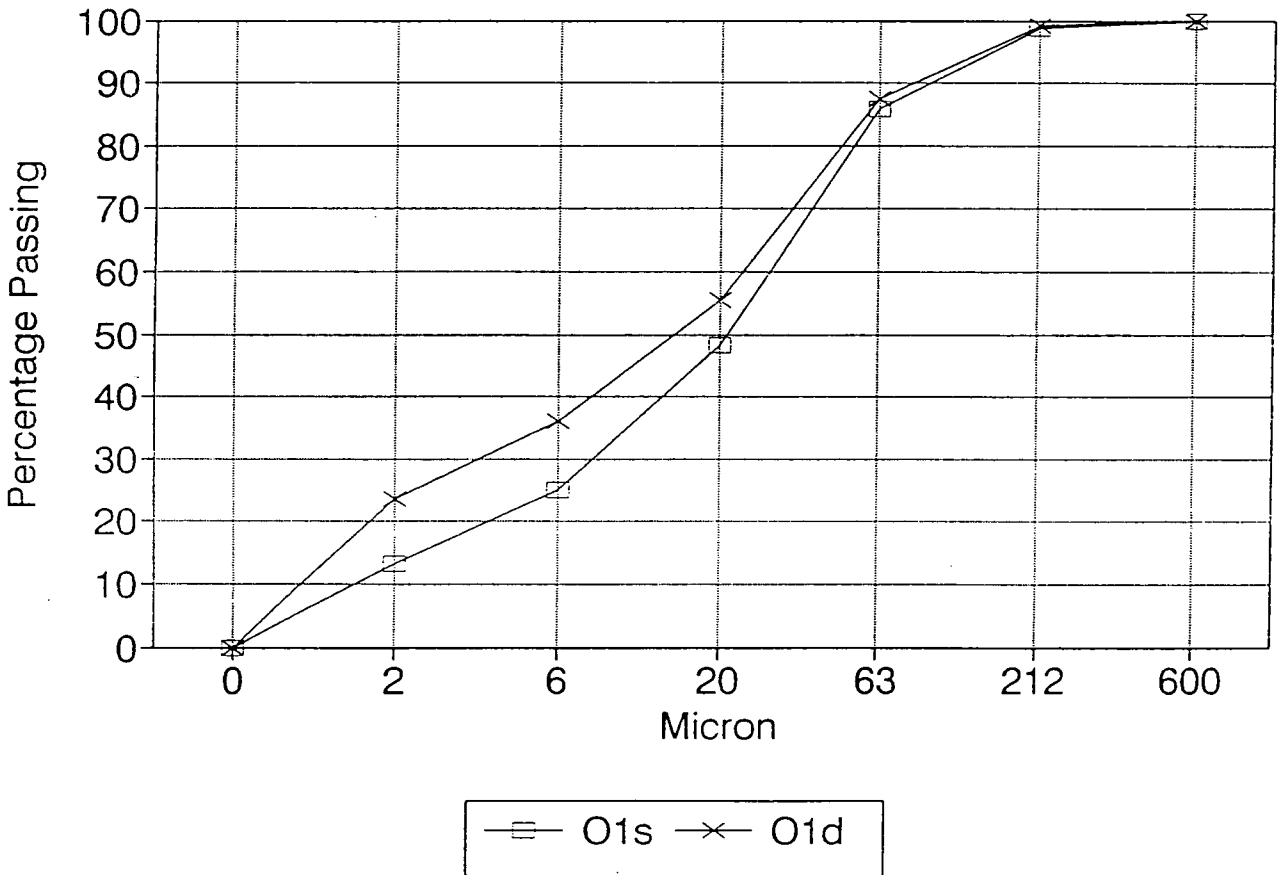


Figure 3.4 a-j **Comparison of the first resampled stations with the particle size analysis from 1990/91.**

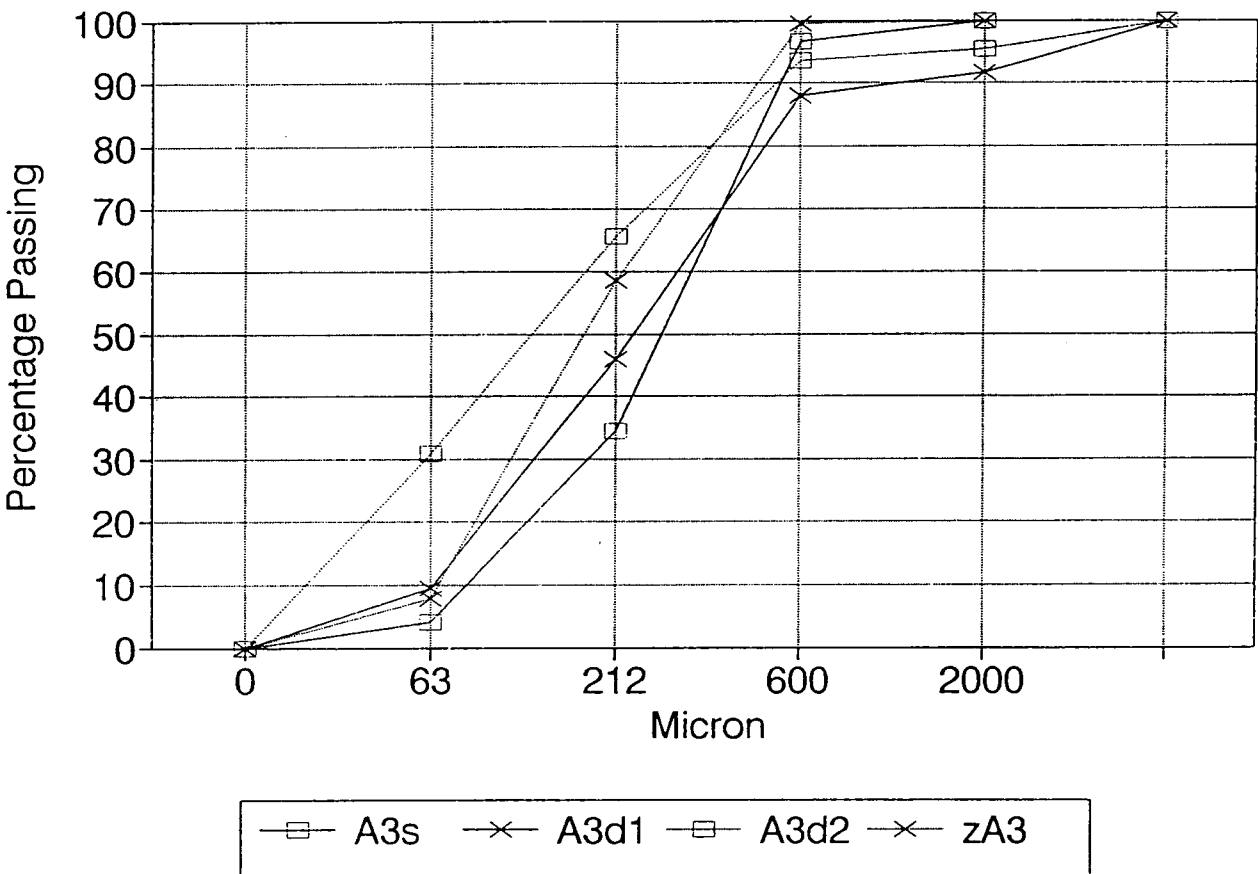
s = **surface**

d = **2 to 3 cm depth**

z = **Dr Zongs' particle size analysis (Donoghue & Zong 1992).**

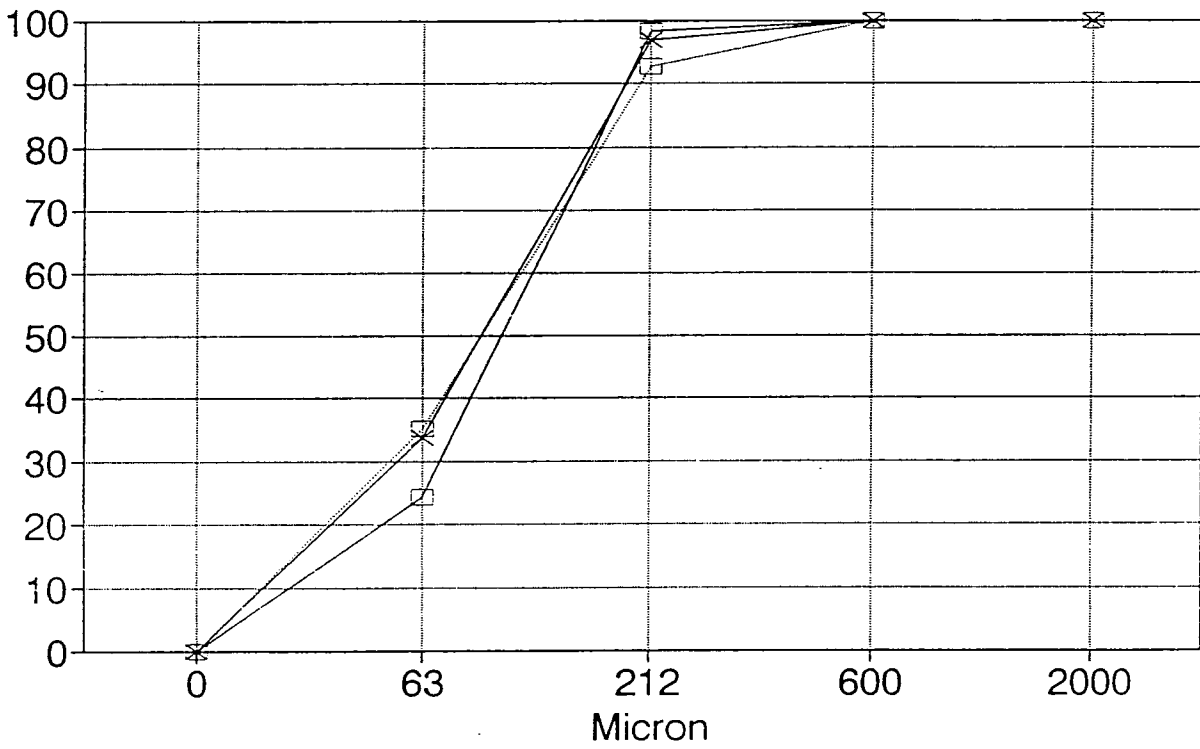
PARTICLE SIZE DISTRIBUTION

Sealsands



PARTICLE SIZE DISTRIBUTION

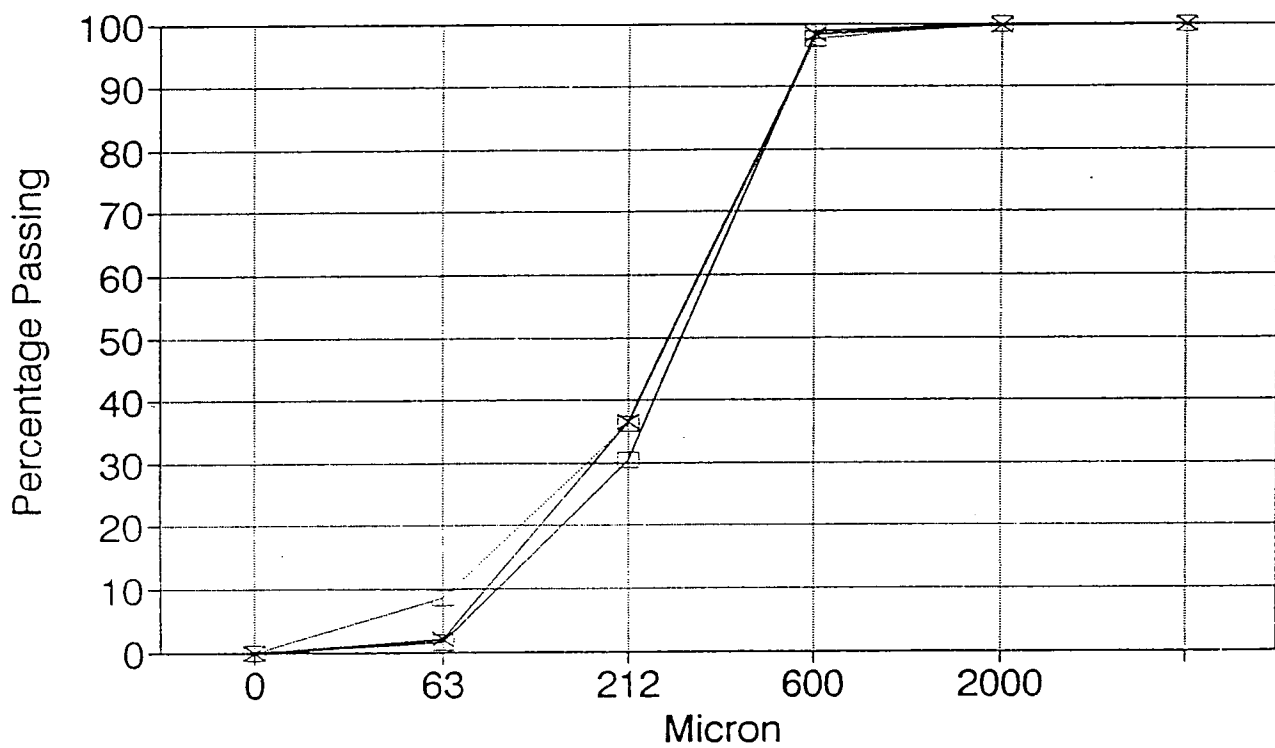
Sealsands



—□— C6s —×— C6d —○— zC6

PARTICLE SIZE DISTRIBUTION

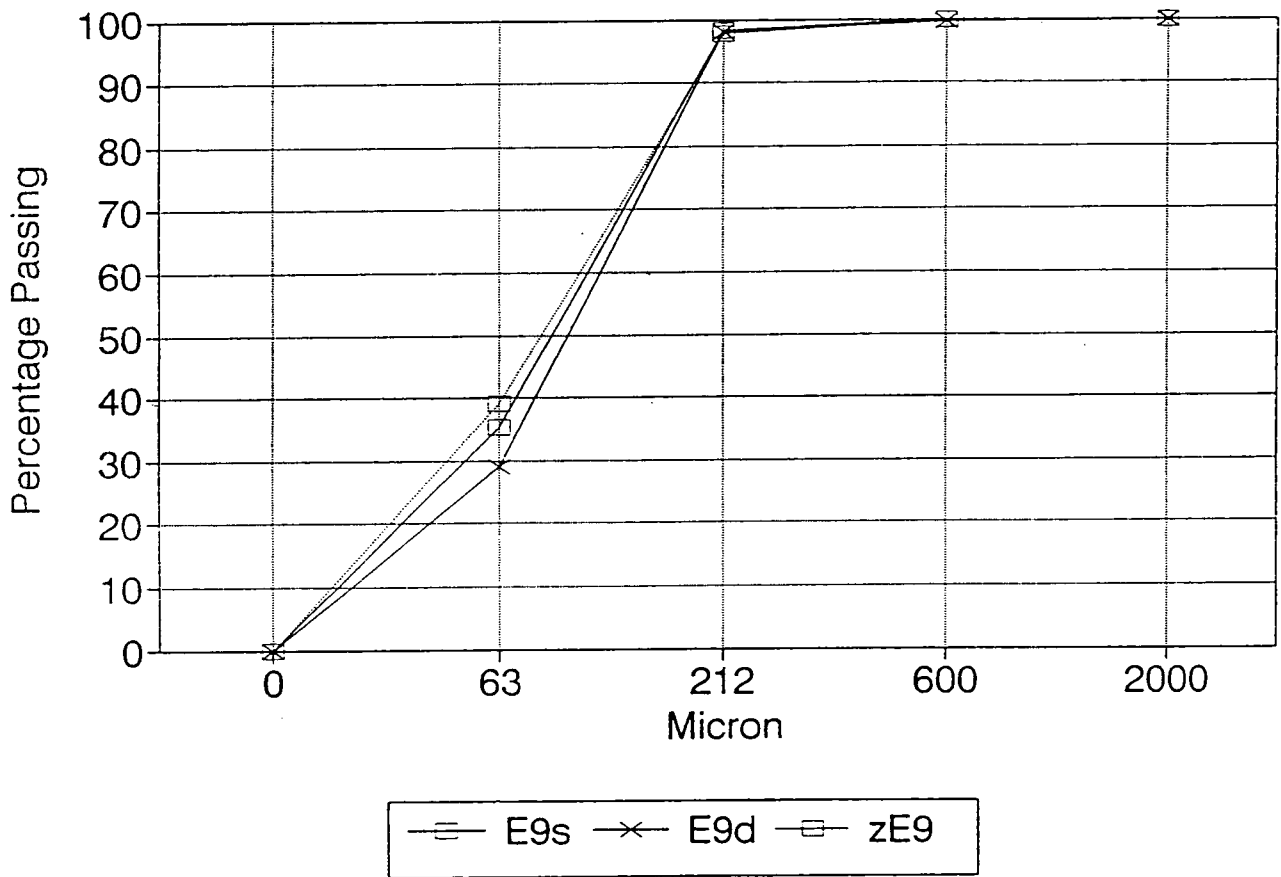
Sealsands



—□— D2s —×— D2d —○— zD2

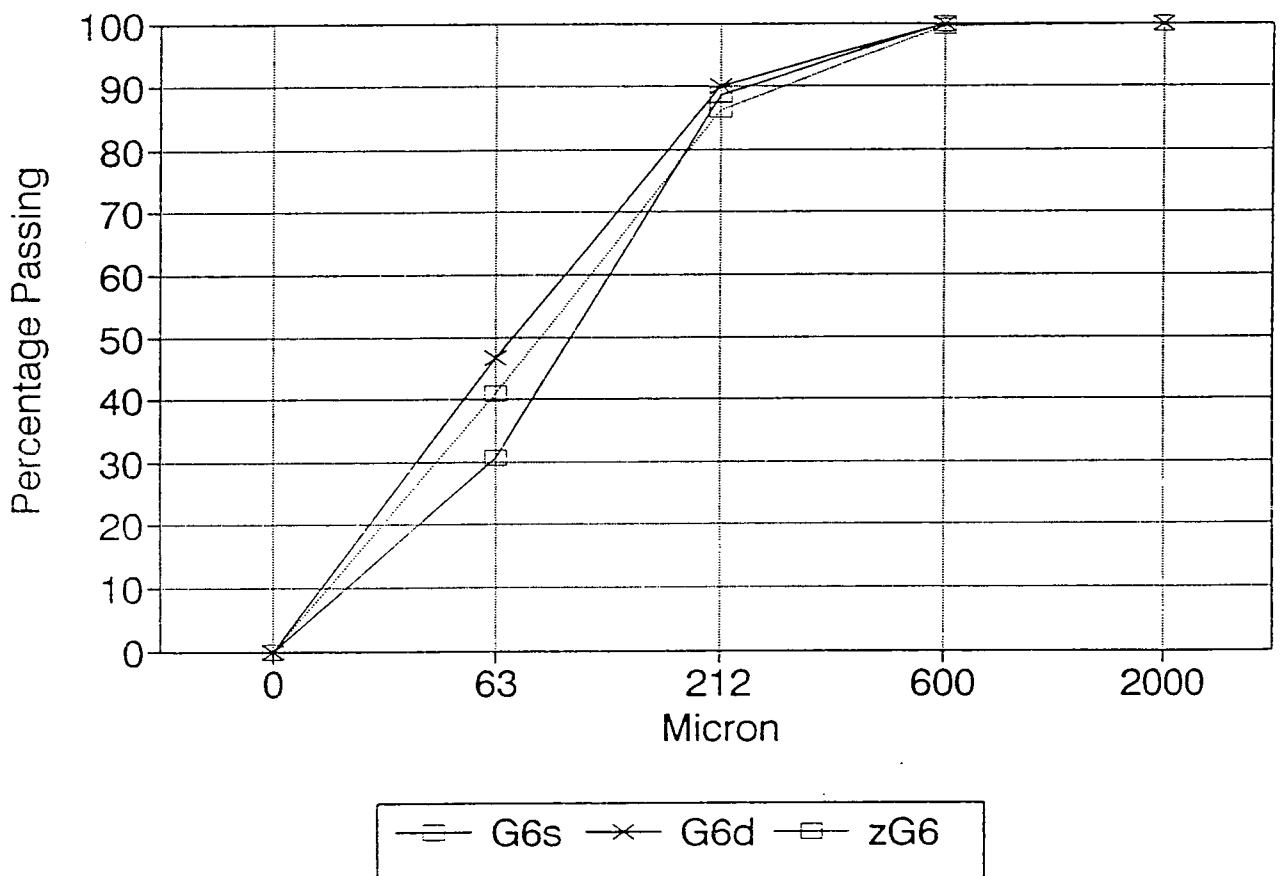
PARTICLE SIZE DISTRIBUTION

Sealsands



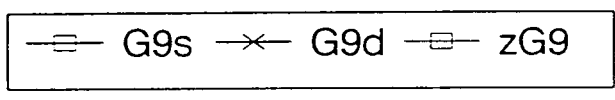
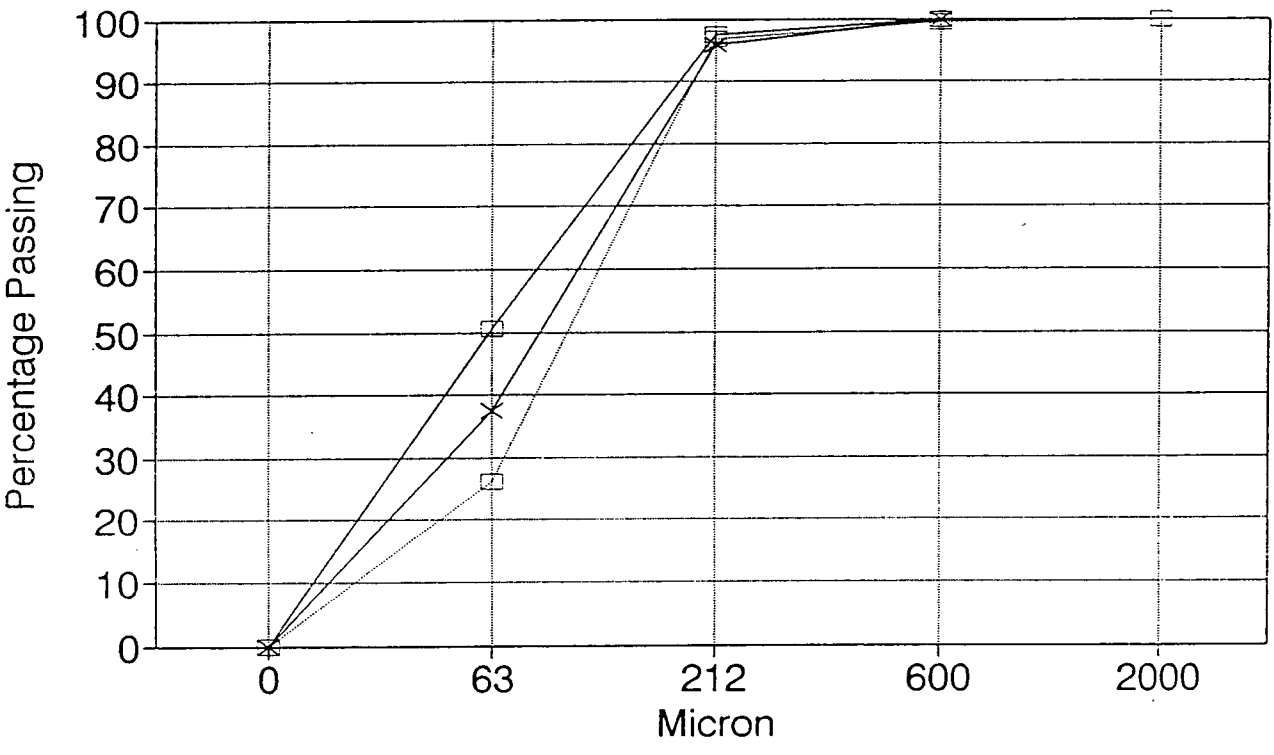
PARTICLE SIZE DISTRIBUTION

Sealsands



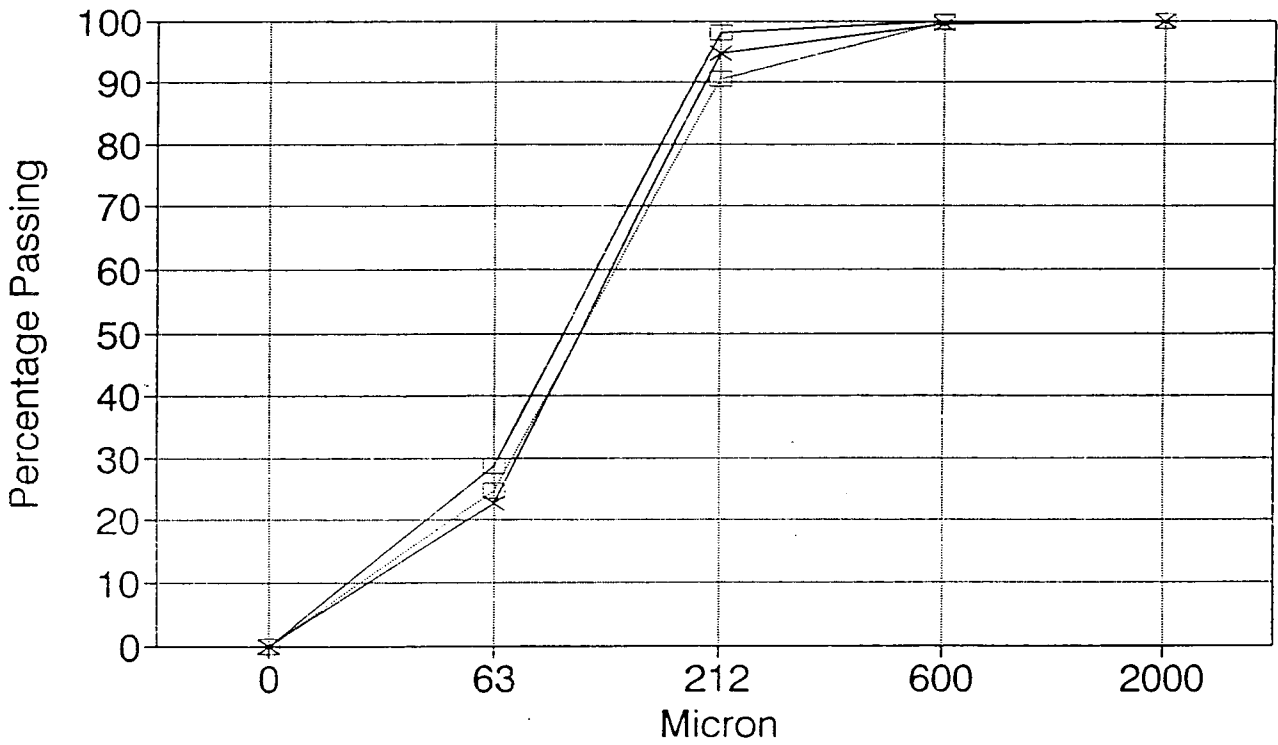
PARTICLE SIZE DISTRIBUTION

Sealsands



PARTICLE SIZE DISTRIBUTION

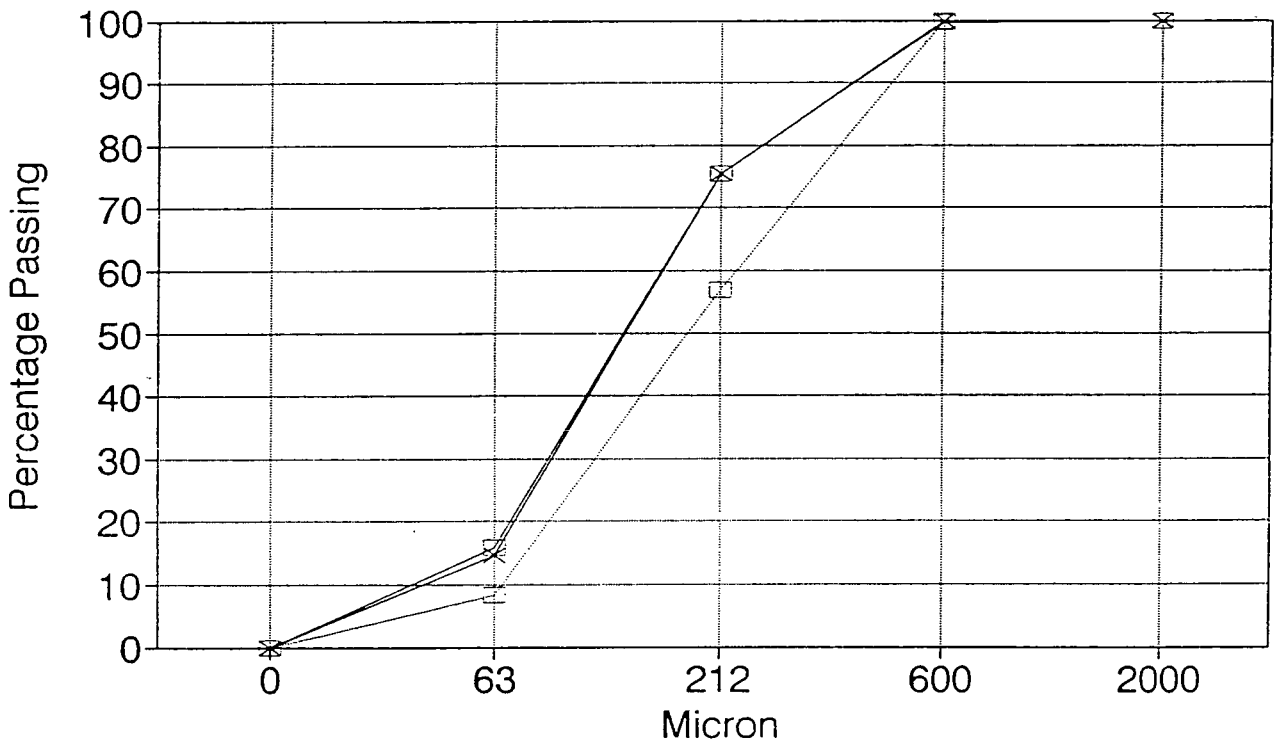
Sealsands



—□— H9s —×— H9d —○— zH9

PARTICLE SIZE DISTRIBUTION

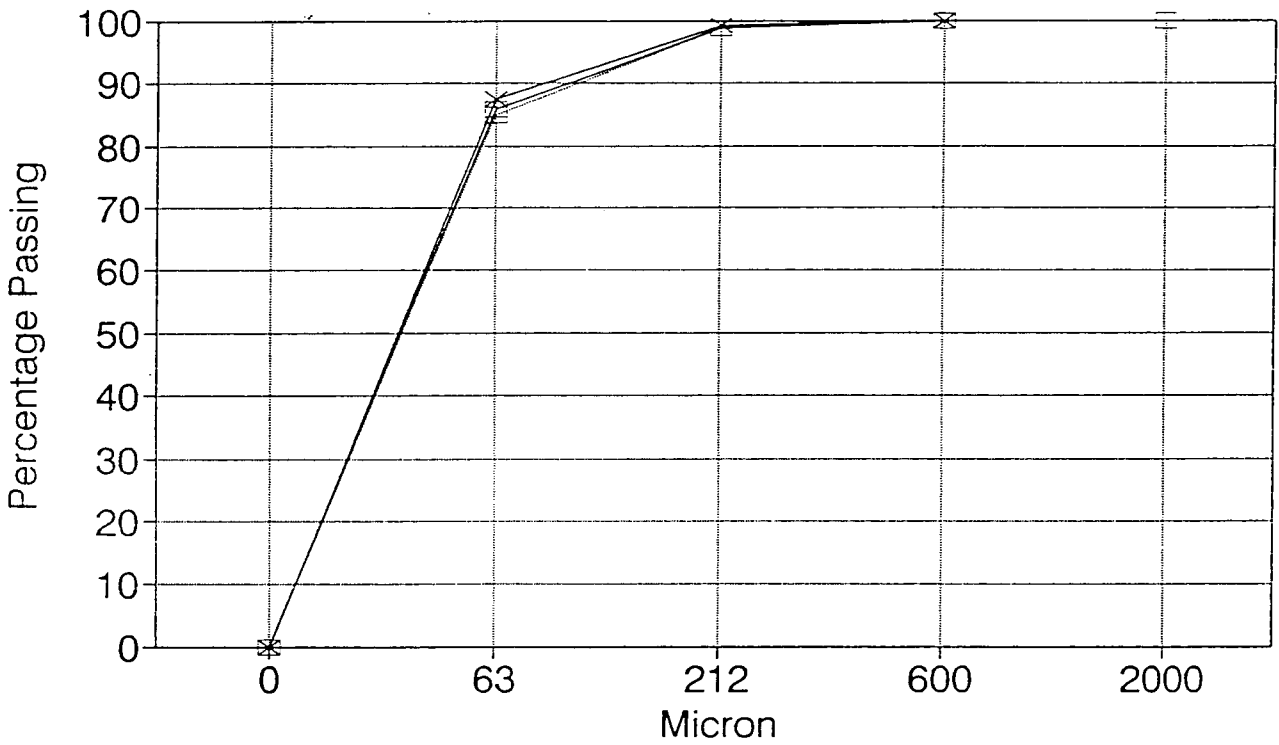
Sealsands



—□— M2s —x— M2d -.-□- zM2

PARTICLE SIZE DISTRIBUTION

Sealsands



—□— O1s —×— O1d —○— zO1

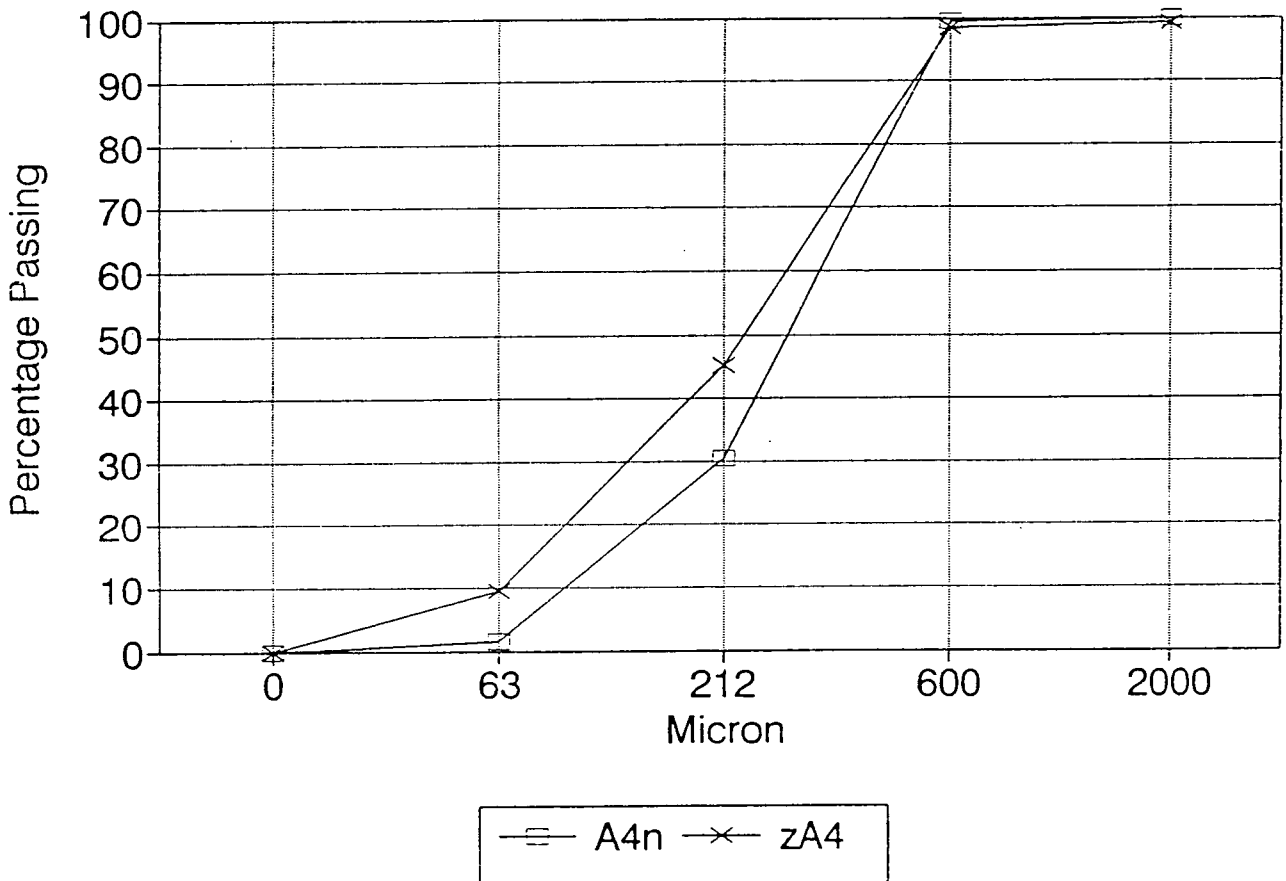
Figure 3.5 a-r **Second resampling of the tidal sediments over Seal Sands.**

n = **new sampling at surface**

z = **Dr Zongs' particle size analysis (Donoghue & Zong 1992)**

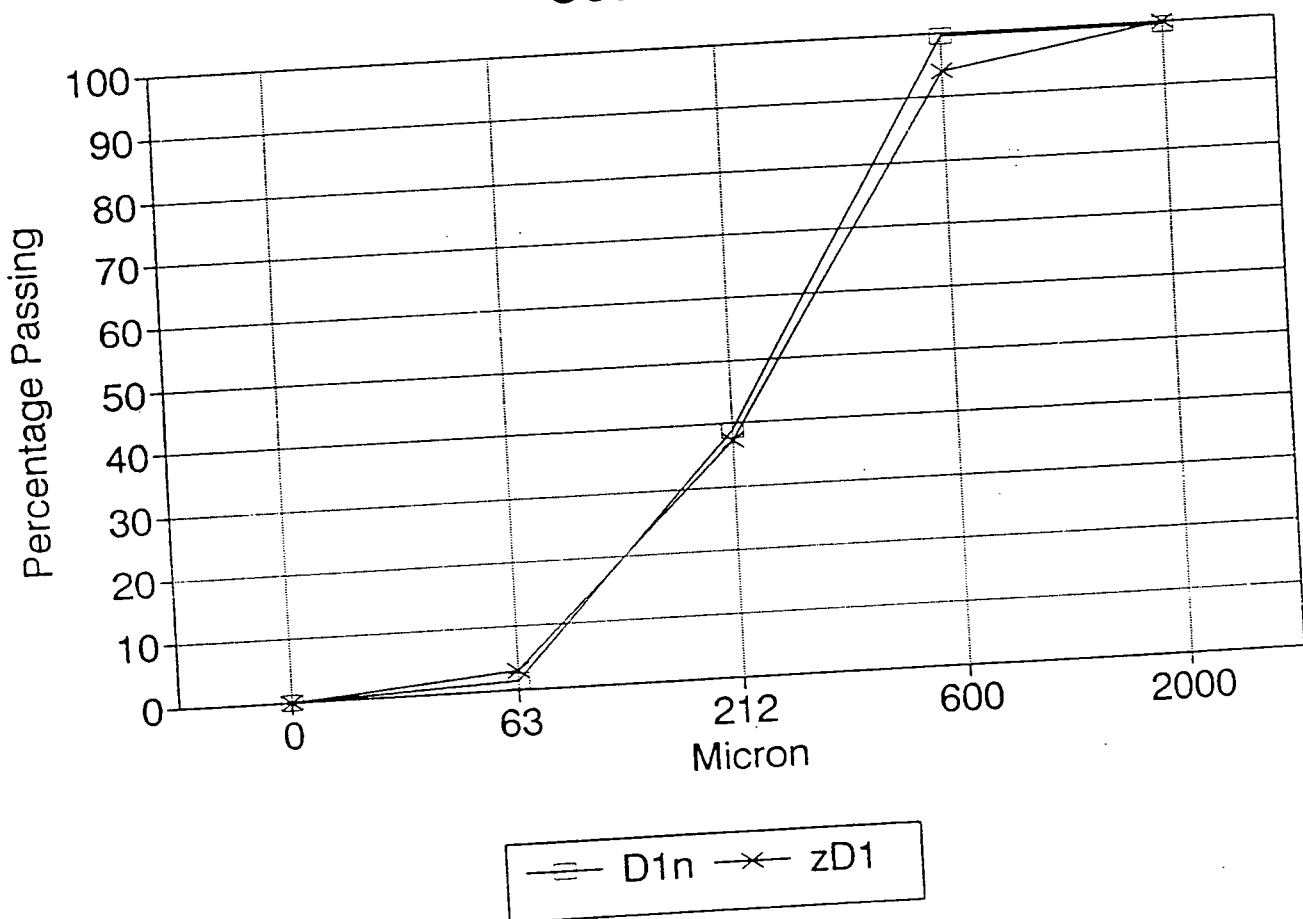
PARTICLE SIZE DISTRIBUTION

Sealsands



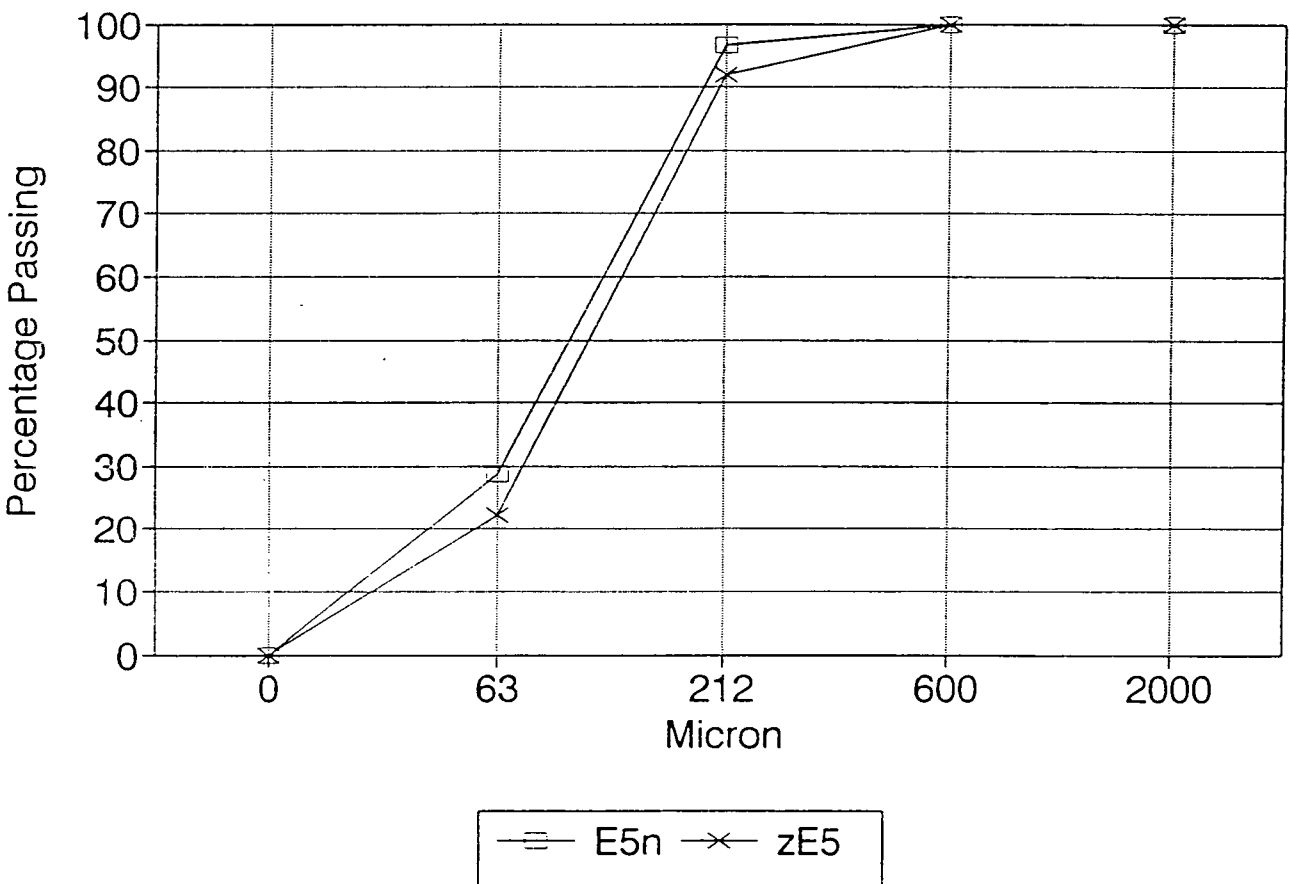
PARTICLE SIZE DISTRIBUTION

Sealsands



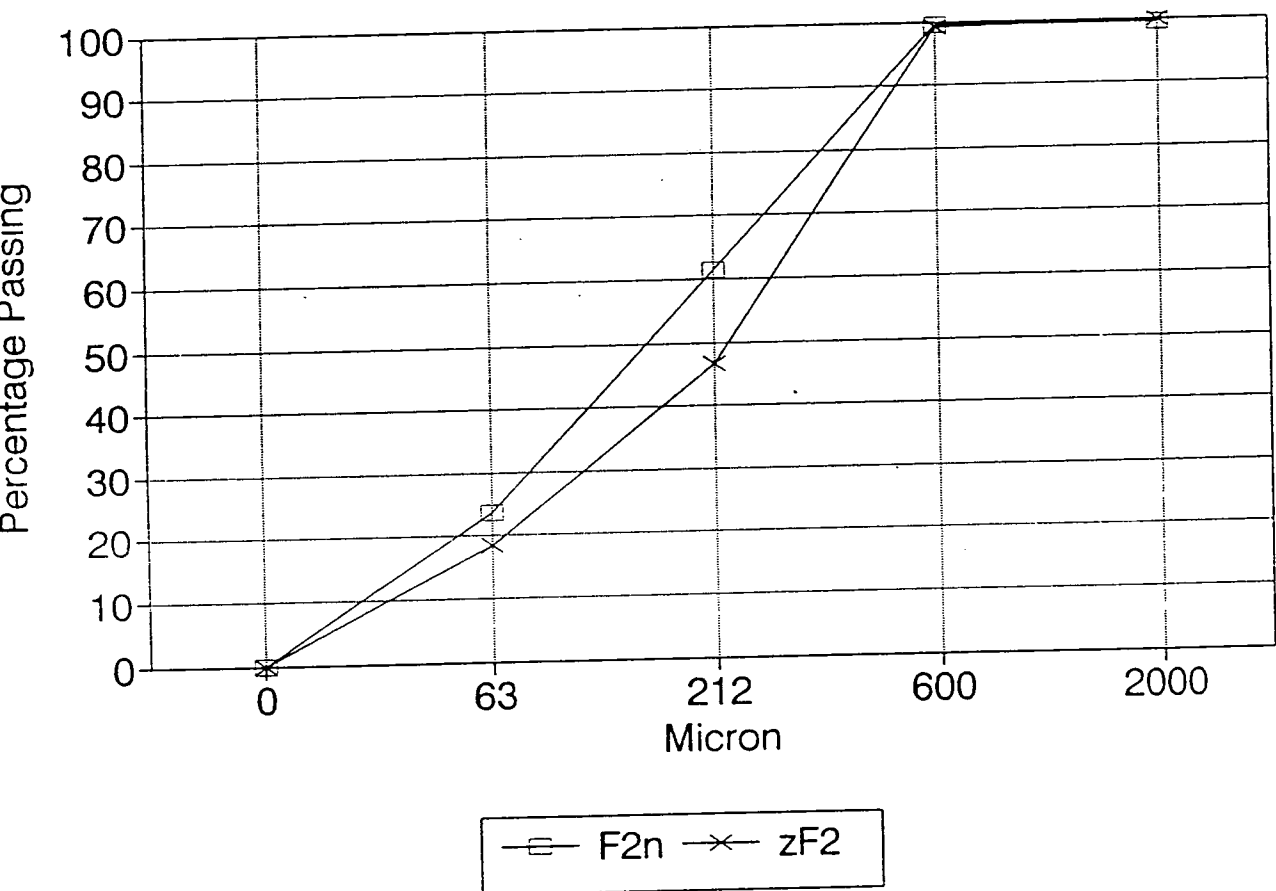
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Sealsands



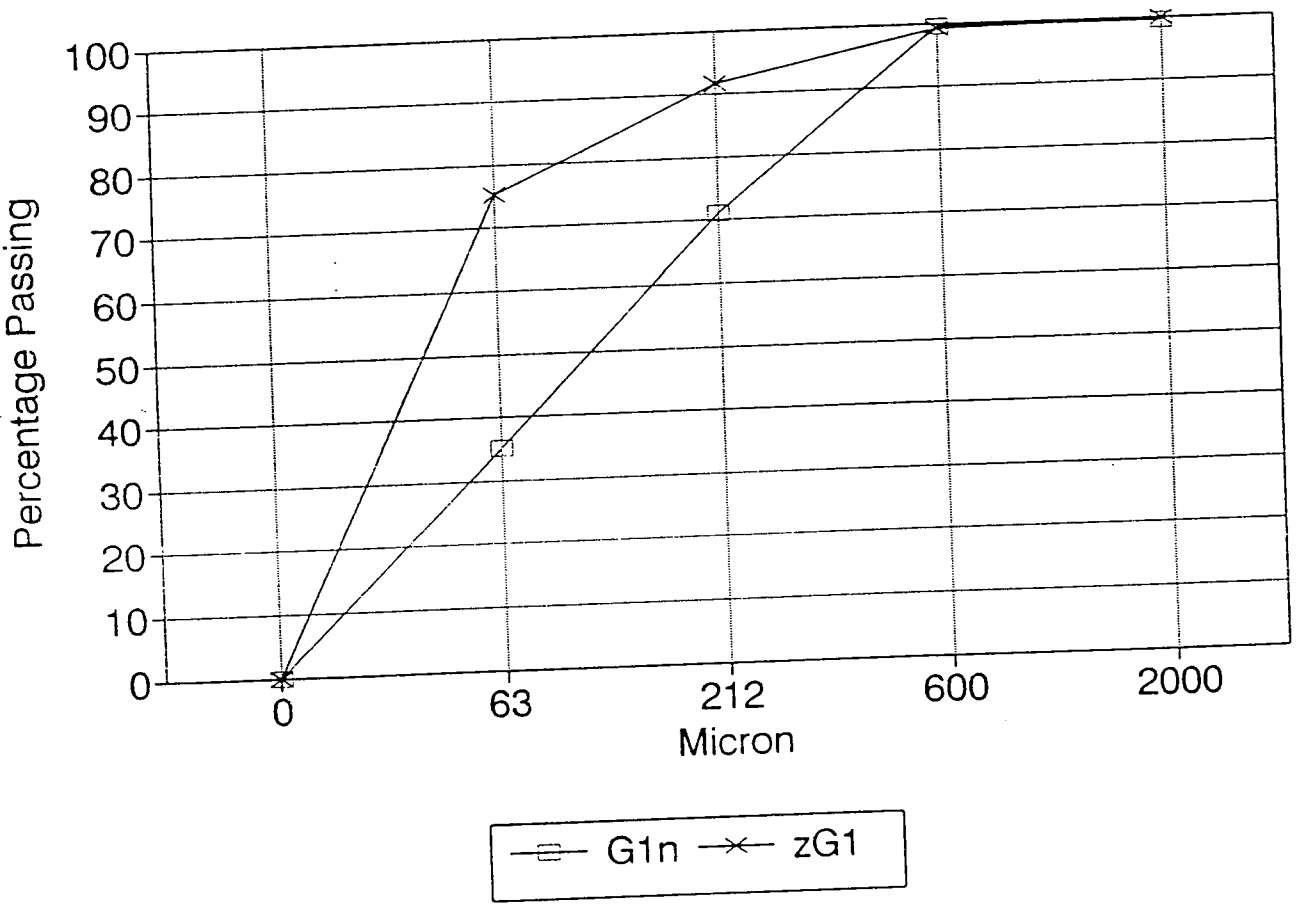
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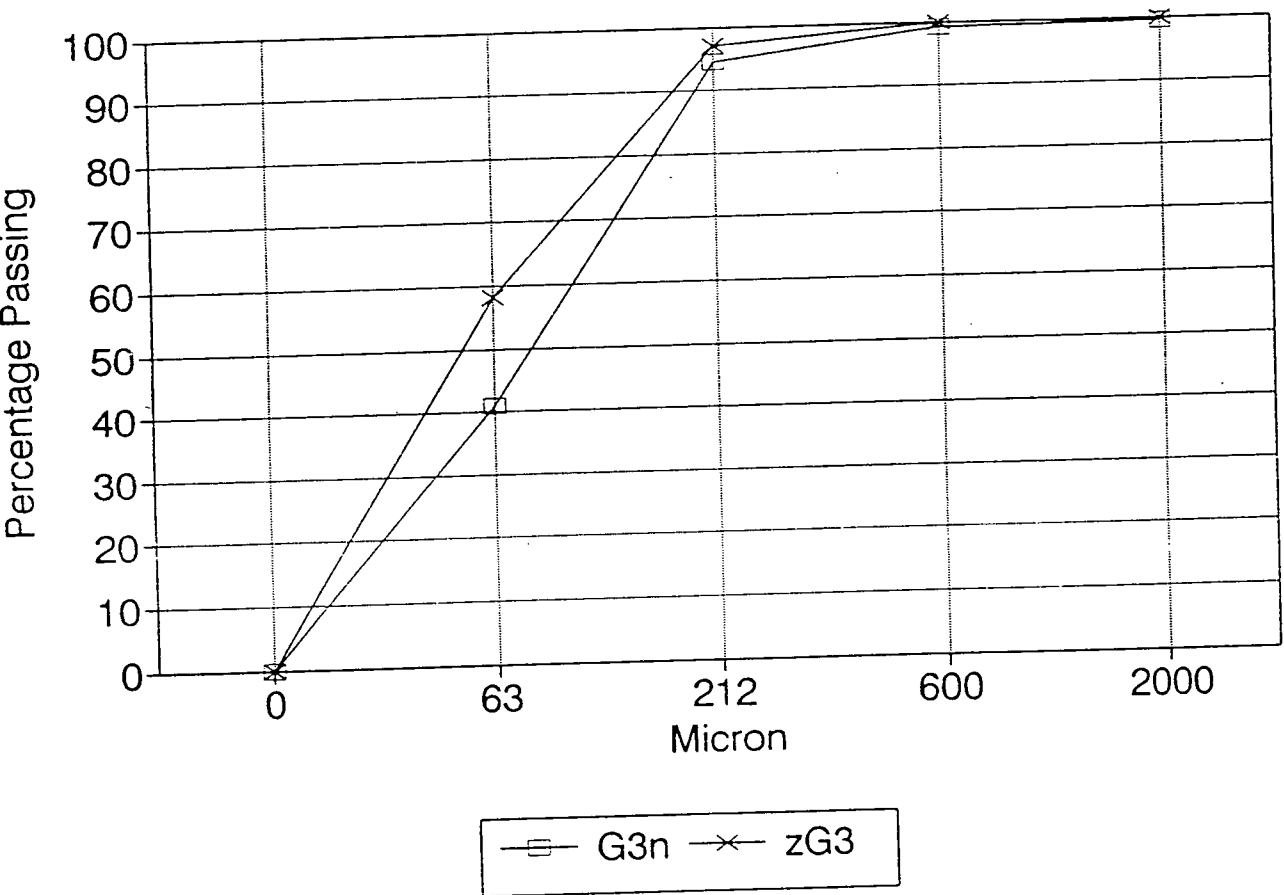
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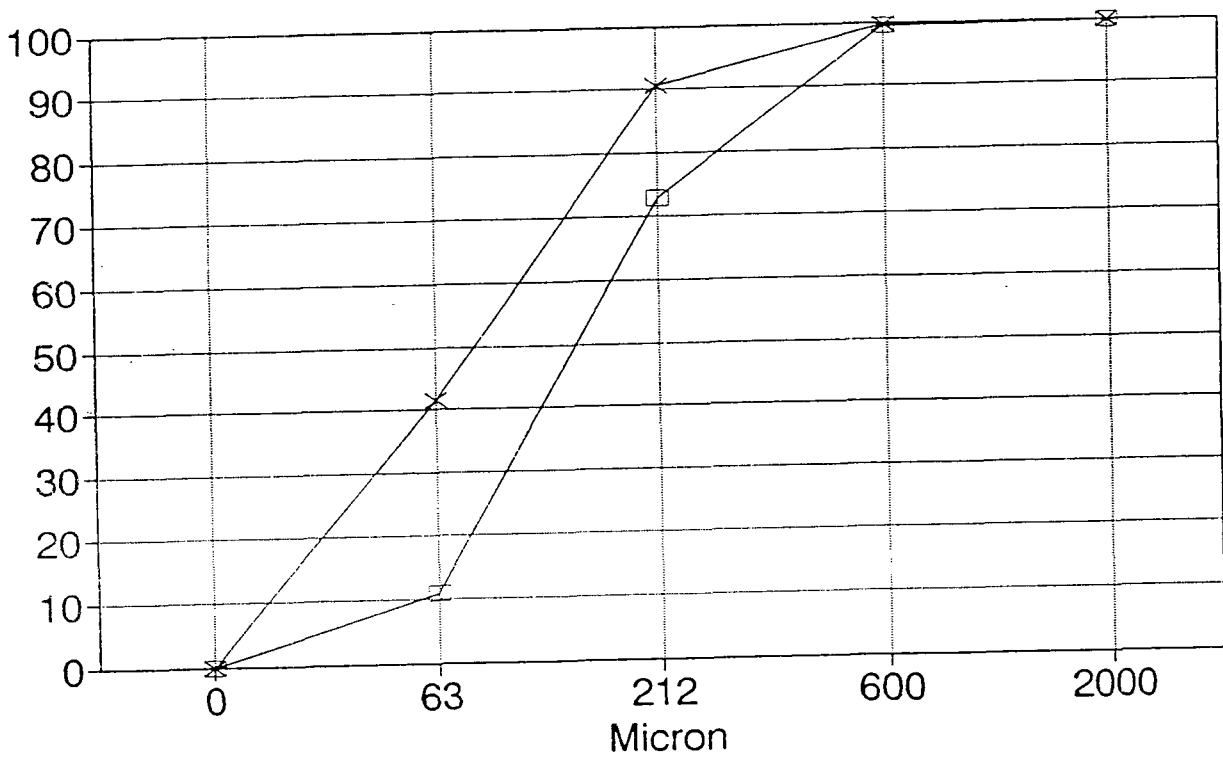
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Sealsands



PARTICLE SIZE DISTRIBUTION

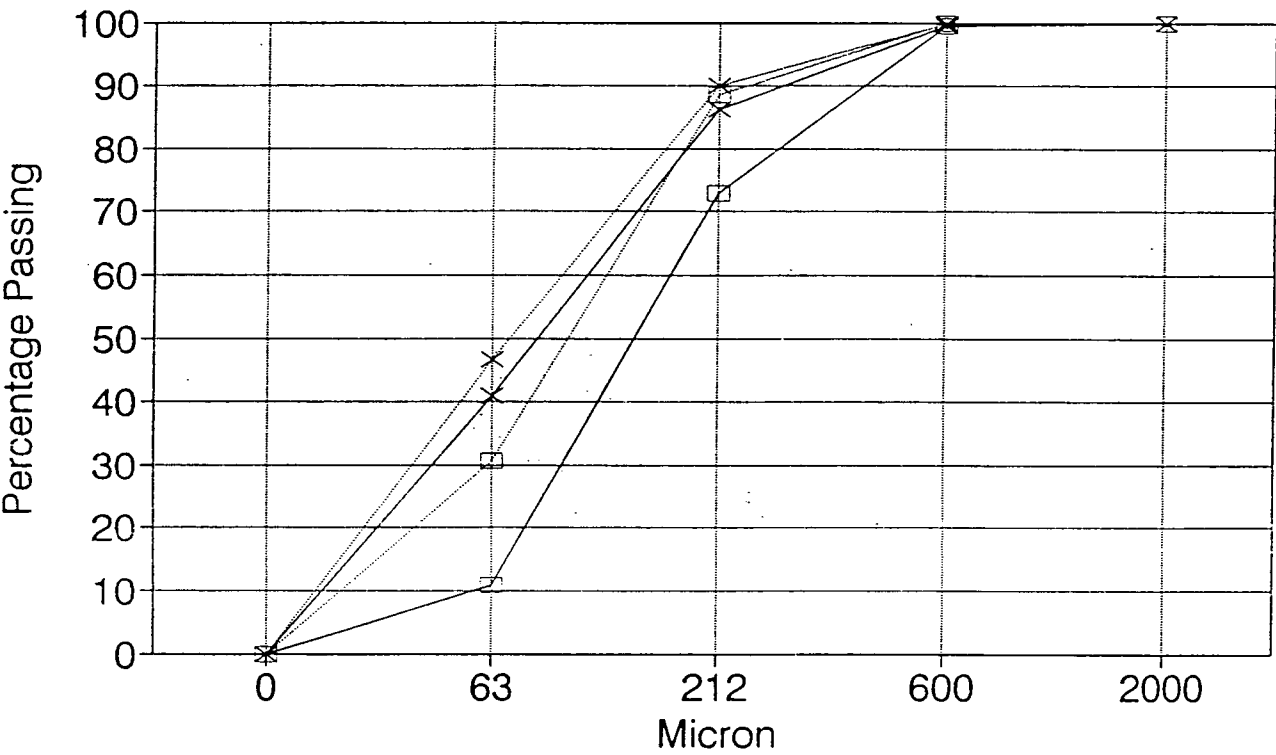
Sealsands



—□— G5n —×— zG5

PARTICLE SIZE DISTRIBUTION

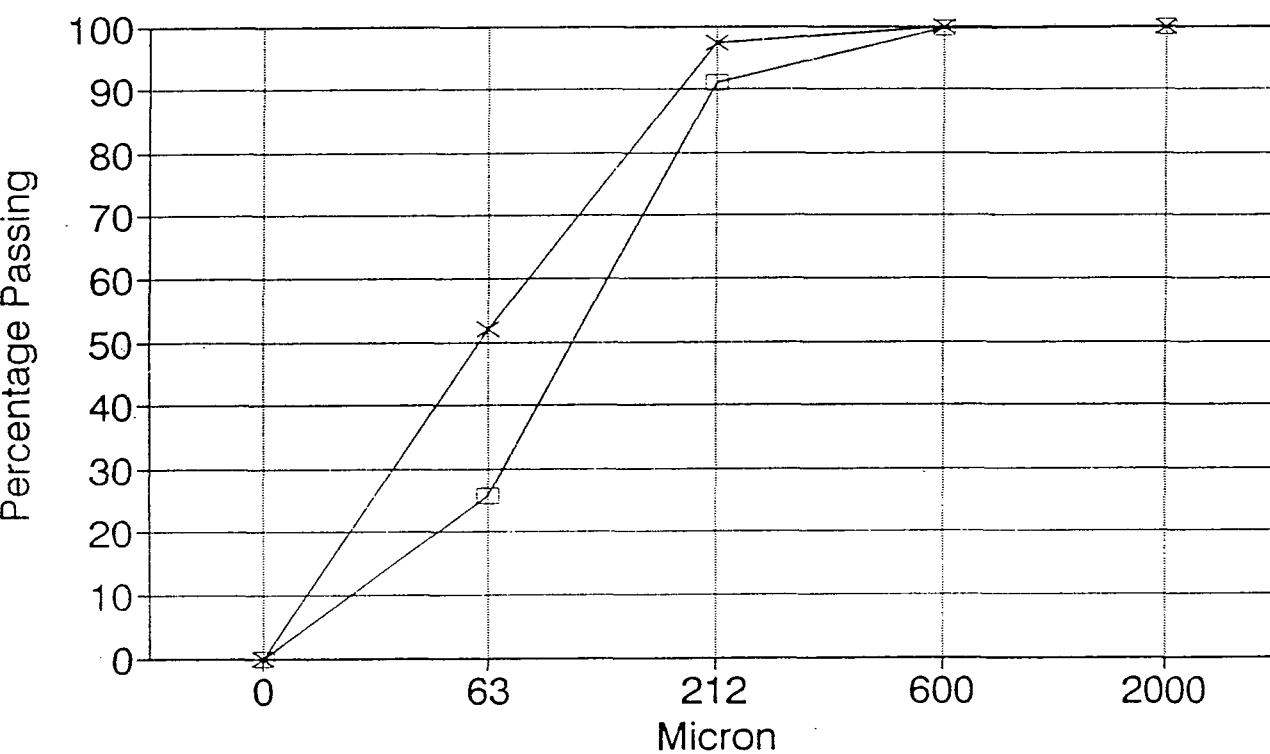
Sealsands



—□— G6n —×— zG6 —□— G6s —×— G6d

PARTICLE SIZE DISTRIBUTION

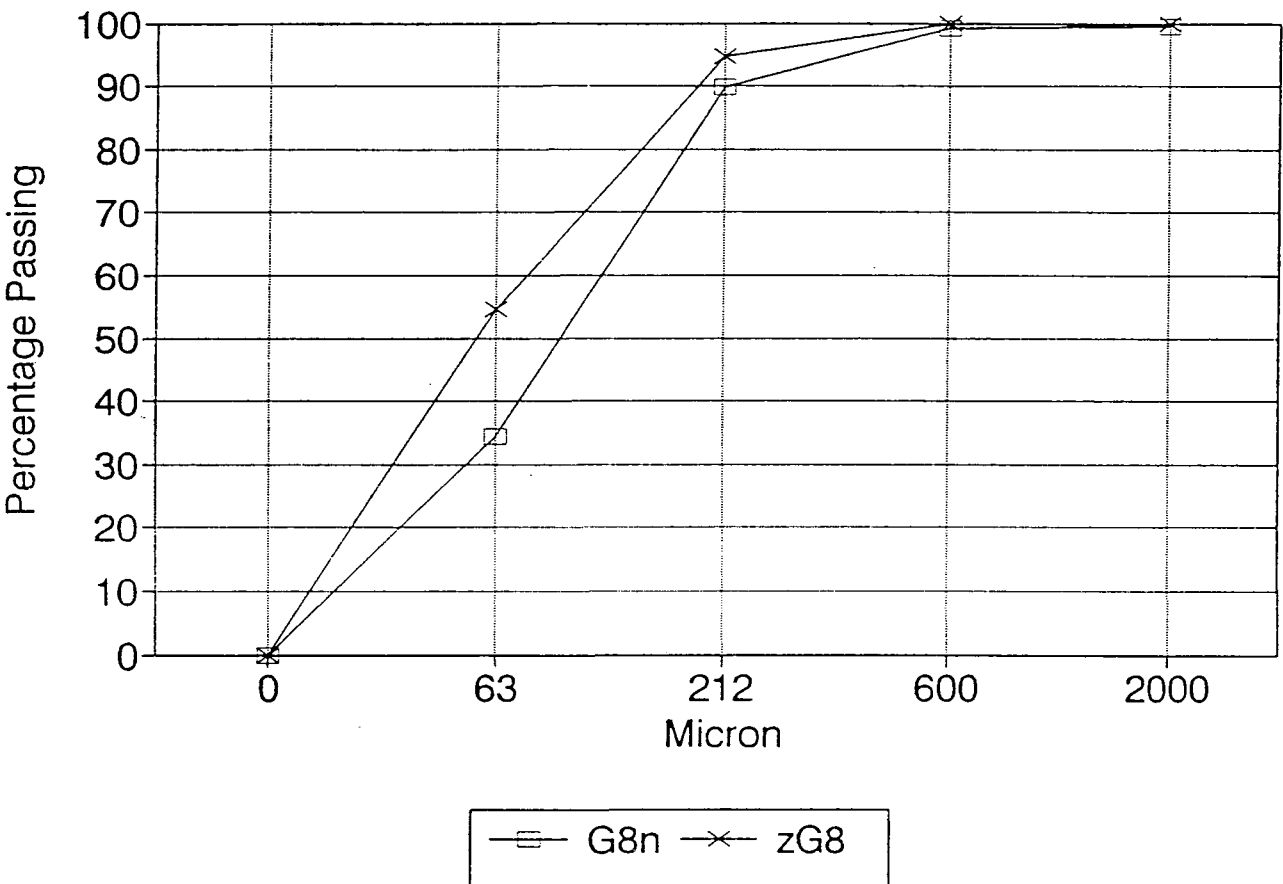
Sealsands



—□— G7n —×— zG7

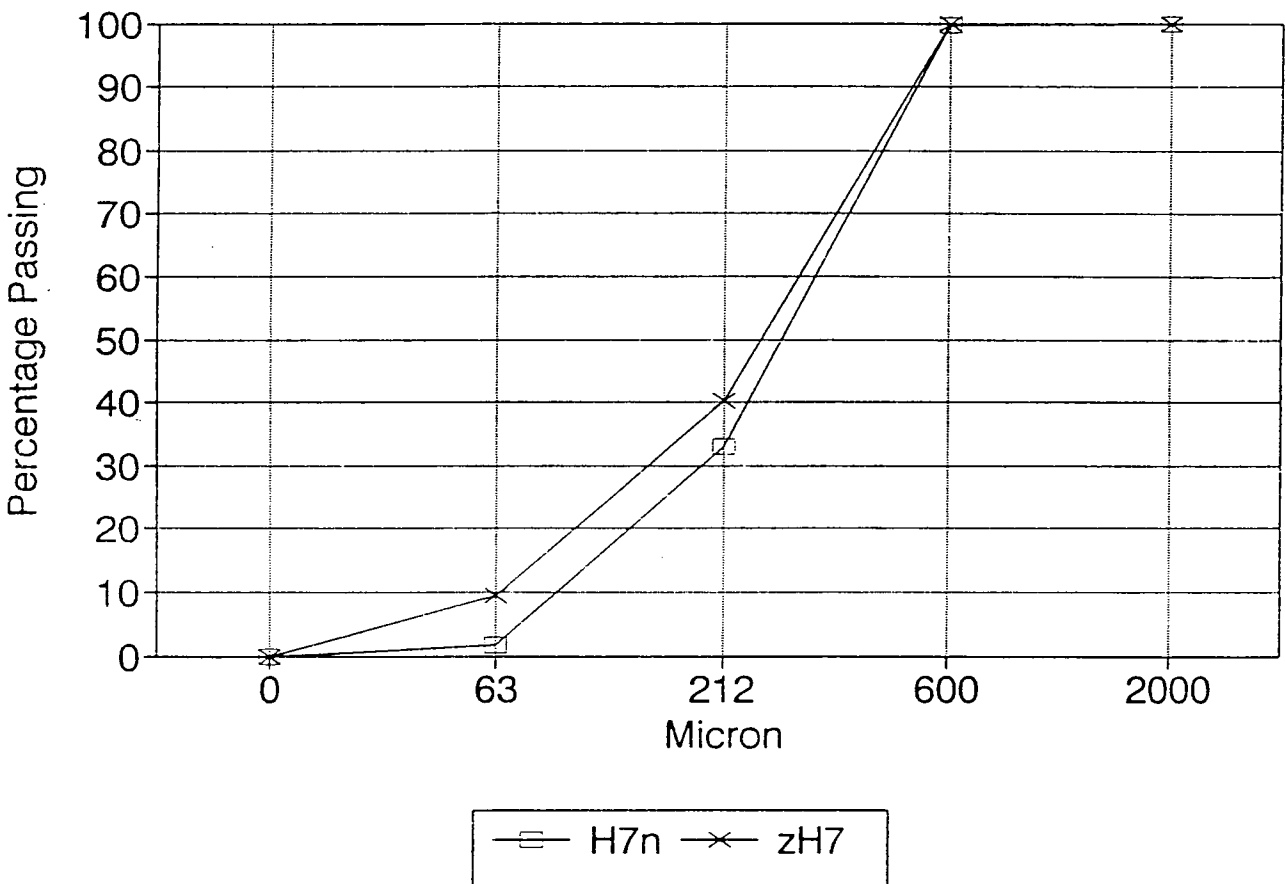
PARTICLE SIZE DISTRIBUTION

Sealsands



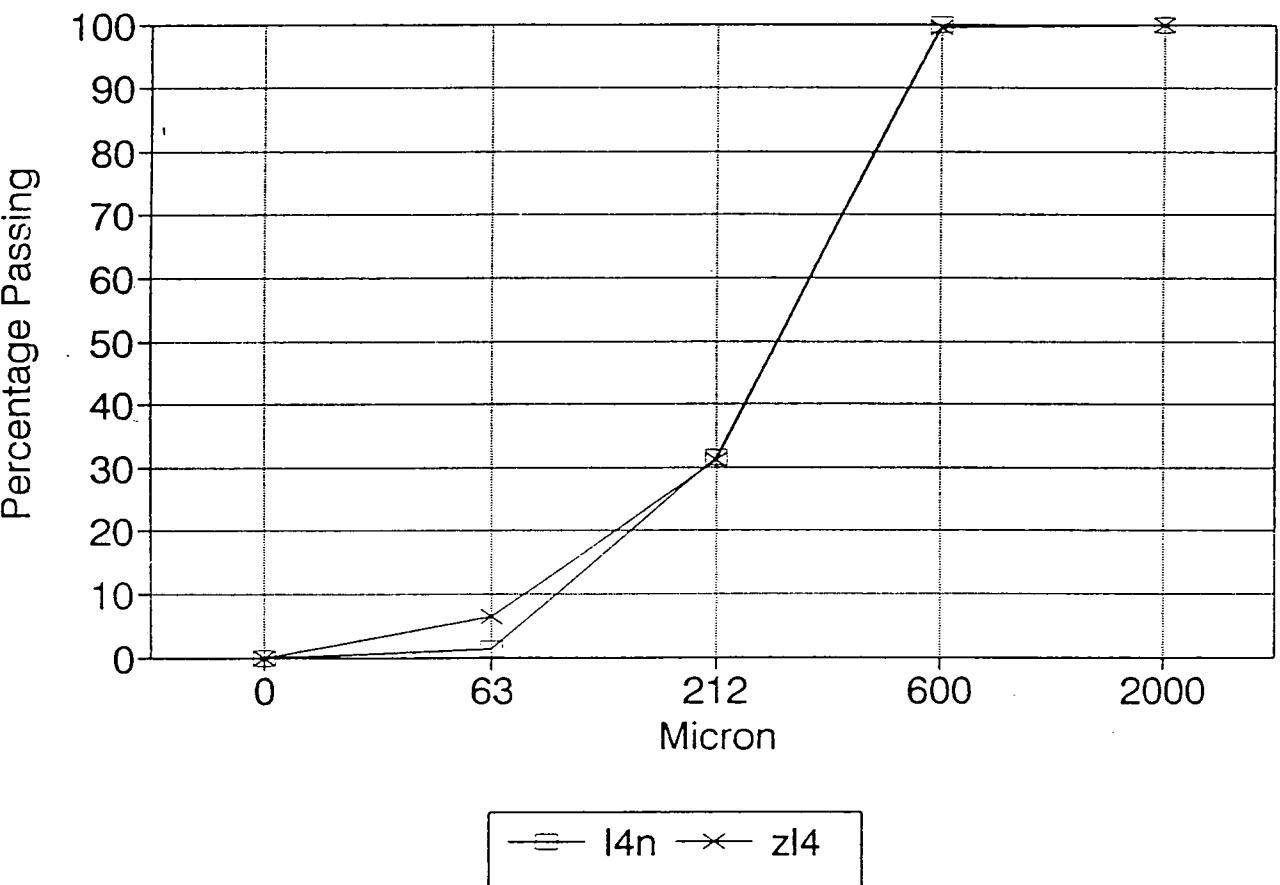
PARTICLE SIZE DISTRIBUTION

Sealsands



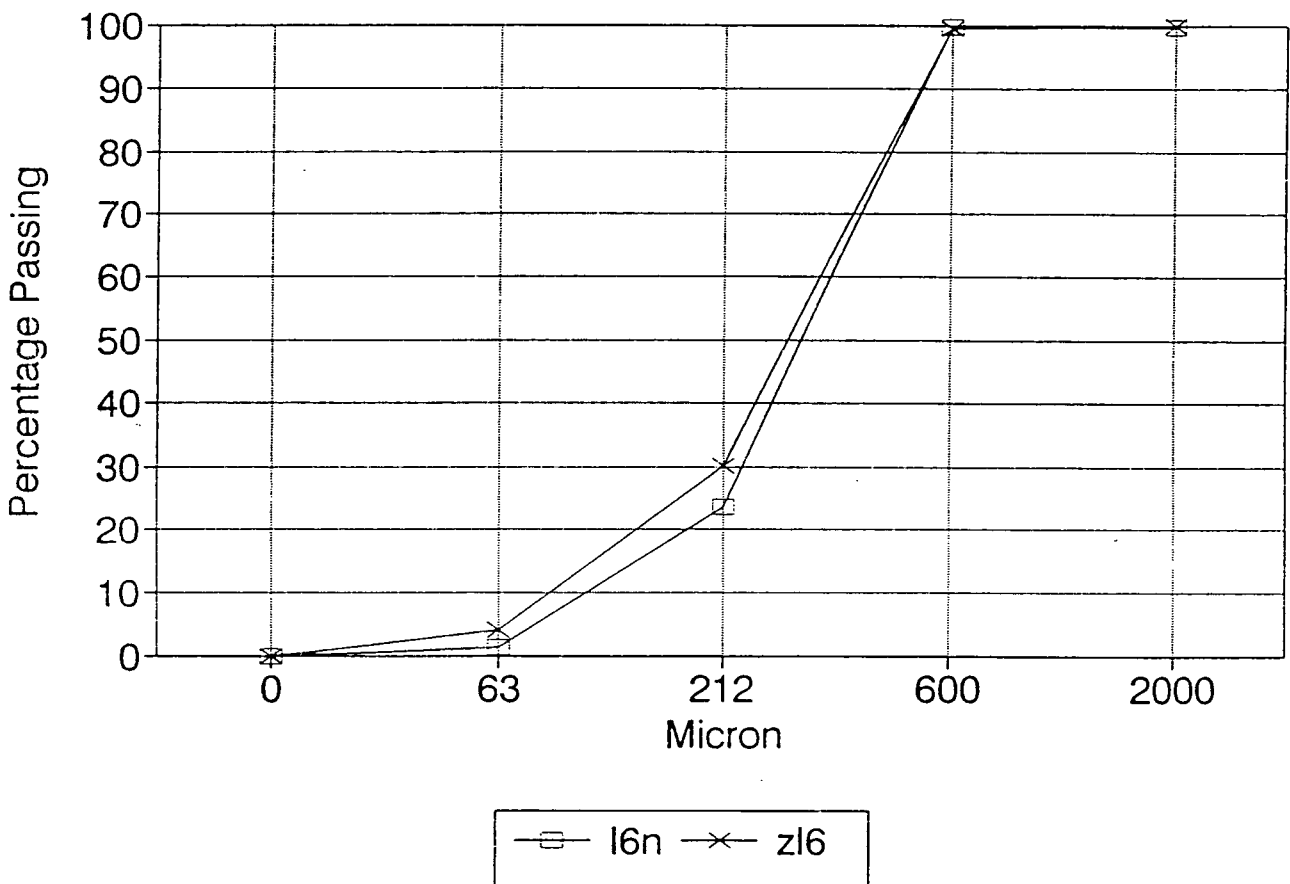
PARTICLE SIZE DISTRIBUTION

Sealsands



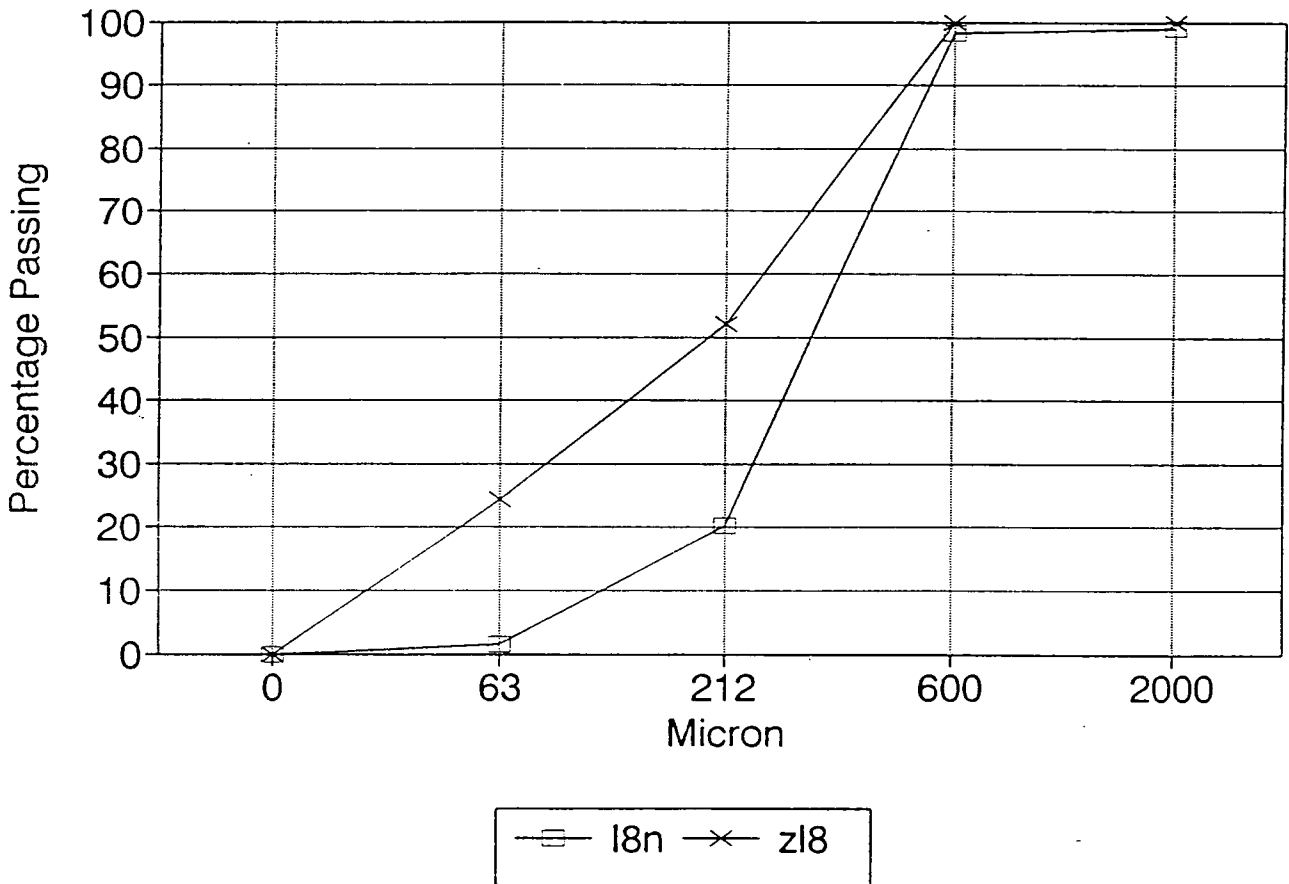
PARTICLE SIZE DISTRIBUTION

Sealsands



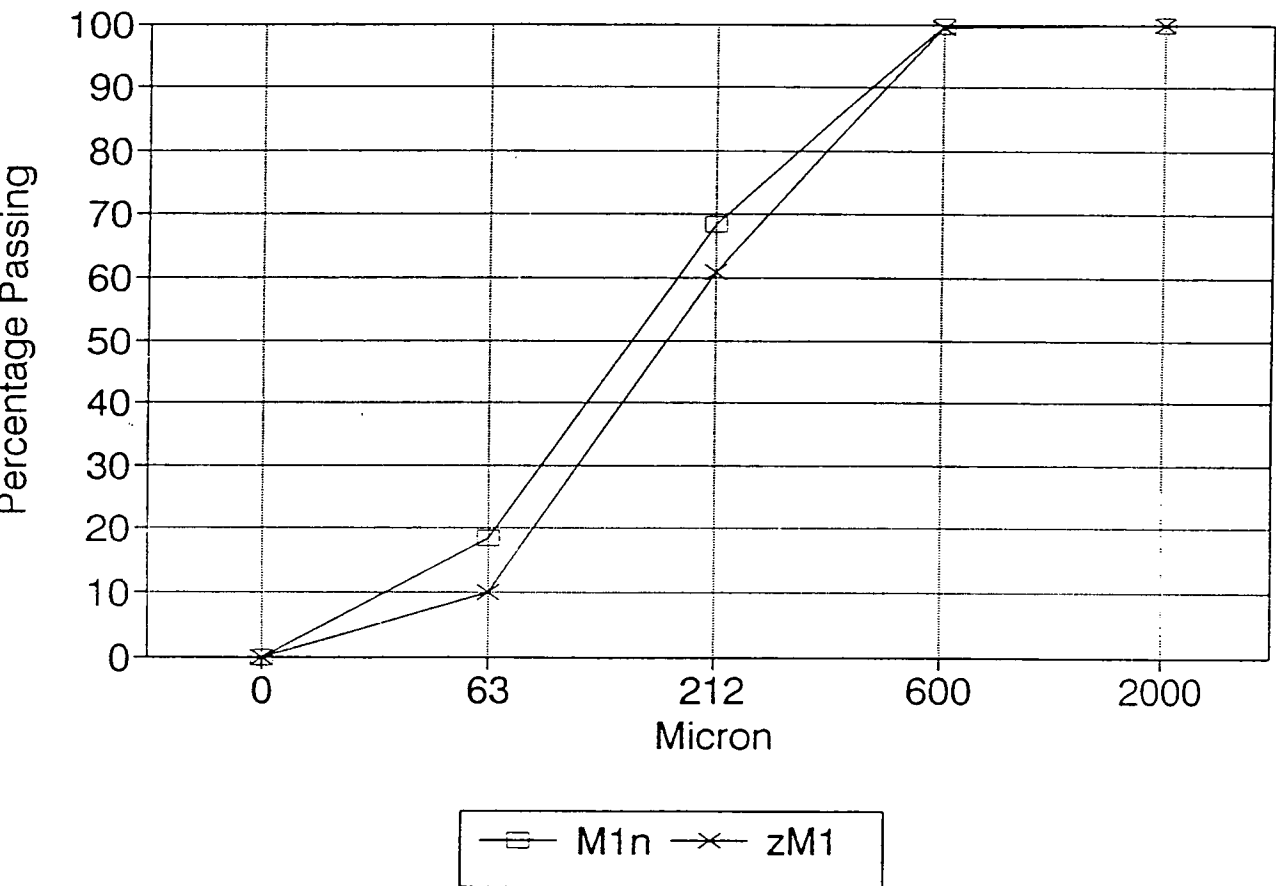
PARTICLE SIZE DISTRIBUTION

Sealsands



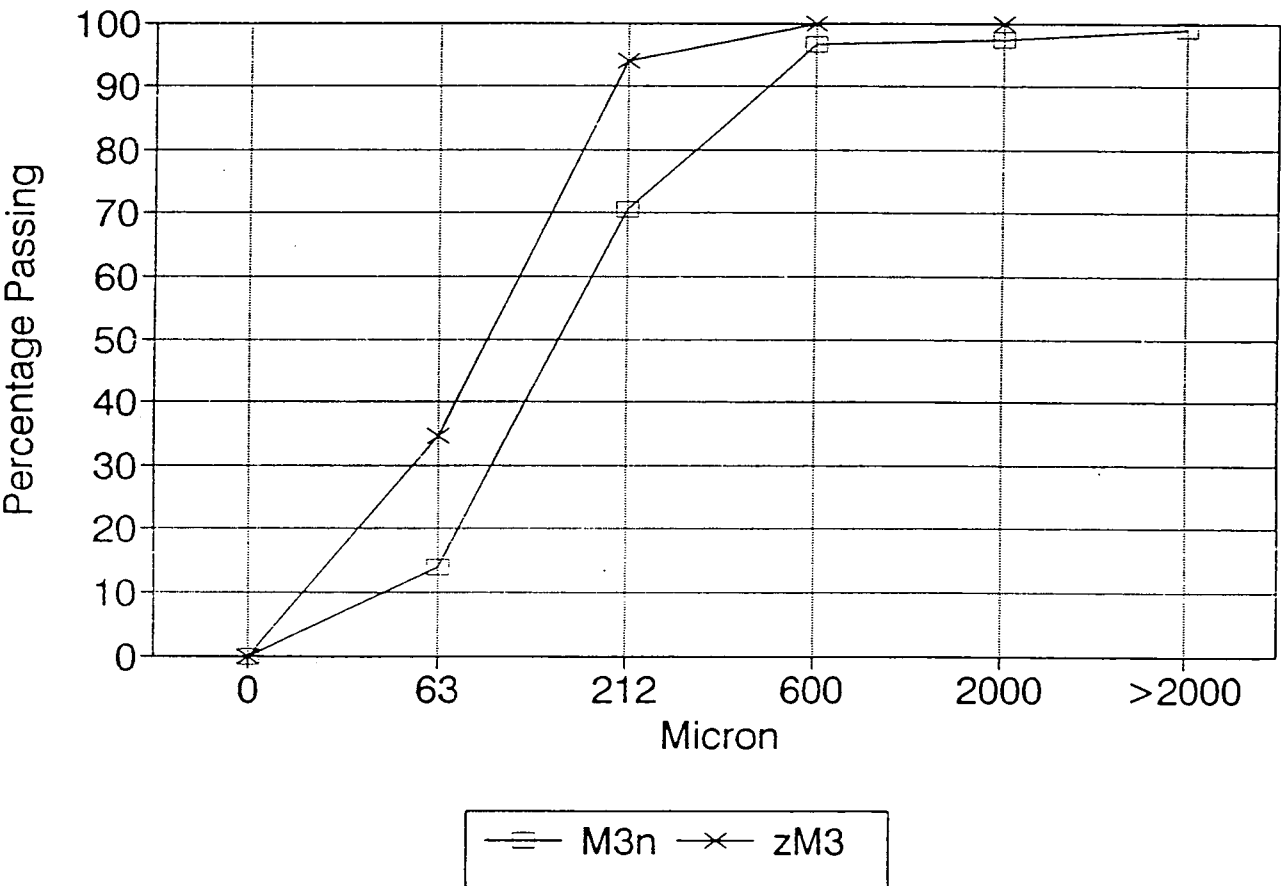
PARTICLE SIZE DISTRIBUTION

Sealsands



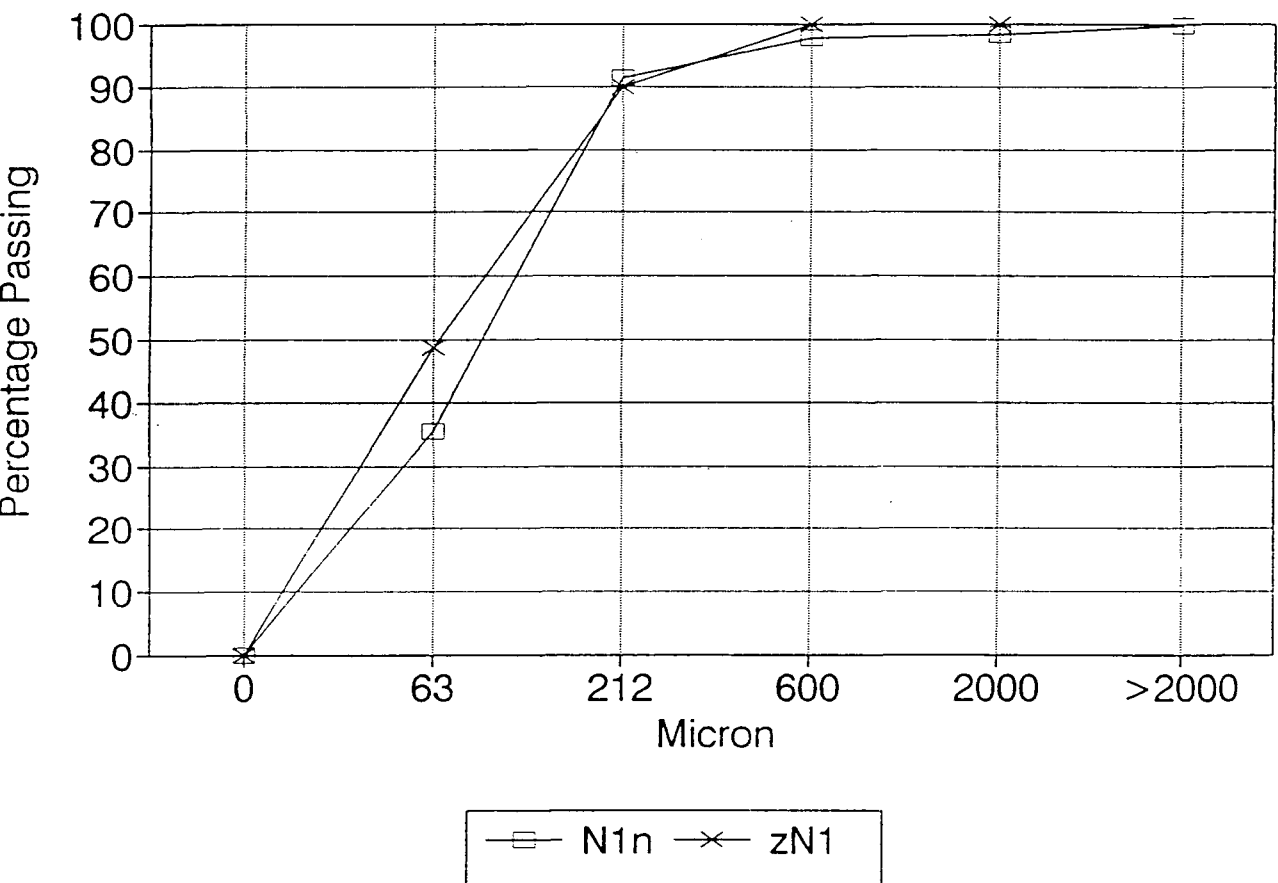
PARTICLE SIZE DISTRIBUTION

Sealsands



PARTICLE SIZE DISTRIBUTION

Sealsands



PARTICLE SIZE DISTRIBUTION

Sealsands

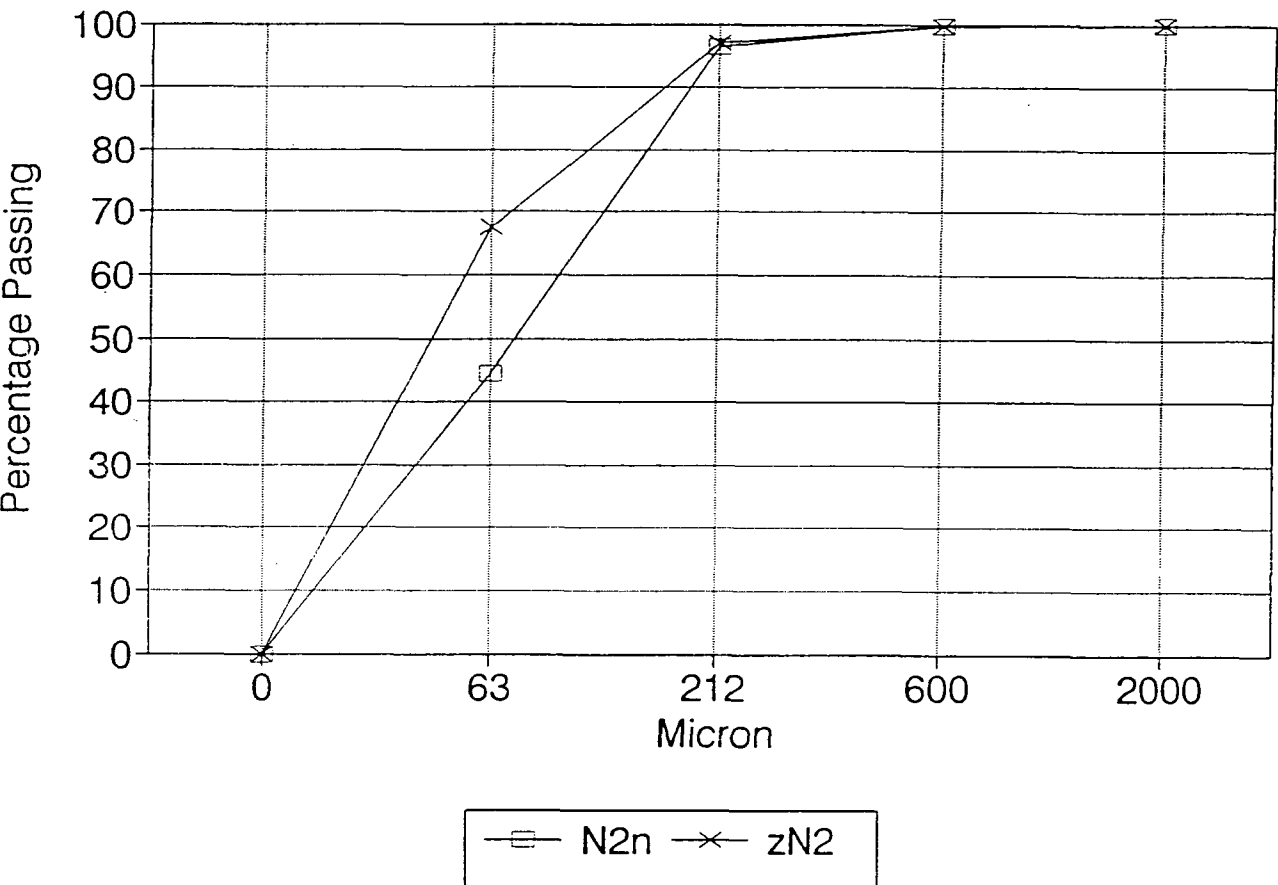


Figure 3.6 a-m Third resampling of the tidal sediments over Seal Sands.

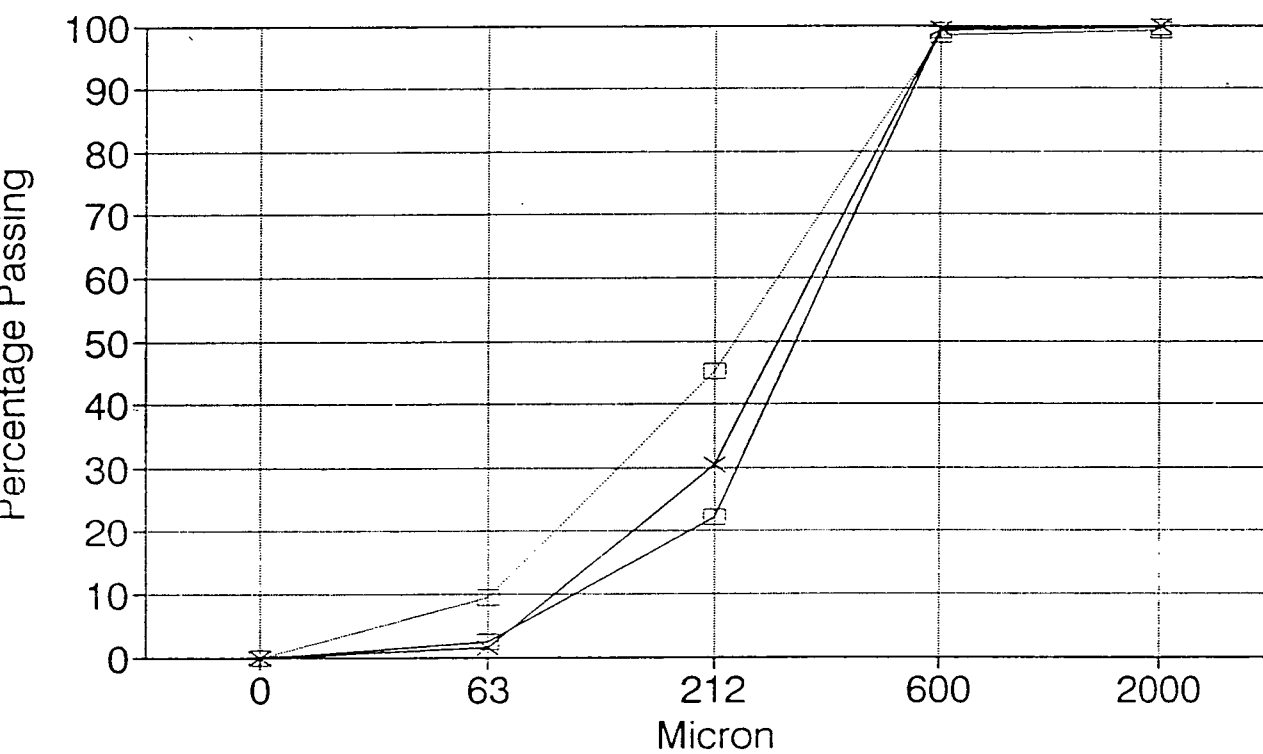
nn = second resampling

n = first resampling

z = Dr Zongs' particle size analysis (Donoghue & Zong 1992).

PARTICLE SIZE DISTRIBUTION

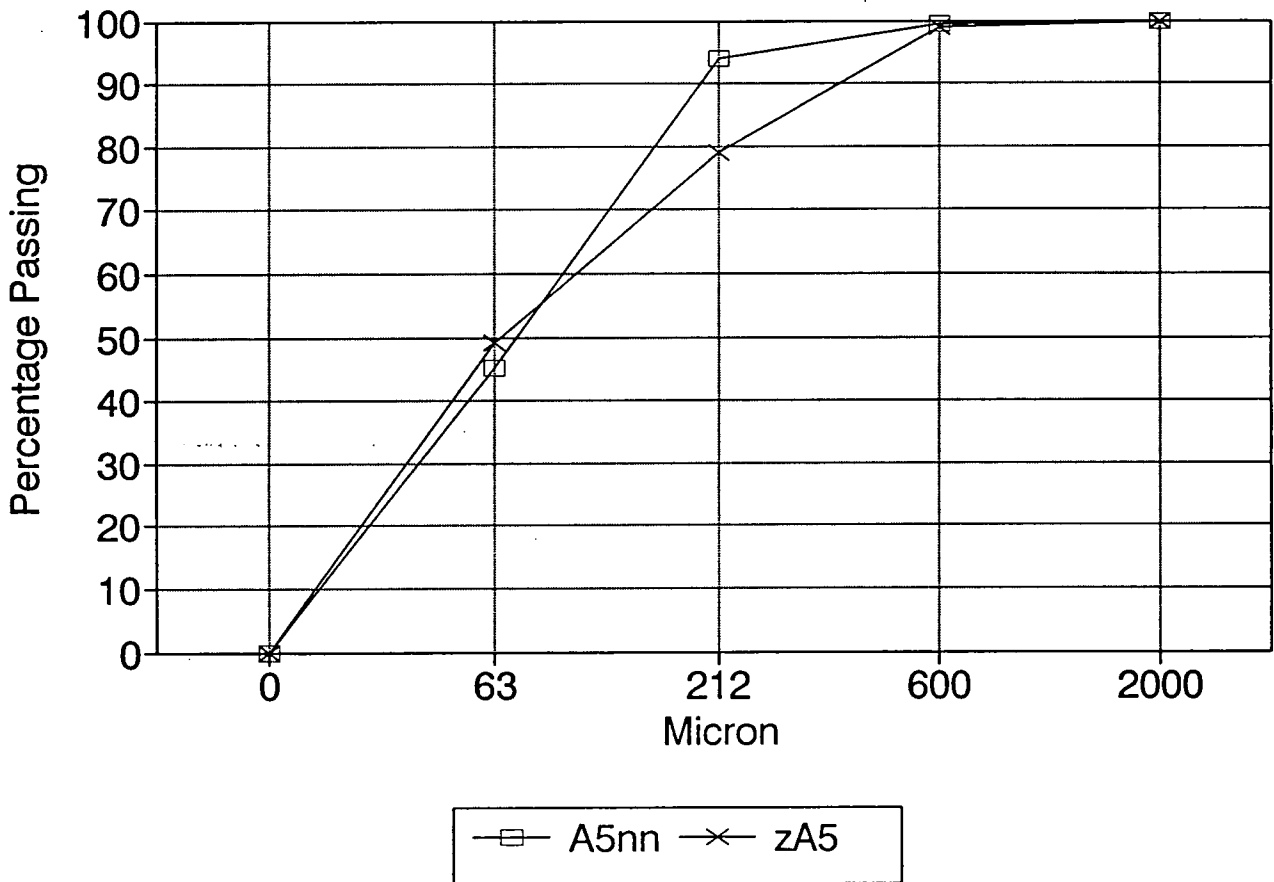
Sealsands



—□— A4nn —×— A4n —○— zA4

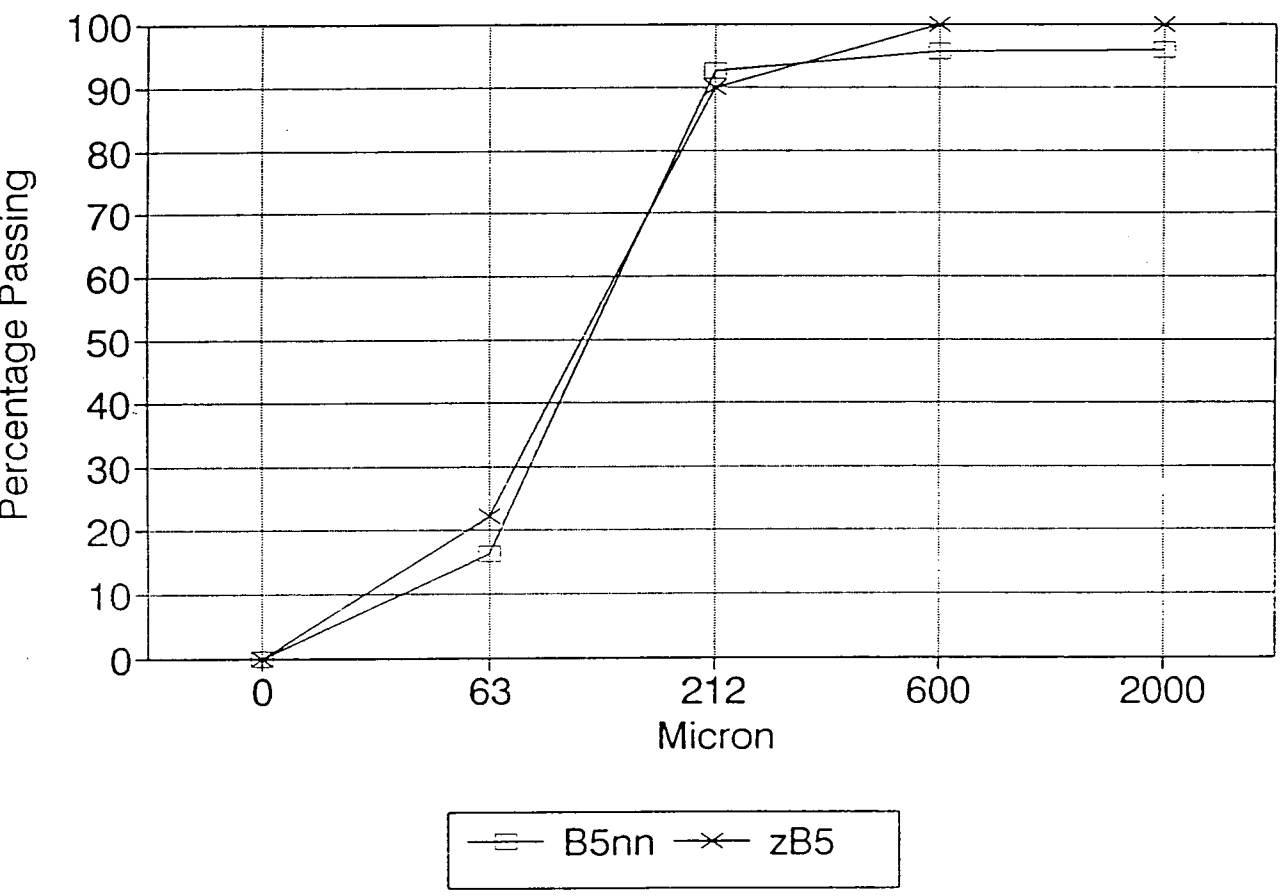
Particle Size Distribution

Sealsands



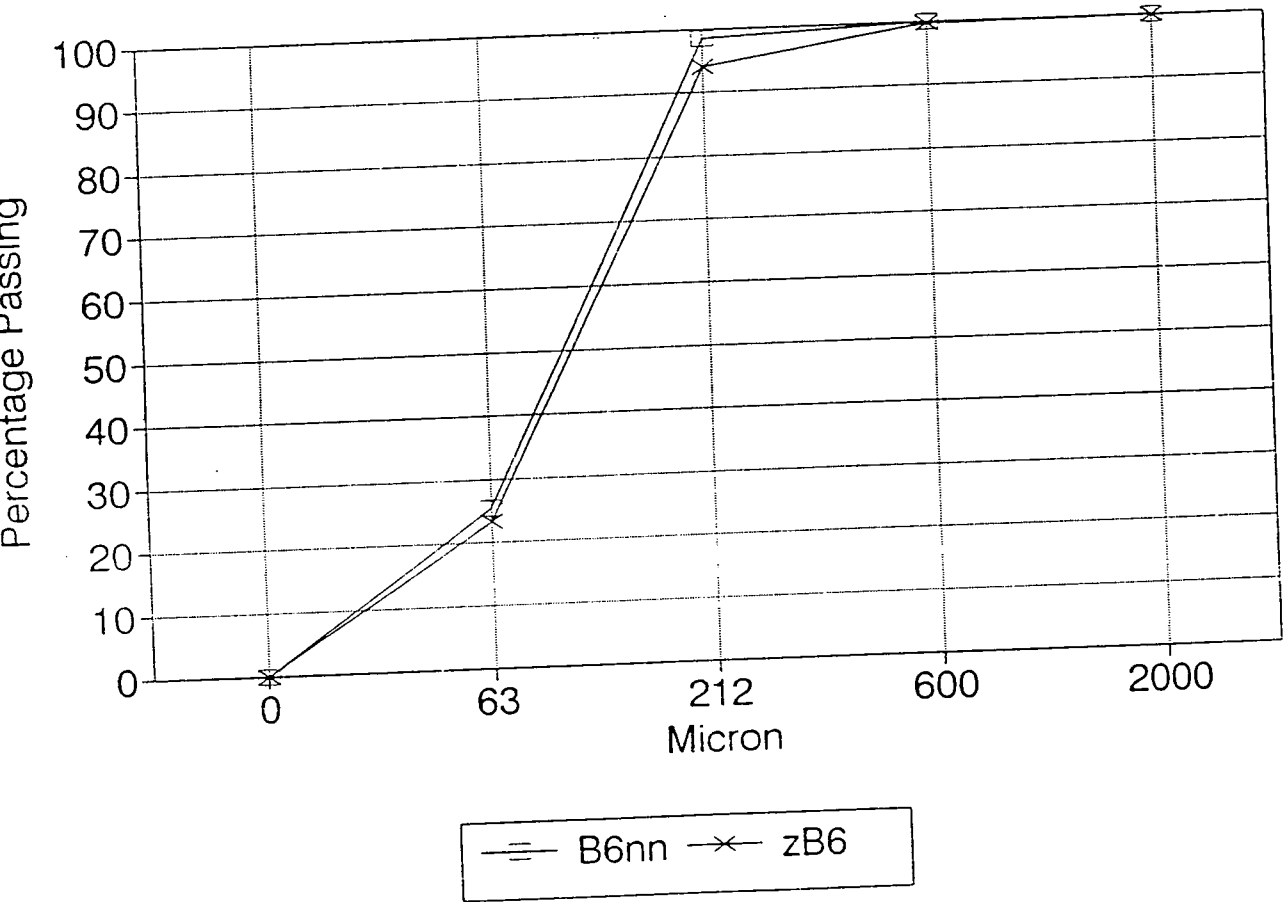
PARTICLE SIZE DISTRIBUTION

Sealsands



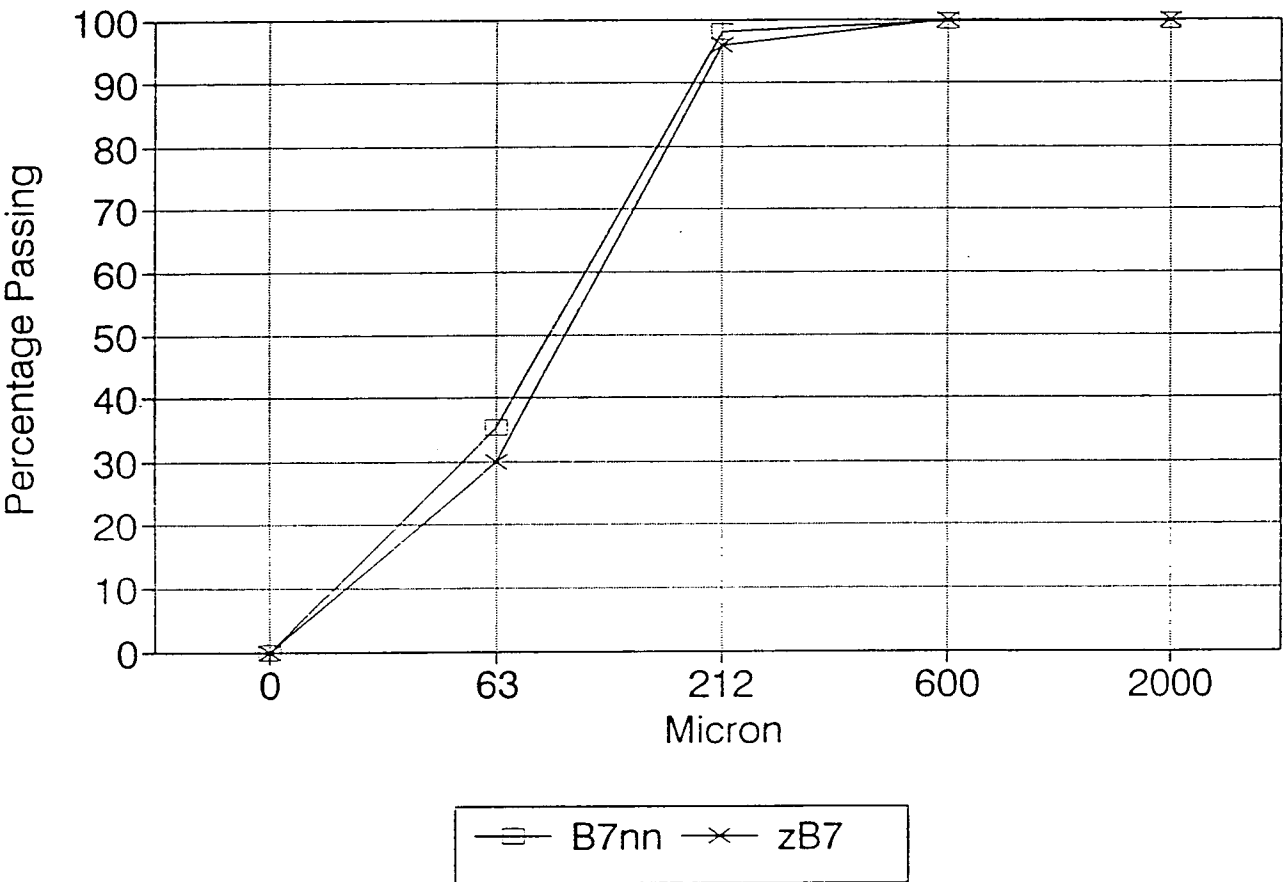
PARTICLE SIZE DISTRIBUTION

Sealsands



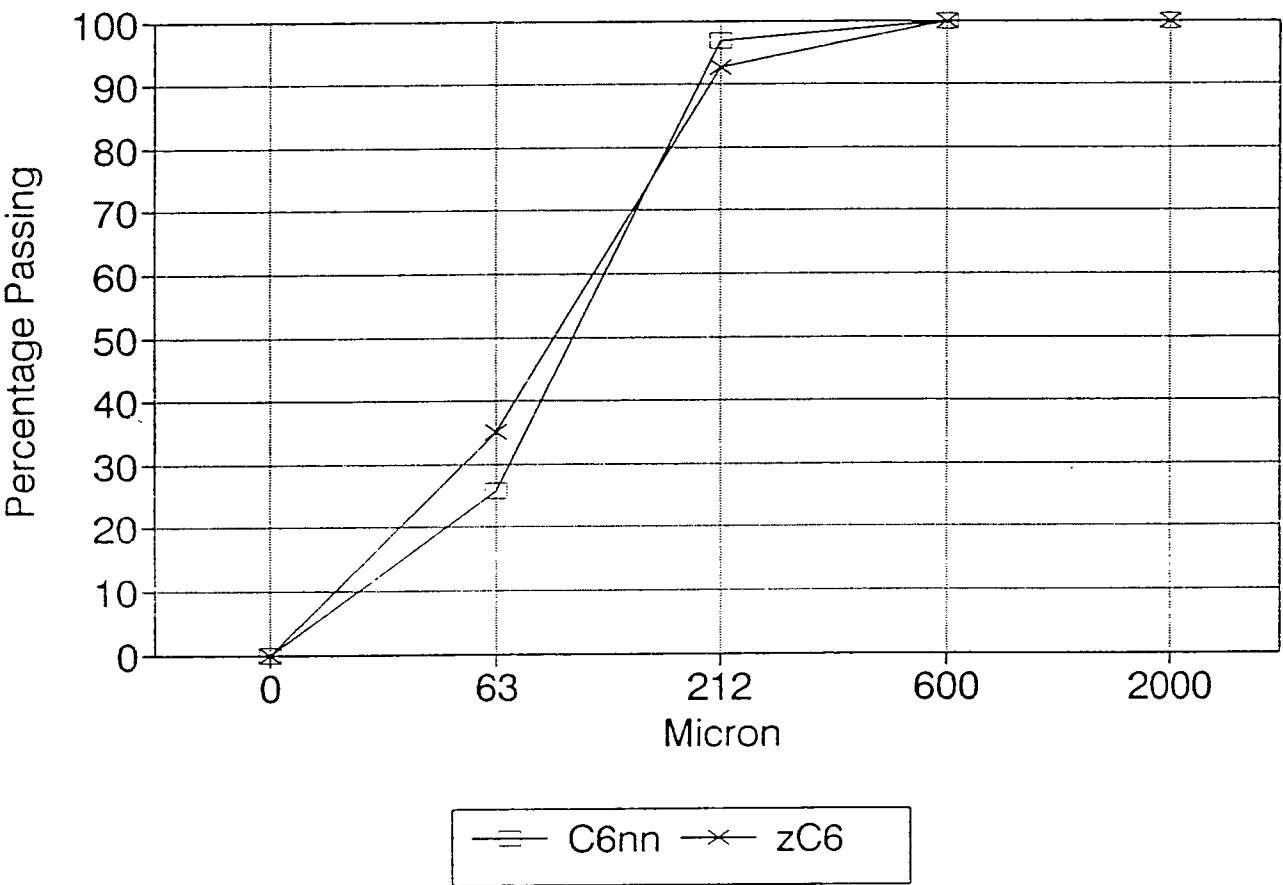
PARTICLE SIZE DISTRIBUTION

Sealsands



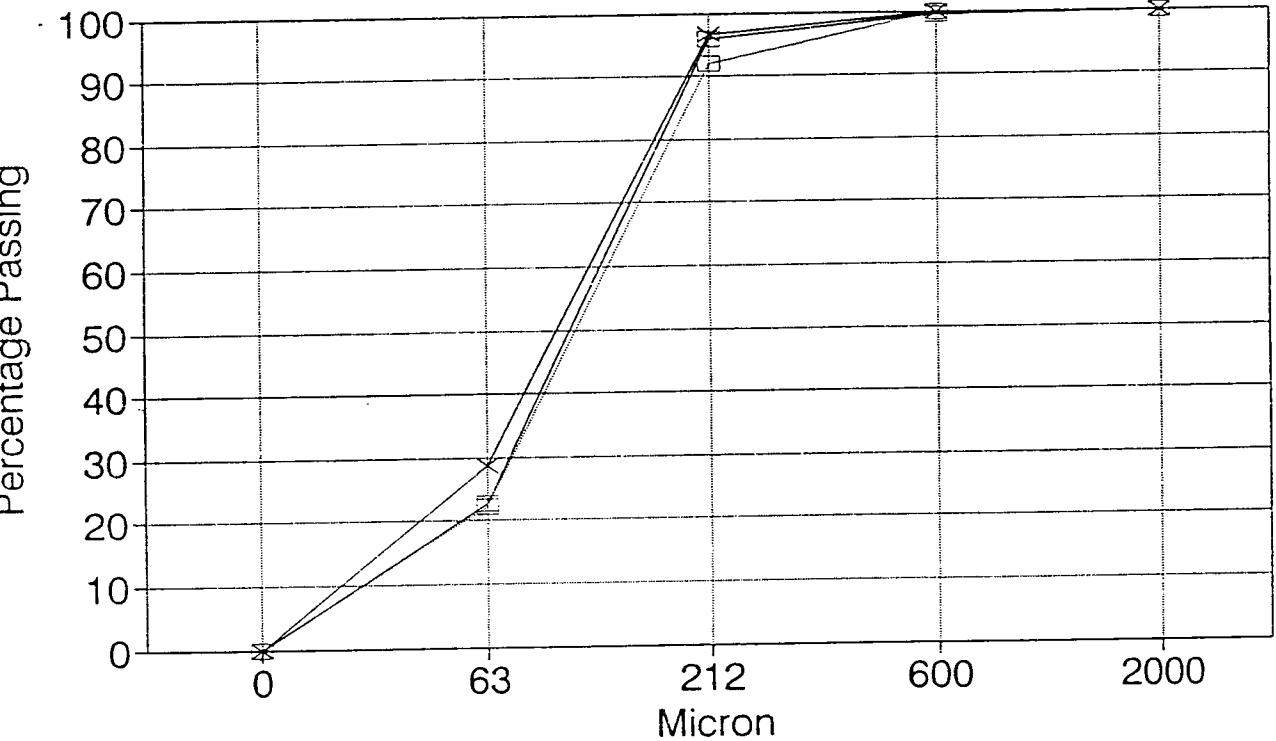
PARTICLE SIZE DISTRIBUTION

Sealsands



PARTICLE SIZE DISTRIBUTION

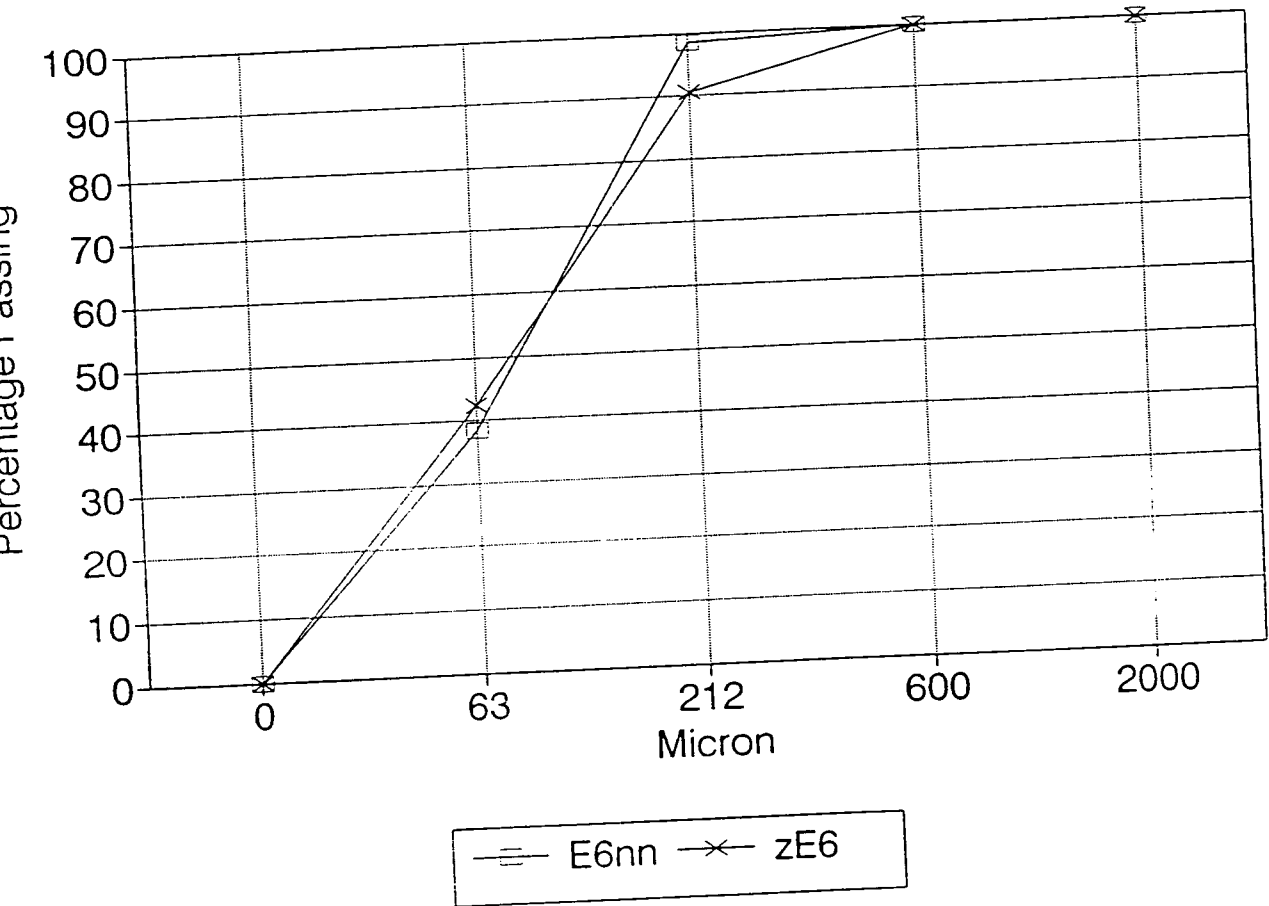
Sealsands



—□— E5nn —×— E5n —○— zE5

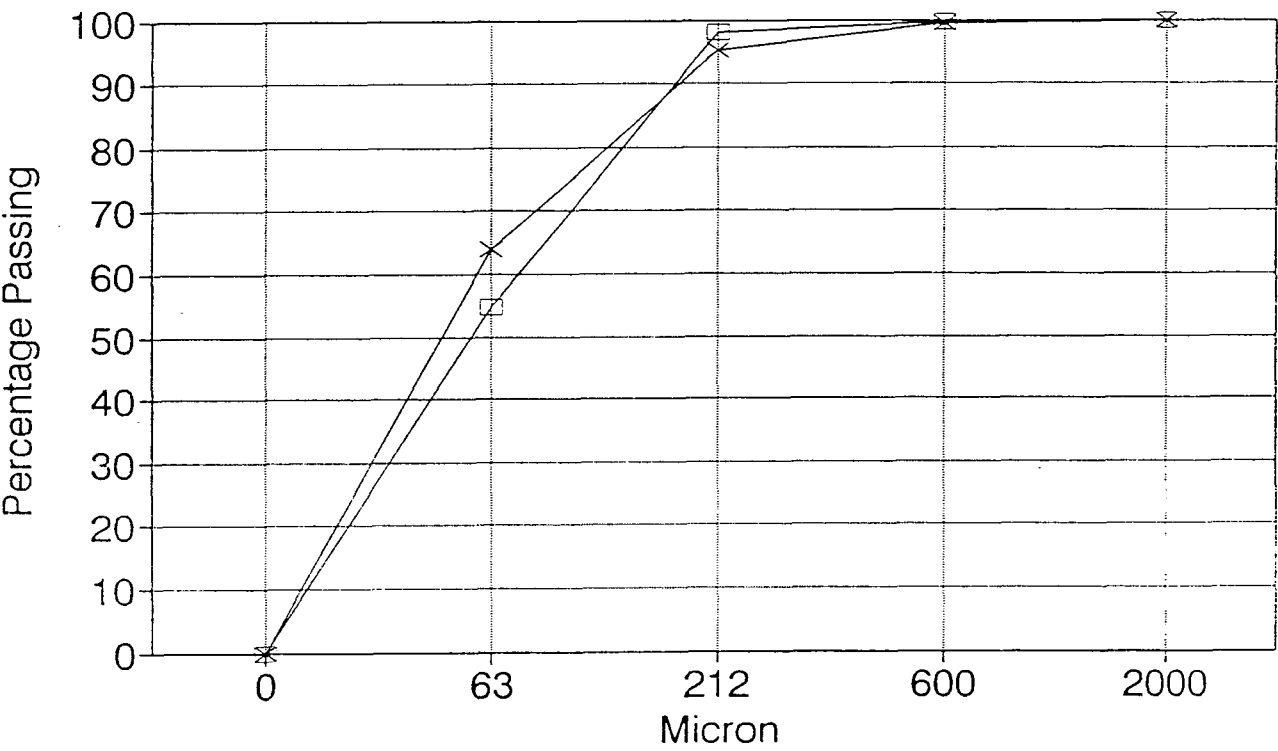
PARTICLE SIZE DISTRIBUTION

Sealsands



PARTICLE SIZE DISTRIBUTION

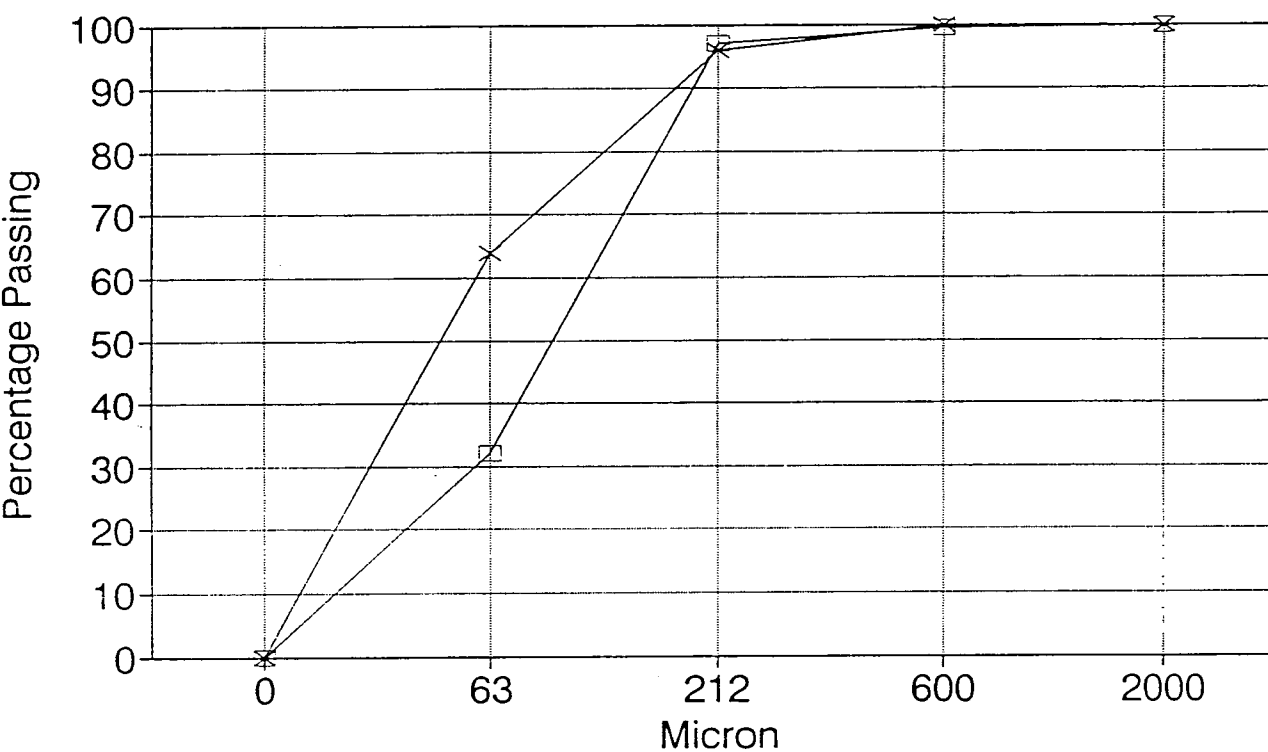
Sealsands



—□— E7nn —×— zE7

PARTICLE SIZE DISTRIBUTION

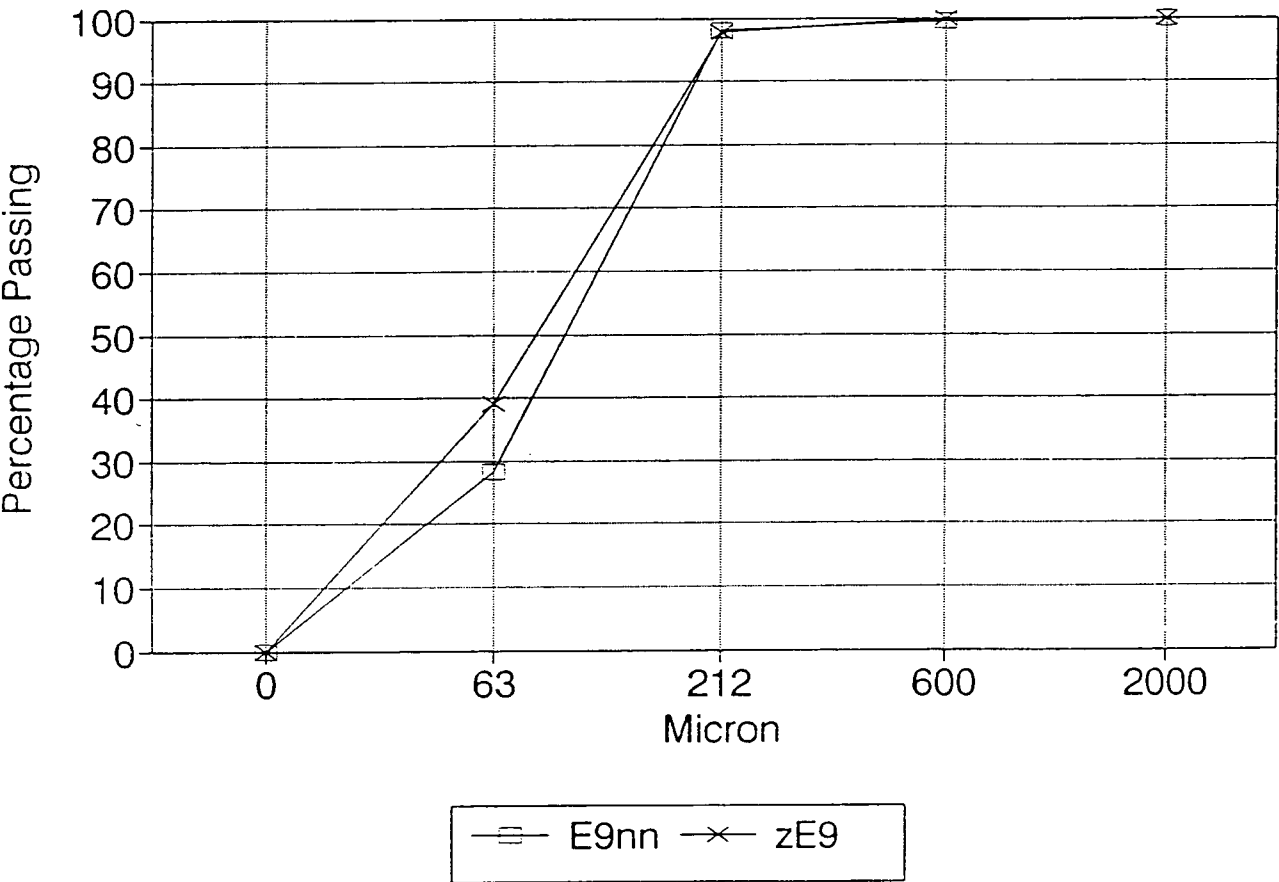
Sealsands



—□— E8nn —×— zE8

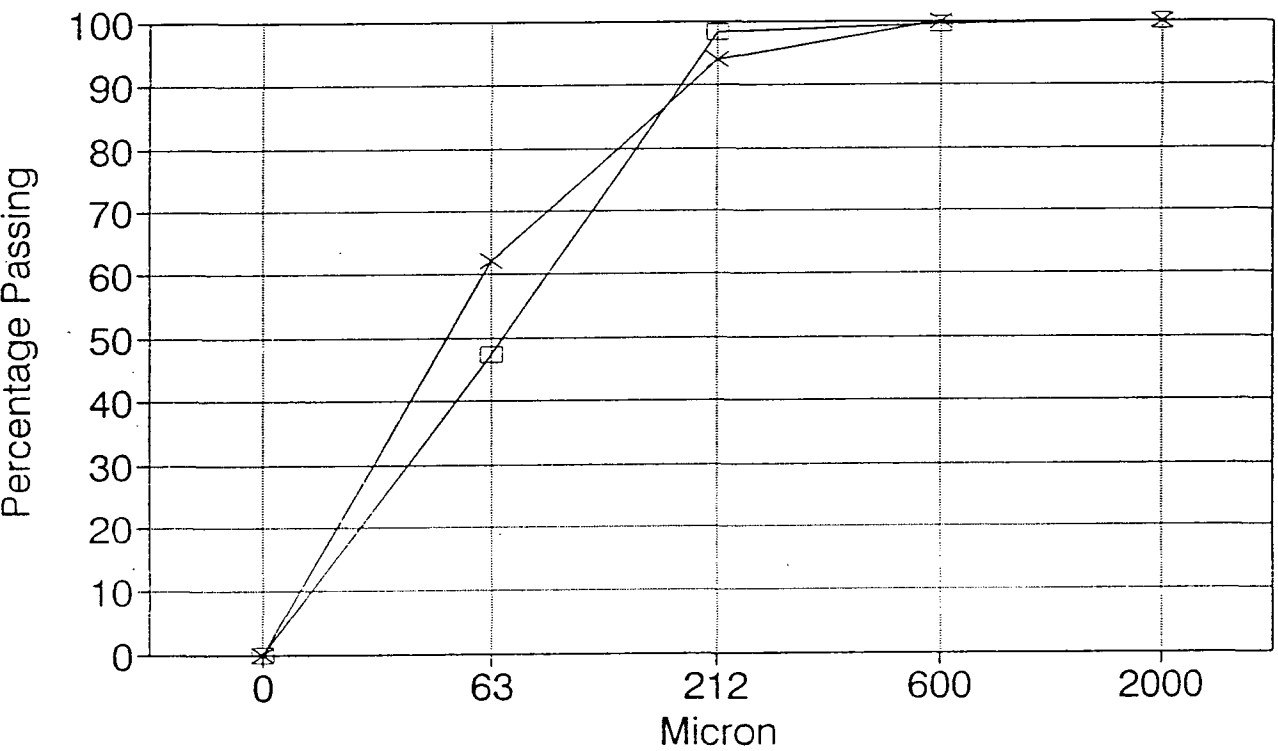
PARTICLE SIZE DISTRIBUTION

Sealsands



PARTICLE SIZE DISTRIBUTION

Sealsands

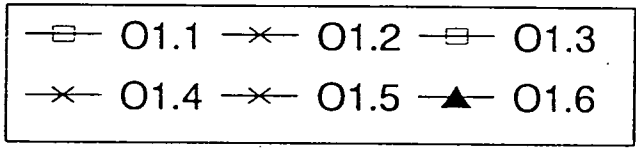
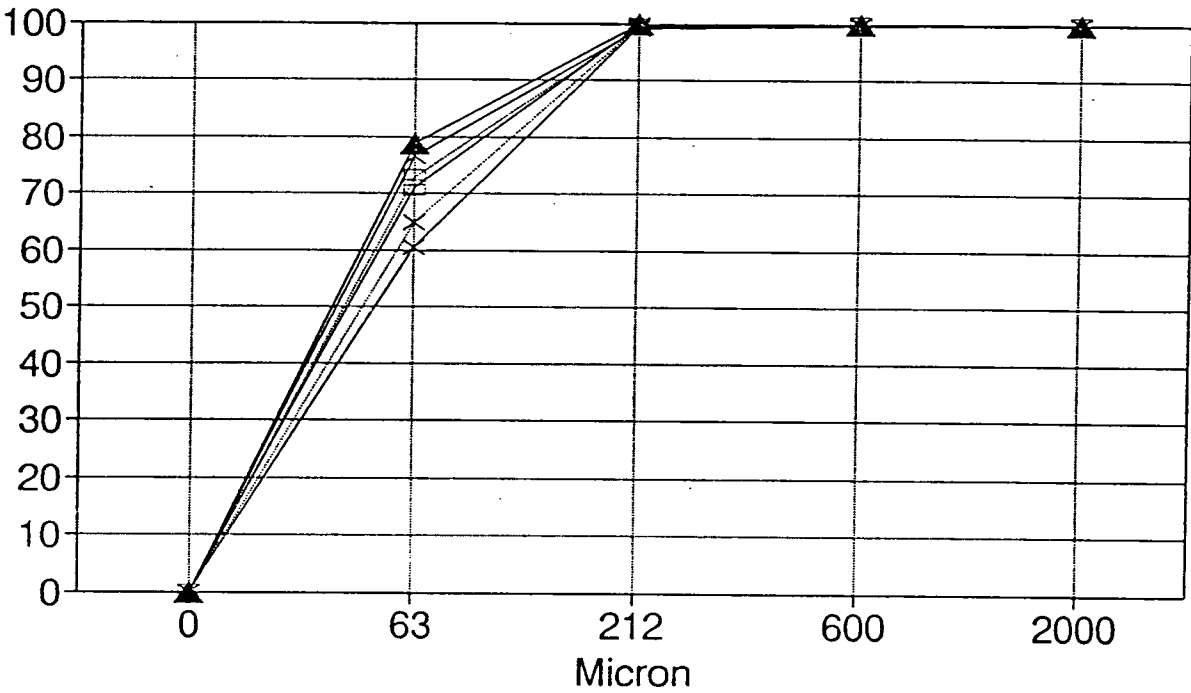


—□— E10 —×— zE10

Figure 3.7 a, b Analysis of change within a sampling site (O1.1 - O1.6 & G9.1 - G9.6).

Particle Size Distribution Seal Sands

Stable Site



Particle Size Distribution Seal Sands

Unstable Site

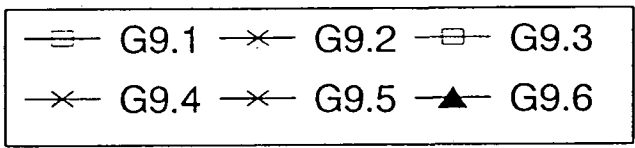
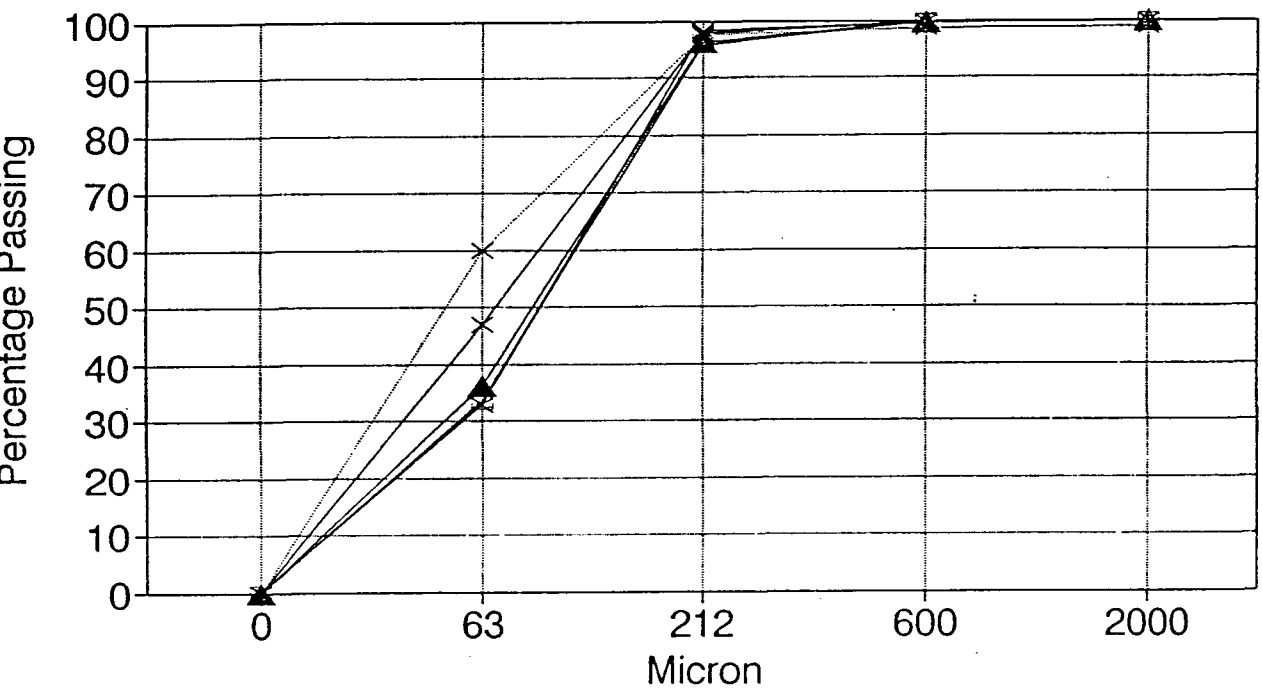
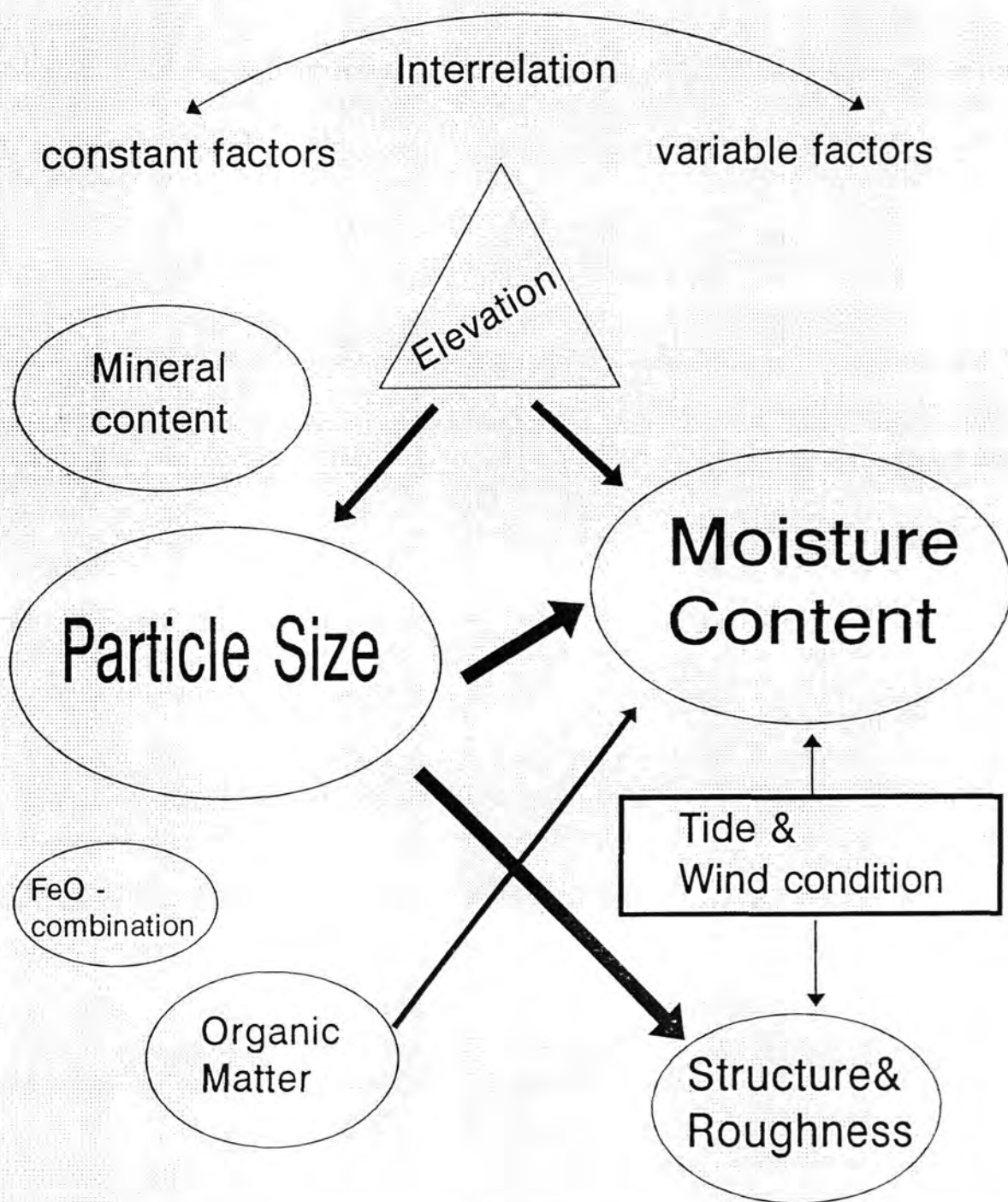
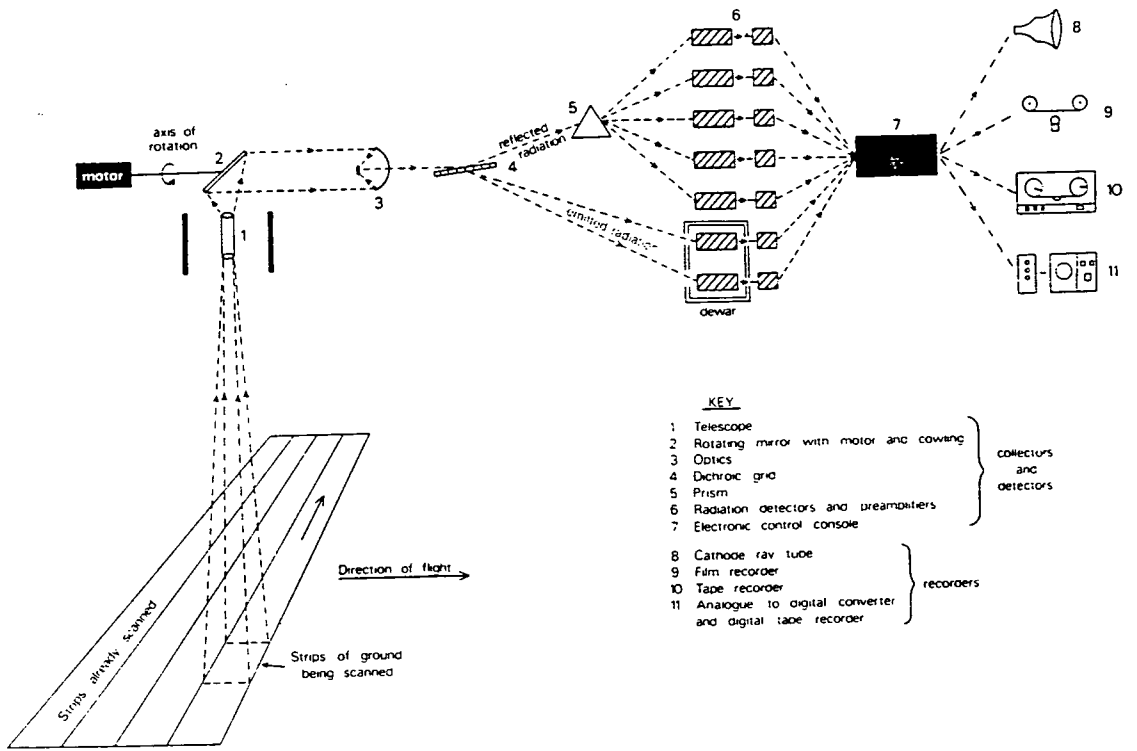


Figure 4.1 Parameters influencing the reflection of intertidal sediments.

Tidal Sediments - Reflection Parameters



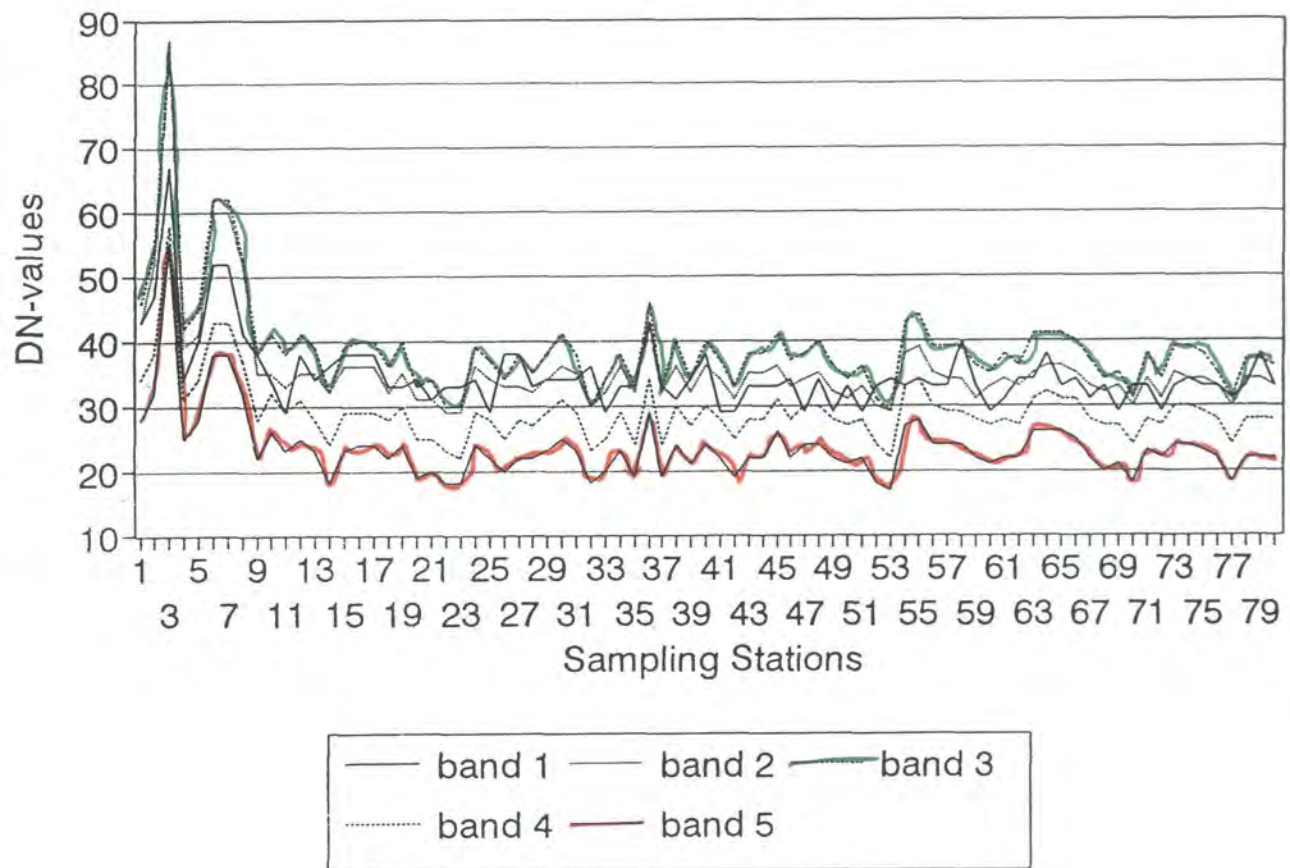
**Figure 4.2 Diagrammatic representation of a multispectral scanner
(Curran 1985).**



**Figure 4.3 Correlation of Spectral Bands of the ATM-Tees data
(Channel 1-5).**

Correlation of the ATM-Tees data

Channel 1 to 5 (visible)



**Figure 4.4 Correlation of Spectral Bands of the ATM-Tees data
(Channel 6 - 9 & 11).**

Correlation of the ATM-Tees data

Channel 6 to 9 & 11 (NIR,SWIR,thermal)

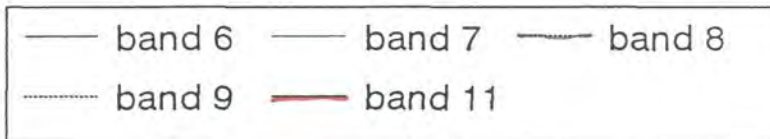
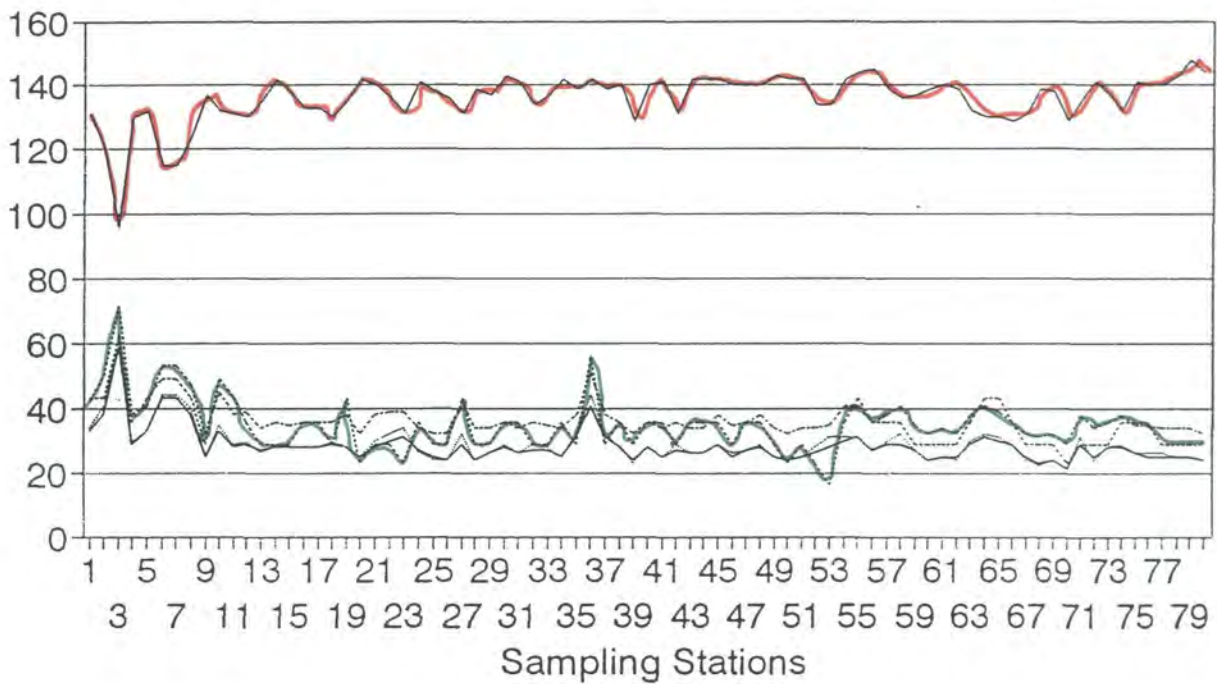
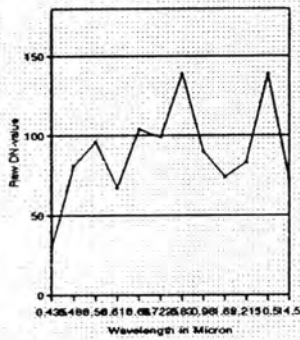


Figure 4.5 Processing steps for the ATM-Tees data.

Image Processing

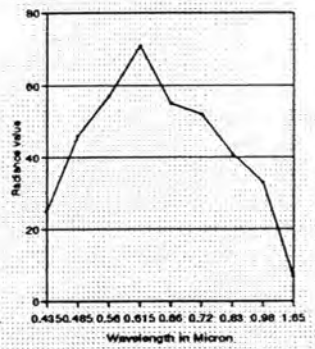
Correction Methods

Raw Imagery data

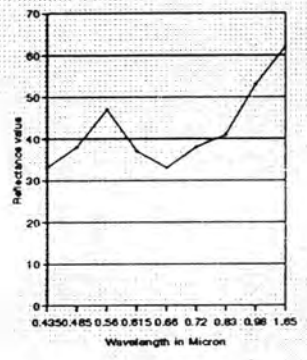


All three spectra are taken from the same point in a sandy area

Calibrated data



Flat-Field corrected data



Geometric Correction



Final Aim



Image Classification

Geometric Correction

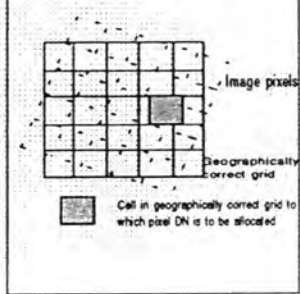


Figure 4.6 Structure of the Radiometric Calibration.

Radiometric Calibration of ATM-data

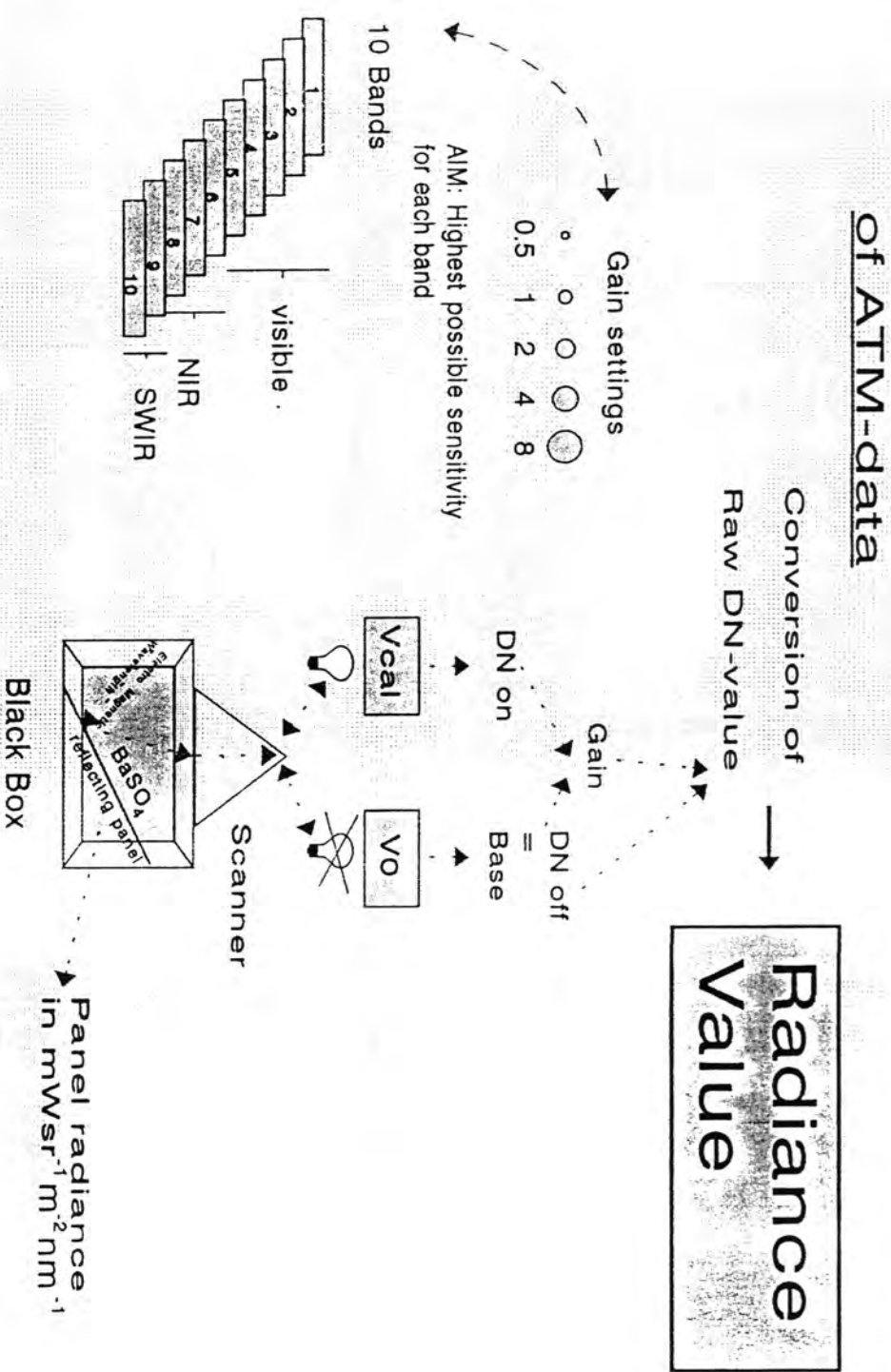


Figure 4.7 Structure of the ATM-imagery data set.

Structure of ATM Daedalus 1268 imagery data

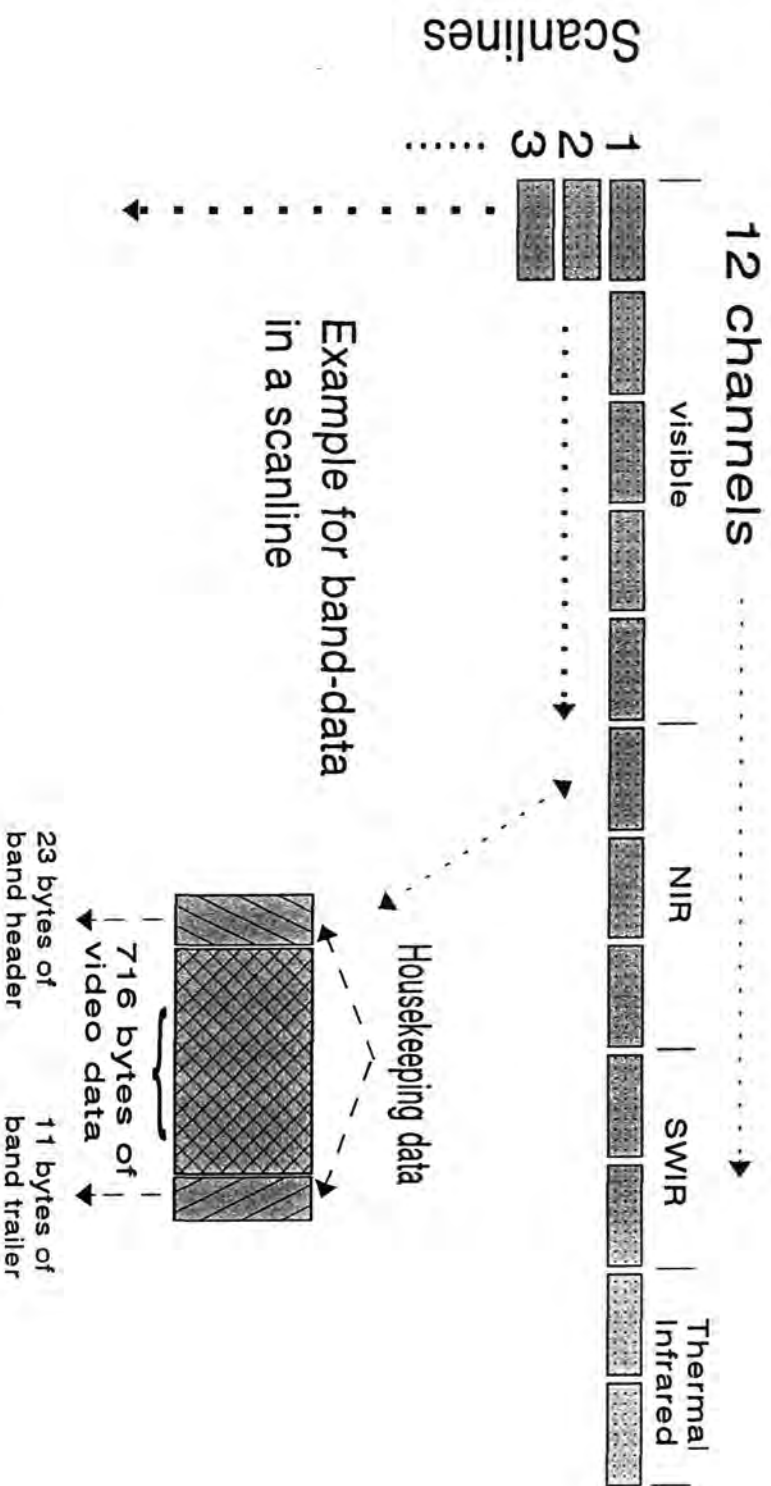
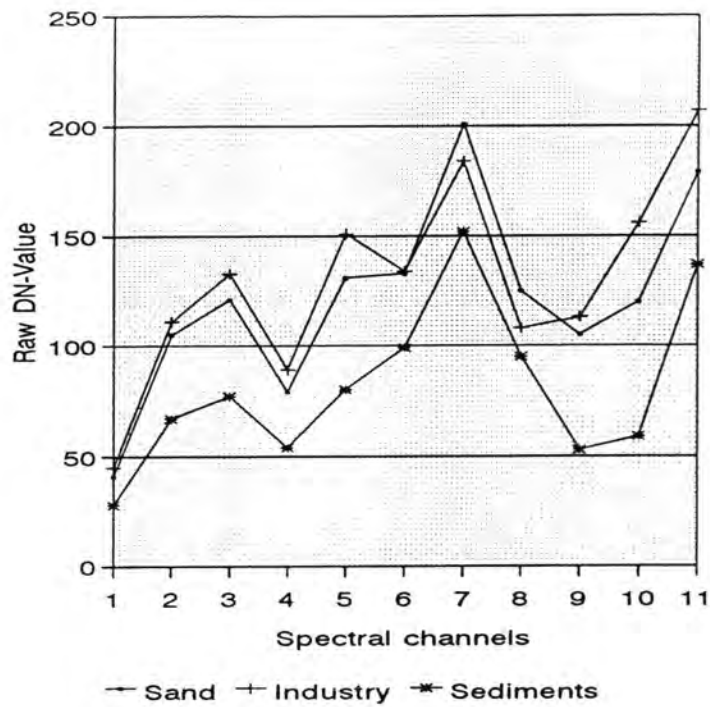


Figure 4.8 Structure of the uncalibrated ATM-data in comparison with the calibrated ATM-data.

UNCALIBRATED DATA



CALIBRATED DATA

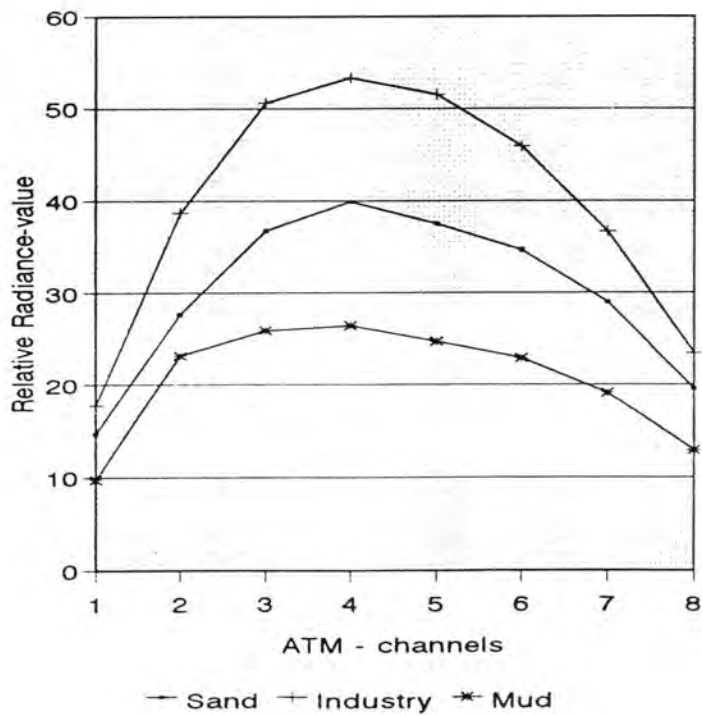


Figure 4.9 a,b Blackbody radiation curve at the Sun's and the Earth's temperature (Curran 1985).

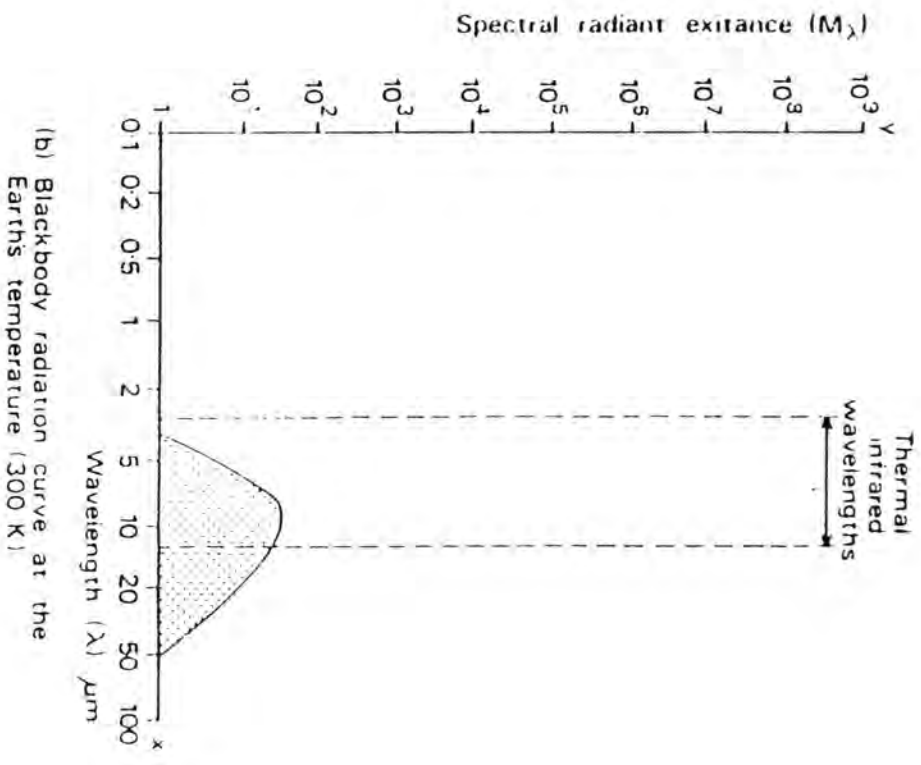
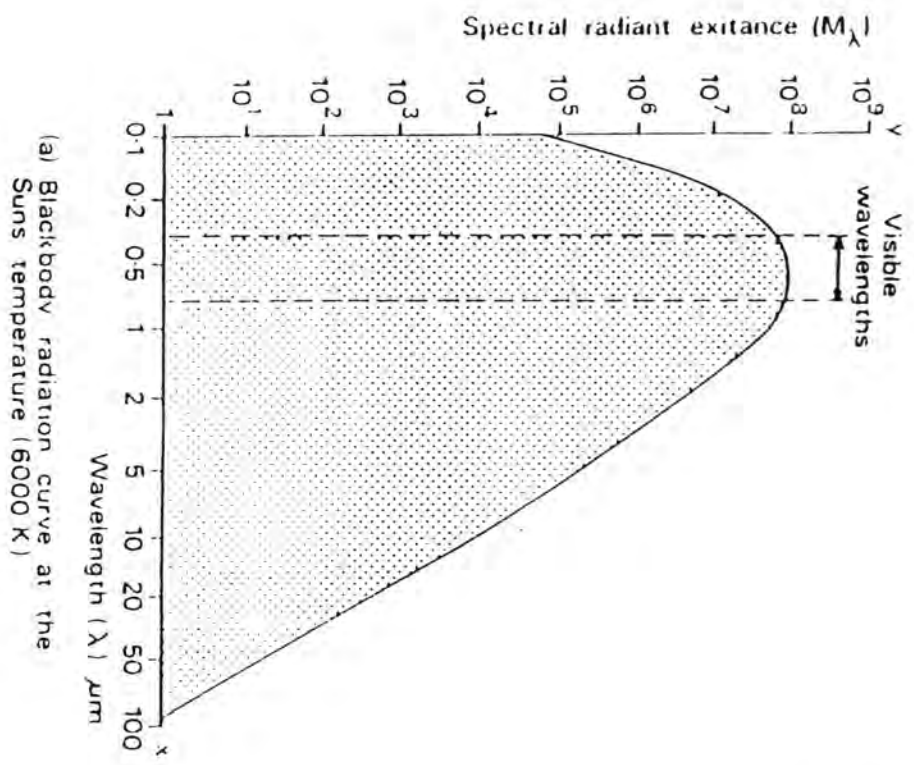


Figure 4.10 **Atmospheric scattering as a function of wavelength**
(Sabins 1987).

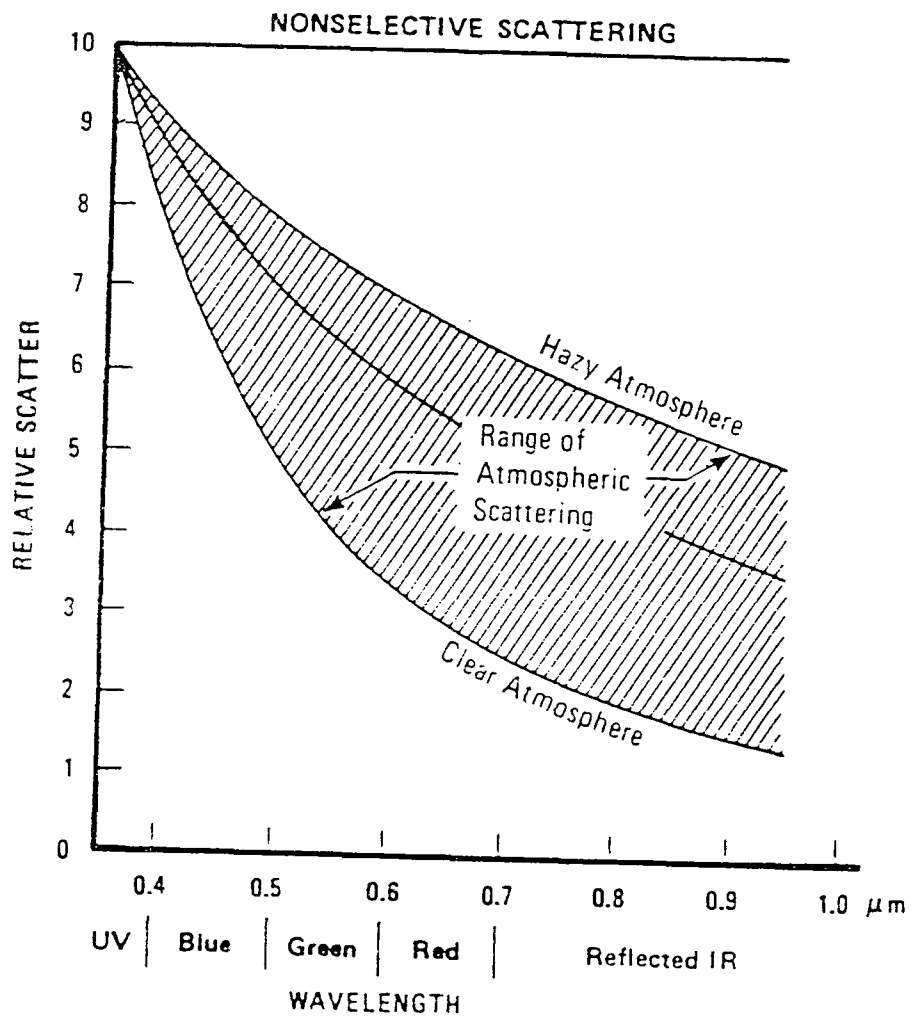


Figure 4.11 **Solar irradiation curve (Drury 1990).**

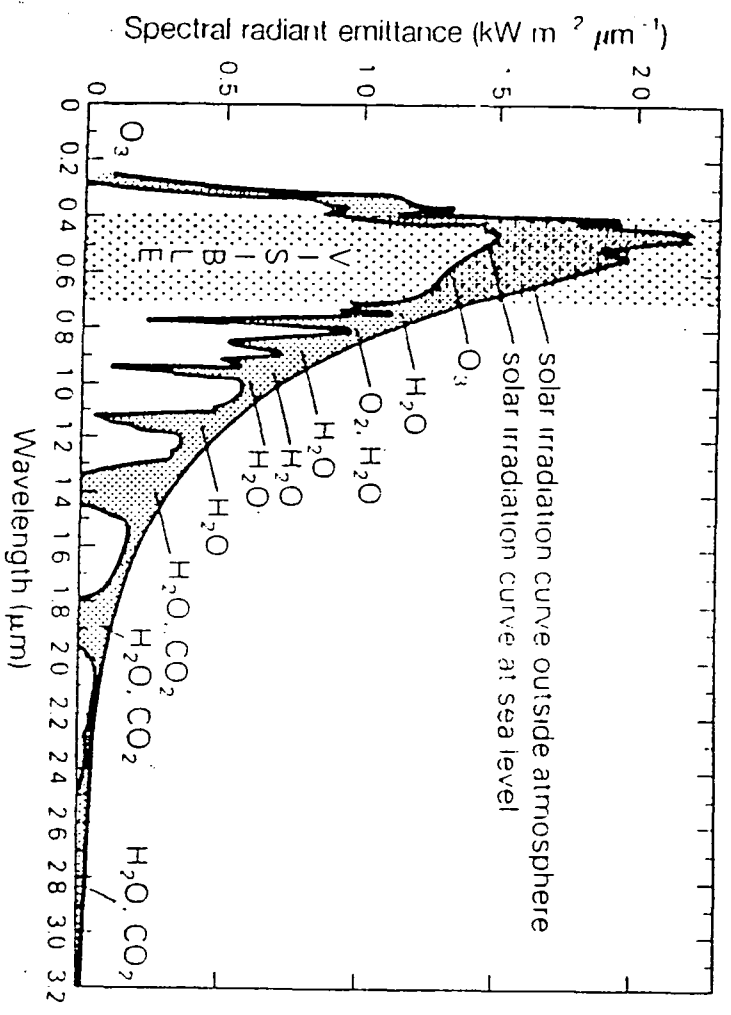
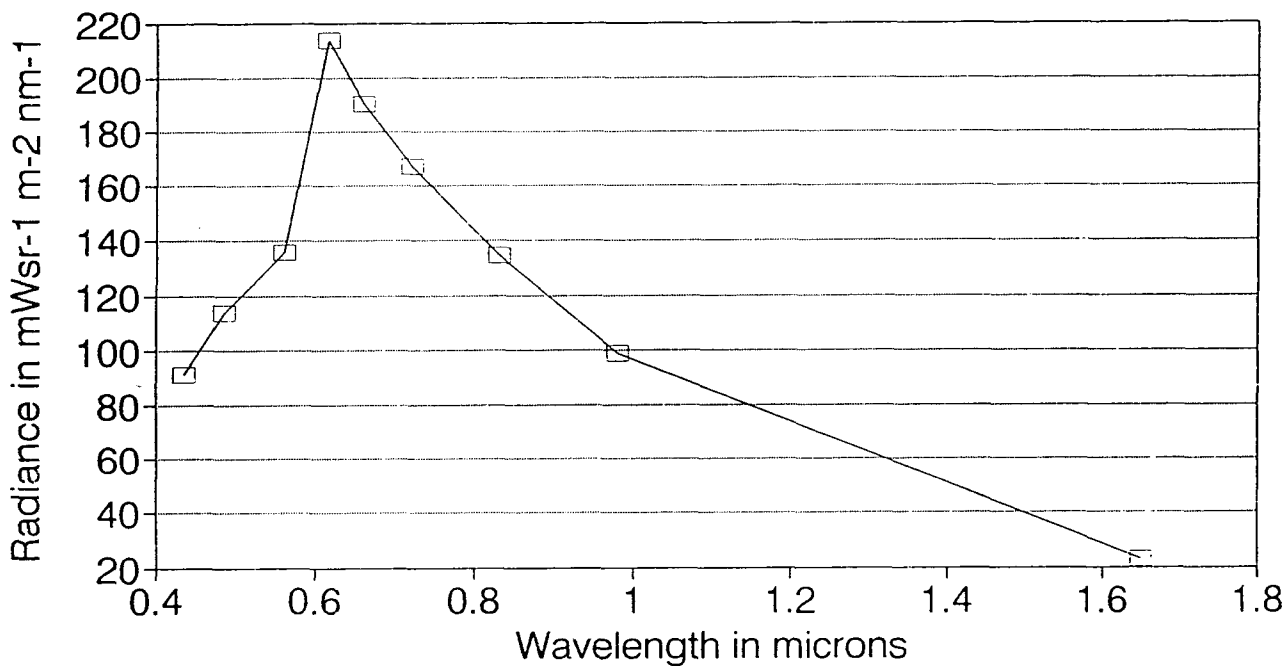


Figure 4.12 **Flat-Field Spectrum from a cloud from the ATM-Tees data.**

Flat-Field Correction



—□— Flat spectrum

Figure 4.13 Comparison of Atmospheric correction methods.

Atmospheric Correction

Comparison of Flat-field/Log residual

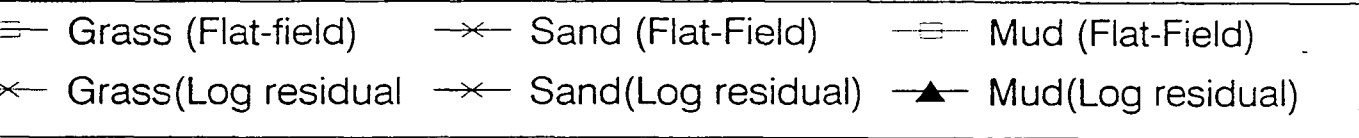
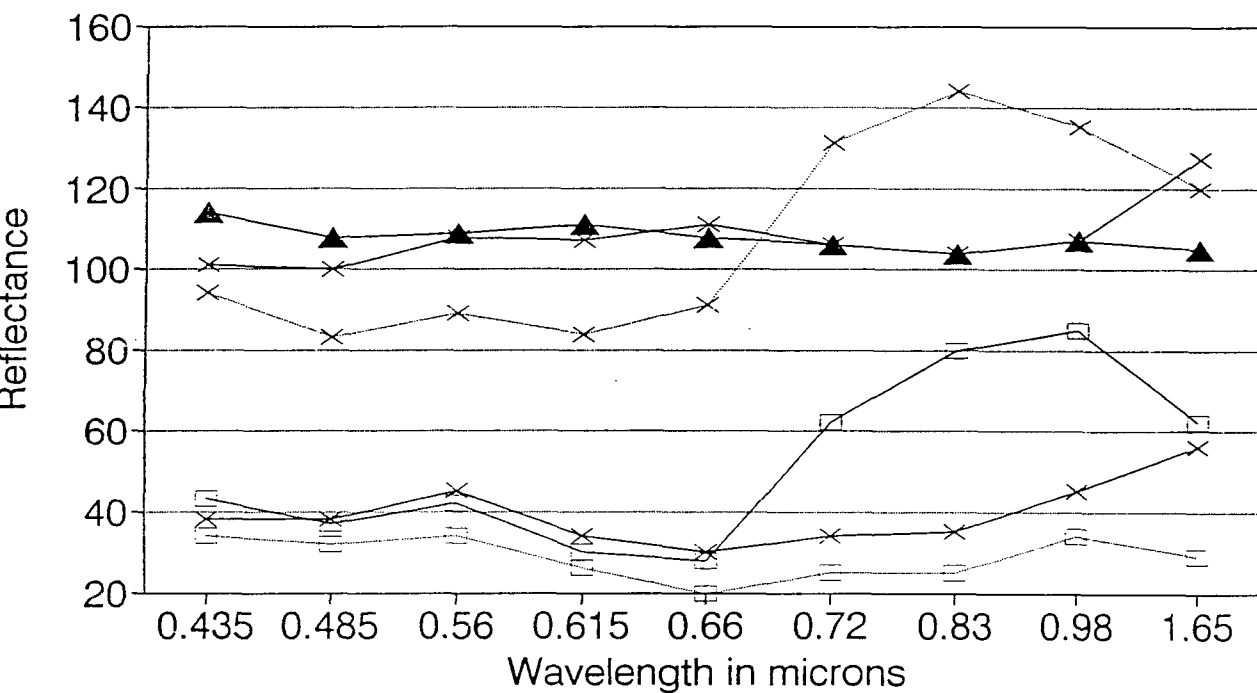
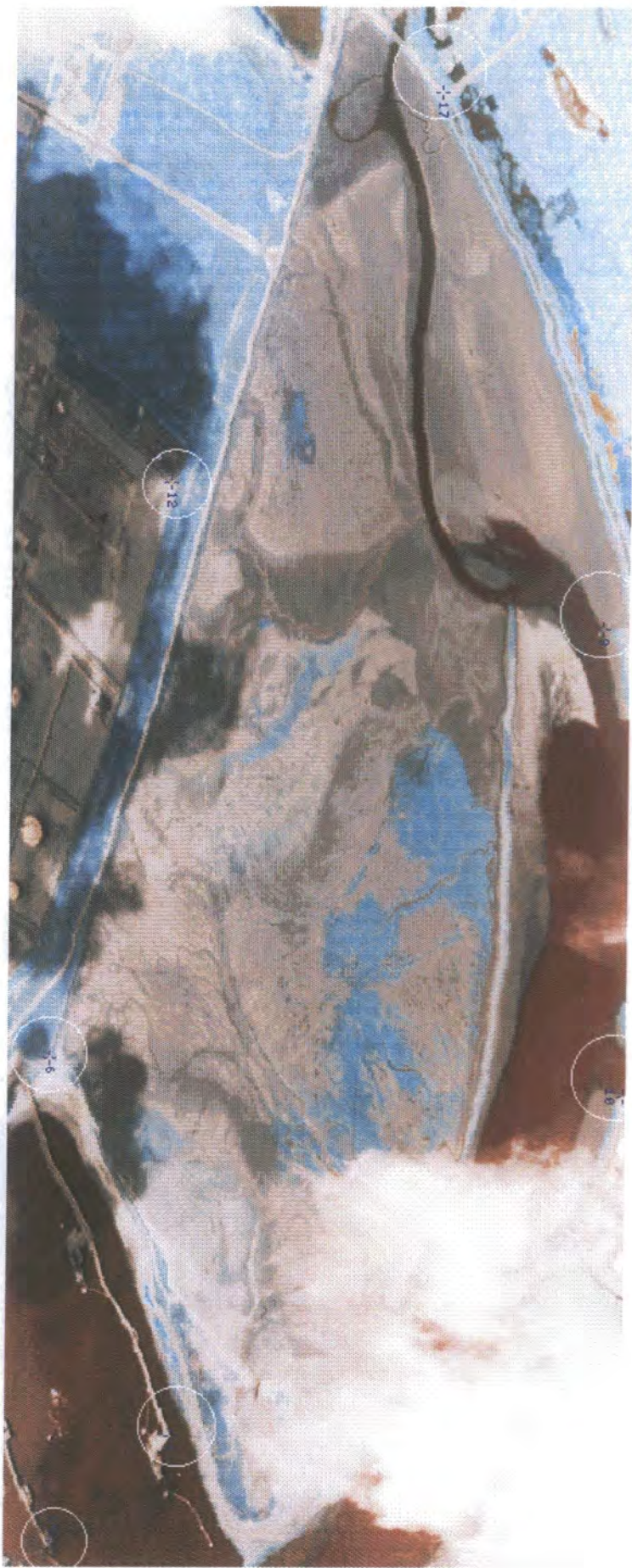


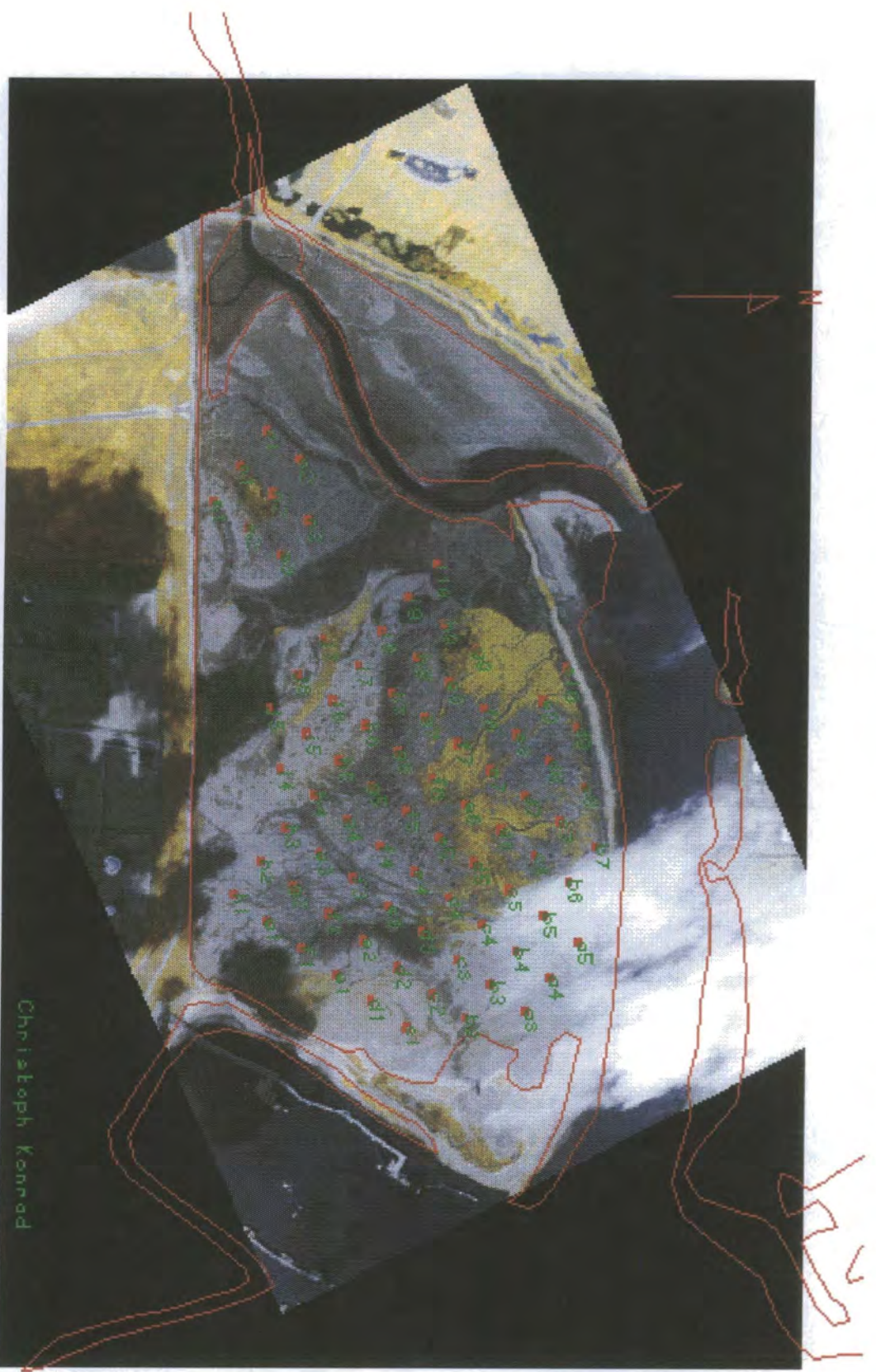
Figure 4.14 a, b Result of the Geometric correction for ATM image of Seal Sands.

a) not geometric correct

b) geometric correct; Scale = 1: 14700



ATM-data of Seal Sands overlaid with HMM + LHM and sampling stations

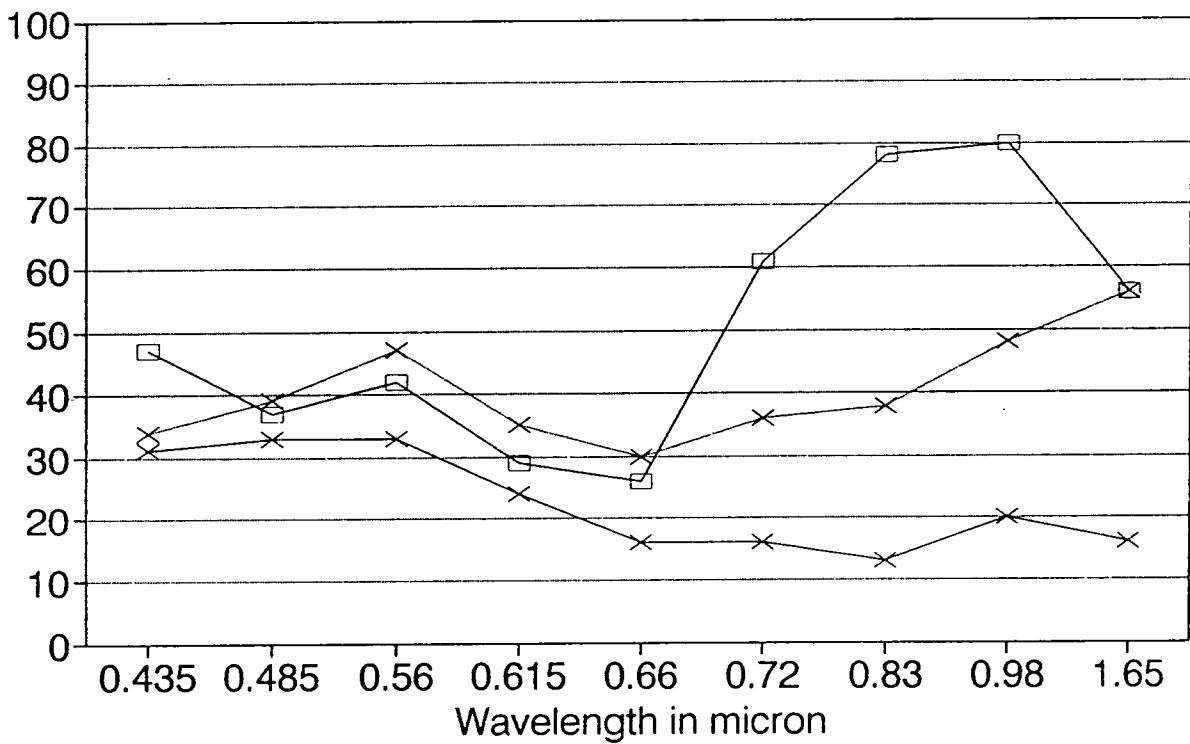


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Figure 4.15 a, b Reflection Spectra of different surface types.

Flat-Field Correction

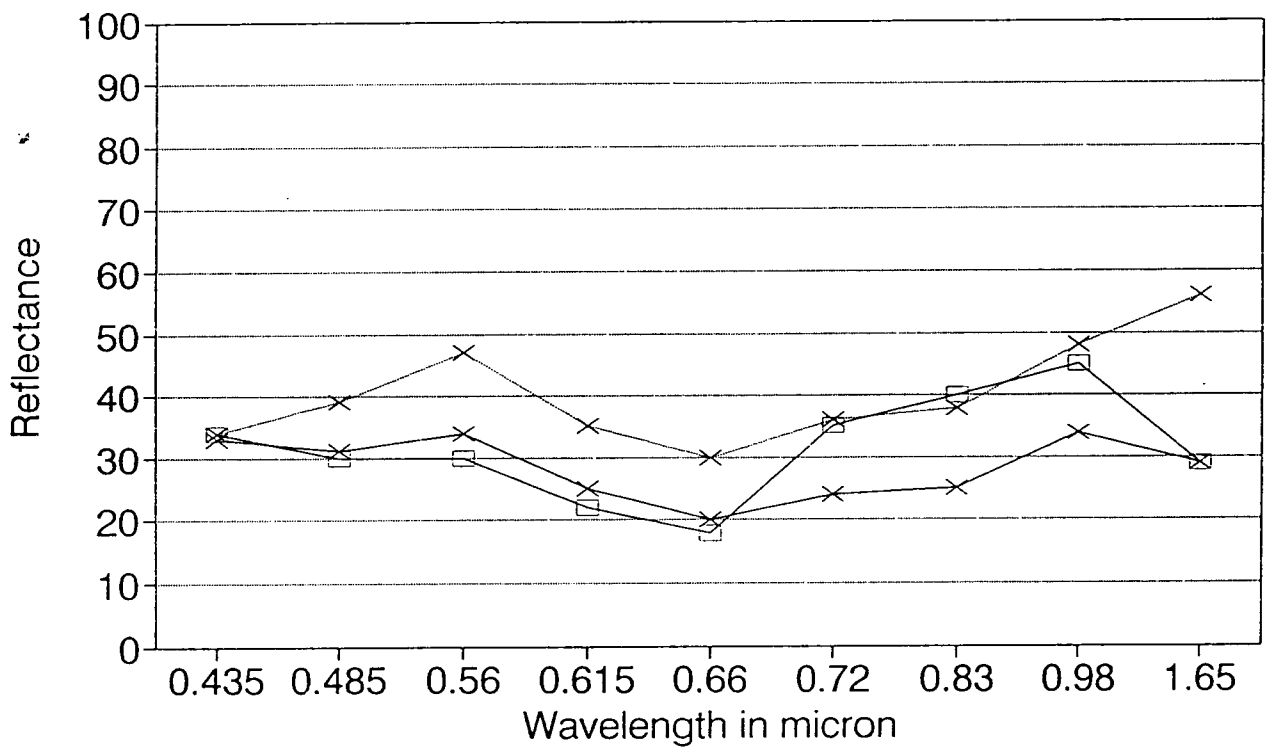
2nd Run Seal Sands



—□— Grass —×— Sand —×— Water

Flat-Field Correction

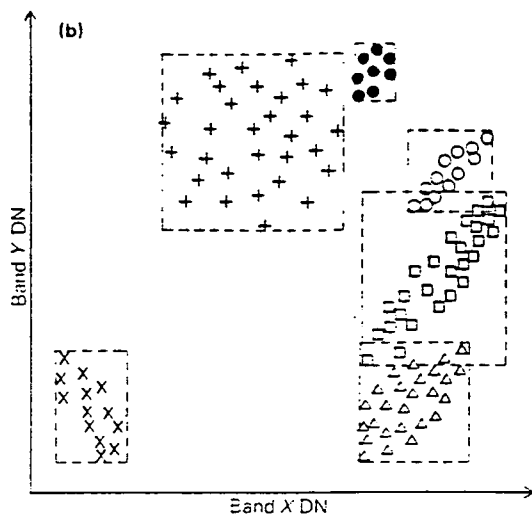
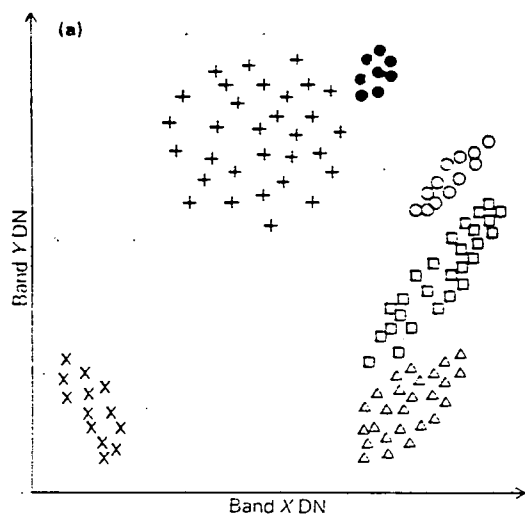
2nd Run Seal Sands



—□— Tidal Vegetation —×— Mudflat —×— Sand

Figure 4.16 **Different classification methods (Drury 1987)**

- a) clusters of different surface types**
- b) Parallelepiped classification**
- c) Minimum-distance to means-method**
- d) see c)**
- e) Maximum likelihood classification method**
- f) 3D model of the maximum likelihood classification.**



- key
- ○ ○ ○ corn
 - △ △ △ △ forest
 - □ □ □ hay
 - ● ● ● sand
 - + + + + urban
 - x x x x water

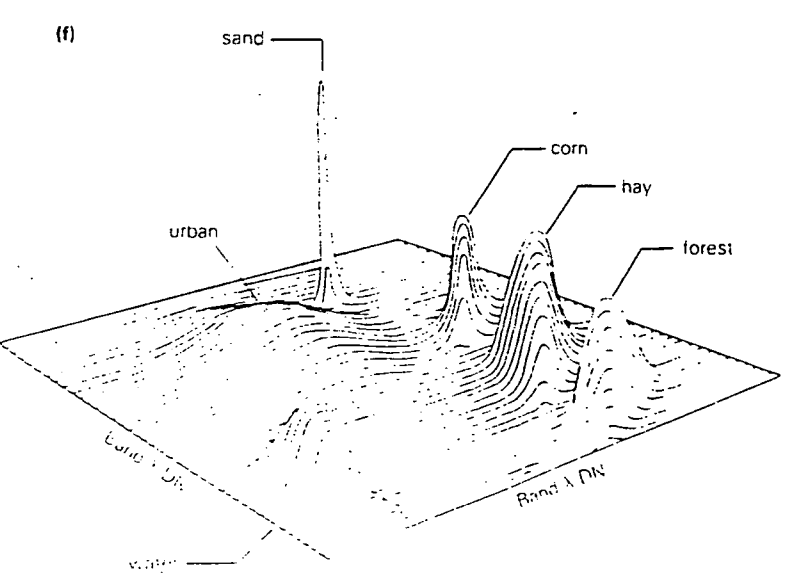
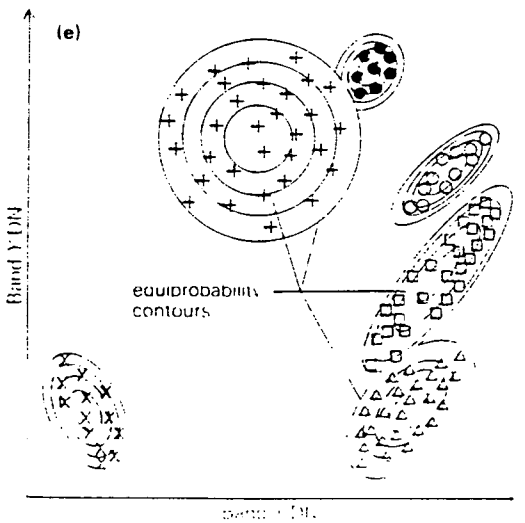
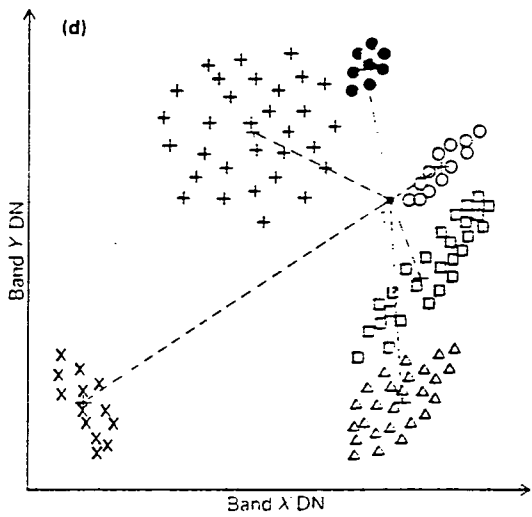
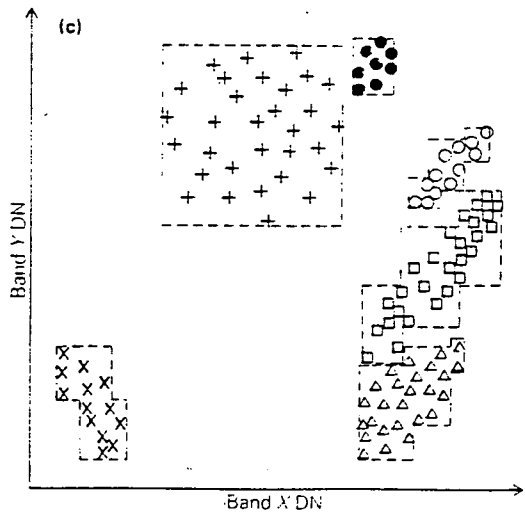


Figure 4.17 **Cluster Analysis of different surface types over Seal Sands.**

Training areas of 1=Industry, 2=Sand, 3=Mud, 4=Vegetation, 5=Water

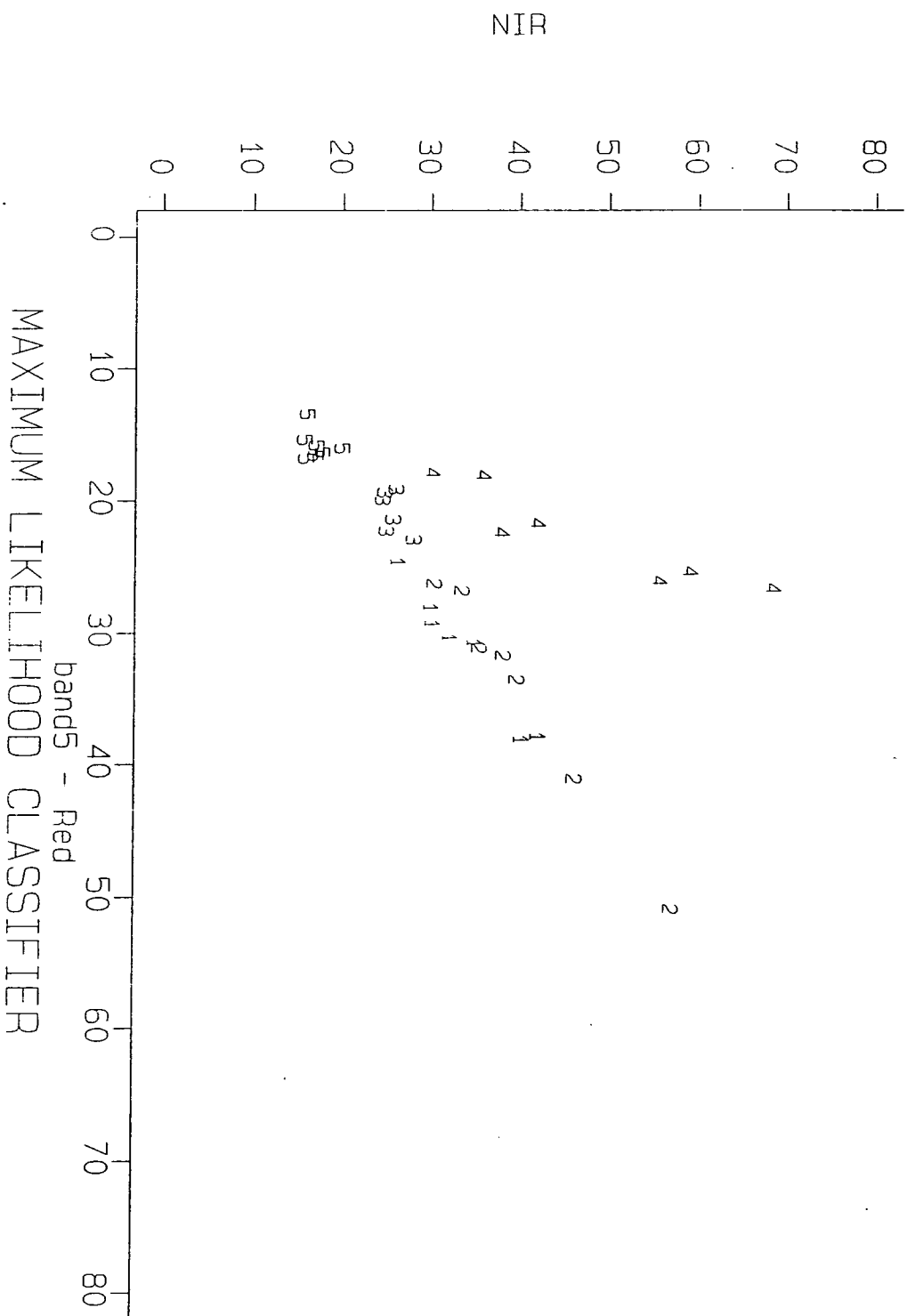


Figure 4.18 **Classified ATM image; Scale = 1:10400.**

blue	= water
white	= clouds
grey	= shadow
green	= Tidal vegetation (<i>Enteromorpha spp.</i>)
yellow	= Pure Sands (> 90 % sand)
orange	= Sandflat (90 - 50 % sand)
dark-blue	= Siltflat (50 - 20 % sand)
magenta	= Mudflat (< 20 % sand)

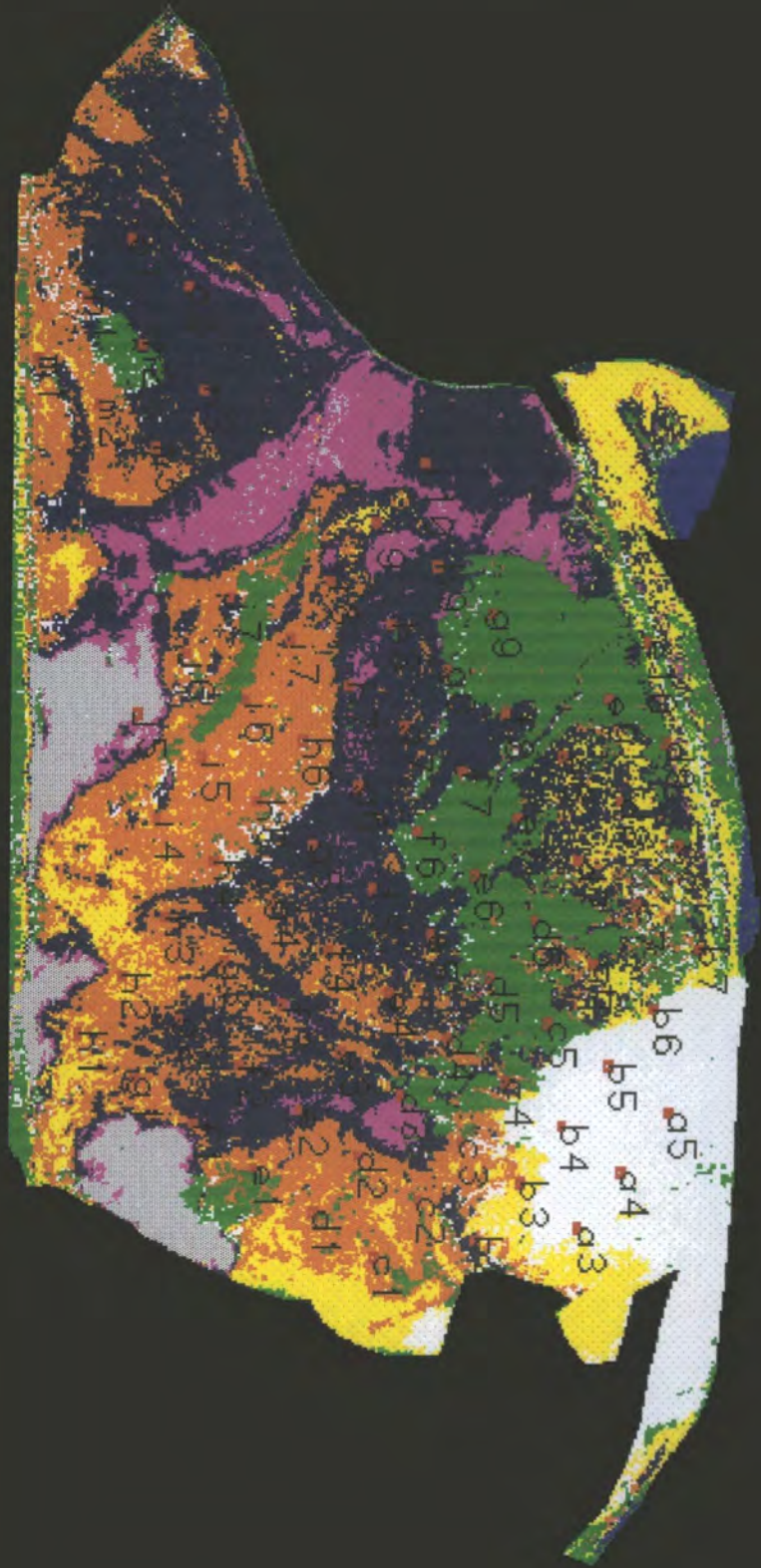
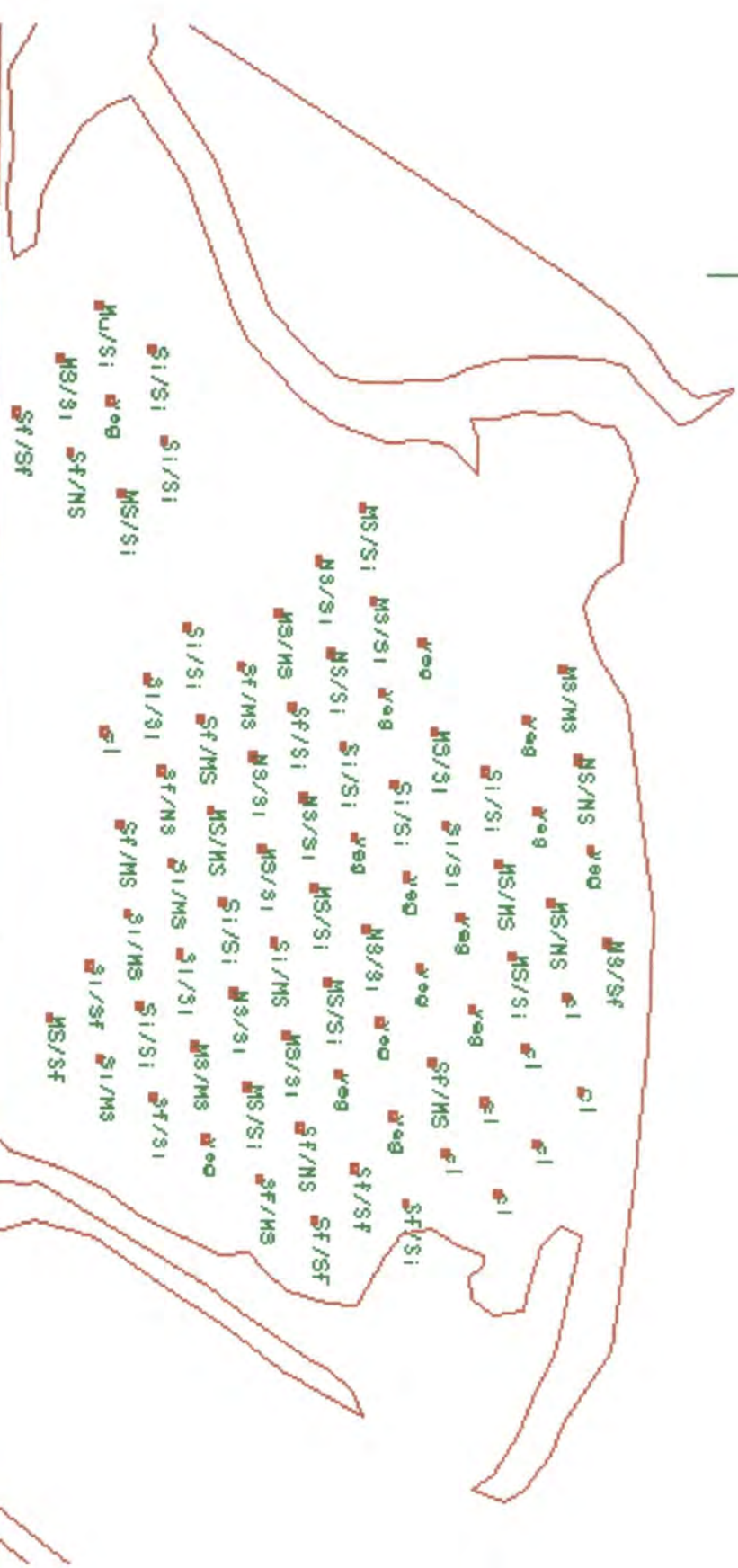


Figure 4.19 **Accuracy check of the MLC; Scale = 1: 10400.**
(First label shows the particle size analysis, second label the classified result)

Verification of the Classification using the Particle Size Analysis



veg = tidal vegetation, cl = cloude
 sf = Sandflat, NS = Mixed Sandflat, SI = Siltflat, Mu = Mudflat



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Figure 5.1 Function of the MMR field spectrometer.

Field Spectrometer

Milton Multiband Radiometer

Sensor Unit

Output Unit

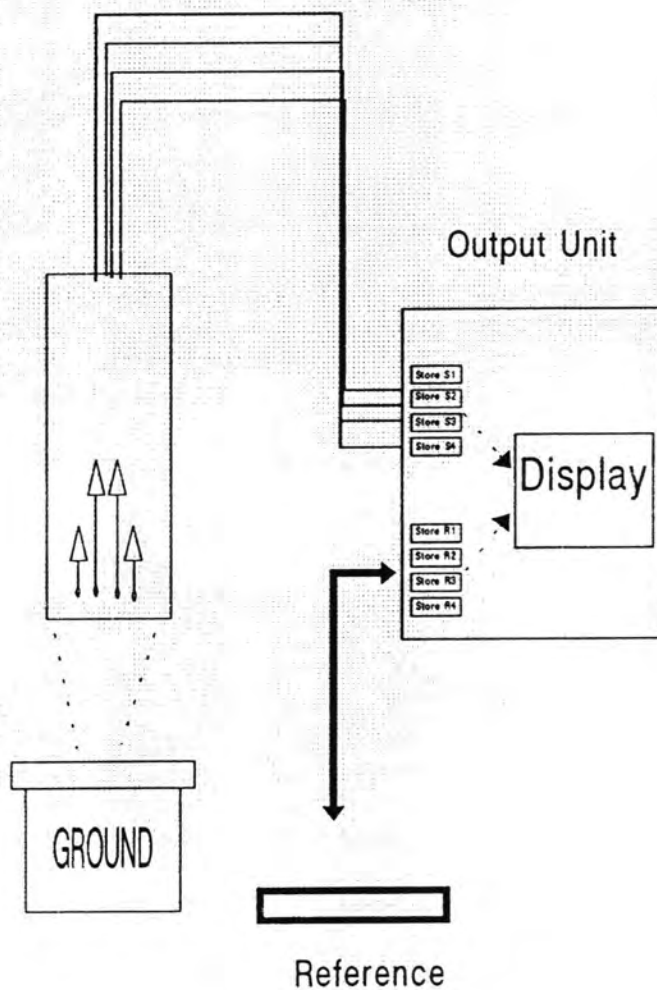
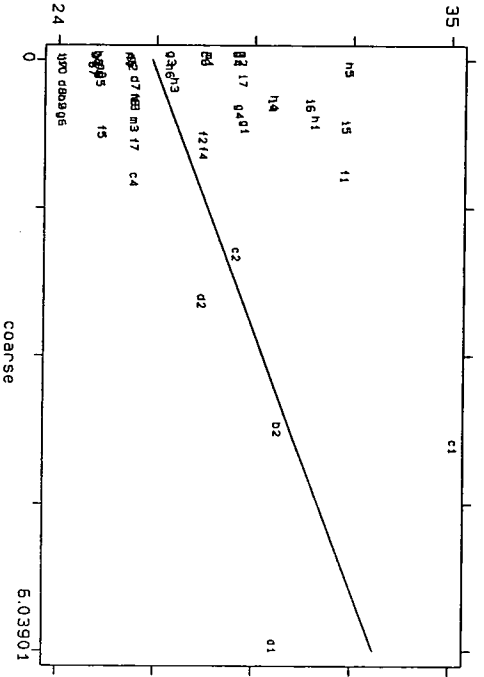
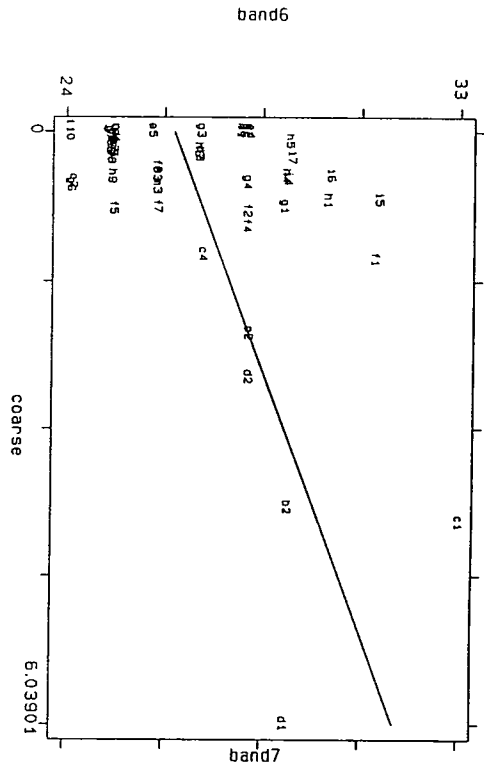


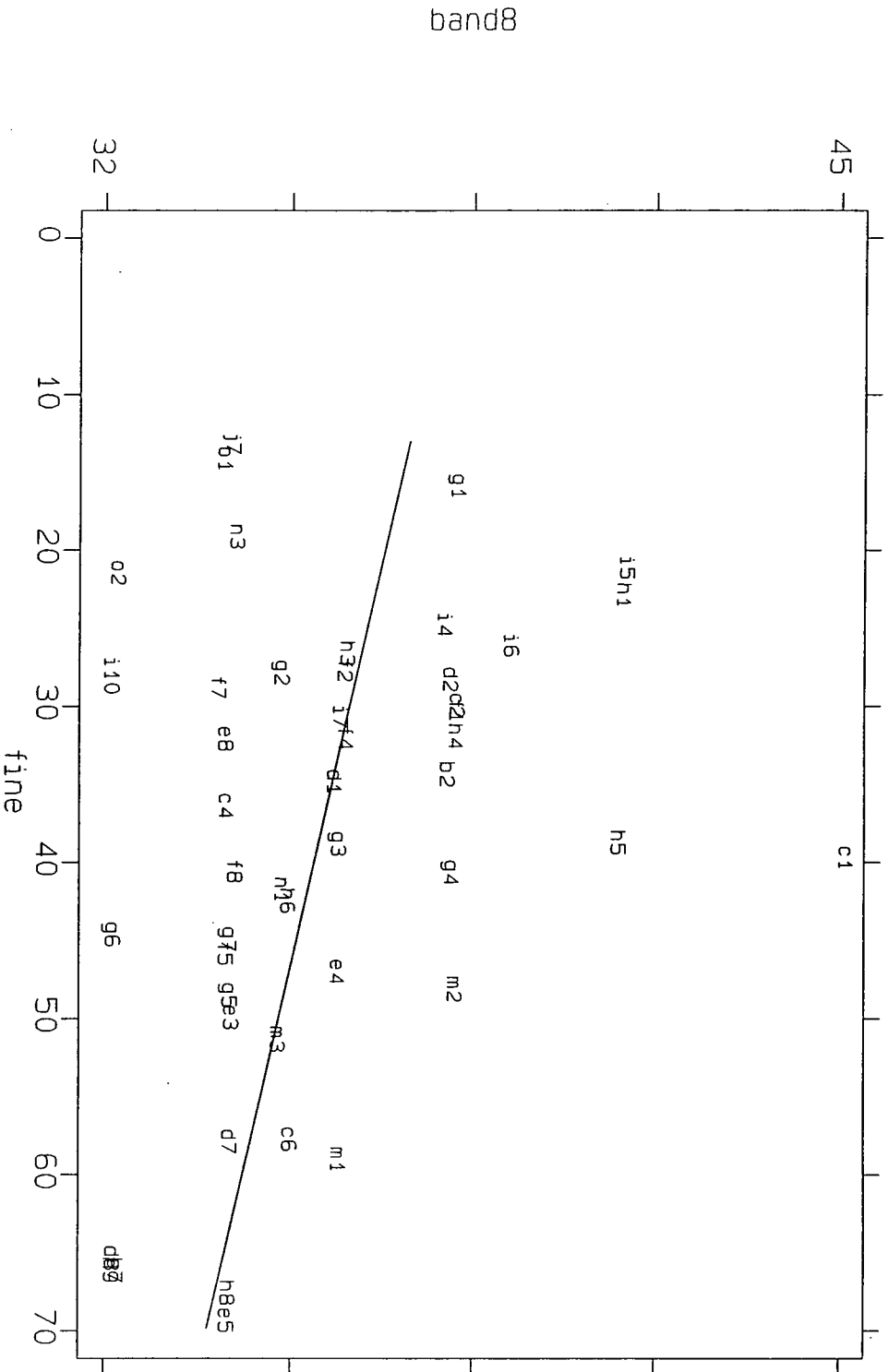
Figure 5.2 a-f Scatter plots of ATM measurements over Seal Sands with regression line.

ATM Tees data from Seal Sands



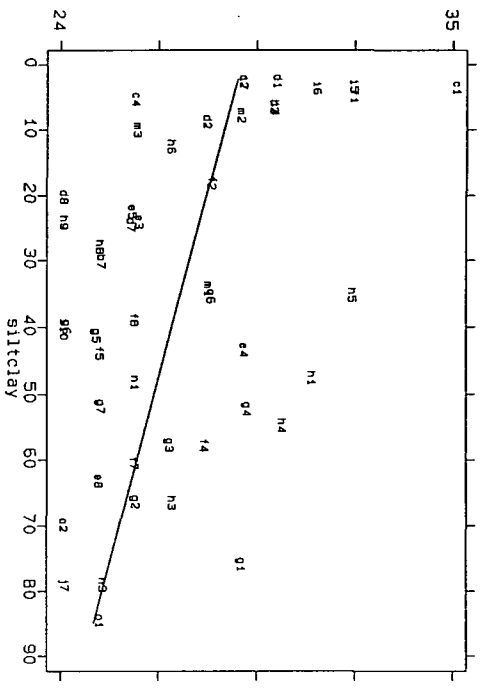
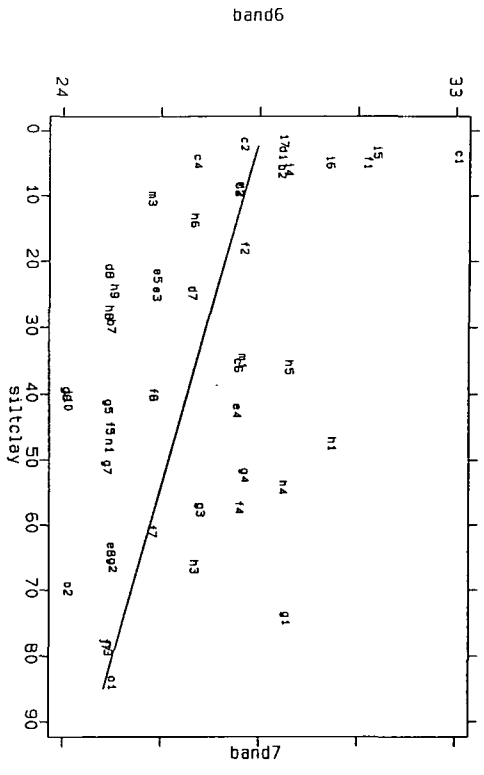
Correlation of Reflection & Particle Size

ATM Tees data from Seal Sands



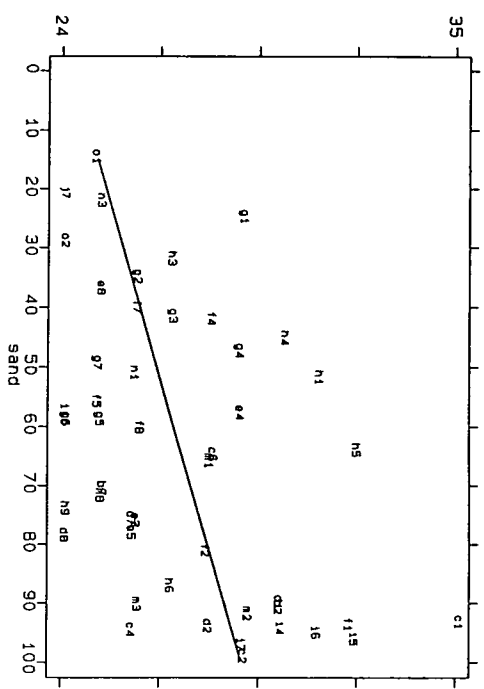
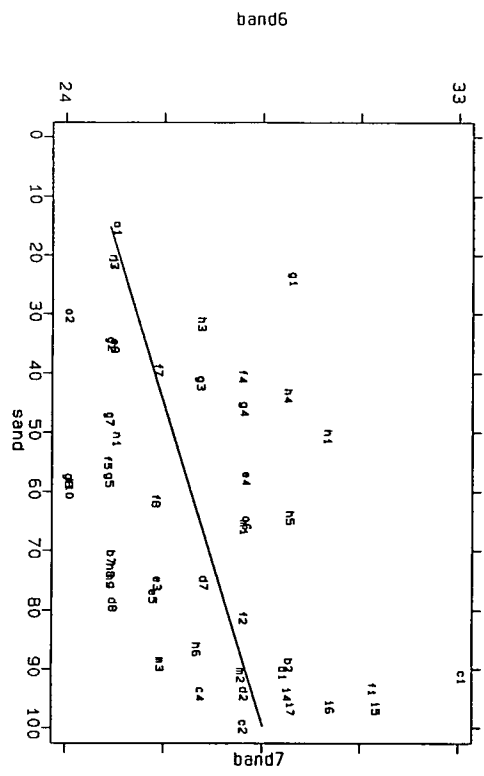
Correlation of Reflectance & Particle Size

ATM Tees data from Seal Sands



Correlation of Reflectance & Particle Size

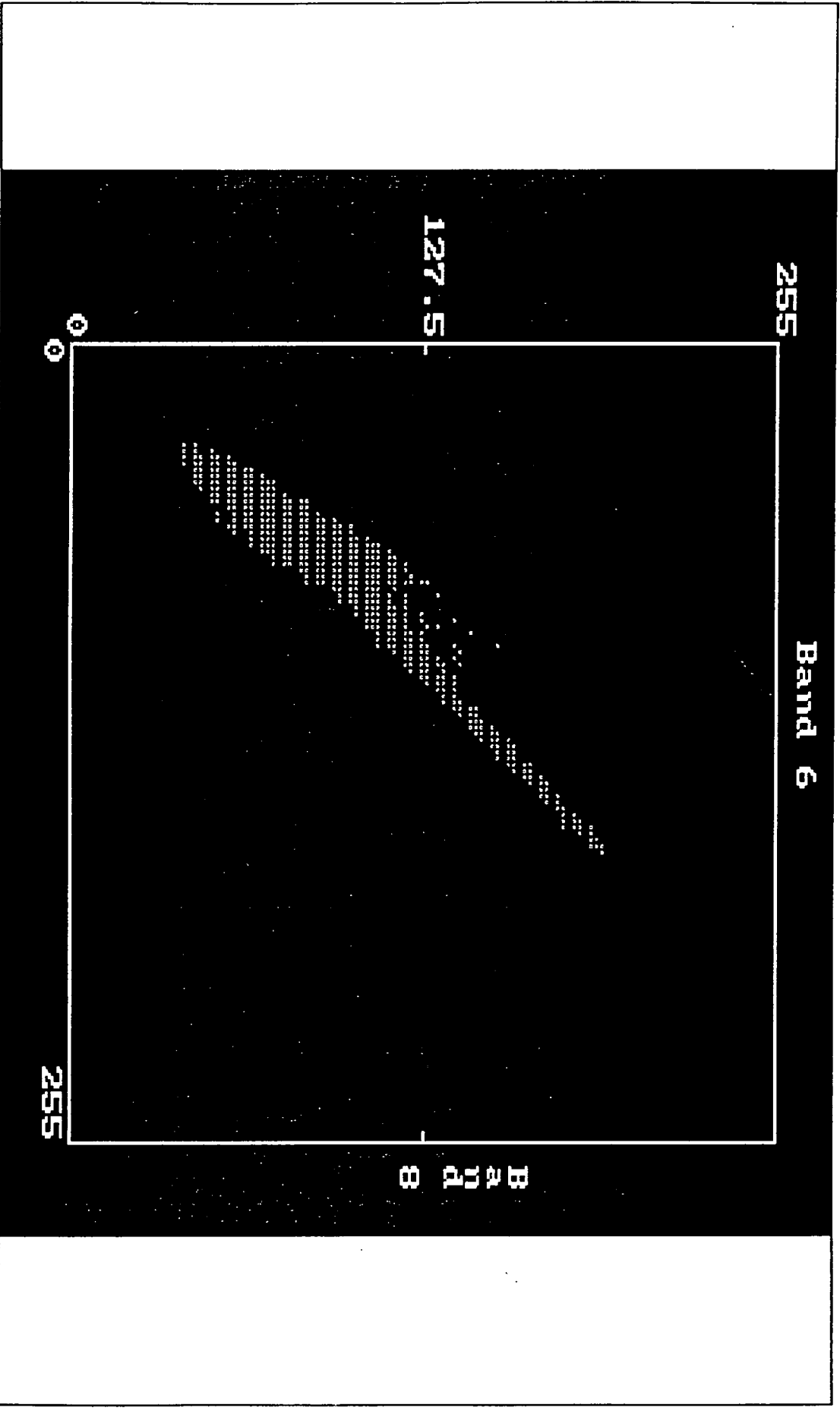
ATM Tees data from Seal Sands



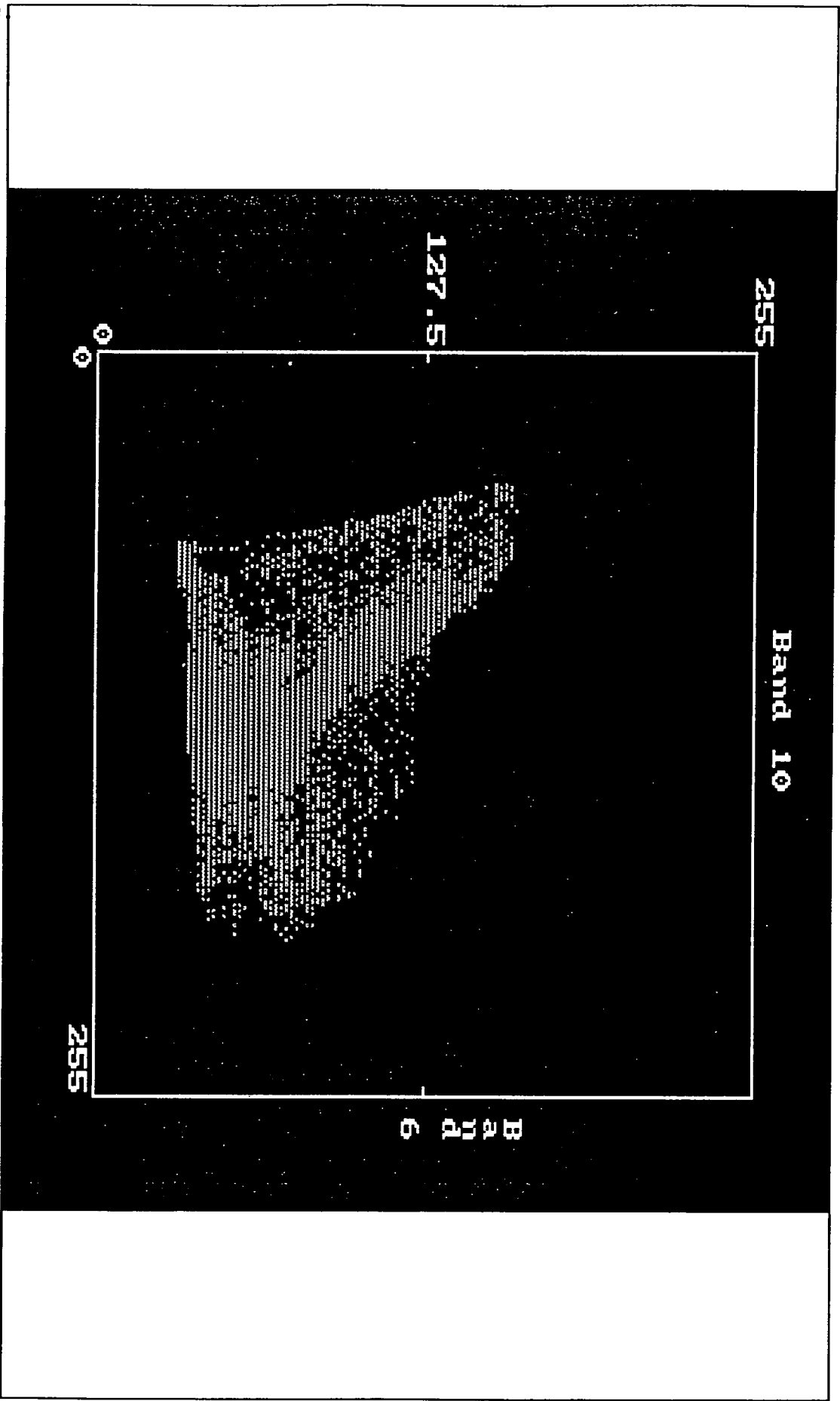
Correlation of Reflectance & Particle Size

Figure 5.3 a - c Scatter plots of band 6, 8 & 11.

(note: thermal Band11 is named in this plots Band10)



Scatter Plot of Band 6 (NIR) and Band 8 (NIR).



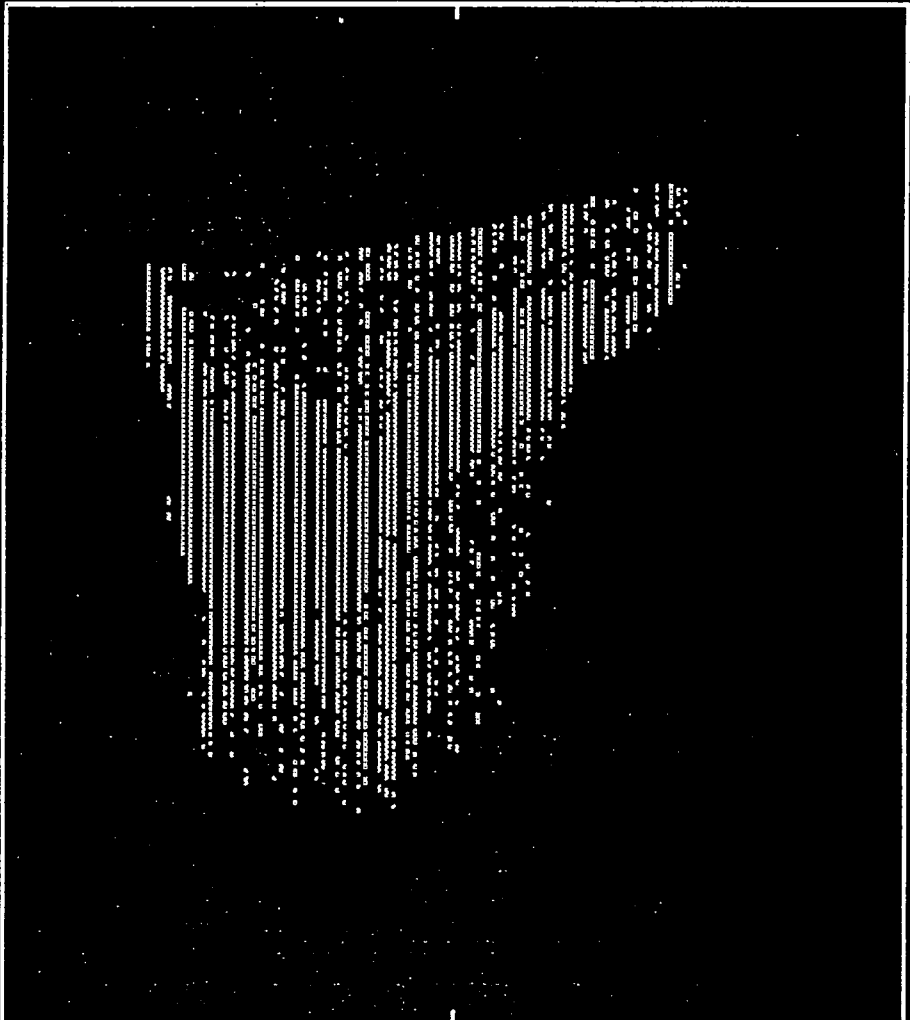
Scatter Plot of Band 8 (NIR) and Thermal Channel Band 10 (normally Band 11).

255

Band 10

127.5

0 0



255

Band 6

Scatter Plot of Band 6 (NIR) and the Thermal Channel Band 10 (normally Band 11).

**Figure 6.1 a - c Prediction Model of Particle Size Classes (gray values);
Scale = 1: 16400.**

Prediction of Total Sand amount with Channel 11, 8 & 6
Based on Regression Analysis



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Prediction of Medium Sand amount with Channel 11 & 6

Based on Regression Analysis

N



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Prediction of Silt & Clay amount with Channel 11, 8 & 6

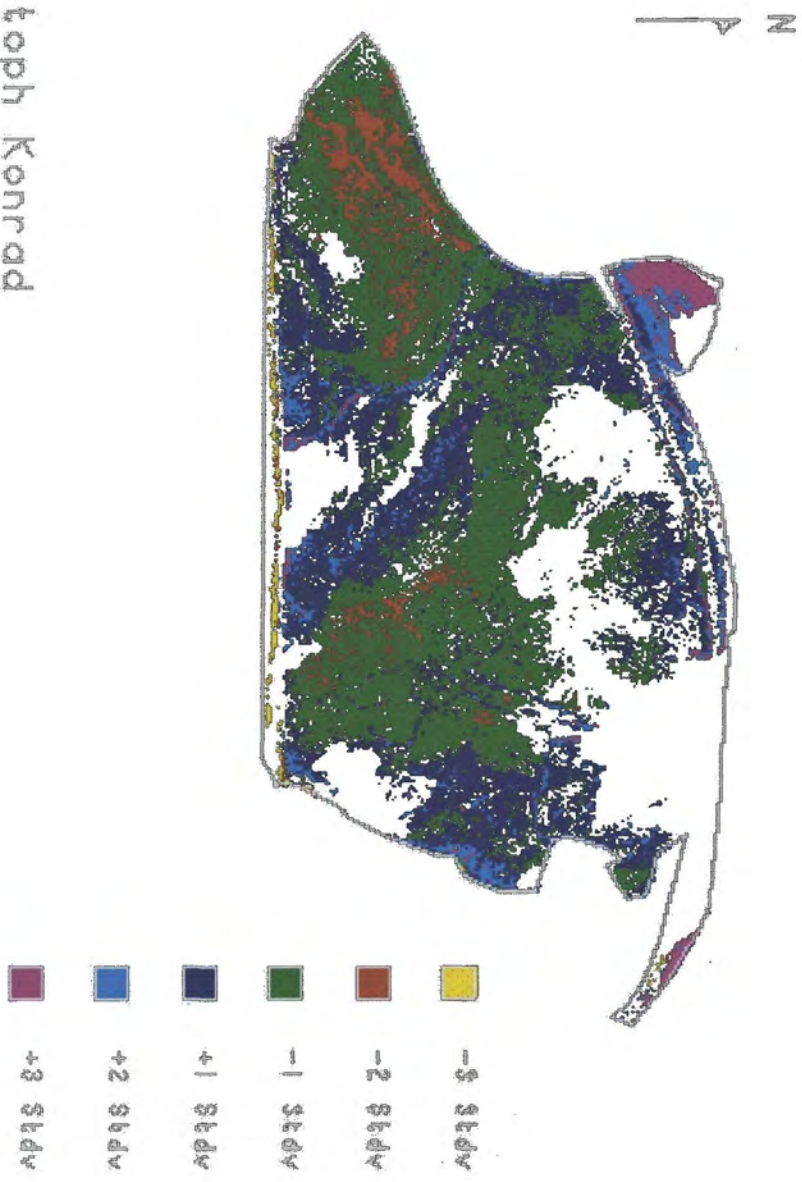
N Based on Regression Analysis



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**Figure 6.2 a - c Prediction Model of Particle Size Classes (6 STDs’);
Scale = 1: 16400**

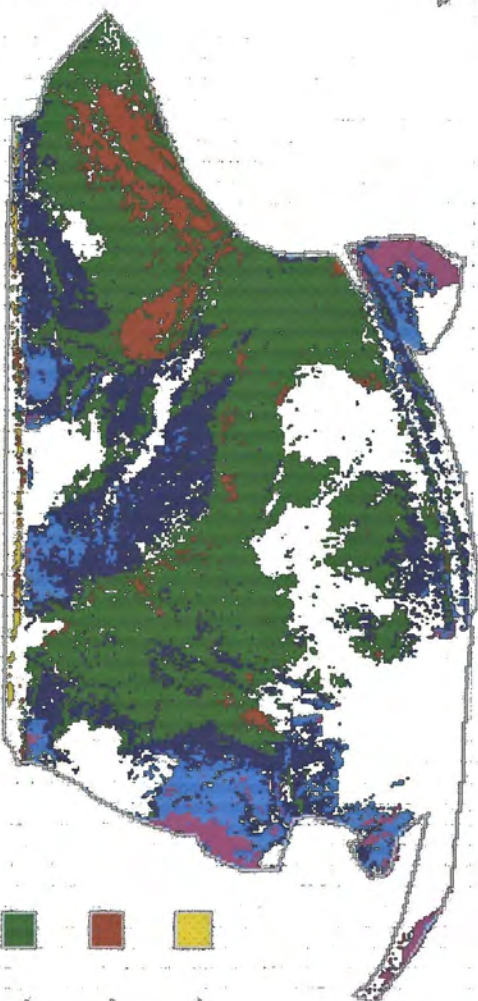
Prediction of Total Sand amount with Channel 11, 8 & 6
Based on Regression Analysis



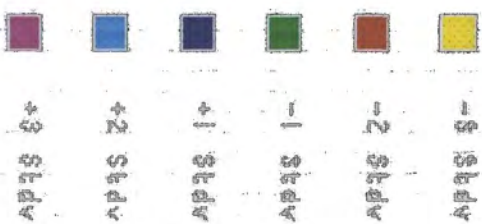
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Prediction of Medium Sand amount with Channel 11 & 6
Based on Regression Analysis

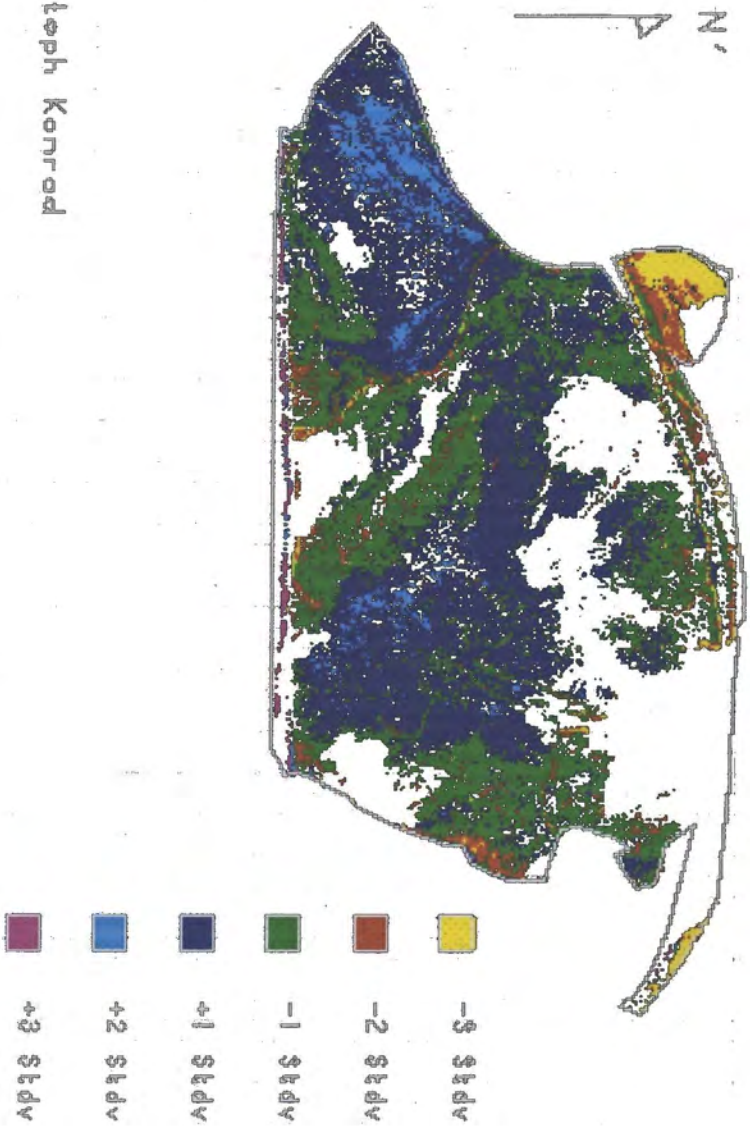
N



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Prediction of Silt&Clay amount with Channel 11, 8 & 6
Based on Regression Analysis



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Figure 6.3 Histogram of Band 11

Histogram for Thermal Channel
excluding Vegetation, Clouds,
Shadow & Water

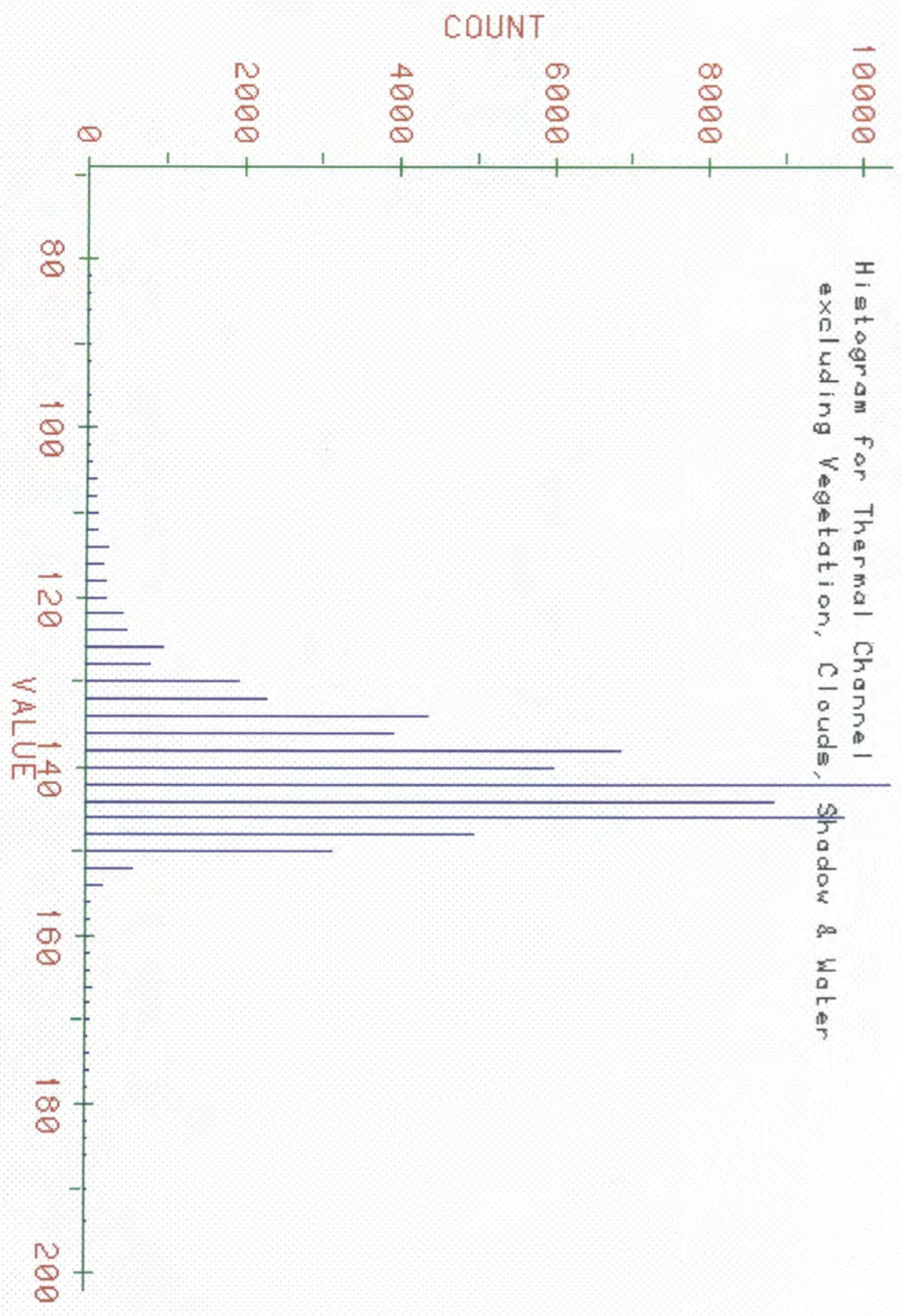
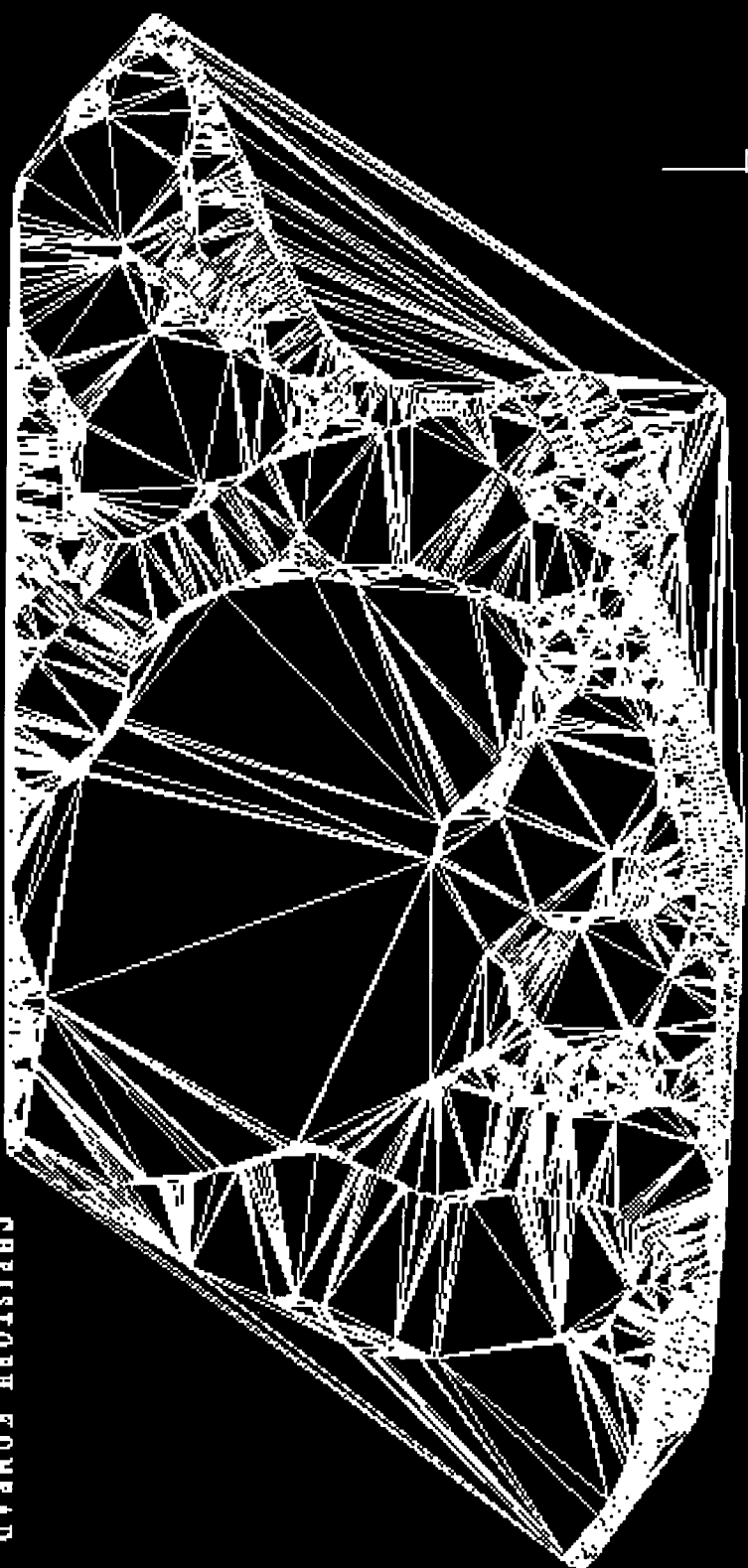


Figure 6.4 Tin Model of Seal Sands; Scale = 1: 12300

Triangulated Irregular Network (TIN) over Seal Sands

N

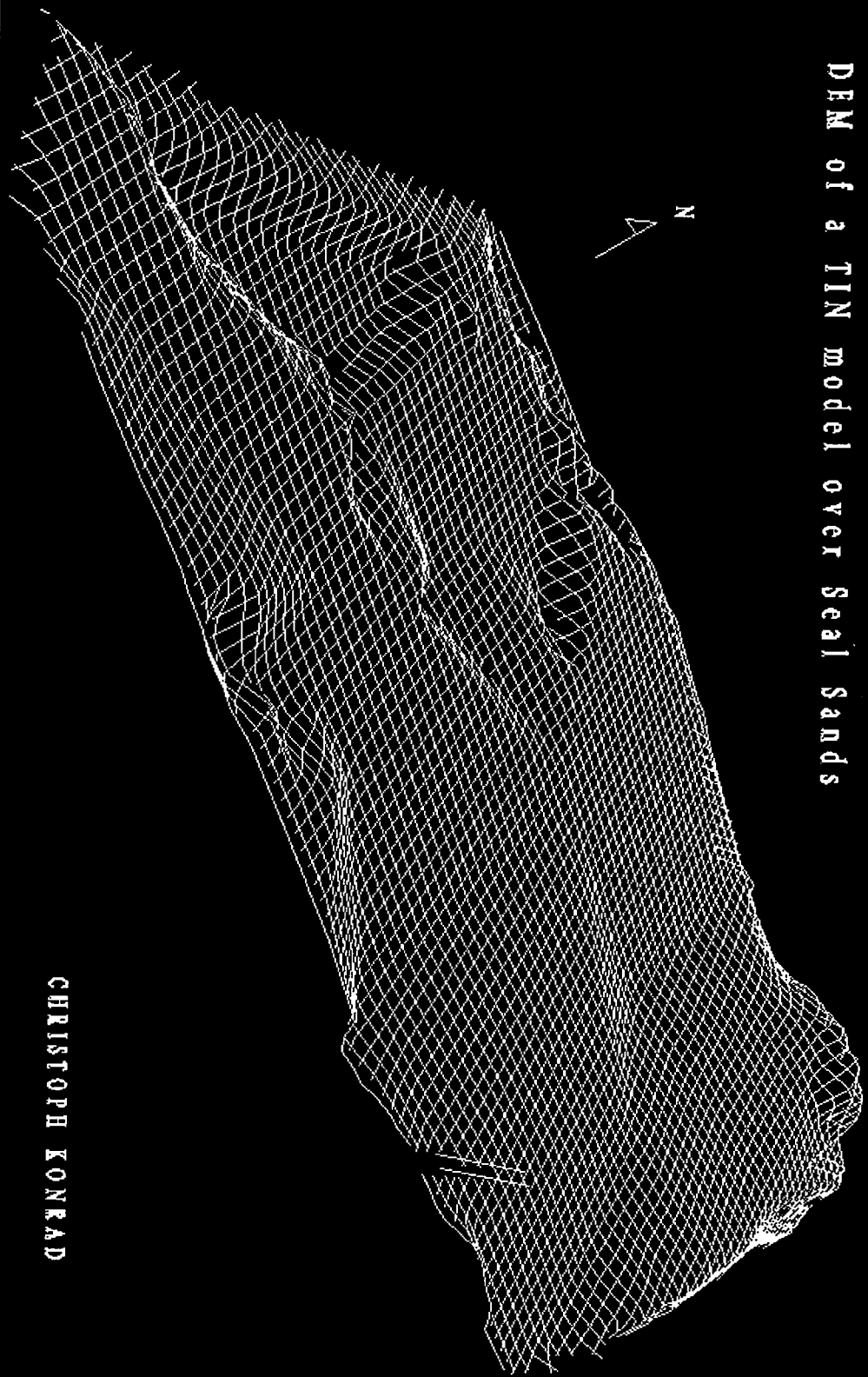
4



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Figure 6.5 3D-Tin Model of Seal Sands; Scale = 1: 7160.

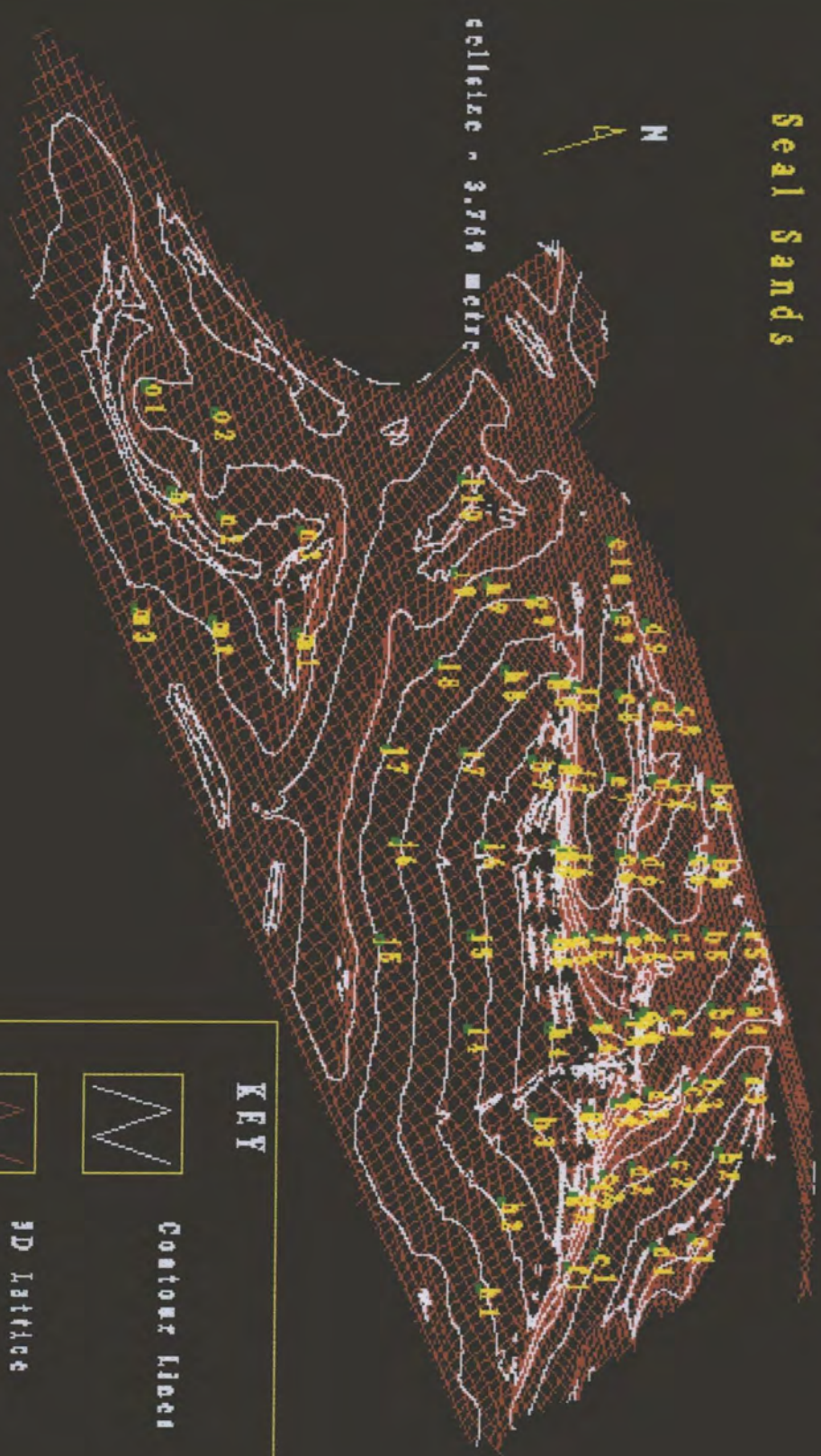
DEM of a TIN model over Seal Sands



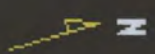
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**Figure 6.6 3D-Tin Model of Seal Sands with contour lines;
Scale = 1: 9600.**

3D Lattice with 0.5 m Interpolated contour lines Seal Sands



cellsize = 3.769 metre



KEY

	Contour Lines
	3D Lattice

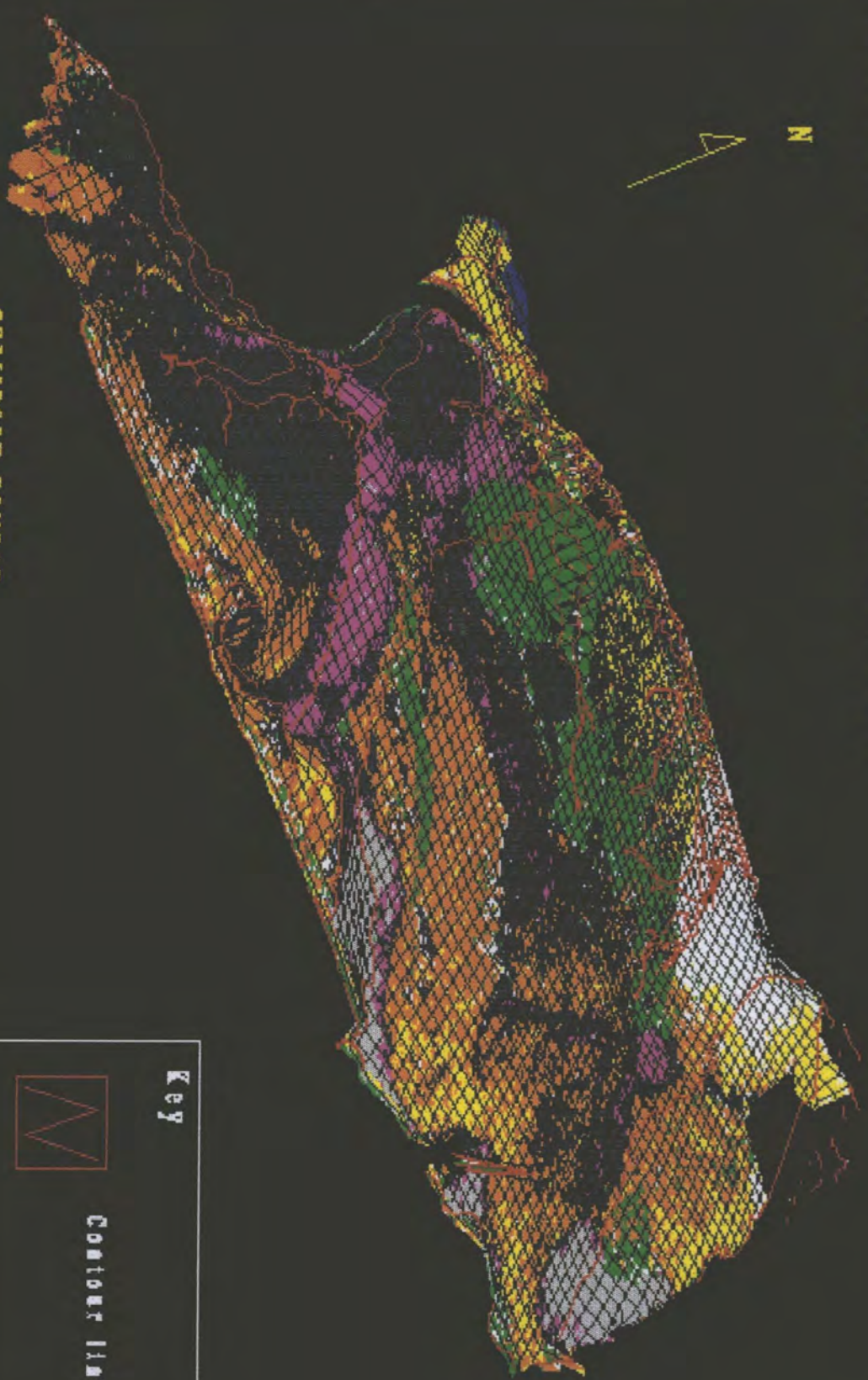
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Figure 6.7 Classified 3D-ATM images from Seal Sands**Scale = 1: 8150.**

blue	= water
white	= clouds
grey	= shadow
green	= Tidal vegetation (<i>Enteromorpha spp.</i>)
yellow	= Pure Sands (> 90 % sand)
orange	= Sandflat (90 - 50 % sand)
dark-blue	= Siltflat (50 - 20 % sand)
magenta	= Mudflat (< 20 % sand)

Classified 3D ATM Image from Seal Sands

N



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Key

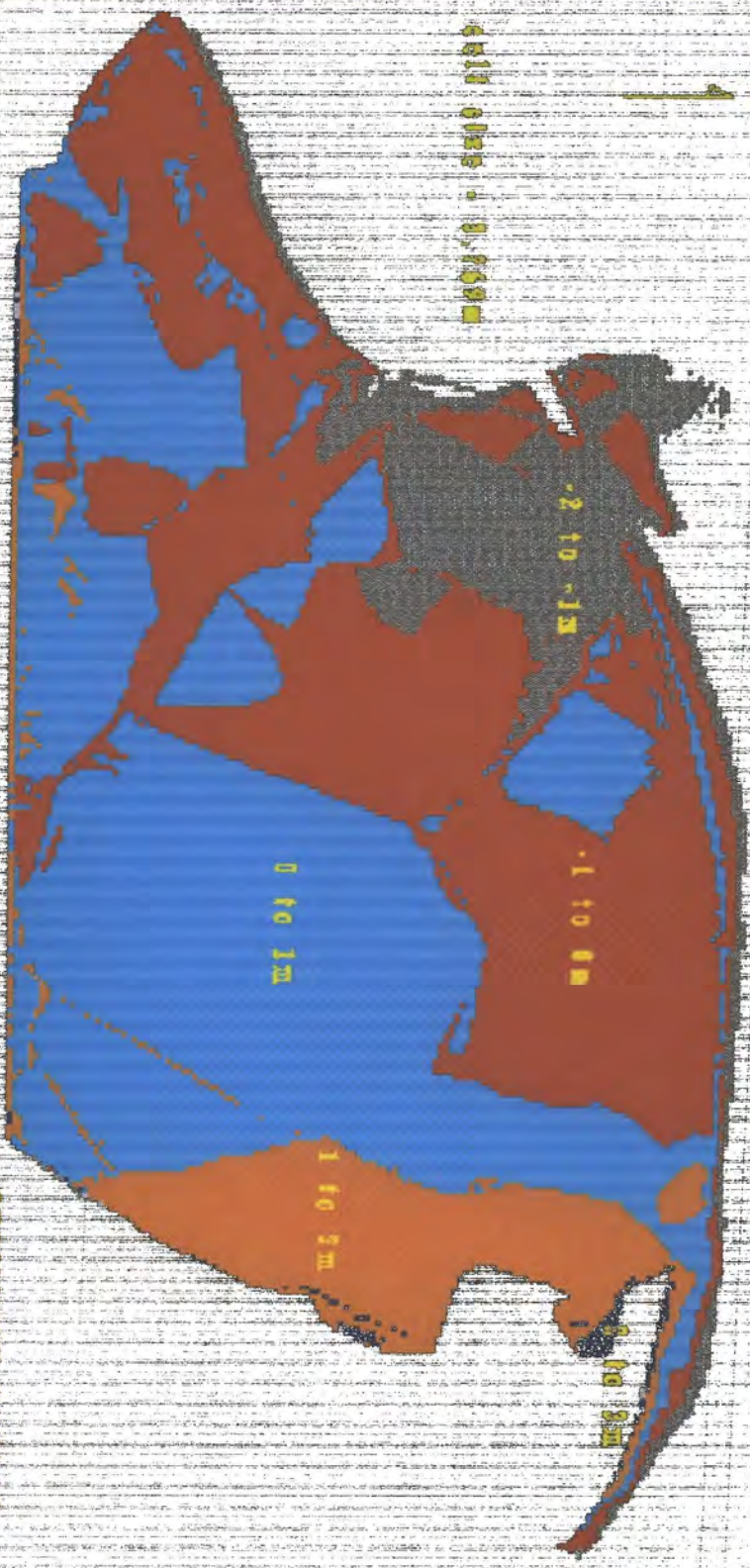


Contour Line

Figure 6.8 One metre elevation model of Seal Sands; Scale = 1: 12300.

Birds' feeding areas in dependency to the tidal range on Seal Sands

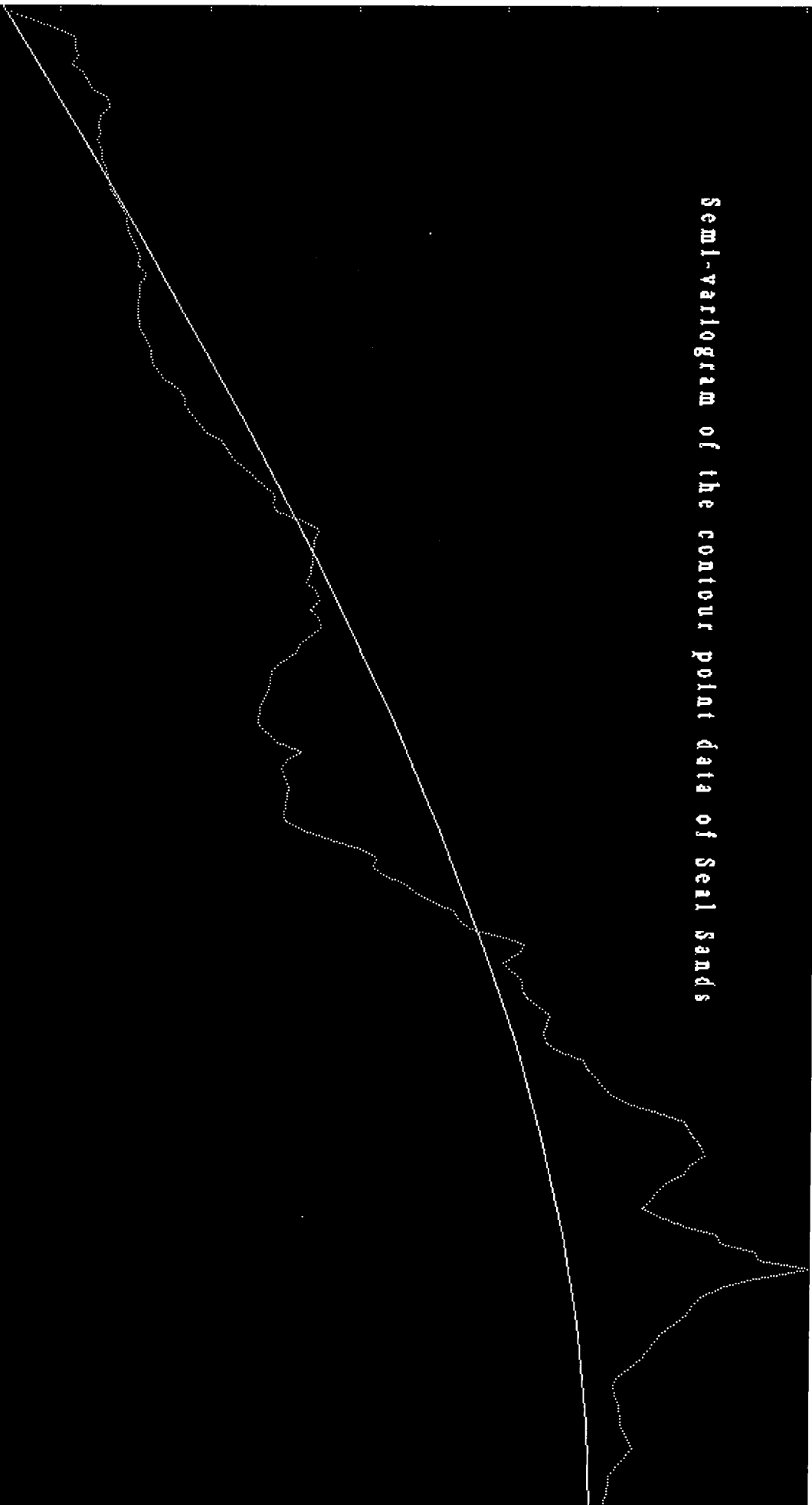
Scale 1:100,000
contour lines - 0.100m



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Figure 6.9 Example of semi-variogram of the contour data of Seal Sands.

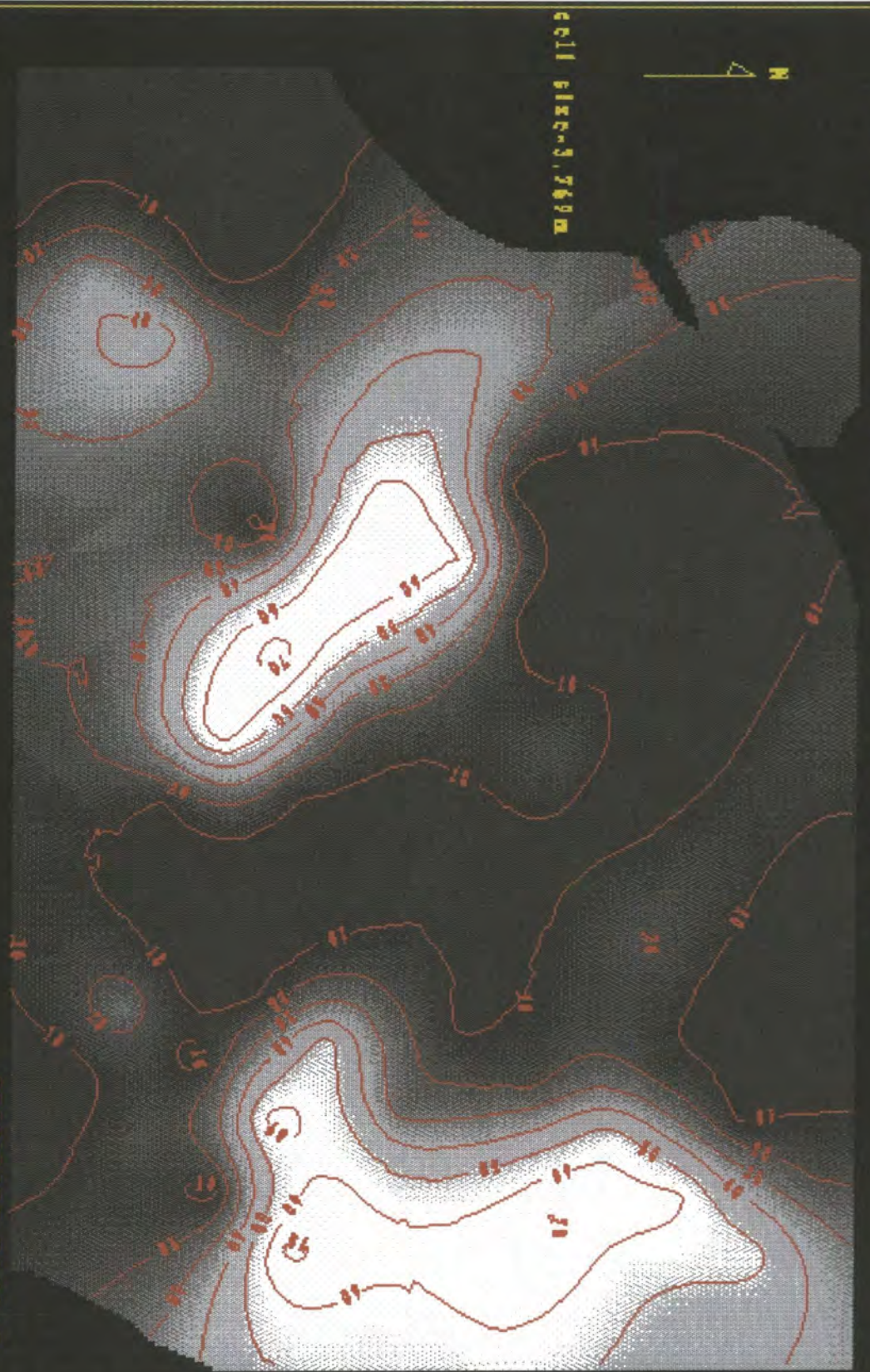
Semi-variogram of the contour point data of Seal Sands



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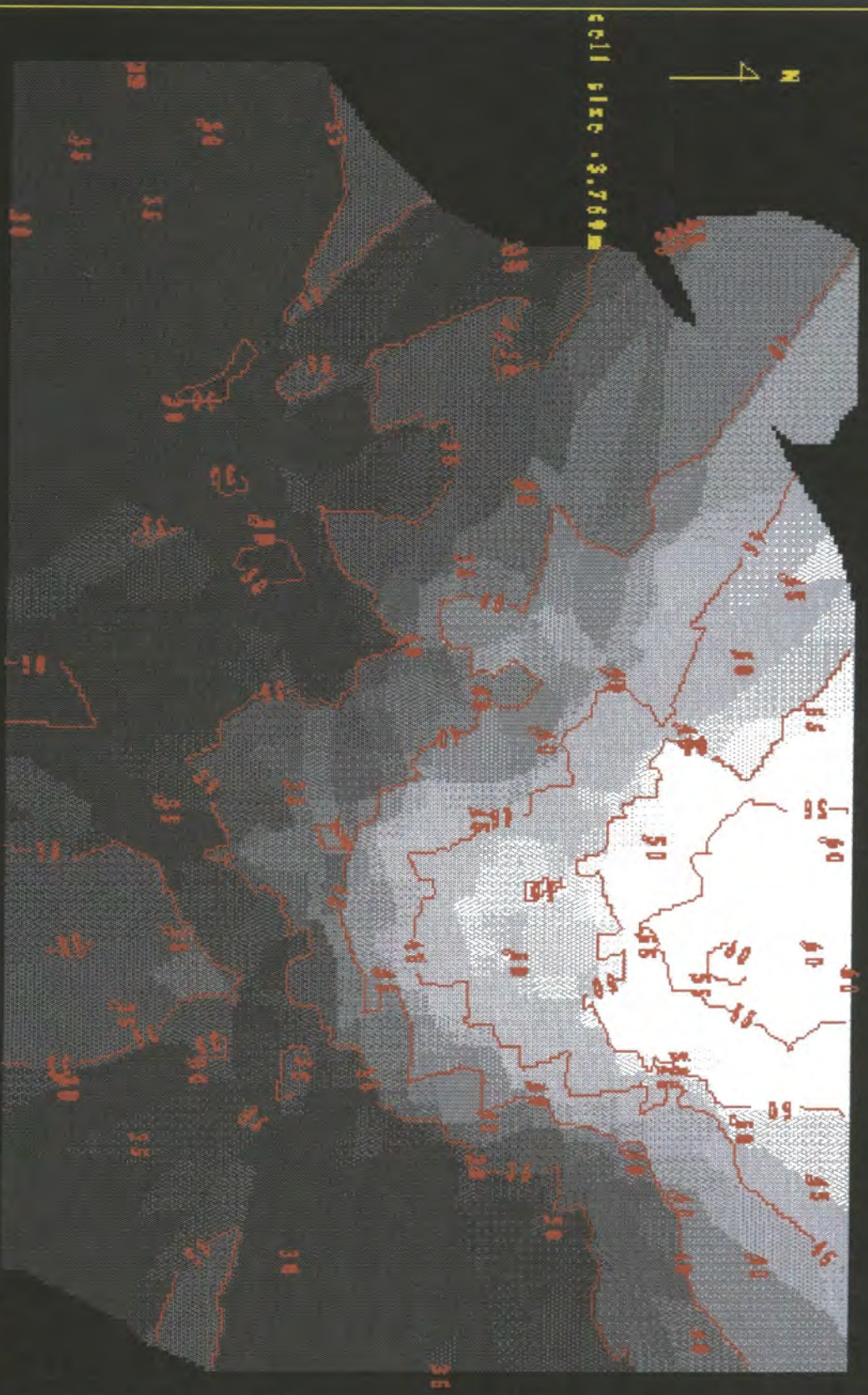
Figure 6.10 a - c Interpolated particle size analysis data from Seal Sands (1990/91); Scale = 1: 9500.

Medium Sand distribution on Seal Sands



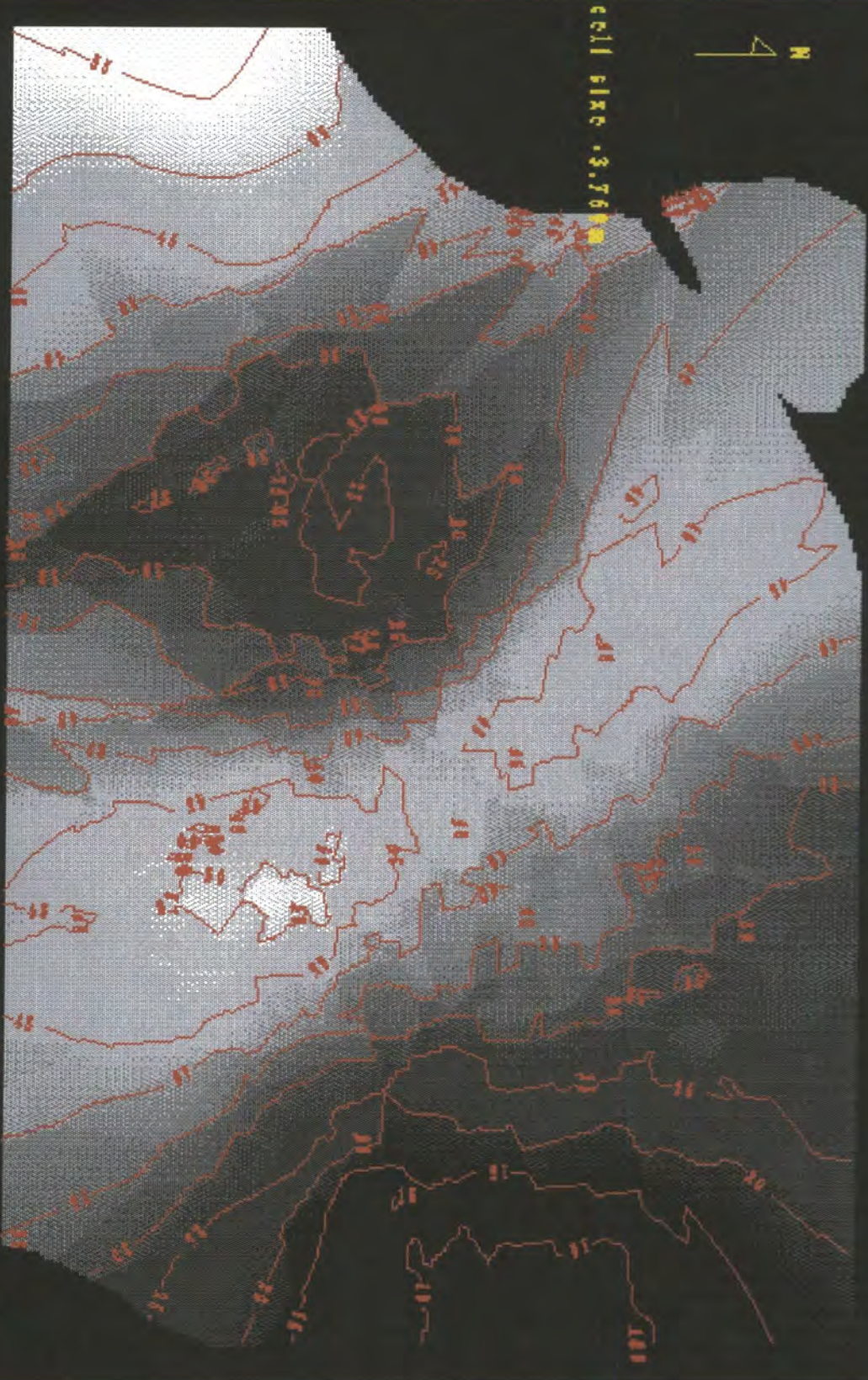
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Fine Sand distribution on Seal Sands



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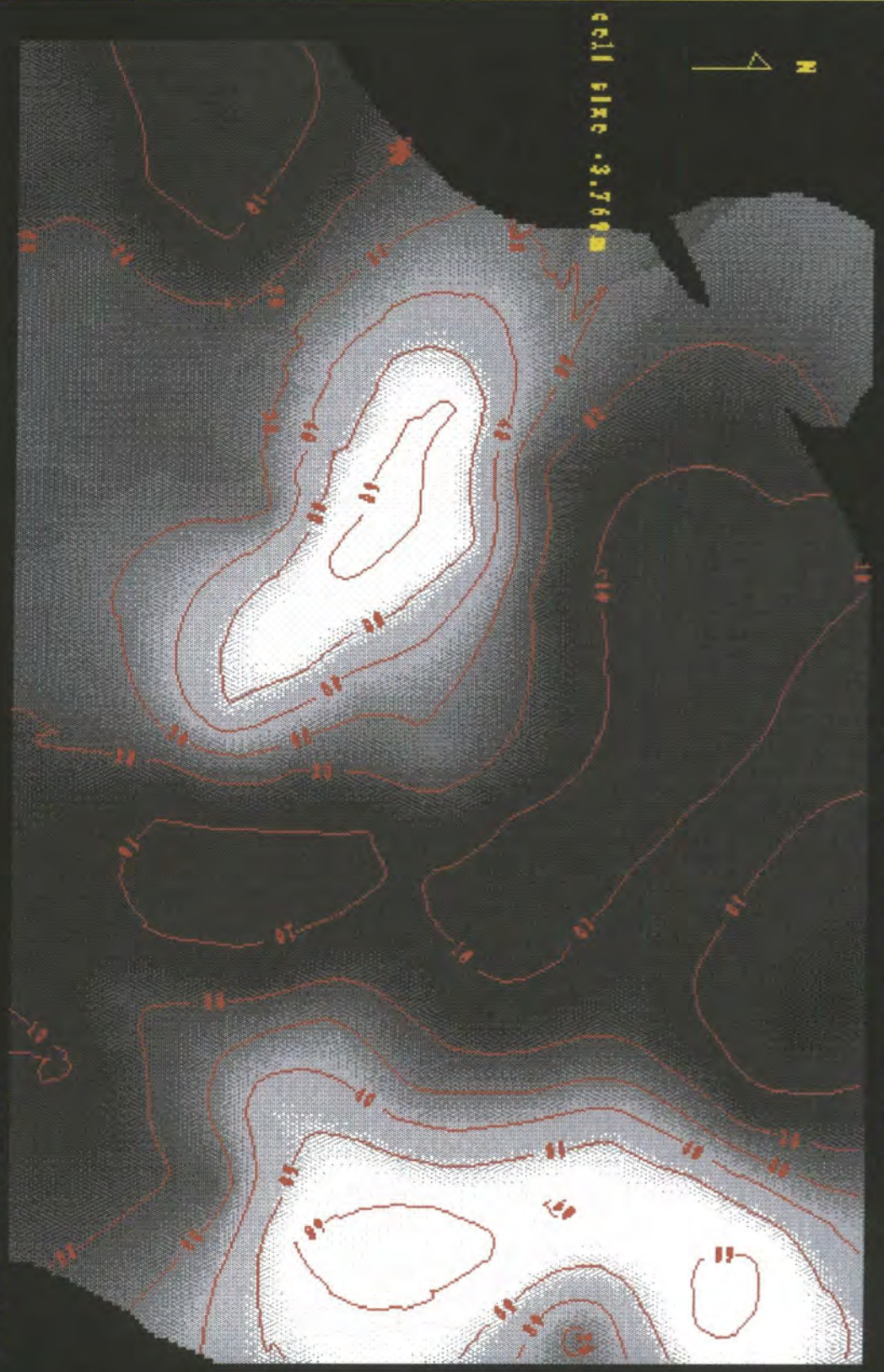
Silt & Clay distribution on Seal Sands



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Figure 6.11 a - c Interpolated particle size analysis data from Seal Sands (1992/93); Scale = 1: 9500.

Resampled Medium Sand distribution on Seal Sands

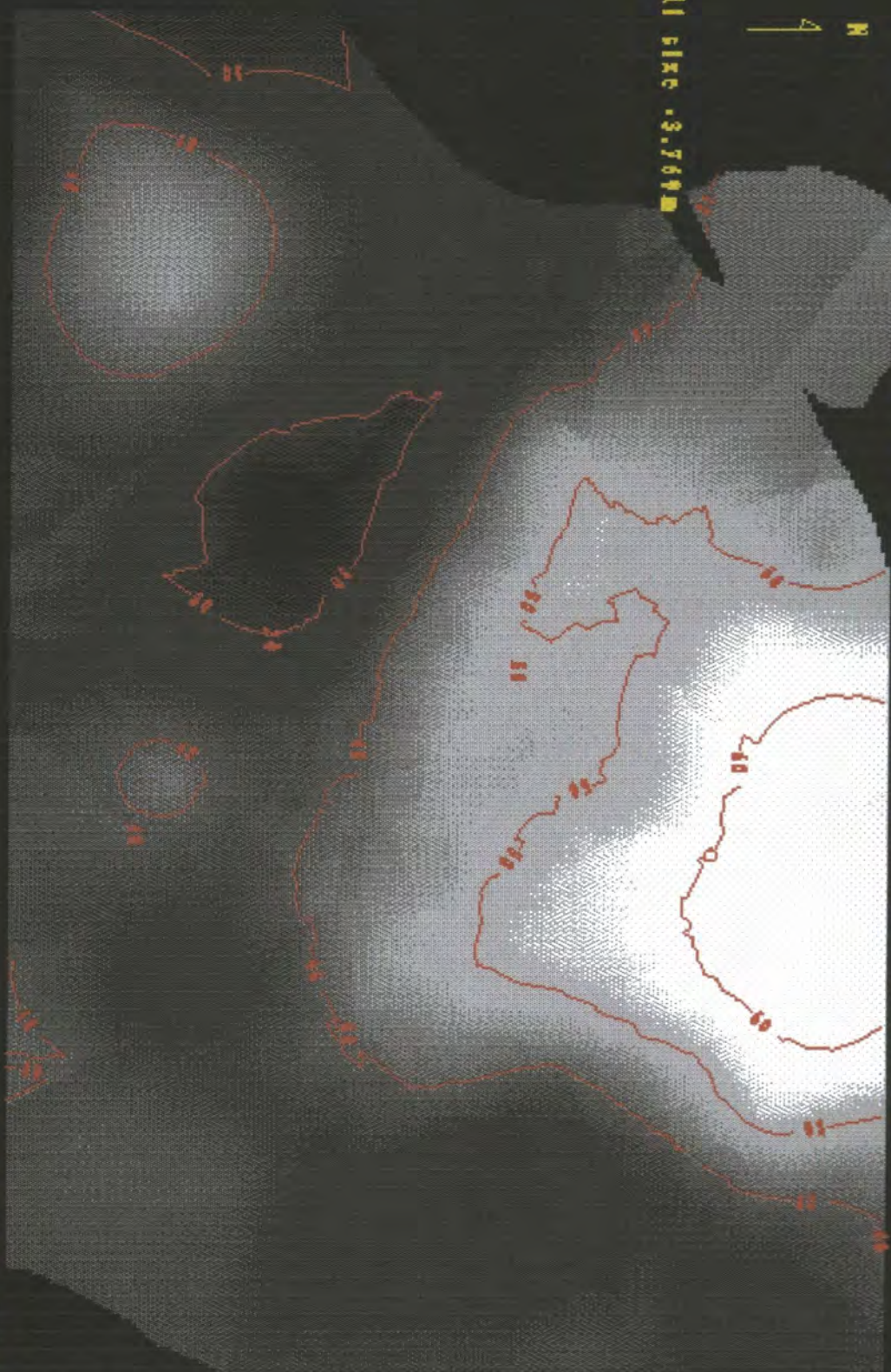


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Resampled Pine Sand distribution on Seal Sands

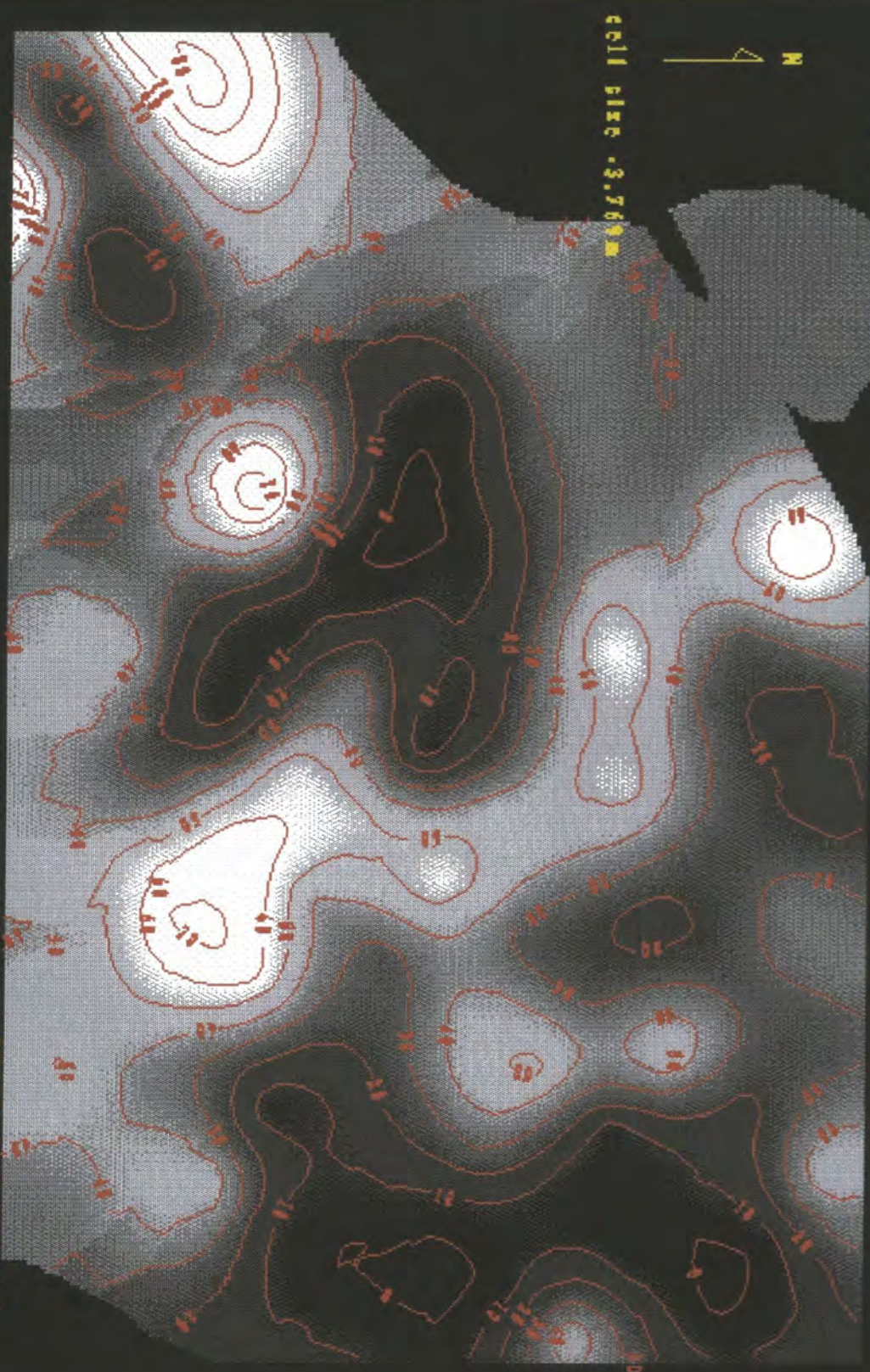
M
4

cell size = 3.76mm



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Resampled Silt & Clay distribution on Seal Sands



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**Figure 6.12 a - c Changes of the particle size distribution -
sampling of 90/91 & 92/93; Scale = 1: 9500.**

Results of the Particle Size Analysis 90/91 & 92/93

Medium Sand distribution over Seal Sands

N
P

- -10% change
- +10% change
- +20% change





Christoph Konrad

Results of the Particle Size Analysis 90/91 & 92/93

Fine Sand distribution over Seal Sands

N

P

-  -5% change
-  +5% change



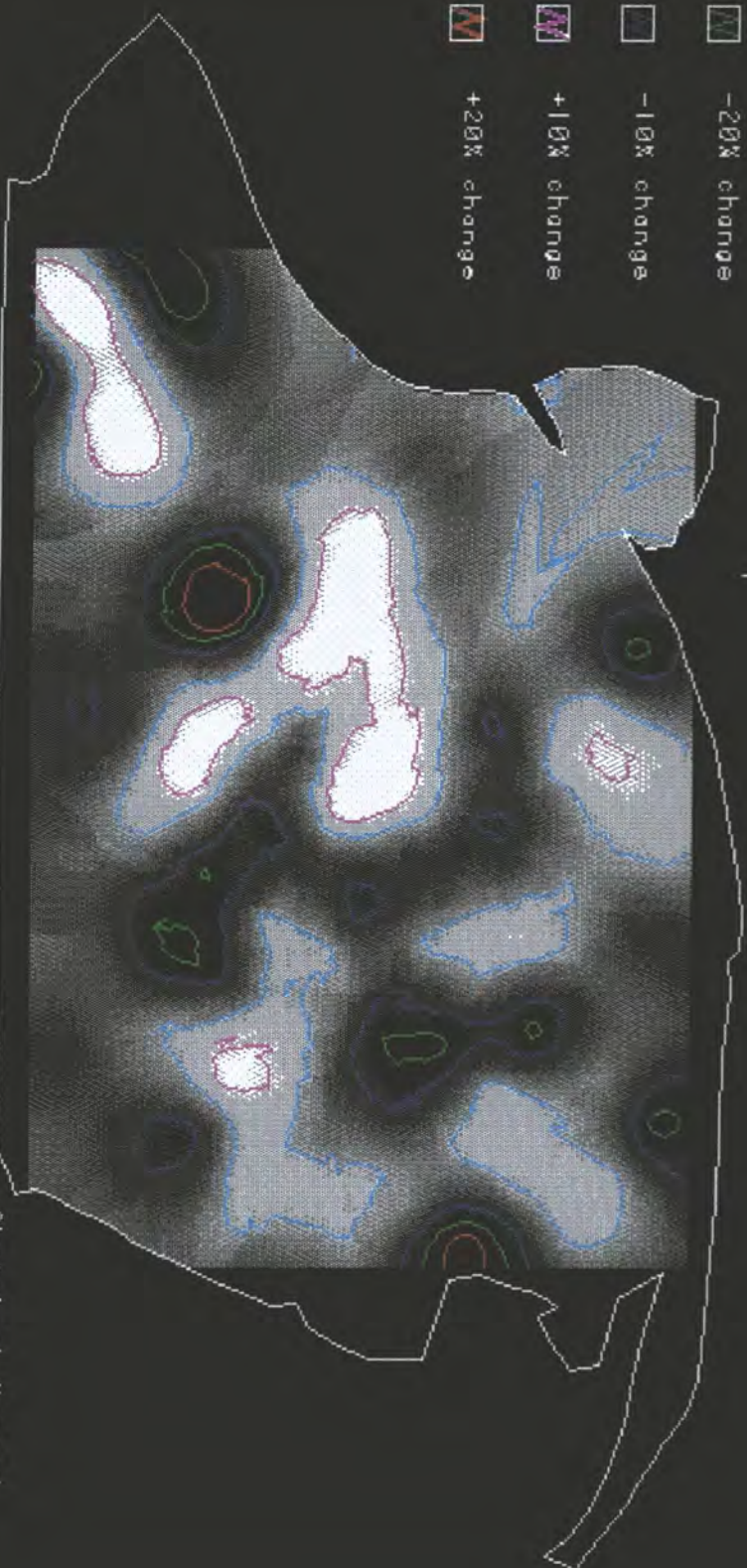
Christoph Konrad

Results of the Particle Size Analysis 90/91 & 92/93

Silt&Clay distribution over Seal Sands

N

- -30% change
- -20% change
- -10% change
- +10% change
- +20% change



Christoph Konrad

Appendix I.

/**

Authors: Dave Robinson and Christoph Konrad

RADIOMETRIC CALIBRATION PROGRAMME FOR BSQ OR BIL DATA FORMAT

*Note - you must fill in the values where *FILL* appears*

- this is pretty PC-specific

- program dies on 5 conditions, setting ERRORLEVEL:

- 1 the v0 and vk arrays will cause division by 0*
- 2 the calculated max & min are the same*
- 3 there is a read error when getting raw max & min*
- 4 there is a read error when doing the calibration*
- 5 there is a write error when doing the calibration*

***/

```
#include <dos.h>          /* for x87 detection */
#include <stdio.h>
#include <io.h>           /* for unbuffered i/o - faster on a PC */
#include <fcntl.h>       /* for file access modes */
#include <sys\stat.h>     /* for file attribute macros in creat() */
#include <stdlib.h>      /* for max() & min() macros */
#include <ctype.h>       /* for toupper() */
#include <string.h>      /* for strcmp */
#include <values.h>     /* for MAXDOUBLE & MINDOUBLE */
#include <math.h>        /* for ceil() & floor() */
```

/*

Values need to be redefined for different sizes of
image & recompile. All SIZES are in BYTES

```

*/
#define NBANDS/*fill in*/           /* Number of bands in the image */
#define NSAMPS/*fill in*/         /* Number of samples in a scan line */
#define LHSIZE/*fill in*/        /* Size of Line header in bytes */
#define LSIZE/*fill in*/         /* Size of complete scan line in bytes */
#define FHSIZE/*fill in*/        /* Size of any file header in bytes */
#define NLINES/*fill in*/        /* Number of lines of the image data*/
#endif

/*
   Function prototypes
*/
unsigned char roundtochar(double val);    /* do proper rounding */
int          YNprompt(char *msg);        /* ask a question, accept Y | N */
void         getmaxandmin(FILE *fh, int *mx, int *mn, int fmt);
int          band;

/*
   roundtochar()      Take a double-precision value in the unsigned char
                      range & round it properly.
*/
unsigned char roundtochar(double val)
{
    double high = ceil(val),
           low  = floor(val);

    return (unsigned char) (high - val <= (double) 0.5 ? high : low);
} /* roundtochar */

```

```

/*
  YNprompt()          Issue a prompt & wait for only Y or N. Return 1 if Y
*/
int YNprompt(char *msg)
{
  char ch = 0;

  fflush(stdin);

  while( ch != 'Y' && ch != 'N' ) {
    printf("\n%s (Y/N) ? ", (msg==NULL) ? "<no prompt sent>" : msg );
    ch = toupper( getchar() );
  } /* while ch */

  return ch == 'Y';
} /* YNprompt */

/*
  getmaxandmin()      Run through the image & gather the max & min for each
                    band into mx & mn
*/
void getmaxandmin(FILE *fh, int *mx, int *mn, int fmt)
{
  register int  b,
              l,
              s;

  unsigned char scanline[LFSIZE],
              *data;

```

```

data = scanline + LHSIZE;    /* points past the line header */

for(b=0; b<NBANDS; b++) {
    mx[b] = 0;
    mn[b] = 256;
} /* for b */

fseek(fh, (long) FHSIZE, SEEK_SET);

if(fmt != 1) {
    while( !feof(fh) ) {
        for(b=0; b<NBANDS; b++) {
            if( fread(scanline, 1, LSIZE, fh) == 0 )
                if( feof(fh) )
                    goto ResetFilePointer;
            else {
                perror("Read error");
                exit(3);
            } /* if eof() ... else */

            for(s=0; s<NSAMPS; s++) {
                mn[b] = min(mn[b], data[s]);
                mx[b] = max(mx[b], data[s]);
            } /* for s */
        } /* for b */
    } /* while !eof */
} /* if format */
else {
    for(b=0; b<NBANDS; b++) {
        for(l=0; l<NLINES; l++) {
            if( fread(scanline, 1, LSIZE, fh) == 0 )
                if( feof(fh) )

```

```

        goto ResetFilePointer;
    else {
        perror("Read error");
        exit(3);
    } /* if eof() ... else */

    for(s=0; s<NSAMPS; s++) {
        mn[b] = min(mn[b], data[s]);
        mx[b] = max(mx[b], data[s]);
    } /* for samples */
} /* for lines */
} /* for bands */
} /* if...else format */

```

ResetFilePointer:

```

fseek(fh, (long) FHSIZE, SEEK_SET);

/*
    Sanity check those maxes & mins
*/
for(b=0; b<NBANDS; b++)
    if( mx[band] == mn[band] )
        printf("\nWARNING: Max & min identical (%d), band %d\n", mx[band],
                band);

} /* getmaxandmin */

```

```

main()
{
FILE      *handlein,           /* file handle for input file */
          *handleout;         /* file handle for output file */

int        rawmax[NBANDS],
          rawmin[NBANDS];

int        band,              /* band counter */
          lines,
          sample,
          format = 1;

long       linesin = 0L,
          linesout = 0L;

double     vk[NBANDS] = { /*fill in*/},      /*Values need to be filled in*/
          v0[NBANDS] = { /*fill in*/ },      /*Values need to be filled in*/
          panelrad[NBANDS] = { /*fill in*/}  /*Values need to be filled in*/
          dnoff[NBANDS],
          gain[NBANDS],
          dnon,
          calibmax,
          calibmin,
          scale;

unsigned char scanline[LSIZE],
          *data,
          calib_luts[NBANDS][256],          /* lookup tbls calibrated val */
          fnin[64],                        /* name of input file */
          fnout[64];                       /* name of output file */

```

```

if( _8087 == 0 )
    puts( "\nWarning - this program seems to have problems with the"
          "\nTC emulation library & it looks like you DON'T have a"
          "\nco-processor installed. Check the size of the output"
          "file.");
/*
    Calculate the gain for each band. Do this first as it gives us a sanity
    check for the dnon & dnoff values
*/
for(band=0; band<NBANDS; band++) {
    dnoff[band] = v0[band] * 0.064;
    dnon = vk[band] * 0.064;

    if( dnon == dnoff[band] ) {
        printf("\nInsane values for dnoff & dnon cause division by 0"
              "\nPlease check the vk & v0 arrays in CALIB.C and then"
              "\nrecompile...");
        exit(1);
    } /* if dnon */

    gain[band] = panelrad[band] / ( dnon - dnoff[band] );
} /* for band */

fflush(stdin); /* Prevent rubbish on kbd buffer zapping what we type in */

/*
    Open input & output files
*/

```

GetInputFileName:

```
printf("\nName of file to calibrate >> ");
scanf("%s", fnin);
/*
handlein = fopen(fnin , O_RDONLY | O_BINARY);
*/

if( (handlein = fopen(fnin, "rb")) == NULL ) {
    perror("Cannot open that file");
    goto GetInputFileName;
} /* if handlein */
```

GetOutputFileName:

```
printf("\nName of file to create >> ");
scanf("%s", fnout);

if( strcmp(fnin, fnout) == 0 ) {
    printf("\nCannot create file with same name as input file");
    goto GetOutputFileName;
} /* if strcmp */

if( (handleout = fopen(fnout, "wb")) == NULL ) {
    perror("Cannot create that file");
    goto GetOutputFileName;
} /* if handlein */
/*
handleout = fopen(fnout, O_BINARY);
*/
/*
    Need the max & min of each band to scale the calibrated data within the
    char range
*/
```

AskAboutFormat:

```
printf("\nType 0 for BIL data format OR 1 for BSQ data format > ");
scanf("%d", &format);
```

AskAboutMaxAndMin:

```
if( YNprompt("Do you have the maxs & mins for each image band") ) {
```

```
    for(band=0; band<NBANDS; band++) {
```

TryThisBandAgain:

```
        printf("\nBAND %d: What's the max ? >> ", band+1);
```

```
        scanf("%d", rawmax + band);
```

```
        printf("And the min ? >> ");
```

```
        scanf("%d", rawmin + band);
```

```
        /*
```

```
        Sanity check
```

```
        */
```

```
        if( rawmin[band] >= rawmax[band] ) {
```

```
            printf("\nThose seem a bit stupid");
```

```
            if( !YNprompt("Start again from scratch") )
```

```
                goto AskAboutMaxAndMin;
```

```
            else {
```

```
                printf("\nTrying band %d again then...", band+1);
```

```
                goto TryThisBandAgain;
```

```
            } /* if !YNprompt ... else */
```

```
        } /* if rawmin */
```

```
    }
```

```
    } /* if YNprompt */
```

```
else {
```

```
    printf("\nWorking them out ...");
```

```

getmaxandmin(handlein, rawmax, rawmin, format);
for(band=0; band<NBANDS; band++)
    printf("\nBAND %d, max %d, min %d", band+1,
           rawmax[band],
           rawmin[band]);

} /* if YNprompt ... else */

/*
work out the scale factor from max & min
*/
calibmax = MINDOUBLE;
calibmin = MAXDOUBLE;
for(band=0; band<NBANDS; band++) {
    calibmax = max(calibmax, gain[band] * (rawmax[band]-dnoff[band]));
    calibmin = min(calibmin, gain[band] * (rawmin[band]-dnoff[band]));
} /* for band */

/*
Sanity check
*/
if( calibmax == calibmin ) {
    printf("\nCalibmax == calibmin ? Check vk, v0, panelrad arrays"
           "& recompile.");
    exit(2);
} /* if calibmax */
if( (scale = 255.0 / (calibmax - calibmin)) > 1.0 )
    scale = 1.0;

/*
Now create the LUT's for every possible value of each band
*/

```

```

printf("\nCalculating calibration lookup tables ...");
for(band=0; band<NBANDS; band++)
    for(sample=0; sample<256; sample++)
        calib_luts[band][sample]
            = roundtochar( ( (double) sample - calibmin)
                * scale * gain[band] );

printf("\nStarting calibration ...");
fseek(handlein, (long) FHSIZE, SEEK_SET);
data = scanline + LHSIZE;

if(format != 1) {

    for(lines=0; lines<NLINES; lines++) {
        for(band=0; band<NBANDS; band++) {
            fread(data, 1, LSIZE, handlein);

            for(sample=0; sample<NSAMPS; sample++)
                scanline[sample] = calib_luts[band][ scanline[sample] ];

            fwrite(data, 1, LSIZE, handleout);

        } /* for band */

        ++linesin;
        ++linesout;

    } /* end for ...lines */
} /* if format */
else {

for(band=0; band<NBANDS; band++) {

```

```
for(lines=0; lines<NLINES; lines++) {
    fread(data, 1, LSIZE, handlein);

    for(sample=0; sample<NSAMPS; sample++)
        scanline[sample] = calib_luts[band][ scanline[sample] ];

    fwrite(data, 1, LSIZE, handleout);
    ++linesin;
    ++linesout;
} /* for lines */

} /* end for ...bands */
} /* if...else format */
```

FileExhausted:

```
printf("Finished.\n%d lines in\n%d lines out\n", linesin, linesout);
```

```
fclose(handlein);
```

```
fclose(handleout);
```

```
} /* main */
```

```
/*End of Radiometric Calibration Programme*/
```

