ministerie van verkeer en waterstaat

rijkswaterstaat

dienst getijdewateren

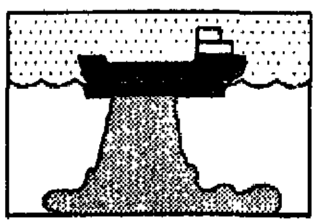
nota GWWS-91.002

Sedimenttransport in het
Eems-Dollard estuarium,
volgens de methode McLaren.

auteur(s) : Tj. van Heuvel

datum : februari 1991

samenvatting :



BAGHWAD PRODUKT 36

Inhoudsopgave

Samenvatting en conclusies

1) Een sedimenttransport analyse is uitgevoerd op basis van korrelverdelingen van 668 bodemmonsters, die genomen zijn in het Eems-Dollard estuarium. De "methode Mclaren" levert patronen op van netto transporten voor een 3 tal sediment fracties. Deze worden gekenmerkt als zand, gemengd sediment en slib. De patronen zijn gebaseerd op optimale statistische relaties en niet op gebiedskennis.

2) De transportpaden voor de 3 verschillende fracties komen zeer goed overeen en vullen elkaar aan. De enige uitzondering is de rivier de Eems, waar een slibtransport in stroomopwaartse richting vastgesteld is, terwijl zand stroomafwaarts getransporteerd blijkt te worden. Een mogelijke verklaring voor dit verschijnsel is dat marien slib tijdens Hoog Water kentering bezinkt en door haar cohesieve eigenschappen zich niet laat resuspenderen en transporteren tijdens eb.

3) De trendanalyse volgens Mclaren levert een ingewikkeld, maar eenduidig patroon van eb en vloed gedomineerde transportpatronen op. De vele ondiepten in het gebied scheiden de eb- en vloedgeulen van elkaar. Vrijwel alle transportpaden duiden op een netto aanzanding/aanslibbing. Over het geheel genomen duiden deze paden op een sediment-importerend estuarium. De resultaten zijn weergegeven in de figuren 8,9 en 10.

4) De huidige vaargeul, die met baggerwerk wordt onderhouden, kruist het pad met een "natuurlijk" sedimenttransport op twee plaatsen. Op basis van de gevonden transportpaden wordt verwacht dat op deze plaatsen meer dan gemiddeld gebaggerd moet worden, tijdens het onderhoud.
Deze gebieden bevinden zich in de versmallingen nabij Mond van de Dollard en Oost Friese Gaatje, en het gebied tussen de Oude Wester Eems en de geul in het Doekegat. In de praktijk blijkt ook op deze lokaties het meeste onderhoudsbaggerwerk voor te komen.

5) De hoofdroute voor de scheepvaart loopt voor een deel door geulen/geulgedeelten met een vloeddominerend sedimenttransport. Onderhoudsbaggerwerk zou mogelijk kunnen worden verminderd door als transportweg een geul/geulgedeelte met een ebdominerend transport van sediment te gebruiken. De vaargeul zou dan door de ebstroom "schoongespoeld" kunnen worden.

6) Baggerspecie uit de haven van Delfzijl, die gestort wordt in de geul nabij de Bocht van Watum, wordt verspreid in de bocht van Watum tot aan de westelijke helft van de zandplaat Hond-Paap.

7) De nieuwe stortlocatie in de westelijke geul van de Oude Wester Eems, nabij de Eems haven, is gekozen in een vloed gedomineerde transportbaan. Hierdoor zal sediment mogelijk sneller terugkeren in de richting van de Eemshaven, dan wanneer de stortlokatie in een eb gedomineerde geul gekozen was.

8) Op basis van de korrelverdelingen zijn percentages zand, percentages slib en de mediane korreldiameter (D50) berekend. De verdeling van deze grootheden is weergegeven in kaarten van het onderzoeksgebied (zie hoofdstuk 4.1).

1. Inleiding

In opdracht van de Directie Groningen verricht de Dienst Getijdewateren onderzoek naar de invloed van baggeractiviteiten op het Ecosysteem in het Eems-Dollard gebied. Voor een goed advies worden de vraagstukken met betrekking tot de slibhuishouding benaderd langs twee sporen, namelijk de "modelbenadering" en de "empirische/waarnemingen benadering".
Om de invloed van baggeren op de troebelheid te kunnen afschatten, wordt in het kader van het projekt BAGHWAD (BAggeren Havens WADden) een numeriek slibtransportmodel gebouwd, met daarin "genest" een nearfield stortmodel [1].
Naast de modelmatige aanpak zijn veldwaarnemingen essentieel voor het verkrijgen van basisgegevens. Bij het maken van een slibbalans vormde met name de verouderde kennis omtrent de bodemsamenstelling, een belangrijk basisgegeven, een probleem. Om deze reden is het Engels-Canadese bedrijf GeoSea Consulting Ltd. opdracht gegeven tot een inventarisatie van de bodemsamenstelling.
Naast de bodemsamenstelling is door GeoSea, met een door hen ontwikkelde methode, vastgesteld langs welke transportpaden zand en slib zich bewegen in het estuarium. Kennis omtrent de bodemsamenstelling en empirische netto (rest)-transportrichtingen van sediment wordt gebruikt om het slibtransportmodel te optimaliseren.

Het Engels-Canadese bedrijf GeoSea Consulting Ltd. heeft al eerder een dergelijk onderzoek voor DGW uitgevoerd voor het kustgebied in de Mond van het Haringvliet [2] en het kustgebied rond de slibstortlokatie Loswal Noord [3].
Voor het Eems-Dollard estuarium heeft GeoSea de analyse uitgevoerd op basis van de 668 korrelverdelingen van bodemmonsters, die in het gebied genomen zijn tussen oktober en december 1989.
De korrelverdelingen van de monsterlokaties leveren een beeld op van de zand/slib verdeling over het estuarium. De methode van Mclaren en Bowles is gebruikt om de transportpaden van zand, slib en gemengd sediment te bepalen. De beschrijving van de methode en de resultaten van het Eems-Dollard onderzoek zijn in een engelstalig rapport vast gelegd. Het is in deze nota bijgevoegd als appendix A .

[1] Van Heuvel Tj., 1988. Verspreiding van baggerspecie tijdens en na het storten vanuit een baggerschip. RWS- Dienst Getijdewateren: nota GWAO-88.034.
[2] GeoSea, juli 1988. The sediment transport regime in Mond Haringvliet.
[3] GeoSea, augustus 1989. The dipersal of dredge material and nearshore sediment transport between Rotterdam and Scheveningen.

2. Doel van het onderzoek

Een belangrijk doel van dit onderzoek was om de bodemsamenstelling in het estuarium vast te leggen voor 1989/1990. Dit ten behoeve van een slibbalans en het ontwikkelen van (sediment)transportmodellen en ecologische beleidsmodellen.

De methode Mclaren is gekozen omdat op grond van de korrelverdelingen, empirische netto transportpaden van zand en slib bepaald kunnen worden. De resultaten zullen gebruikt worden voor het afregelen van sediment-transportmodellen. Op grond van de kaarten kan ook direkt geadviseerd worden als het gaat om beleid ten aanzien van storten en lozen in het Eems-Dollard estuarium.

In de opdracht naar GeoSea zijn deze doelen verwoord in een aantal deelopdrachten:

1) Het vaststellen van netto eb/vloed transportpaden van sediment in het Eems-Dollard estuarium.

2) Het vaststellen van transportpaden voor de verschillende sediment-fracties: zand, slib en gemengd. Hierbij moet tevens aangegeven worden of er een erosie-, evenwichts- of sedimentatie-trend bestaat.
Voor de transportrichting moet vastgesteld worden of het sediment fijner of grover wordt.

3) Het inschatten van de invloed die baggeractiviteiten hebben op het sedimenttransport.

4) Het inschatten van het transportgedrag van baggerspecie die op specifieke lokaties gestort is (Bocht van watum, Oude Wester Eems).

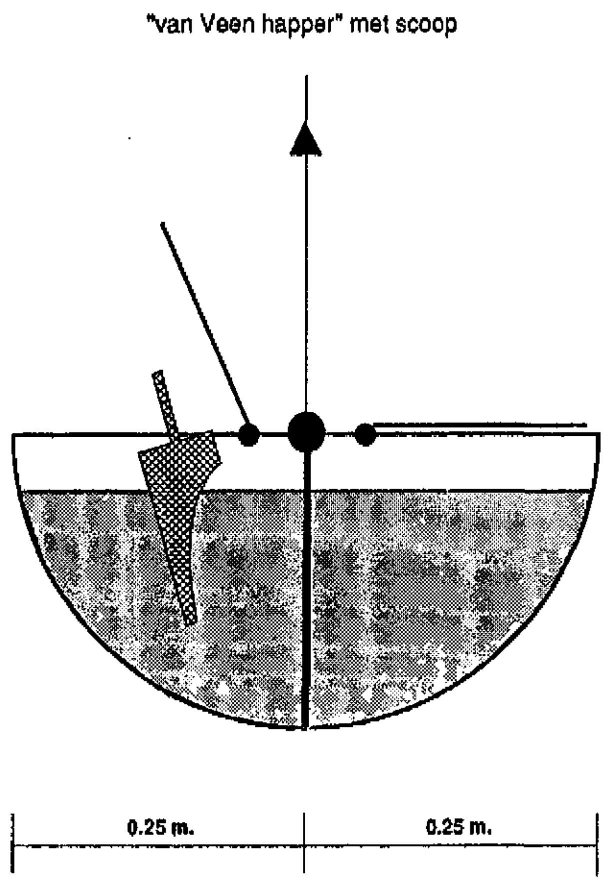
5) Suggesties (indien mogelijk) om de hoeveelheid baggerwerk te verminderen (Dit op wetenschappelijke basis).

3. Opzet en uitvoering van het onderzoek

Bij de opzet van het onderzoek is gebruik gemaakt van de ervaringen die opgedaan zijn bij het onderzoek rond Loswal Noord. Dit geldt zowel voor het veldonderzoek als de vervolgwerkzaamheden. In het kort komt het neer op:

* Vaststellen van een basisrooster van meetlokaties in het onderzoeksgebied. Dit basisrooster heeft een maaswijdte van 1*1 km, en houdt geen rekening met geulen en platen. Indien nodig is het verdicht met een lokatie in het centrum van een vierkant. (zie figuur 8)

* De bodemmonsters, die geanalyseerd zijn op korrelgrootteverdeling, zijn gestoken met een speciale lepel (scoop). De monsters vertegenwoordigen daardoor de bovenste 8-10 cm uit een groter bodemmonster. Deze bodemmonsters zijn genomen met een grote van Veen-happer. Op basis van deze grote bodemmonsters (10-20 liter) werd ook informatie ingewonnen omtrent gelaagdheid en bodemfauna. Tevens werd een reserve monster genomen. Deze monsters worden diepgevroren bewaard voor eventueel nog nader uit te voeren analyses.



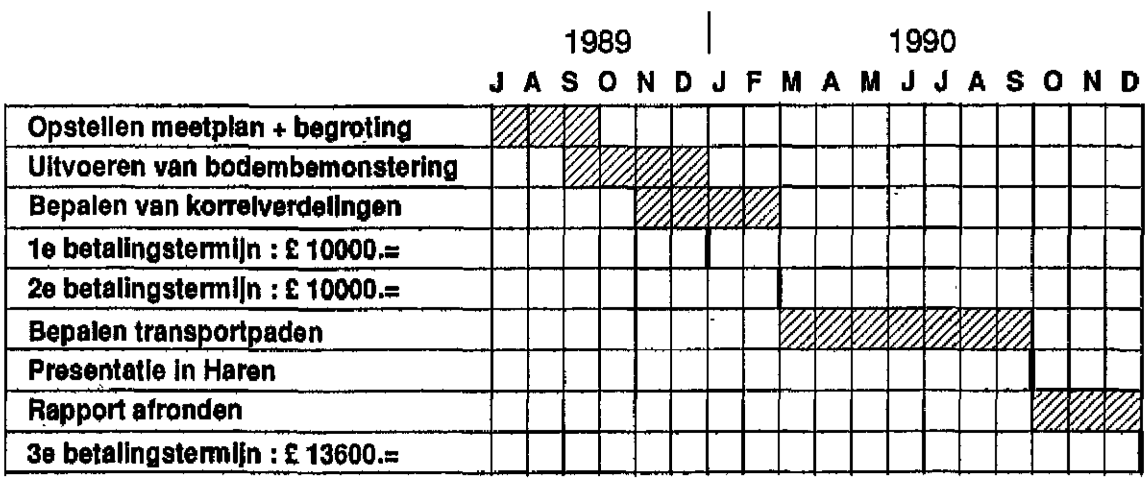
Figuur 1: Het nemen van een deelmonster uit een van Veen bodemhapper.

* Er zijn 24 bootdagen besteed om alle 668 lokaties langs te gaan. Met toestemming van de Duitse autoriteiten zijn de lokaties in de Ooster Eems en Eems-rivier door de meetdienst Delfzijl bezocht. Gedurende de eerste week is een medewerker van GeoSea meegeweest. De bodemmonsters zijn genomen tussen 25 september en 13 december 1989.
Omdat in deze periode van bemonstering geen stormen zijn geweest, en baggeractiviteiten nauwelijks hebben plaatsgevonden, kan er gesteld worden dat er een synoptische opname gemaakt is van het Eems-Dollard estuarium.

* De analyse van de sediment-monsters is uitgevoerd door GeoSea Engeland. Het monster wordt gezeefd om de deeltjes grover dan 2 mm te verwijderen. Vervolgens worden de monsters door het systeem van de Malvern geanalysserd. Dit gebeurt met een tweetal lenzen.
De totale korrelverdeling wordt digitaal opgeslagen in een database. De database gegevens zijn aan Rijkswaterstaat beschikbaar gesteld voor verdere verwerking tot bijvoorbeeld bodemsoort-kaarten.

* De interpretatie van de data en verwerking tot transport-paden is uitgevoerd door GeoSea Canada Ltd.. Hierbij wordt gebruik gemaakt van een programma dat daar ontwikkeld is om de onderlinge statistische relaties tussen korrelverdelingen te bepalen. De methode van "trial and error" moet echter gehanteerd worden om tot optimale transportpaden te komen [zie appendix A]. De gevonden eb/vloed tranportpaden zijn tot stand gekomen op basis van optimale statistische correlatie, en niet op basis van "gebiedskennis".

* Het tijdschema van het verloop van het projekt is in onderstaande tabel weergegeven.



4. Resultaten

De resultaten van het onderzoek zijn twee-ledig:

1) Een database met kwalitatieve gegevens over de korrelverdelingen van 668 monsterlokaties (zie bijlagen 1)

2) De transportpaden voor zand, slib en gemengd sediment; deze zijn bepaald en vastgelegd op gebiedskaarten. (zie de figuren 8 t/m 11 en ook Appendix A)

4.1 De korrelverdeling

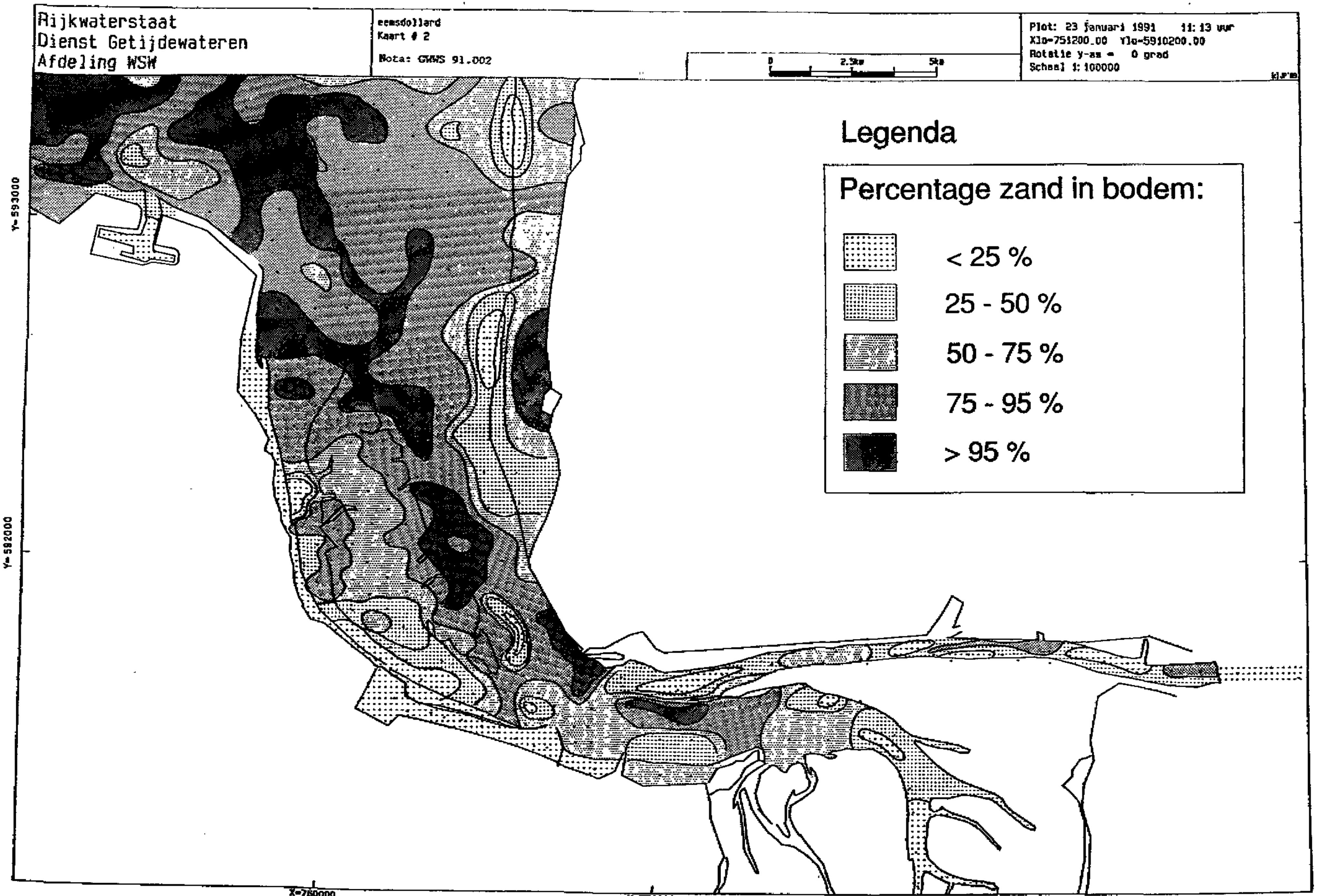
De korrelverdelingen zijn gegeven in gewichtspercentages per klasse van 0.5 phi ($-{}^{2}\log$ (diameter in mm)). Hieruit zijn onder andere het zand-percentage, slib-percentage en de mediane korreldiameter (D50) van het monsterpunt berekend. Deze informatie is weergegeven in bijlage 1.

De verdeling van het zandpercentage (korrels > 64 micrometer) over het estuarium is weergegeven in de figuren 2 en 3. Uit de verdeling blijkt dat de buitendelta voornamelijk uit zand bestaat. In de omgeving van Delfzijl is de verspreiding van zand beperkt tot de diepere delen van geulen.

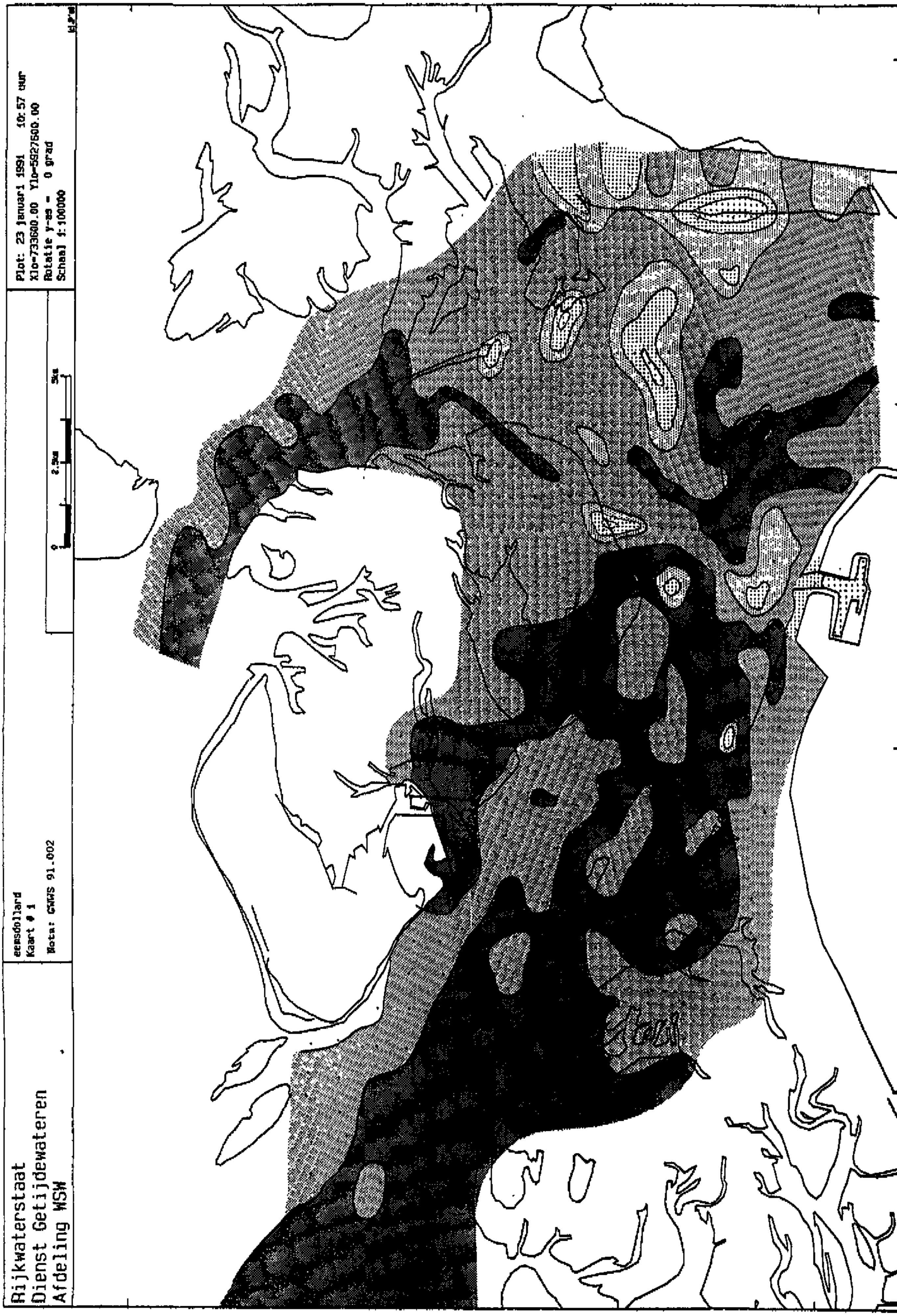
De verdeling van het slibpercentage (korrels < 64 micrometer) over het estuarium is weergegeven in de figuren 4 en 5. De lokaties met de hogere slib-percentages liggen in de toegangsgeul tot Delfzijl, de Eemshaven en de Bocht van Watum. Verder zijn de kweldergebieden en de Dollard slibrijke gebieden. De rivier de Eems, die in de as bemonsterd is, toont hier en daar een lokatie met slib.
De slibrijke gebieden worden voornamelijk aangetroffen in het trajekt tussen Delfzijl en Emden, waar ook het troebelheidsmaximum zich bevind.

De mediane korreldiameter (de diameter waarbij 50% van de korrels in het monster groter danwel kleiner zijn) is berekend voor alle monsterpunten. De isolijnen-kaarten (zie figuur 6 en 7) tonen dat met name in de hoofdgeulen grof sediment aangetroffen wordt. De D50 ligt hier boven de 300 micrometer. De lagere waarden voor de D50 komen overeen met de slibrijke gebieden.
Bij sedimenttransport berekeningen wordt in het algemeen de verdeling van de mediane korreldiameter over een gebied gebruikt.

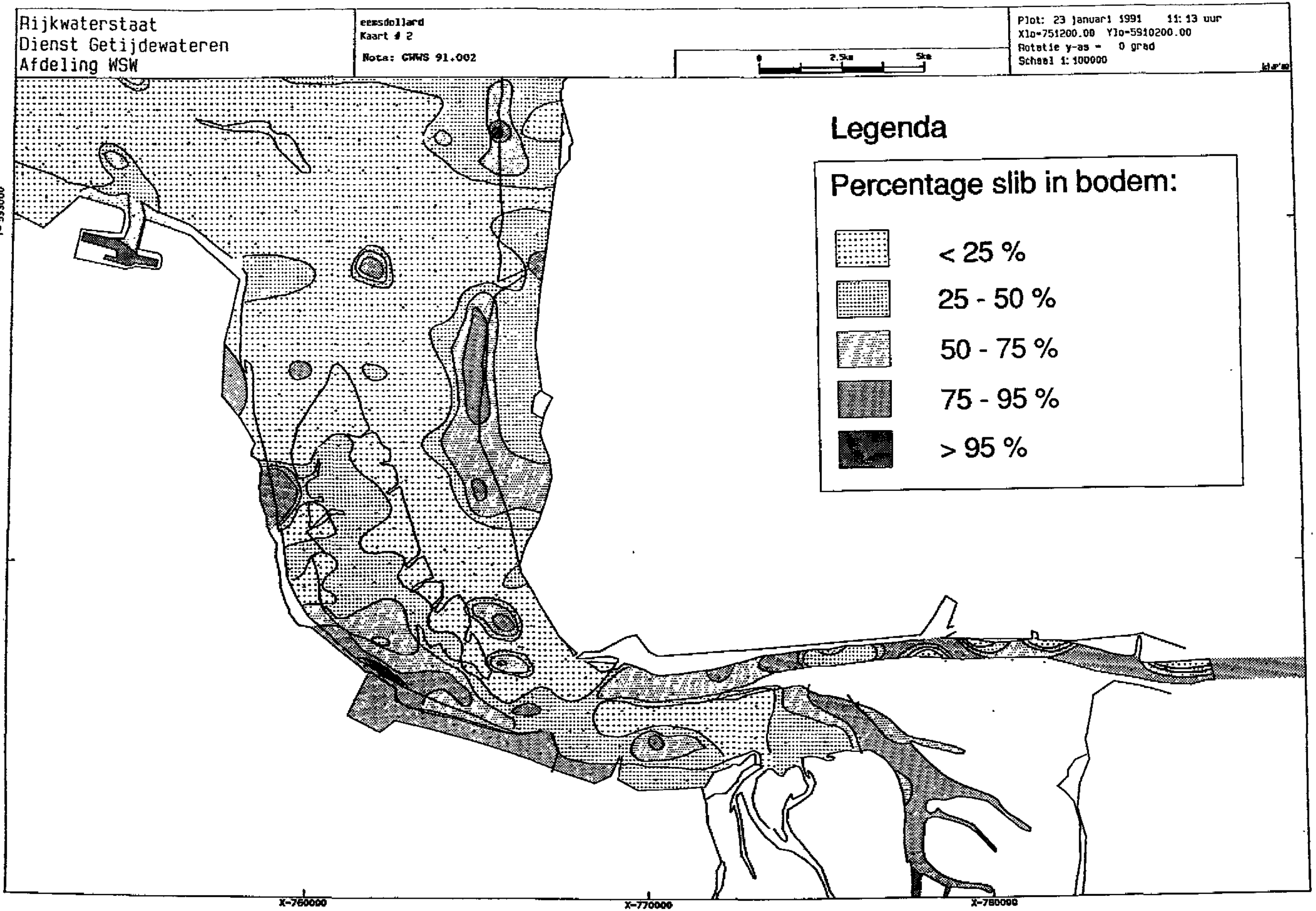
De gegevens komen beschikbaar als bestand in een GIS-computer met een ARC-INFO database systeem.



Figuur 2: Verdeling van het zandpercentage in het zuidelijk deel van het Eems-Dollard estuarium

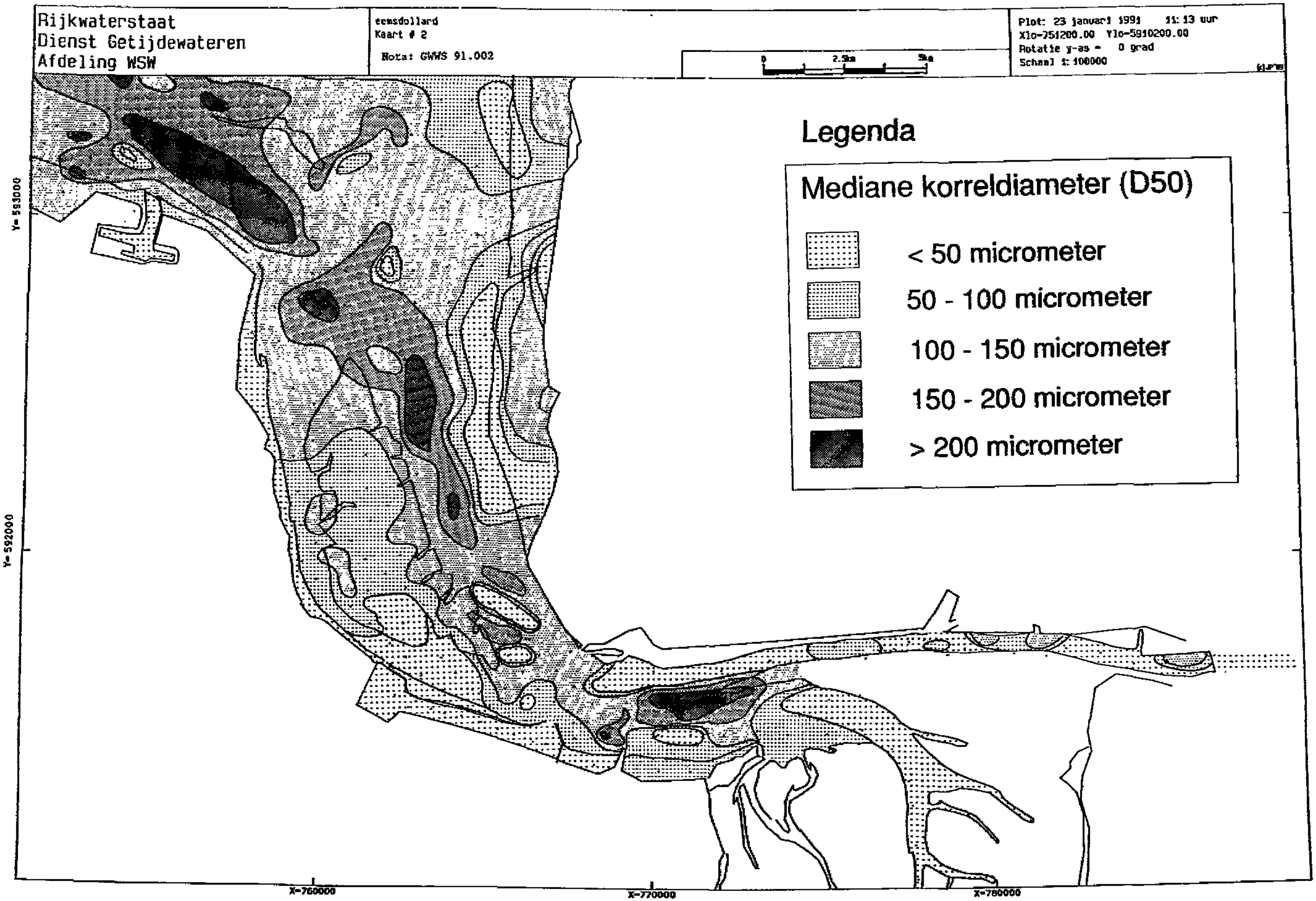


Figuur 3: Verdeling van het zandpercentage in het noordelijk deel van het Eems-Dollard estuarium

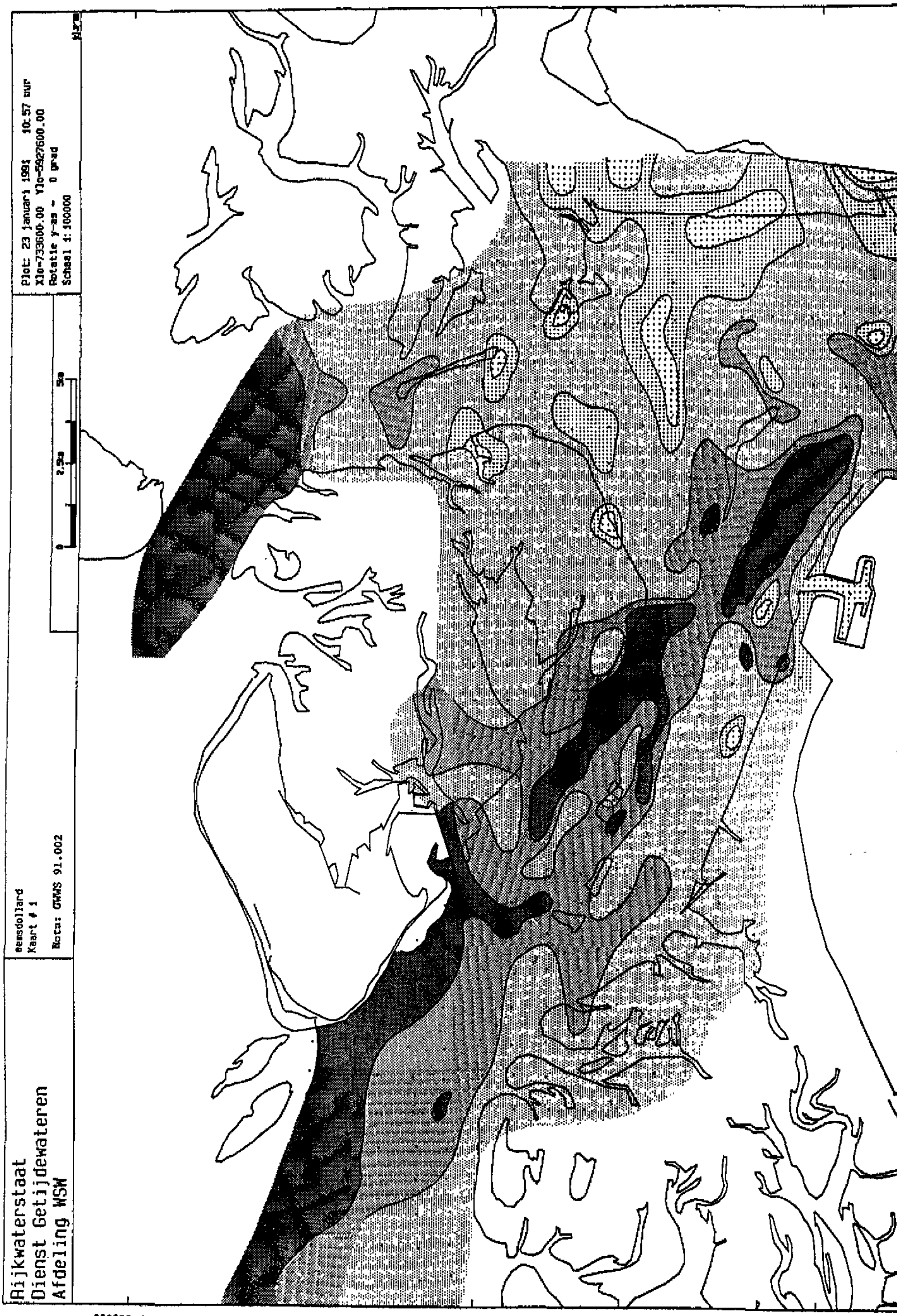


Figuur 4: Verdeling van het slibpercentage in het zuidelijk deel van het Eems-Dollard estuarium

Figuur 5: Verdeling van het slibpercentage in het noordelijk deel van het Eems-Dollard estuarium



Figuur 6: Verdeling van de mediane korreldiameter in het zuidelijk deel van het Eems-Dollard estuarium



Figuur 7: Verdeling van de mediane korreldiameter in het noordelijk deel van het Eems-Dollard estuarium

4.2 De transportpaden

De transportpaden zijn bepaald volgens een methode die uitvoerig beschreven staat in appendix II van het GeoSea rapport (Appendix A).

Op basis van de korrelverdelingen worden 3 typen transportpaden onderscheiden:

* Zand-transportbanen die monsterpunten "onderling verbinden", waarbij het slibpercentage kleiner is dan 20% .

* Slib-transportbanen die monsterpunten "onderling verbinden", waarbij het zandpercentage kleiner is dan 20% .

* Gemengd sediment-transportbanen, die monsterpunten "onderling verbinden" waarbij de korrelverdeling tweetoppig is. Ter plaatse van het monsterpunt bestaat het sediment uit een mengsel van slib en zand.

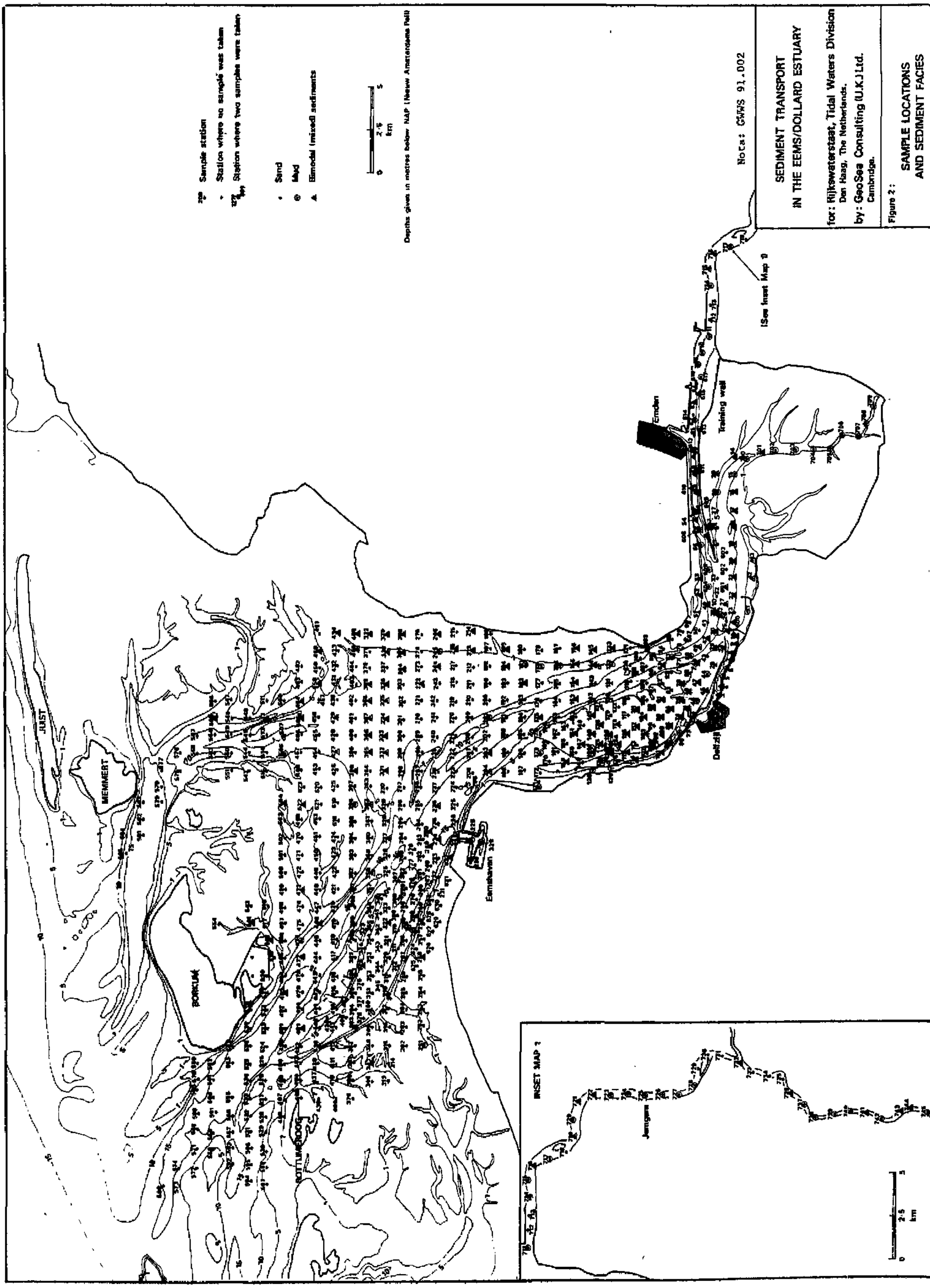
In figuur 8 is het sedimenttype voor de monsterlokaties weergegeven.

De transportpaden van het zand (zie figuur 9) tonen een aanvoer vanuit zee het estuarium in. Dit gebeurt via het Ranselgat, de westzijde van de Oude Wester Eems en de Ooster Eems tussen Borkum en Memmert. Dieper in het estuarium loopt het vloedgedomineerde sedimenttransport via de westzijde van het Oost Friesche gaatje langs de Hond-Paap in de richting van de Dollard. Uit de analyse blijkt in het gebied tussen Delfzijl en de Dollard een evenwicht te bestaan tussen sedimentatie en erosie.

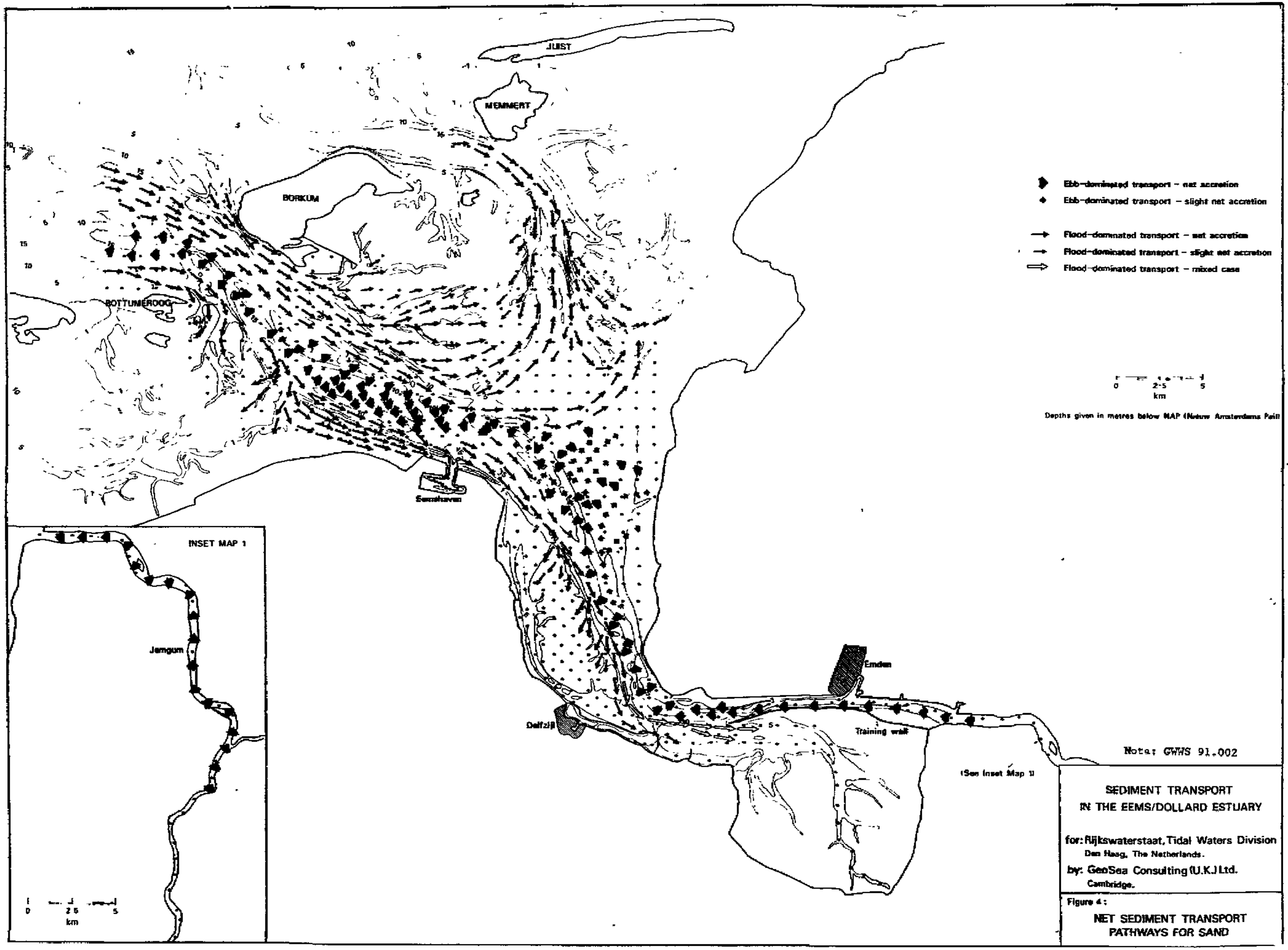
Het ebgedomineerde zandtransport loopt van Emden via de oostzijde van het Oost Friesche Gaatje naar de Oude Wester Eems. Het transport tussen Rotummeroog en Borkum in de richting van de zee lijkt relatief klein.
Hoewel het bij transportbanen om kwalitatieve resultaten gaat, blijkt uit de analyse dat het transport geen erosief karakter heeft en er waarschijnlijk weinig export van zand plaats zal vinden. Vermoed wordt dat zand ten noorden en zuiden van de Meeuwenstaart "overstapt" van de eb naar de vloedgeul.

De gemengd sediment transportpaden bevinden zich voornamelijk tussen de Eemshaven en Emden (zie figuur 10). Deze transportpaden komen overeen met die van het zand voor wat betreft de geulen. Nabij Delfzijl blijkt dat dit sedimenttype zich beweegt in de richting van de haven van Delzijl, door het toegangskanaal.
Tevens is er een pad via de Gaatjebocht in de richting van de Bocht van Watum. Vanuit deze geul vinden we transport naar de hoogste delen van de Hond-Paap plaat.

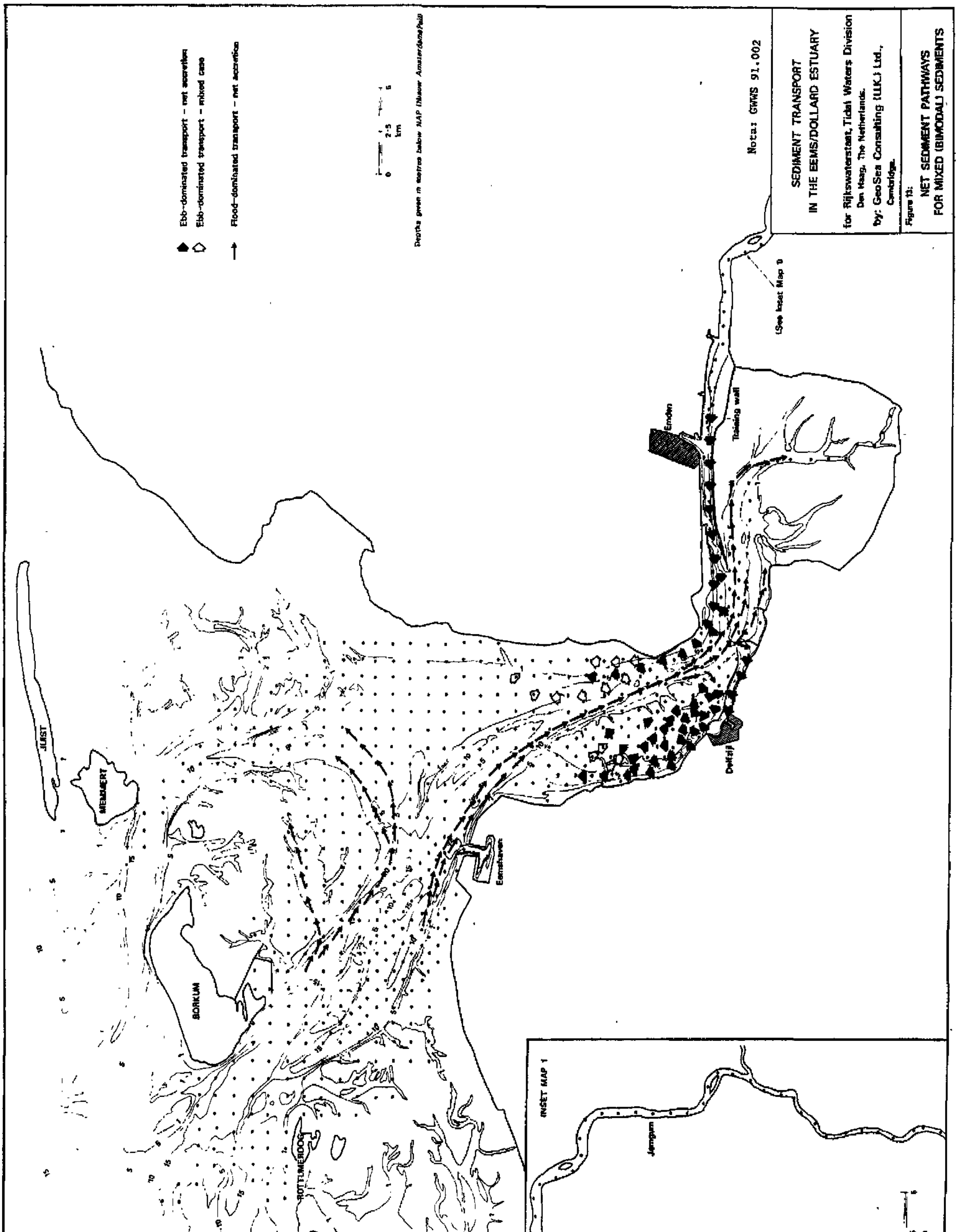
De Slib transportpaden zijn te vinden ten westen van de Hond-Paap, in de Dollard en de Eems-rivier (zie figuur 11). Deze paden vullen de reeds besproken transportpaden aan. Alleen bij de Eems is te zien dat het slib een richting heeft die tegengesteld is aan die van het zandtransport.
Op basis van de 3 kaarten kan rond de Hond-Paap een transport vastgesteld worden, dat in de richting van de klok beweegt. Zowel van de Oost als Westzijde wordt de plaat gevoed met sediment.



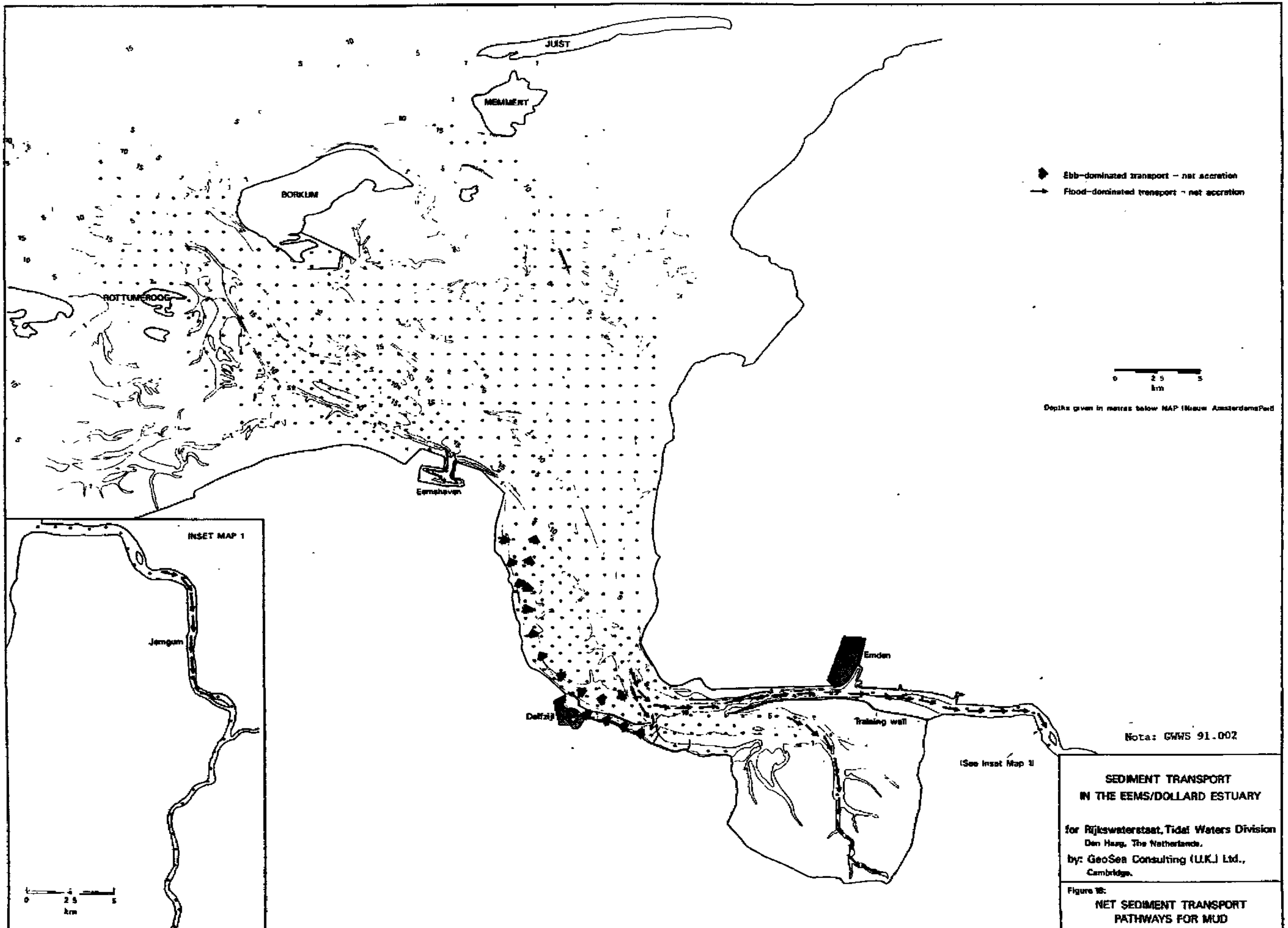
Figuur 8: Overzicht van monsterlokaties in het Eems-Dollard estuarium



Figuur 9: Resttransportpaden voor het zand in het Eems-Dollard estuarium



Figuur 10: Resttransportpaden voor het gemengde sediment in het Eems-Dollard estuarium



Figuur 11: Resttransportpaden voor het slib in het Eems-dollard estuarium

5. Aanbevelingen voor het gebruik van de resultaten

Ten aanzien van de bodemsamenstelling (kwantitatieve resultaten):

* Er dienen bodem/grondsoorten-kaarten worden gemaakt van het Eems-Dollard gebied. Dit zal uitgevoerd moeten worden samen met de Direktie Groningen en Duitsland. Omdat in 1990 het gehele Nederlandse beheersgebied opnieuw gepeild is, zijn dieptecijfers en bodemsamenstelling-gegevens zeer actueel.

* De verdeling van zand, slib en de mediane korreldiameter in het estuarium dienen te worden gebruikt om een sediment-transportmodel af te regelen. Waar in het veld slibrijke gebieden aanwezig zijn, zullen ook door het rekenmodel zogenaamde "sedimentatie gebieden" berekend moeten worden.

* In het kader van het DGW-projekt ISOS*2 moeten o.a. de relaties bepaald worden tussen de bodemsamenstelling, de waterdiepte en de lokale flora en fauna. Omdat voor het Eems-Dollard gebied deze parameters nu redelijk bekend zijn, moet gezocht worden naar een dergelijke relatie.

* De bodemsamenstelling van lokaties op de droogvallende platen kan gebruikt worden om remote sensing beelden van de Wadden te calibreren. In een pilot studie [4] is vastgesteld dat er relaties bestaan tussen de Remote Sensing beelden en het klei-percentage in het bodemoppervlak. De Meetkundige Dienst zet dit onderzoek voort.

* De bodemsamenstelling kan gekoppeld worden aan de bodemschematisatie van het WAQUA model van het Eems-Dollard estuarium. Een modelafregeling vindt dan plaats op basis van de bodemruwheid (Chezy).

[4] I. van der Ven, juni 1990. Sediment-samenstelling in het Eems-Dollard gebied. Een kartering met behulp van Landsat 5 TM. (Afstudeeropdracht Hogeschool Utrecht, studierichting Landmeetkunde).

Ten aanzien van de sediment-transportpaden (kwalitatieve resultaten):

* De trends die in het gebied gevonden zijn moeten gebruikt worden om het sediment-transportmodel te calibreren. Modelresultaten zullen goed moeten overeenkomen met de empirisch vastgestelde paden.

* De trends moeten gebruikt worden om deeltjesmodellen van het Hond-Paap gebied te calibreren [5].

* De trendkaarten kunnen gebruikt worden bij de keuze van toekomstige stortlokaties, als de modellen nog niet optimaal zijn.

* De trends kunnen gebruikt worden bij het beleid van vergunningen van lozingen etc.

* De trends kunnen gebruikt worden als een keuze gemaakt moet worden m.b.t. vaargeulen.

* De trends kunnen gebruikt worden als het baggeronderhoud van de Eemshaven en het storten in de Oude Wester Eems geevalueerd wordt.

* De trends kunnen gebruikt worden bij de evaluatie van morfologische ontwikkelingen van het gebied [middellange termijn].

[5] G.C. van Dam and R.A. Louwersheimer, 1991. A three-dimensional transport model for dissolved and suspended matter in estuaries and coastal seas. Proceedings of 5th International Biennial conference, Wales, UK.

6. Suggesties voor vervolg-onderzoek

De resultaten beschreven in deze nota, zijn gebaseerd op een onderzoek dat uitgevoerd is door het bedrijf GeoSea Ltd. De methode die zij ontwikkeld hebben om, op basis van korrelverdelingen, resttransportpaden voor zand en slib vast te stellen, is voor het Eems-Dollard estuarium vruchtbaar geweest.

Dit type onderzoek kan bij andere watersysteem-beheerders ook zinvolle resultaten opleveren, als de (beleids)vraagstukken betrekking hebben op:

* de samenstelling van waterbodems en de resttransporten van zand en slib. Hiermee zijn morfologische ontwikkelingen in een gebied in te schatten. Met de verkregen empirische (veld)resultaten zijn ook numerieke transportmodellen (beleidsinstrumenten) te calibreren.

* het vaststellen van toekomstige stortlokaties voor bijvoorbeeld baggerspecie en het evalueren van reeds bestaande lokaties. Slib en zandtransportpaden vanaf dergelijke lokaties kunnen in kaart gebracht worden.

* het optimaliseren van scheepvaartroutes, of het toewijzen van zandwinlokaties. Door kennis van de sedimenttransportpaden kan een schatting gemaakt worden hoe gevoelig een gebied is voor aanzanding danwel aanslibbing. Met gecalibreerde sedimentmodellen is het transport te kwantificeren.

* het transport van aan slib gebonden verontreinigingen. Door kennis van de slibtransportpaden kan effectiever onderzoek gedaan worden naar de verontreiniging van waterbodems.

Door het GeoSea onderzoek in de overige kombergingsgebieden van de Waddenzee uit te voeren, zouden meerdere doelen worden gediend.

Op de eerste plaats levert het onderzoek informatie omtrent de bodemsamenstelling. Deze basisinformate wordt in het kader van allerlei, zowel regionale als landelijke projekten, gevraagd. Tot nu toe moet teruggegrepen worden op de bodemkaart van alleen de intergetijdegebieden uit het eind van de jaren vijftig.
Daarnaast is ontwikkeling van de kennis van de transportbanen in de Waddenzee van belang voor baggerstortproblematiek (lokatiekeuze en effecten van baggeren/storten), verontreinigingsproblematiek (transportrichtingen van aan slib gebonden verontreinigingen) en zeespiegelrijzingsproblematiek (sedimentbalansen).

Lijst van Figuren

BIJLAGE 1

UTM X-coor	Y-coor	monster nr.	% zand	% silt	% klei	% slib	D50 mum
762316.6	5915953.0	1.0	13.9	74.5	11.6	86.1	11.9
762717.9	5915578.0	2.0	13.8	74.9	11.3	86.2	11.3
763391.6	5915524.0	3.0	61.6	32.8	5.5	38.4	111.3
763788.9	5915402.0	4.0	37.0	53.3	9.8	63.0	27.7
764283.6	5915330.0	5.0	0.8	83.6	15.6	99.2	8.5
764899.6	5915148.0	6.0	22.5	67.7	9.7	77.5	14.0
765372.4	5914956.0	7.0	6.5	81.8	11.7	93.5	10.1
765887.7	5914778.0	8.0	7.5	80.1	12.4	92.5	10.3
766468.1	5914573.0	9.0	2.4	84.1	13.5	97.6	9.4
766855.9	5914519.0	10.0	24.6	65.5	9.9	75.4	14.7
768296.1	5913923.0	11.0	16.7	71.9	11.4	83.3	11.0
770222.4	5913761.0	12.0	64.4	31.3	4.3	35.6	77.1
771120.6	5913741.0	13.0	64.7	30.9	4.4	35.3	78.4
777088.6	5915007.0	14.0	39.0	50.9	10.1	61.0	26.8
776166.8	5914959.0	15.0	14.9	72.7	12.4	85.1	10.5
775138.7	5914850.0	16.0	70.5	25.3	4.2	29.5	101.5
773993.7	5914836.0	17.0	67.6	28.7	3.8	32.4	105.0
773102.3	5914978.0	18.0	75.5	21.6	2.9	24.5	116.3
772118.3	5914817.0	19.0	87.0	12.4	0.6	13.0	143.7
771142.5	5914826.0	20.0	41.3	49.4	9.3	58.7	27.9
770206.1	5914829.0	21.0	20.0	68.6	11.3	80.0	12.1
769172.9	5914742.0	22.0	52.1	41.2	6.6	47.9	72.4
768194.6	5914711.0	23.0	82.3	17.1	0.6	17.7	138.6
766221.1	5915213.0	24.0	51.5	42.3	6.2	48.5	70.7
767177.6	5915053.0	25.0	57.3	37.0	5.7	42.7	74.1
767687.1	5915175.0	26.0	85.4	14.0	0.6	14.6	127.0
768083.8	5915192.0	27.0	72.6	23.2	4.2	27.4	133.1
765127.1	5915606.0	28.0	92.3	7.2	0.4	7.7	173.7
766142.4	5915717.0	29.0	13.6	73.5	12.9	86.4	10.1
767065.9	5915785.0	30.0	67.7	27.6	4.7	32.3	131.9
768208.1	5915718.0	31.0	60.6	34.5	4.9	39.4	136.7
769232.3	5915776.0	32.0	96.4	3.4	0.2	3.6	200.9
770174.6	5915790.0	33.0	94.1	5.6	0.3	5.9	259.6
772132.8	5915839.0	35.0	95.4	4.3	0.3	4.6	275.6
773123.1	5915930.0	36.0	81.0	18.7	0.4	19.0	176.9
774018.9	5915886.0	37.0	36.2	54.4	9.4	63.8	27.4
775194.6	5915889.0	38.0	1.1	79.5	19.5	98.9	8.5
776116.4	5916009.0	39.0	55.3	39.1	5.7	44.7	79.8
768636.1	5916235.0	40.0	47.1	47.1	5.8	52.9	42.5
767686.3	5916256.0	41.0	96.3	3.6	0.1	3.7	155.8
766593.1	5916150.0	42.0	61.4	33.8	4.8	38.6	108.7
765577.5	5916162.0	43.0	95.9	3.9	0.2	4.1	178.4
764603.1	5916118.0	44.0	13.4	75.0	11.6	86.6	11.2
763721.1	5916088.0	45.0	29.9	59.9	10.2	70.1	19.6
763096.3	5916535.0	46.0	16.4	72.4	11.3	83.6	13.3
764101.4	5916609.0	47.0	24.7	64.0	11.3	75.3	15.1
765105.9	5916711.0	48.0	75.2	20.2	4.6	24.8	127.2
766132.5	5916659.0	49.0	77.3	16.6	6.0	22.7	165.1
767147.3	5916711.0	50.0	93.1	6.6	0.3	6.9	153.7
768162.5	5916771.0	51.0	95.4	4.5	0.1	4.6	154.3
769082.9	5916665.0	52.0	35.3	58.4	6.3	64.7	23.9
770062.3	5916727.0	53.0	47.2	47.1	5.8	52.8	50.7
773476.6	5917073.0	54.0	62.0	33.5	4.5	38.0	90.7
772037.9	5916768.0	55.0	18.8	69.9	11.3	81.2	14.5
772894.3	5916813.0	56.0	26.2	65.4	8.4	73.8	23.7
774097.0	5917068.0	57.0	42.9	49.8	7.3	57.1	33.2
774997.2	5917143.0	58.0	69.3	27.3	3.4	30.7	130.9
776124.0	5917252.0	59.0	52.9	42.4	4.6	47.1	73.0
777159.6	5917376.0	60.0	23.7	67.0	9.4	76.3	13.4
778229.1	5917379.0	61.0	82.0	16.2	1.7	18.0	122.4
779228.3	5917374.0	62.0	16.2	72.7	11.1	83.8	12.7
780208.8	5917362.0	63.0	57.1	37.5	5.4	42.9	108.0
781164.1	5917302.0	64.0	93.9	5.9	0.2	6.1	151.3
782209.9	5917335.0	65.0	13.9	76.4	9.7	86.1	13.6

-- VERVOLG Bijlage 1

UTM X-coor	Y-coor	monster nr.	% zand	% silt	% klei	% slib	D50 mum
767565.7	5917295.0	66.0	96.4	3.4	0.1	3.6	147.6
766601.8	5917155.0	67.0	92.7	7.0	0.3	7.3	150.6
765664.3	5917149.0	68.0	19.8	66.8	13.4	80.2	14.1
764630.8	5917091.0	69.0	95.2	4.7	0.1	4.8	149.5
763681.9	5917071.0	70.0	35.5	55.3	9.2	64.5	27.6
762641.1	5917080.0	71.0	41.1	49.7	9.2	58.9	25.6
762189.1	5916857.0	72.0	2.4	85.1	12.6	97.6	9.7
761731.8	5917075.0	73.0	5.0	81.7	13.2	95.0	10.0
762152.6	5917485.0	74.0	44.2	48.1	7.8	55.8	38.9
763114.0	5917481.0	75.0	39.0	53.0	8.0	61.0	29.0
764061.4	5917558.0	76.0	64.3	31.6	4.2	35.7	91.9
765072.1	5917597.0	77.0	93.6	6.1	0.3	6.4	185.5
766209.8	5917649.0	78.0	97.5	2.4	0.1	2.5	150.7
766314.3	5917633.0	79.0	96.3	3.6	0.1	3.7	151.7
766567.6	5918261.0	80.0	96.4	3.4	0.1	3.6	160.3
765560.4	5918224.0	81.0	19.7	73.5	6.8	80.3	23.9
764656.8	5918214.0	82.0	90.7	8.8	0.5	9.3	186.8
763691.3	5918148.0	83.0	82.2	17.0	0.7	17.8	138.9
762538.4	5918083.0	84.0	32.6	60.0	7.4	67.4	33.5
761565.8	5918063.0	85.0	55.9	38.1	5.9	44.1	71.5
761110.4	5917566.0	86.0	10.7	77.6	11.7	89.3	11.2
760608.8	5918019.0	88.0	23.3	66.6	10.1	76.7	14.5
760998.1	5918568.0	89.0	51.2	46.5	2.3	48.8	63.7
762030.1	5918602.0	90.0	36.1	56.2	7.6	63.9	35.1
763135.1	5918638.0	91.0	52.1	42.3	5.6	47.9	65.9
764045.4	5918704.0	92.0	95.7	4.1	0.1	4.3	147.6
765108.6	5918666.0	93.0	29.2	65.7	5.1	70.8	39.9
766053.1	5918679.0	94.0	92.9	6.8	0.3	7.1	142.7
765532.6	5919167.0	95.0	86.8	13.0	0.2	13.2	245.3
764582.9	5919287.0	96.0	95.7	4.2	0.1	4.3	150.2
763586.0	5919101.0	97.0	93.2	6.6	0.2	6.8	131.0
762611.1	5919131.0	98.0	65.4	31.0	3.7	34.6	86.5
761492.2	5919035.0	99.0	54.5	40.4	5.2	45.5	69.0
760436.8	5919003.0	100.0	90.1	9.5	0.4	9.9	122.1
760065.4	5918576.0	101.0	44.0	47.7	8.3	56.0	37.2
759932.9	5919368.0	102.0	83.3	15.1	1.6	16.7	136.4
761007.4	5919459.0	103.0	61.9	34.0	4.1	38.1	80.2
762011.4	5919546.0	104.0	70.7	26.4	2.9	29.3	95.5
763053.8	5919510.0	105.0	93.5	6.4	0.1	6.5	132.9
763982.0	5919602.0	106.0	96.7	3.3	0.1	3.3	153.1
764884.0	5919797.0	107.0	95.1	4.7	0.2	4.9	173.5
765920.0	5919600.0	108.0	62.0	33.5	4.5	38.0	102.0
765391.7	5920055.0	109.0	0.0	0.0	0.0	0.0	0.0
764547.9	5920148.0	110.0	97.4	2.5	0.1	2.6	175.0
762440.9	5920096.0	111.0	69.3	26.8	3.9	30.7	100.7
761410.8	5919979.0	112.0	61.7	34.6	3.7	38.3	79.5
760343.3	5920026.0	113.0	93.7	6.1	0.2	6.3	134.0
759516.0	5919899.0	114.0	33.0	58.4	8.7	67.0	19.7
759917.3	5920462.0	115.0	66.0	29.8	4.2	34.0	117.1
760989.0	5920523.0	116.0	68.5	27.9	3.6	31.5	96.5
762064.1	5920563.0	117.0	84.5	14.9	0.6	15.5	126.9
763083.3	5920563.0	118.0	95.3	4.6	0.1	4.7	143.2
764025.4	5920490.0	119.0	87.2	12.5	0.2	12.8	219.7
765018.2	5920557.0	120.0	98.0	2.0	0.1	2.0	170.7
765969.8	5920630.0	121.0	90.6	10.4	0.3	10.7	328.7
762538.9	5921118.0	122.0	89.8	9.8	0.4	10.2	141.7
761542.9	5921107.0	123.0	64.2	32.0	3.8	35.8	84.0
760399.9	5920981.0	124.0	78.6	19.1	2.3	21.4	109.9
759456.4	5920971.0	125.0	93.2	6.6	0.3	6.8	141.2
758974.6	5921433.0	126.0	15.9	73.7	10.4	84.1	12.6
759875.6	5921499.0	127.0	79.0	19.9	1.1	21.0	135.8
760940.6	5921524.0	128.0	52.4	41.3	6.3	47.6	67.2
762019.3	5921560.0	129.0	63.8	32.3	3.9	36.2	84.9
762963.9	5921523.0	130.0	94.3	5.6	0.1	5.7	131.7

-- VERVOLG Bijlage 1

UTM X-coor	Y-coor	monster nr.	% zand	% silt	% klei	% slib	D50 mum
763884.4	5921617.0	131.0	98.6	1.3	0.1	1.4	274.1
764998.8	5921620.0	132.0	8.1	80.5	11.4	91.9	12.4
765904.0	5921750.0	133.0	48.9	46.2	4.9	51.1	57.8
759361.7	5921969.0	134.0	14.9	75.9	9.3	85.1	13.7
760345.7	5922086.0	135.0	72.2	24.8	3.0	27.8	97.3
761418.1	5922080.0	136.0	55.5	39.2	5.4	44.5	68.4
762523.6	5922068.0	137.0	95.2	4.7	0.1	4.8	134.4
758818.1	5922642.0	138.0	14.3	76.1	9.6	85.7	13.6
759860.7	5922491.0	139.0	64.0	31.3	4.7	36.0	88.1
760880.6	5922573.0	140.0	54.8	39.0	6.2	45.2	70.0
762000.9	5922575.0	141.0	76.9	20.9	2.2	23.1	107.2
762890.5	5922504.0	142.0	94.3	5.5	0.2	5.7	140.3
763835.3	5922588.0	143.0	84.1	15.7	0.3	15.9	200.7
764853.9	5922661.0	144.0	25.3	64.7	10.0	74.7	19.5
765818.4	5922650.0	145.0	41.6	52.1	6.4	58.4	41.0
761377.2	5923077.0	146.0	83.6	16.0	0.5	16.4	115.0
760325.5	5923110.0	147.0	65.1	30.0	4.9	34.9	93.1
759208.4	5923020.0	148.0	83.7	14.2	2.1	16.3	223.6
759775.9	5923486.0	150.0	92.5	7.2	0.3	7.5	138.5
760910.9	5923519.0	151.0	72.6	24.1	3.3	27.4	103.1
761857.6	5923554.0	152.0	90.7	9.0	0.3	9.3	130.7
762818.3	5923626.0	153.0	103.6	2.0	0.1	2.1	412.6
763877.8	5923681.0	154.0	50.0	42.9	7.1	50.0	62.6
764966.1	5923623.0	155.0	34.8	58.3	6.9	65.2	35.4
765816.9	5923656.0	156.0	74.5	22.3	3.2	25.5	126.8
761330.1	5924068.0	157.0	91.5	8.2	0.3	8.5	143.0
760286.3	5924009.0	158.0	94.2	5.6	0.2	5.8	148.4
759180.8	5923963.0	159.0	58.7	36.6	4.8	41.3	89.9
759807.1	5924561.0	161.0	94.7	5.2	0.1	5.3	135.7
760830.8	5924553.0	162.0	96.1	3.8	0.2	3.9	168.2
761814.4	5924564.0	163.0	95.3	4.6	0.1	4.7	147.5
762858.3	5924549.0	164.0	103.7	2.1	0.1	2.2	439.9
763861.1	5924574.0	165.0	83.8	16.0	0.3	16.2	206.1
764807.9	5924625.0	166.0	11.3	77.4	11.3	88.7	10.8
765831.0	5924696.0	167.0	95.1	4.7	0.2	4.9	170.2
761286.6	5925101.0	168.0	98.0	1.9	0.1	2.0	181.9
760330.8	5925091.0	169.0	84.8	14.6	0.5	15.2	125.7
759173.7	5925008.0	170.0	97.4	2.5	0.1	2.6	164.6
757740.4	5925542.0	171.0	11.0	73.7	15.3	89.0	9.8
758608.0	5925443.0	172.0	94.0	5.7	0.3	6.0	169.5
759752.1	5925573.0	173.0	8.5	74.6	16.9	91.5	9.8
760804.4	5925592.0	174.0	97.6	2.3	0.1	2.4	256.6
761793.8	5925551.0	175.0	68.6	28.5	2.9	31.4	146.7
762777.5	5925616.0	176.0	91.3	8.3	0.4	8.7	256.0
763820.7	5925627.0	177.0	89.4	10.3	0.3	10.6	138.1
764747.6	5925685.0	178.0	13.8	77.0	9.2	86.2	11.4
765707.9	5925708.0	179.0	84.2	15.2	0.6	15.8	132.7
765749.0	5926709.0	180.0	82.2	17.1	0.7	17.8	128.9
764851.8	5926618.0	181.0	18.2	73.4	8.3	81.8	14.3
763820.3	5926630.0	182.0	61.1	34.6	4.3	38.9	89.3
762793.6	5926580.0	183.0	92.3	7.4	0.3	7.7	217.8
761761.0	5926504.0	184.0	97.8	2.1	0.1	2.2	203.1
760806.6	5926504.0	185.0	92.9	6.8	0.3	7.1	184.1
759704.9	5926492.0	186.0	97.0	2.9	0.1	3.0	207.9
758715.8	5926415.0	187.0	98.2	1.8	0.1	1.8	173.3
758595.9	5927397.0	188.0	97.6	2.3	0.1	2.4	173.0
759727.6	5927454.0	189.0	91.2	12.2	0.2	12.4	292.5
760690.6	5927497.0	190.0	92.5	7.1	0.4	7.5	192.8
761839.6	5927618.0	191.0	96.8	3.1	0.2	3.2	192.1
762780.1	5927570.0	192.0	90.3	9.2	0.4	9.7	172.7
763762.8	5927598.0	193.0	93.9	5.9	0.1	6.1	146.9

-- VERVOLG Bijlage 1

UTM X-coor	Y-coor	monster nr.	% zand	% silt	% klei	% slib	D50 mum
764769.4	5927656.0	194.0	24.6	66.4	9.0	75.4	16.2
765733.4	5927695.0	195.0	69.1	26.9	4.0	30.9	98.6
766629.3	5928696.0	196.0	8.3	80.5	11.2	91.7	10.7
765725.6	5928683.0	197.0	85.3	14.1	0.6	14.7	145.5
764732.0	5928668.0	198.0	81.8	17.5	0.7	18.2	111.1
763696.3	5928625.0	199.0	94.5	5.4	0.2	5.5	169.4
762698.0	5928511.0	200.0	96.1	3.7	0.2	3.9	171.6
761713.5	5928561.0	201.0	8.4	82.1	9.5	91.6	12.4
760669.9	5928508.0	202.0	97.4	2.5	0.1	2.6	183.1
759665.7	5928441.0	203.0	71.8	24.6	3.6	28.2	175.3
758604.2	5928462.0	204.0	55.2	39.3	5.5	44.8	98.9
757636.8	5929425.0	205.0	97.9	1.9	0.1	2.1	209.9
758431.0	5929414.0	206.0	96.8	4.9	0.2	5.1	368.5
759672.2	5929485.0	207.0	97.4	2.6	0.1	2.6	155.0
760579.2	5929493.0	208.0	94.5	5.3	0.2	5.5	151.0
761648.4	5929623.0	209.0	80.3	17.4	2.2	19.7	189.3
762714.9	5929559.0	210.0	95.9	3.9	0.2	4.1	169.3
763622.7	5929591.0	211.0	86.5	13.0	0.5	13.5	132.5
764605.8	5929597.0	212.0	94.4	5.5	0.1	5.6	137.3
765578.7	5929658.0	213.0	66.9	29.9	3.2	33.1	120.7
766670.1	5929703.0	214.0	65.5	30.5	4.0	34.5	111.5
766631.9	5930627.0	215.0	84.7	14.8	0.5	15.3	173.8
765661.7	5930638.0	216.0	76.4	20.8	2.8	23.6	136.0
764684.8	5930598.0	217.0	89.8	9.8	0.4	10.2	119.4
763692.3	5930550.0	218.0	90.3	9.4	0.3	9.7	136.3
762574.6	5930502.0	219.0	94.8	5.0	0.2	5.2	158.0
761609.1	5930476.0	220.0	93.3	6.4	0.3	6.7	167.2
760638.0	5930454.0	221.0	83.2	16.2	0.7	16.8	136.5
759593.5	5930393.0	222.0	98.0	1.9	0.1	2.0	174.2
758619.5	5930318.0	223.0	91.0	8.6	0.4	9.0	267.2
757686.2	5930219.0	224.0	95.5	4.4	0.2	4.5	315.5
756575.6	5930215.0	225.0	90.0	9.5	0.5	10.0	204.6
755706.1	5930267.0	226.0	79.9	18.1	2.0	20.1	132.2
754822.9	5930205.0	227.0	31.0	60.4	8.7	69.0	16.3
754602.5	5929324.0	228.0	5.6	81.7	12.7	94.4	9.5
754505.3	5928774.0	229.0	2.0	86.3	11.7	98.0	9.6
753546.3	5929372.0	230.0	1.5	86.1	12.5	98.5	8.9
751453.0	5931402.0	231.0	95.5	4.3	0.1	4.5	126.7
752506.1	5931204.0	232.0	96.3	3.5	0.2	3.7	240.3
753510.0	5931200.0	233.0	97.1	2.7	0.1	2.9	220.1
754539.9	5931384.0	234.0	55.3	40.5	4.3	44.7	97.0
755449.8	5931423.0	235.0	92.3	9.5	0.1	9.6	409.0
756489.4	5931432.0	236.0	98.4	2.5	0.1	2.6	467.1
757510.6	5931340.0	237.0	96.2	3.6	0.2	3.8	249.8
758512.3	5931420.0	238.0	96.8	3.1	0.1	3.2	156.9
759624.1	5931486.0	239.0	96.3	3.5	0.2	3.7	179.7
760555.1	5931570.0	240.0	80.3	17.5	2.2	19.7	108.5
761589.6	5931565.0	241.0	81.6	16.2	2.2	18.4	131.0
762616.0	5931642.0	242.0	92.7	7.0	0.3	7.3	142.7
763609.1	5931506.0	243.0	91.5	8.1	0.4	8.5	151.0
764566.6	5931616.0	244.0	70.1	26.7	3.2	29.9	94.5
765582.3	5931626.0	245.0	19.7	70.9	9.4	80.3	14.8
766434.6	5931695.0	246.0	56.7	38.3	5.0	43.3	81.2
752068.9	5931716.0	247.0	91.0	8.6	0.4	9.0	207.4
752990.7	5931769.0	248.0	97.4	2.5	0.1	2.6	161.1
754065.6	5931790.0	249.0	39.8	51.4	8.9	60.2	29.3
755008.1	5931900.0	250.0	97.7	3.3	0.1	3.4	312.6
742621.9	5931927.0	251.0	18.9	71.1	10.1	81.1	11.3
743732.2	5931983.0	252.0	89.6	10.1	0.4	10.4	136.3
744601.6	5932008.0	253.0	93.9	5.9	0.2	6.1	120.4
745595.5	5931993.0	254.0	94.7	5.1	0.2	5.3	151.1
746539.5	5932063.0	255.0	87.2	12.2	0.5	12.8	146.7
747587.3	5932122.0	256.0	73.3	23.8	3.0	26.7	114.2
748640.6	5932104.0	257.0	96.1	3.8	0.1	3.9	135.2

-- VERVOLG Bijlage 1

UTM X-coor	Y-coor	monster nr.	% zand	% silt	% klei	% slib	D50 mum
749515.4	5932136.0	258.0	96.7	3.1	0.1	3.3	147.2
750484.8	5932144.0	259.0	95.5	4.3	0.2	4.5	166.8
751575.1	5932189.0	260.0	97.4	2.5	0.1	2.6	153.7
752548.6	5932258.0	261.0	88.9	14.2	0.2	14.5	303.7
753494.3	5932360.0	262.0	96.2	3.7	0.1	3.8	165.7
754530.5	5932291.0	263.0	89.1	11.9	1.2	13.1	1245.6
755454.6	5932326.0	264.0	98.7	1.2	0.1	1.3	324.4
756453.2	5932373.0	265.0	98.5	1.4	0.1	1.5	207.9
757513.9	5932471.0	266.0	95.3	4.4	0.3	4.7	205.7
758489.1	5932389.0	267.0	96.3	3.6	0.1	3.7	165.1
759586.3	5932389.0	268.0	93.0	6.7	0.3	7.0	149.3
760581.4	5932501.0	269.0	95.7	4.2	0.2	4.3	155.0
761477.3	5932429.0	270.0	97.6	2.3	0.1	2.4	196.7
762594.6	5932540.0	271.0	89.4	10.2	0.4	10.6	134.1
763518.9	5932492.0	272.0	49.5	44.8	5.7	50.5	60.1
764489.6	5932608.0	273.0	59.8	36.2	4.0	40.2	84.7
765412.9	5932618.0	274.0	1.2	93.6	5.3	98.8	11.9
766368.3	5932729.0	275.0	81.3	16.8	1.9	18.7	140.7
753969.4	5932808.0	276.0	89.4	10.4	0.2	10.6	243.1
753071.9	5932781.0	277.0	97.2	2.7	0.1	2.8	159.7
751930.1	5932725.0	278.0	97.6	2.4	0.1	2.4	166.7
751000.6	5932638.0	279.0	97.0	2.8	0.1	3.0	169.3
750036.6	5932568.0	280.0	35.1	56.3	8.6	64.9	17.7
749046.8	5932521.0	281.0	90.4	9.2	0.4	9.6	158.5
742564.8	5932969.0	282.0	89.8	9.8	0.4	10.2	149.0
743626.0	5932999.0	283.0	94.5	5.3	0.2	5.5	145.2
744612.5	5933067.0	284.0	96.2	3.7	0.1	3.8	151.3
745514.9	5933046.0	285.0	97.8	2.1	0.1	2.2	160.4
746483.8	5933052.0	286.0	96.3	3.7	0.1	3.7	152.1
747522.1	5933035.0	287.0	89.1	9.0	2.0	10.9	162.9
748515.8	5933138.0	288.0	96.4	3.5	0.1	3.6	137.7
749560.1	5933189.0	289.0	95.6	4.3	0.1	4.4	144.6
750476.3	5933184.0	290.0	95.5	4.4	0.1	4.5	153.1
751662.8	5933246.0	291.0	95.4	4.4	0.2	4.6	175.3
752542.0	5933180.0	292.0	97.6	2.3	0.1	2.4	172.1
753489.5	5933260.0	293.0	97.2	2.7	0.1	2.8	218.9
754621.2	5933271.0	294.0	98.5	1.4	0.1	1.5	216.8
755473.8	5933341.0	295.0	83.7	16.1	0.3	16.3	190.8
756488.2	5933358.0	296.0	98.1	1.8	0.1	1.9	240.8
757580.2	5933312.0	297.0	91.9	7.7	0.4	8.1	234.0
758408.0	5933318.0	298.0	96.7	3.1	0.2	3.3	189.8
759464.0	5933411.0	299.0	96.3	3.5	0.1	3.7	162.7
760470.1	5933462.0	300.0	95.8	3.9	0.2	4.2	197.1
761387.4	5933458.0	301.0	94.6	5.1	0.2	5.4	167.5
762545.4	5933455.0	302.0	90.1	9.4	0.5	9.9	151.5
763465.1	5933570.0	303.0	79.8	19.7	0.5	20.2	103.1
764372.3	5933564.0	304.0	68.4	27.3	4.3	31.6	91.3
765369.1	5933655.0	305.0	26.0	63.9	10.1	74.0	13.7
766390.1	5933644.0	306.0	69.3	27.1	3.6	30.7	127.5
752028.1	5933679.0	307.0	97.5	2.4	0.1	2.5	168.5
750990.0	5933637.0	308.0	96.5	3.4	0.2	3.5	183.1
749936.4	5933722.0	309.0	95.7	4.1	0.1	4.3	158.8
749117.1	5933619.0	310.0	97.2	2.7	0.1	2.8	155.6
748057.8	5933580.0	311.0	96.6	3.3	0.1	3.4	155.5
747041.4	5933527.0	312.0	93.9	5.9	0.2	6.1	144.0
740547.6	5933940.0	313.0	94.8	5.0	0.2	5.2	150.3
741520.8	5933942.0	314.0	96.5	3.4	0.1	3.5	154.8
742545.4	5933949.0	315.0	92.9	6.8	0.2	7.1	145.2
743629.0	5934002.0	316.0	95.7	4.2	0.1	4.3	139.4
744546.4	5934085.0	317.0	92.2	7.5	0.3	7.8	150.3
745489.2	5934073.0	318.0	95.4	4.4	0.2	4.6	159.6
746407.1	5934062.0	319.0	97.0	2.9	0.1	3.0	150.1
747555.1	5934014.0	320.0	97.4	2.5	0.1	2.6	154.6
748588.9	5934057.0	321.0	96.8	3.2	0.1	3.2	153.7

-- VERVOLG Bijlage 1

UTM X-coor	Y-coor	monster nr.	% zand	% silt	% klei	% slib	D50 mum
749532.4	5934158.0	322.0	64.7	31.7	3.6	35.3	135.7
750401.9	5934170.0	323.0	85.3	14.1	0.6	14.7	143.3
751517.3	5934229.0	324.0	91.5	8.1	0.3	8.5	195.3
752526.9	5934216.0	325.0	95.4	4.4	0.2	4.6	191.2
753502.3	5934253.0	326.0	99.3	2.6	0.1	2.7	306.7
754534.2	5934270.0	327.0	39.5	52.2	8.3	60.5	24.7
755527.9	5934288.0	328.0	96.5	3.4	0.2	3.5	220.0
756418.1	5934309.0	329.0	86.6	12.8	0.6	13.4	164.2
757418.1	5934382.0	330.0	96.9	3.0	0.1	3.1	157.8
758474.9	5934417.0	331.0	76.2	20.6	3.1	23.8	125.1
759519.6	5934389.0	332.0	35.7	55.2	9.1	64.3	21.1
760474.3	5934537.0	333.0	25.0	63.9	11.1	75.0	13.2
761512.1	5934455.0	334.0	70.2	26.5	3.3	29.8	106.5
762515.8	5934487.0	335.0	43.0	51.6	5.4	57.0	40.6
763615.8	5934532.0	336.0	65.5	29.9	4.6	34.5	104.3
764510.5	5934552.0	337.0	83.1	16.2	0.6	16.9	107.0
765343.0	5934558.0	338.0	63.1	31.2	5.7	36.9	85.3
766317.7	5934630.0	339.0	77.3	20.3	2.4	22.7	152.7
750920.9	5934617.0	340.0	99.3	0.7	0.0	0.7	286.2
750142.9	5934665.0	341.0	84.8	15.0	0.2	15.2	212.7
749137.1	5934652.0	342.0	95.8	4.0	0.1	4.2	168.5
748158.0	5934562.0	343.0	96.5	3.4	0.1	3.5	150.4
747039.3	5934569.0	344.0	95.8	4.1	0.1	4.2	169.9
745940.0	5934505.0	345.0	98.4	1.5	0.1	1.6	192.9
740501.8	5934847.0	346.0	95.1	4.7	0.2	4.9	169.5
741508.1	5934935.0	347.0	76.7	20.8	2.5	23.3	152.7
742511.1	5934968.0	348.0	93.6	6.1	0.2	6.4	156.8
743552.4	5934973.0	349.0	96.4	3.5	0.1	3.6	148.7
744454.0	5934984.0	350.0	97.0	3.0	0.1	3.0	152.5
745425.4	5935032.0	351.0	97.0	2.8	0.1	3.0	191.2
746497.9	5934987.0	352.0	98.6	1.4	0.1	1.4	185.8
747485.5	5935113.0	353.0	94.7	5.2	0.2	5.3	150.1
748568.6	5935093.0	354.0	96.2	5.1	0.2	5.3	356.9
749515.6	5935123.0	355.0	98.8	1.1	0.0	1.2	242.6
750404.3	5935155.0	356.0	98.5	1.4	0.0	1.5	184.0
751454.7	5935152.0	357.0	92.4	7.3	0.3	7.6	251.8
752426.9	5935264.0	358.0	92.7	11.6	0.2	11.8	341.8
753491.1	5935222.0	359.0	82.8	16.9	0.3	17.2	254.4
754469.4	5935268.0	360.0	97.4	2.5	0.1	2.6	162.4
755506.7	5935246.0	361.0	96.1	3.8	0.2	3.9	176.7
756418.8	5935318.0	362.0	74.6	22.6	2.8	25.4	130.0
757463.0	5935361.0	363.0	80.5	17.9	1.6	19.5	137.5
758387.4	5935396.0	364.0	97.2	2.7	0.1	2.8	173.5
759455.7	5935392.0	365.0	78.8	18.5	2.7	21.2	128.3
760456.5	5935425.0	366.0	76.4	20.2	3.5	23.6	128.4
761467.4	5935451.0	367.0	22.5	67.6	9.8	77.5	14.1
762450.6	5935526.0	368.0	50.3	43.0	6.7	49.7	63.1
763504.1	5935492.0	369.0	74.8	22.0	3.3	25.2	133.4
764416.9	5935579.0	370.0	89.9	9.7	0.4	10.1	141.2
765354.0	5935601.0	371.0	82.3	15.8	1.9	17.7	127.4
766354.1	5935610.0	372.0	25.8	62.5	11.7	74.2	12.3
749038.3	5935494.0	373.0	97.5	2.4	0.1	2.5	173.0
747976.4	5935583.0	374.0	96.8	3.0	0.1	3.2	230.4
747070.9	5935573.0	375.0	62.0	34.1	3.9	38.0	127.5
745945.9	5935605.0	376.0	98.2	1.7	0.1	1.8	174.1
744982.0	5935540.0	377.0	97.9	2.0	0.1	2.1	194.6
744048.3	5935539.0	378.0	97.1	2.8	0.1	2.9	158.6
739469.5	5935914.0	379.0	96.4	3.4	0.1	3.6	167.1
740450.3	5935873.0	380.0	95.1	4.8	0.1	4.9	144.2
741499.8	5935939.0	381.0	94.2	5.7	0.1	5.8	142.5
742524.7	5935950.0	382.0	96.2	3.7	0.1	3.8	150.9
743510.9	5935928.0	383.0	37.2	55.0	7.8	62.8	25.4
744522.1	5935854.0	384.0	98.9	1.0	0.1	1.1	227.2
745441.2	5935929.0	385.0	97.4	2.6	0.1	2.6	156.0

-- VERVOLG Bijlage 1

UTM X-coor	Y-coor	monster nr.	% zand	% silt	% klei	% slib	D50 mum
746486.6	5935991.0	386.0	49.8	45.6	4.6	50.2	59.8
747466.2	5936082.0	387.0	98.8	1.1	0.0	1.2	248.9
748449.9	5936089.0	388.0	97.1	2.8	0.1	2.9	149.3
749529.4	5936041.0	389.0	89.0	10.5	0.5	11.0	163.5
750349.6	5936255.0	390.0	100.1	2.3	0.1	2.4	353.9
751485.2	5936165.0	391.0	95.5	4.4	0.2	4.5	373.2
752396.0	5936217.0	392.0	98.1	1.9	0.1	1.9	177.1
753482.6	5936246.0	393.0	96.8	3.0	0.2	3.2	191.2
754416.6	5936261.0	394.0	95.4	4.4	0.2	4.6	162.9
755381.3	5936318.0	395.0	95.9	3.9	0.2	4.1	153.4
756384.8	5936353.0	396.0	11.8	76.3	11.9	88.2	10.6
757311.4	5936349.0	397.0	86.0	13.5	0.6	14.0	150.9
758346.9	5936382.0	398.0	72.6	25.2	2.2	27.4	104.9
759425.9	5936369.0	399.0	82.6	14.9	2.5	17.4	113.0
760396.1	5936451.0	400.0	85.2	14.2	0.7	14.8	140.8
761377.1	5936511.0	401.0	94.0	5.8	0.2	6.0	143.7
762405.9	5936516.0	402.0	83.7	15.7	0.6	16.3	135.8
763327.8	5936550.0	403.0	92.5	7.3	0.3	7.5	143.6
764444.9	5936565.0	404.0	92.3	7.5	0.2	7.7	132.7
765304.1	5936658.0	405.0	52.2	41.5	6.2	47.8	67.8
766343.9	5936658.0	406.0	63.6	30.2	6.2	36.4	101.3
745065.3	5936459.0	407.0	98.0	1.9	0.1	2.0	170.5
744129.8	5936489.0	408.0	93.6	6.1	0.4	6.4	200.5
739450.3	5936868.0	409.0	95.6	4.3	0.1	4.4	161.3
740497.7	5936896.0	410.0	96.7	3.2	0.1	3.3	147.2
741457.6	5936941.0	411.0	98.2	1.7	0.1	1.8	172.9
742451.5	5936998.0	412.0	98.4	1.5	0.1	1.6	204.0
743478.2	5937001.0	413.0	98.6	1.3	0.1	1.4	209.9
744488.5	5937005.0	414.0	98.5	1.4	0.1	1.5	190.2
745493.0	5937025.0	415.0	98.8	1.1	0.1	1.2	192.7
746332.5	5937055.0	416.0	98.7	1.2	0.1	1.3	199.5
747409.3	5937103.0	417.0	95.8	4.0	0.2	4.2	193.4
748502.7	5937143.0	418.0	80.7	17.0	2.2	19.3	148.9
749409.3	5937109.0	419.0	101.2	2.5	0.1	2.6	470.5
750371.9	5937201.0	420.0	89.7	9.8	0.6	10.3	189.6
751488.4	5937171.0	421.0	97.3	2.6	0.1	2.7	183.0
752480.2	5937215.0	422.0	96.9	3.0	0.1	3.1	193.1
753429.4	5937256.0	423.0	95.8	4.0	0.2	4.2	221.7
754436.7	5937294.0	424.0	86.8	12.8	0.4	13.2	125.0
757335.0	5937364.0	425.0	94.6	5.2	0.2	5.4	173.1
758311.4	5937370.0	426.0	92.0	7.6	0.3	8.0	174.5
759348.6	5937443.0	427.0	77.5	20.5	2.0	22.5	96.3
760298.9	5937452.0	428.0	89.8	9.8	0.3	10.2	120.3
761304.4	5937461.0	429.0	77.0	20.9	2.1	23.0	146.7
762359.6	5937530.0	430.0	23.5	66.8	9.7	76.5	14.8
763370.4	5937565.0	431.0	96.1	3.8	0.1	3.9	156.0
764349.9	5937585.0	432.0	90.0	9.6	0.4	10.0	141.6
765305.7	5937604.0	433.0	96.7	3.2	0.1	3.3	167.7
766278.3	5937627.0	434.0	35.7	55.6	8.8	64.3	24.2
744016.2	5937496.0	435.0	98.6	1.4	0.1	1.4	197.5
739444.5	5937907.0	436.0	96.8	3.1	0.1	3.2	177.5
740382.2	5937981.0	437.0	97.7	2.2	0.1	2.3	163.7
741390.3	5938005.0	438.0	98.6	1.4	0.1	1.4	173.5
742407.9	5937990.0	439.0	96.7	3.2	0.1	3.3	165.0
743503.7	5937998.0	440.0	97.9	2.0	0.1	2.1	161.2
744540.6	5938007.0	441.0	98.8	1.2	0.0	1.2	210.7
745456.1	5938054.0	442.0	92.7	7.0	0.3	7.3	244.4
746430.1	5938028.0	443.0	93.6	6.2	0.2	6.4	175.4
747464.8	5938064.0	444.0	104.9	0.9	0.1	1.0	1143.6
748406.9	5938041.0	445.0	98.4	1.5	0.1	1.6	450.7
749420.0	5938120.0	446.0	76.1	21.7	2.3	23.9	207.9
750411.5	5938198.0	447.0	95.1	4.7	0.2	4.9	234.2
751426.9	5938185.0	448.0	97.5	2.5	0.1	2.5	168.2
752398.6	5938238.0	449.0	97.5	2.4	0.1	2.5	156.7

-- VERVOLG Bijlage 1

UTM X-coor	Y-coor	monster nr.	% zand	% silt	% klei	% slib	D50 mum
753426.4	5938243.0	450.0	95.6	4.2	0.2	4.4	152.2
754435.3	5938307.0	451.0	82.0	17.4	0.7	18.0	133.9
755435.1	5938330.0	452.0	83.4	16.0	0.7	16.6	139.4
758312.5	5938429.0	453.0	95.7	4.1	0.2	4.3	150.8
759268.6	5938490.0	454.0	86.0	13.4	0.6	14.0	140.4
760390.1	5938511.0	455.0	95.2	4.7	0.1	4.8	145.8
761319.0	5938541.0	456.0	91.6	8.1	0.3	8.4	138.7
762334.6	5938542.0	457.0	96.8	3.1	0.1	3.2	153.5
763277.9	5938627.0	458.0	78.9	18.5	2.6	21.1	143.2
764205.1	5938579.0	459.0	95.2	4.6	0.1	4.8	148.9
765161.4	5938665.0	460.0	67.7	27.9	4.3	32.3	138.4
766178.1	5938700.0	461.0	87.6	11.9	0.6	12.4	154.9
764273.4	5939611.0	462.0	93.0	6.9	0.2	7.0	141.0
763357.1	5939620.0	463.0	94.8	5.1	0.1	5.2	143.6
762256.8	5939507.0	464.0	77.5	19.3	3.2	22.5	155.5
761256.6	5939514.0	465.0	39.6	52.7	7.6	60.4	22.8
760306.1	5939488.0	466.0	87.2	12.4	0.4	12.8	110.6
759247.8	5939493.0	467.0	95.9	3.9	0.2	4.1	150.3
758253.9	5939450.0	468.0	86.7	12.8	0.5	13.3	110.4
755383.3	5939359.0	469.0	94.8	5.0	0.1	5.2	143.0
754318.5	5939333.0	470.0	91.9	7.8	0.3	8.1	152.9
753393.4	5939142.0	471.0	95.0	4.8	0.2	5.0	156.2
752396.9	5939249.0	472.0	96.7	3.2	0.1	3.3	158.6
751368.0	5939213.0	473.0	22.2	66.6	11.2	77.8	11.0
750372.8	5939186.0	474.0	96.9	2.9	0.1	3.1	180.1
749327.7	5939136.0	475.0	98.7	1.2	0.1	1.3	192.7
748378.6	5939134.0	476.0	17.5	69.7	12.9	82.5	11.4
747441.0	5939110.0	477.0	71.4	26.0	2.6	28.6	134.4
746466.8	5939078.0	478.0	80.2	19.4	0.4	19.8	205.3
745468.1	5939030.0	479.0	98.8	1.2	0.1	1.2	217.7
744540.7	5938978.0	480.0	101.2	0.8	0.0	0.8	345.8
743356.3	5938914.0	481.0	76.3	20.6	3.0	23.7	146.8
742378.8	5938984.0	482.0	98.6	1.4	0.1	1.4	175.2
741304.3	5938969.0	483.0	97.5	2.5	0.1	2.5	156.1
740429.5	5938917.0	484.0	98.1	1.9	0.0	1.9	158.1
739436.1	5938886.0	485.0	98.1	1.9	0.0	1.9	167.3
738449.3	5939835.0	486.0	98.1	1.8	0.1	1.9	188.0
739451.1	5939808.0	487.0	97.6	2.3	0.1	2.4	164.6
740417.4	5939827.0	488.0	98.9	1.1	0.1	1.1	184.3
741430.4	5939901.0	489.0	98.8	1.1	0.1	1.2	225.1
742291.3	5939838.0	490.0	99.1	0.8	0.1	0.9	213.1
743455.5	5939814.0	491.0	98.1	1.8	0.1	1.9	193.7
744412.5	5939931.0	492.0	97.9	2.0	0.1	2.1	187.7
745501.7	5939937.0	493.0	96.7	3.7	0.1	3.8	389.5
746319.4	5939997.0	494.0	96.2	3.6	0.2	3.8	205.6
747418.8	5940048.0	495.0	97.8	2.0	0.1	2.2	199.5
748349.8	5940103.0	496.0	97.9	2.0	0.1	2.1	187.1
749368.9	5940119.0	497.0	96.4	3.4	0.2	3.6	172.6
750275.3	5940181.0	498.0	96.7	3.1	0.2	3.3	205.2
751365.2	5940173.0	499.0	91.9	7.7	0.3	8.1	163.1
752358.0	5940217.0	500.0	89.1	10.5	0.4	10.9	156.8
753350.6	5940257.0	501.0	94.1	5.7	0.2	5.9	158.3
754293.4	5940309.0	502.0	87.9	11.5	0.5	12.1	147.6
755381.3	5940359.0	503.0	96.8	3.1	0.1	3.2	167.5
756353.3	5940376.0	504.0	68.3	28.1	3.6	31.7	105.4
759165.0	5940389.0	506.0	9.4	80.3	10.3	90.6	10.9
760221.8	5940427.0	507.0	95.7	4.2	0.1	4.3	143.4
761149.8	5940504.0	508.0	92.0	7.7	0.3	8.0	145.5
762219.4	5940596.0	509.0	90.4	9.3	0.3	9.6	144.9
762214.1	5941516.0	511.0	94.9	4.9	0.2	5.1	143.2
761186.3	5941479.0	512.0	68.0	27.2	4.8	32.0	182.2
760216.1	5941483.0	513.0	94.6	5.3	0.2	5.4	160.4
759200.7	5941447.0	514.0	96.8	3.2	0.1	3.2	149.7
758177.9	5941392.0	515.0	94.7	5.2	0.1	5.3	143.1

-- **VERVOLG Bijlage 1**

UTM X-coor	Y-coor	monster nr.	% zand	% silt	% klei	% slib	D50 mum
750351.0	5941155.0	516.0	98.7	1.2	0.0	1.3	206.5
749339.0	5941098.0	517.0	98.3	1.6	0.1	1.7	202.1
748447.8	5940850.0	518.0	34.4	53.7	12.0	65.6	16.6
747335.9	5940479.0	519.0	97.0	2.8	0.1	3.0	264.2
746244.4	5941051.0	520.0	99.5	0.5	0.0	0.5	266.4
745369.6	5940970.0	521.0	97.9	2.1	0.1	2.1	179.4
744313.5	5941004.0	522.0	99.8	1.8	0.1	1.9	297.4
743365.5	5940931.0	523.0	90.9	12.6	0.2	12.8	295.9
742361.0	5940978.0	524.0	97.8	2.1	0.1	2.2	197.6
741169.4	5940930.0	525.0	98.9	1.1	0.0	1.1	209.5
740288.8	5940944.0	526.0	99.0	0.9	0.1	1.0	210.4
739308.0	5940975.0	527.0	98.1	1.8	0.1	1.9	241.9
738255.1	5940834.0	528.0	97.9	2.0	0.1	2.1	171.0
737361.4	5940847.0	529.0	98.0	2.0	0.1	2.0	182.2
736363.2	5940727.0	530.0	98.1	1.9	0.1	1.9	175.3
737348.0	5941742.0	531.0	98.4	1.6	0.1	1.6	185.0
738317.1	5941709.0	532.0	99.0	1.0	0.1	1.0	214.1
739321.5	5941827.0	533.0	99.0	1.0	0.1	1.0	204.2
740347.3	5941855.0	534.0	99.0	1.0	0.0	1.0	209.1
741232.5	5941991.0	535.0	87.4	12.1	0.5	12.6	190.4
742356.4	5941921.0	536.0	94.4	9.8	0.1	10.0	383.7
743384.6	5941910.0	537.0	104.6	1.5	0.1	1.6	477.0
744322.1	5941767.0	538.0	90.7	9.0	0.3	9.3	154.4
749340.3	5942020.0	541.0	70.0	26.7	3.3	30.0	137.6
750336.1	5942166.0	542.0	93.8	5.9	0.3	6.2	166.9
758158.3	5942414.0	543.0	92.4	7.3	0.3	7.6	146.4
759137.0	5942469.0	544.0	98.6	1.4	0.1	1.4	212.4
760177.4	5942443.0	545.0	97.3	2.6	0.1	2.7	191.2
761168.7	5942474.0	546.0	97.5	2.4	0.1	2.5	170.6
762210.1	5943578.0	547.0	97.5	2.4	0.1	2.5	235.7
761073.2	5943505.0	548.0	82.7	16.2	1.1	17.3	143.5
760178.9	5943492.0	549.0	96.2	3.6	0.1	3.8	175.6
759085.2	5943496.0	550.0	95.8	4.1	0.1	4.2	159.9
758121.6	5943465.0	551.0	95.4	4.5	0.2	4.6	153.1
742365.1	5942812.0	552.0	97.7	2.2	0.1	2.3	316.3
741301.1	5942847.0	553.0	87.5	12.1	0.5	12.5	258.0
740396.4	5942877.0	554.0	0.0	0.0	0.0	0.0	0.0
739271.8	5942885.0	555.0	99.3	0.6	0.0	0.7	223.8
738278.4	5942789.0	556.0	97.6	2.3	0.1	2.4	168.0
737284.6	5942719.0	557.0	93.3	6.4	0.3	6.7	151.4
736289.8	5943805.0	558.0	99.0	1.0	0.0	1.0	296.2
737271.3	5943849.0	559.0	98.5	1.4	0.1	1.5	376.3
739335.0	5943903.0	560.0	109.7	1.1	0.1	1.2	726.3
740362.4	5943943.0	561.0	103.0	1.6	0.1	1.7	454.0
741442.2	5943967.0	562.0	98.2	1.7	0.1	1.8	303.0
759075.1	5944472.0	563.0	96.6	3.3	0.1	3.4	161.2
760134.5	5944453.0	564.0	94.2	5.5	0.3	5.8	215.3
761070.3	5944445.0	565.0	68.5	27.7	3.8	31.5	131.6
762112.9	5944469.0	566.0	82.6	15.0	2.4	17.4	152.3
760008.3	5945451.0	567.0	98.5	1.4	0.1	1.5	307.6
759004.8	5945481.0	568.0	83.6	16.1	0.3	16.4	255.6
741349.2	5944760.0	569.0	98.3	1.6	0.1	1.7	232.8
740505.1	5944840.0	570.0	82.2	17.1	0.7	17.8	189.3
736476.2	5944763.0	571.0	101.3	1.5	0.0	1.5	393.4
735355.9	5944748.0	572.0	98.8	1.1	0.0	1.2	227.3
734222.3	5945745.0	573.0	98.7	1.2	0.1	1.3	248.3
735262.0	5945814.0	574.0	98.8	1.1	0.0	1.2	313.5
757998.7	5946378.0	575.0	98.3	1.7	0.1	1.7	303.7
759016.3	5946407.0	576.0	98.7	1.3	0.0	1.3	270.5
757983.3	5947423.0	577.0	98.6	1.3	0.1	1.4	295.0
757097.3	5947409.0	578.0	91.4	8.3	0.3	8.6	250.6
756174.2	5947408.0	579.0	102.6	2.9	0.1	3.1	664.4
734178.1	5946659.0	580.0	97.3	2.6	0.1	2.7	336.4
754204.1	5948366.0	581.0	98.2	1.7	0.1	1.8	278.7

-- VERVOLG Bijlage 1

UTM X-coor	Y-coor	monster nr.	% zand	% silt	% klei	% slib	D50 mum
755120.4	5948407.0	582.0	97.6	2.3	0.1	2.4	271.9
756175.4	5948390.0	583.0	99.4	0.5	0.0	0.6	336.3
754217.8	5949350.0	584.0	95.2	4.5	0.3	4.8	249.4
753224.2	5949319.0	585.0	98.8	2.9	0.1	3.0	370.9
737548.3	5944759.0	588.0	98.3	3.0	0.1	3.1	344.2
738472.3	5944737.0	589.0	98.3	4.0	0.2	4.1	409.4
739846.2	5944896.0	590.0	83.7	16.0	0.2	16.3	208.1
738649.2	5943700.0	591.0	86.1	13.7	0.2	13.9	260.3
735378.9	5942681.0	592.0	98.0	2.0	0.1	2.0	308.4
736298.6	5942668.0	593.0	95.2	4.6	0.2	4.8	184.4
734345.7	5941585.0	594.0	97.1	2.8	0.1	2.9	168.3
735284.0	5941623.0	595.0	97.4	2.6	0.1	2.6	165.2
736286.4	5941669.0	596.0	97.1	2.8	0.1	2.9	173.1
734498.2	5940694.0	597.0	96.7	3.2	0.1	3.3	157.3
735401.8	5940745.0	598.0	97.7	2.2	0.1	2.3	193.0
750932.5	5931703.0	599.0	94.5	5.3	0.2	5.5	128.1
767721.4	5914701.0	600.0	64.2	32.2	3.6	35.8	89.4
769712.6	5915253.0	601.0	78.3	18.4	3.4	21.7	218.0
770743.4	5915289.0	602.0	97.1	2.7	0.2	2.9	233.8
771686.3	5915266.0	603.0	97.1	4.0	0.2	4.2	307.2
769711.1	5916255.0	604.0	11.3	77.1	11.6	88.7	10.6
770729.0	5916309.0	605.0	14.6	75.1	10.4	85.4	11.7
772718.5	5916493.0	607.0	66.3	29.7	4.0	33.7	100.6
800000.0	6000000.0	608.0	39.2	55.4	5.4	60.8	46.6
774277.6	5917050.0	609.0	86.7	12.8	0.6	13.3	146.9
775371.0	5917468.0	610.0	76.8	20.3	2.8	23.2	122.0
776304.8	5917100.0	611.0	35.6	57.1	7.2	64.4	28.2
777597.3	5917568.0	612.0	9.9	79.7	10.4	90.1	10.9
778720.1	5917193.0	613.0	15.9	74.6	9.5	84.1	16.2
779656.5	5917514.0	614.0	98.6	1.3	0.1	1.4	233.5
780670.4	5917199.0	615.0	37.7	55.4	6.8	62.3	30.2
781610.8	5917477.0	616.0	97.9	2.0	0.1	2.1	225.2
781617.7	5917116.0	617.0	14.0	77.5	8.5	86.0	12.7
755433.8	5937307.0	618.0	93.2	6.5	0.3	6.8	163.9
756431.8	5937355.0	619.0	92.6	7.1	0.3	7.4	161.9
757304.7	5938347.0	620.0	88.4	11.2	0.4	11.6	121.8
756321.8	5938326.0	621.0	93.5	6.3	0.2	6.5	150.4
756270.8	5939326.0	622.0	76.6	22.7	0.6	23.4	123.9
757297.7	5939379.0	623.0	93.1	6.7	0.2	6.9	142.7
748053.2	5932500.0	624.0	97.1	2.8	0.1	2.9	150.8
747080.4	5932467.0	625.0	95.1	4.8	0.1	4.9	137.2
748131.5	5931594.0	626.0	82.7	16.6	0.6	17.3	134.9
749125.1	5931632.0	627.0	92.1	7.7	0.3	7.9	145.4
750125.4	5931685.0	628.0	91.2	8.5	0.3	8.8	120.4
749686.4	5931219.0	629.0	91.2	8.5	0.4	8.8	136.1
750631.6	5931177.0	630.0	89.6	10.0	0.3	10.4	130.4
752154.4	5930732.0	631.0	91.0	8.7	0.3	9.0	111.2
753462.1	5930729.0	632.0	48.4	45.2	6.3	51.6	58.8
777058.6	5914375.0	700.0	9.5	79.3	11.3	90.5	13.1
777510.7	5913417.0	701.0	50.5	46.3	3.2	49.5	63.2
777613.4	5912694.0	702.0	6.7	81.7	11.6	93.3	10.9
777670.3	5911520.0	703.0	14.9	76.1	9.1	85.1	11.8
777716.5	5910512.0	704.0	1.2	84.8	13.9	98.8	9.5
777797.6	5909521.0	705.0	1.6	84.8	13.6	98.4	9.4
778577.1	5908871.0	706.0	10.1	78.1	11.9	89.9	10.6
778517.3	5907894.0	707.0	3.8	83.3	12.8	96.2	9.5
779331.3	5907532.0	708.0	2.1	85.3	12.6	97.9	9.9
780112.4	5907102.0	709.0	1.5	86.1	12.5	98.5	9.8
783223.2	5917172.0	710.0	5.4	83.6	11.0	94.6	9.7
784199.1	5916843.0	711.0	7.2	80.3	12.4	92.8	10.4
785179.1	5916892.0	712.0	96.4	3.4	0.1	3.6	160.8
786027.5	5916866.0	713.0	94.1	5.6	0.3	5.9	171.6
787121.6	5916819.0	714.0	8.1	79.5	12.4	91.9	10.1
788091.4	5916956.0	715.0	21.0	71.2	7.8	79.0	16.2

-- VERVOLG Bijlage 1

UTM X-coor	Y-coor	monster nr.	% zand	% silt	% klei	% slib	D50 mum
788928.5	5916637.0	716.0	37.0	57.0	5.9	63.0	21.9
789354.9	5915727.0	717.0	15.2	74.2	10.6	84.8	10.8
789810.4	5914787.0	718.0	102.7	3.2	0.2	3.4	467.9
790715.6	5914317.0	719.0	38.2	54.0	7.9	61.8	24.9
791670.2	5914443.0	720.0	12.3	77.7	10.0	87.7	11.8
792739.9	5914173.0	721.0	28.6	61.4	9.9	71.4	14.0
793135.8	5913249.0	722.0	26.2	66.2	7.7	73.8	17.8
793156.7	5912316.0	723.0	18.0	73.5	8.5	82.0	20.0
793252.4	5911322.0	724.0	8.6	80.6	10.8	91.4	10.6
793176.1	5910352.0	725.0	10.0	79.9	10.1	90.0	11.3
793268.0	5909330.0	726.0	10.7	79.8	9.5	89.3	10.6
793286.8	5908389.0	727.0	6.0	82.7	11.2	94.0	10.3
793828.3	5907491.0	728.0	9.0	74.2	16.8	91.0	9.8
794781.1	5907295.0	729.0	80.9	18.8	0.3	19.1	234.3
795578.8	5906750.0	730.0	96.1	4.7	0.3	5.0	228.7
795542.9	5905895.0	731.0	86.4	13.4	0.3	13.6	274.3
795184.8	5904829.0	732.0	37.6	56.1	6.3	62.4	24.2
794648.6	5904054.0	733.0	95.2	4.6	0.2	4.8	362.8
794461.7	5903078.0	734.0	81.4	21.8	0.4	22.2	292.8
794300.1	5902300.0	735.0	92.5	7.3	0.2	7.5	321.4
793507.4	5901836.0	736.0	63.2	33.0	3.8	36.8	213.9
792881.1	5901024.0	737.0	15.8	76.1	8.0	84.2	13.3
792165.2	5900370.0	738.0	8.5	83.3	8.2	91.5	12.1
792365.7	5899219.0	739.0	15.1	76.9	8.0	84.9	13.4
792557.2	5898315.0	740.0	7.9	84.3	7.8	92.1	13.0
792505.2	5897360.0	741.0	66.4	30.9	2.7	33.6	152.3
792150.0	5896508.0	742.0	7.0	84.3	8.7	93.0	11.4
792636.0	5895350.0	743.0	70.6	26.8	2.6	29.4	173.6
792799.1	5894828.0	744.0	24.3	67.7	8.0	75.7	15.1
792593.6	5893835.0	745.0	16.5	76.6	6.9	83.5	18.4

Appendix: A

GeoSea Consulting Ltd

RIJKSWATERSTAAT
Tidal Waters Division

Sediment transport pathways in the Eems Estuary.

By:

GeoSea Consulting (UK) Ltd.
Cambridge

January 1991

GeoSea Consulting Ltd
Consultants in Marine Sedimentation

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Dr. Tj. van Heuvel
Rijkswaterstaat
Koningskade 4,
2500 Ex, The Hague,
The Netherlands.

18th January 1991.

Dear Dr. van Heuvel,

GeoSea Consulting is pleased to submit the report, "The Sediment Transport pathways in the Ems Estuary."

Because of the excellent data base of 668 samples, the results of the sediment trend analysis have come out very well. Three facies were identified (sand, mixed or bimodal sediments and mud) and trends determined for each. The pathways were mutually consistent for the different sediment types thereby supporting their validity. One exception occurred in the River Ems itself where mud is evidently accreting in an upstream direction, whereas the sands and mixed sediments are transported seawards on the ebb. Probably the cohesive properties of mud can explain this apparent anomaly.

In the estuary the pathways clearly define ebb and flood-dominated transport. These have been used to predict probable areas of high sedimentation in the existing dredged channel which occur when the channel crosses a transport pathway. A possible new route for the dredged channel is suggested. It follows the ebb transport regime for the entire length of the estuary and should, therefore, be the route that will have the minimum maintenance dredging requirements.

The results also suggest that dredged material from the port of Delfzyl is moved northwards from the disposal site and onto the west half of the Hundpaapsand. A new disposal site for the Port of Emshaven is not recommended as it is in a flood-dominated channel and material is likely to be returned to the harbour. A different site is suggested in the ebb-dominated Alte Ems Channel.

I hope this report will be satisfactory for your needs and I will be pleased to provide you with any further information should you require it.

Yours sincerely,

Patrick McLaren
Managing Director

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1.0 INTRODUCTION

1.1 Background

This report utilises the technique of McLaren and Bowles (1985) to establish the patterns of net sediment transport in the Eems estuary (Fig.1). This approach has been used in two previous studies for the Rijkswaterstaat [1] for which the objectives and method were closely similar. The theory of the method to establish sediment transport paths using relative changes in grain-size distributions are fully discussed in Appendix II.

1.2 Objectives

The principal objectives of this study are to use the grain-size distributions from 668 samples in order to:

1. establish the net sediment transport pathways in the Eems estuary

2. establish specific "transport environments" as determined by sediment type; net erosion, dynamic equilibrium or net accretion; and whether sediment is fining (Case B) or coarsening (Case C) in the direction of transport.

3. assess the consequences of dredging operations on the sediment transport regime

4. determine the behaviour of dredged material at particular disposal sites with emphasis on its transport beyond the designated areas

5. suggest, if possible, procedures to minimize possible adverse effects of dredging and dredge disposal operations.

---

[1]: (a) The sediment transport regime in Mond Haringvliet; GeoSea Consulting report, July 1988.
(b) The dispersal of dredge material and nearshore sediment transport between Rotterdam and Scheveningen; GeoSea Consulting report, August 1989.

1.3 Field Methods

The sediment samples were collected between October and December, 1989. GeoSea Consulting personnel participated in the initial stages of the field programme in order to finalise the sampling grid and monitor sample collection. Collection was achieved using a Van Veen type grab which sampled to a depth of between 10-15 cm below the sediment/water interface. A small core, representing the full depth of sediment recovered, was then taken out of the grab using a plastic trowel. Rijkswaterstaat personnel and vessels were used to carry out sample collection and all samples were sent to Cambridge for analysis.

The sampling was based upon a 1km grid with sample density being increased around Delfzijl and to the west of Eemshaven. A total of 668 samples were collected (Figure 2).

1.4 Grain Size Analyses

All samples were analysed by a standardised method developed by GeoSea Consulting using a Malvern laser particle sizer. Laser measurements of the weight percentages within the clay, silt and sand fractions were combined with sieved weights for the gravel fraction. This method allowed the definition of final distributions within the range -2phi (4mm) to 10phi (1um) using 0.5phi class intervals.

The samples were well mixed in order to ensure a representative subsample for analysis. Three measurements were taken on each sample and the results averaged. The distributions were merged into a database and incorporated into the sediment trend progamming. A copy of this database is supplied in ASCII format on diskette as Appendix I. In this file the data for each sample occupy one line in the database. The weight percentages, at half-phi intervals, are preceded by the moment measures of mean, sorting and skewness.

2.0 PHYSICAL SETTING

The Eems estuary occupies pre-glacial depression and its evolution can be traced through all the glacial stages (Van Straaten, 1960). In its present form, the estuary is funnel-shaped which is characteristic of a macrotidal environment (6m range); however, the presence of the offshore chain of barrier islands and the morphology of the sand banks within the estuary are features common to microtidal environments (Hayes, 1975, 1979). In fact, the Eems estuary falls inside the mesotidal range (2.0 - 4.0m) with a mean spring of 2.3m at Borkum and 3.1m at Emden. According to data from borings reported in Van Straaten (1960) the large shoals (Mowen Steert, Emshörnplate and Hundpaapzand) are built up entirely with recent estuarine sands and are not cored with older Pleistocene sediments.

The main channel into the estuary is nearly everywhere less than 10m deep and is frequently split into two halves by intervening shoals, notably the Ballonplate, Horsbornplate, Mowen Steert, Dukogatplate and the Hundpaapzand (Fig.1). Advantage has been made of the natural channels to maintain a navigable dredged channel from the open sea into the River Eems. This ranges from 13m deep in the outer reaches of the estuary to 8.5m at Emden. Also the ports of Delfzijl and Eemshaven are regularly dredged. Material from dredging operations has been placed in the channel between Eemshaven and the Hundpaapzand (Bocht van Watum) and, more recently (since Nov.1989) in the channel immediately south of the Alte Ems Reede (Fig.1).

3.0 PATTERNS OF SEDIMENT TRANSPORT

To obtain meaningful results from the trend analysis, the sediments were divided into three separate facies based on the weight proportions of sand (-0.5 to 4.0 phi) and mud (4.5 to 10.5 phi). These facies, identified in Figure 2 are:

1. sand which contains less than 20% mud

2. mud which contains less than 20% sand

3. bimodal or mixed sediments (sandy mud or muddy sand).

For each facies numerous sequences of samples were tested for preferred transport directions. The final solutions were accepted when a coherent pattern was obtained in which the derived trends were mutually supportive, both in direction and trend statistics.

3.1 Sand Transport

As seen in Figure 2, sand dominates the estuary. Of all the sample sequences examined, a total of 87 lines produced a coherent pattern of ebb and flood dominated transport paths. The 87 lines themselves form 7 groups (numbered 1 to 7; Fig.3) and the patterns of sand transport are shown in Figure 4. Table 1 provides the trend statistics for all the lines. The following summarises the results of the sediment trend analysis for each group of lines.

Lines 1A to 1C:

These lines are confined to the sand deposits contained within the River Eems. as seen in Figure 2, the sediments in the river are highly variable with sand, mud and bimodal sediments more or less randomly distributed. Although the three lines of sand all produced "down-river" trends the R^2 values are relatively low (average 0.43; Table 1). Possibly dredging and shipping activities within the narrow confines of the river has resulted in the mixture of facies and the low R^2 values. each of the lines produced an X-distribution indicative of net accretion along the transport paths (Fig.5).

Lines 2A to 2C

This large group of lines completes the ebb transport regime for the whole estuary. All the lines originate in the main channel at the head of the estuary. Lines 2A to 2I indicate that ebb transport down the channel"spills" over onto the eastern tidal flats (Rysumer Nacken) as well as onto the Emshörnplate. The R^2 values are all high (average 0.89). Although all the trends indicate accretion, a distinction has been made between those lines where the mode of the X-distribution is clearly finer than the D_1 and D_2 distributions (Fig.6) and those where the X-distribution is interpreted to mean that accretion is minimal along the line (ie. the X-distribution is approaching a shape relative to D_1 and D_2 which is indicative of dynamic equilibrium). Such lines are interpreted accordingly in Table 1 and illustrated in Figure 4.

Lines 2J to 2"O" show that the ebb transport path follows the main channel from the head of the estuary as far as the Dukegatplate where it swings eastwards into the smaller channel lying between the Dukegatplate and the Emshörnplate. North of this channel, however, the ebb-flow moves westwards and into the Alte Ems where the transport diverges onto the Mowen Steert shoal. Nearly all the lines show net accretion (Fig.8) as well as reasonably high R^2 values (average 0.74).

Lines 2P and 2Q continue to follow the main channel of the Alte Ems seawards into the Hubertgat indicating that the ebb transport path continues into the North Sea past the barrier islands. Similar to the accretionary lines onto Mowen Steert, the R^2 values remain at about 0.72 (Table 1). The R^2 values markedly improve for the ebb transport onto the crest of the Alte Ems Reede shoal (Lines 2R to 2W) which all show net accretion out of the alte Ems Channel (average $R^2 = 0.93$). Lines 2X and 2Y suggest that some of the ebb transport joins a flood transport regime in the Dukegat Channel and the remaining lines (2Z to 2C') show that the ebb transport regime provides the sediments on the Dukegatplate. Again the R^2 values are all exceptionally high for these lines.

Lines 3A to 3M

This group of lines originate in the main channel opposite Emshaven and indicate transport in the flood direction as far as the Dollard. Lines 3A to 3J show transport from the main channel (Ostfriesisches Gatje) onto the eastern half of the Hundpaapzand. Most of the lines show net accretion (eg: Line 3F; Fig.9) and the R^2 values generally improve from north to south (R^2 for Line 3A = 0.53 and for Line 3J = 0.82). The remaining lines which continue into the Dollard (Lines 3K to 3M) show high R^2 values (average 0.85). Although Case B (sediment fining with net accretion) dominate the trends, two of the lines also show significant Case C trends (Lines 3L and 3M; Table 1) in the same flood direction. This suggests that high energy transport can occasionally occur into the entrance of the Dollard.

Lines 4A to 4L

Originating in the Osterems, the channel lying between the islands of Borkum and Memmert, these lines show flood dominated transport up the channels that are located on either side of the Schuitensand. Lines 4A to 4E indicate deposition is occurring on the Randzel, the large intertidal flat behind the island of Borkum. With the exception of the rather poor R^2 value for Line 4A, the values are all high with an average of 0.89. Line 4F terminates against the Schuitensand and Lines 4G to 4L all show accretion towards the intertidal flats of the Hamburger Sand and the Pilsumer Watt. As seen in Table 1 and Figure 4, Line 4 is made of both " slight net accretion" lines and "net accretion" lines (compare Figures 10 and 11).

Lines 5A to 5"O"

This group of lines originate in the Westerems, the main channel between the Ballonplate shoal and the Hohesriff shoal. Similar to the flood-dominated regime in the Osterems, these lines also show a flood direction which continues down the Randzelgat as far as the south end of the Mowen Steert shoal.

Here, sediment transport is deflected eastwards up the Emshörninne, a flood channel on the north side of the Emshörnplate. Sediments are also carried out of the Randzelgat and onto the wide intertidal flats which make up the Randzell (Lines 5A to 5K). Most of the lines in this group show net accretion and reasonably high R^2 values (0.64).

Lines 6A to 6K

These lines follow the southwest side of the Alte Ems between the Alte Ems Reede shoal and the shoreline. All the lines show net accretion both in the channel and onto the adjoining intertidal flat (the Uithuizerwad). The R^2 values are exceptionally high (average 0.86).

Lines 7A to 7D

This small group of lines originates in the nearshore area immediately north of the Island of Rottumeroog and suggests a flood transport regime onto the wide intertidal flats behind the barrier island. Of all the groups of lines, these are the most poorly defined with slight ambiguities in the trend statistics (Table 1) and relatively low R^2 values (0.45 for Line 7D). Also the trends could not be continued very far onto the intertidal flat despite the presence of more sand samples up the tidal creeks (eg: samples 313,314,346,347 etc; Fig.3). Attempts made to mesh the flood transport of this group of lines with Line 6 was also not possible. These rather poor results in the trends for this area are surprising given the morphology of the Rottumeroog coastline which contains a flood-directed spit, as well as the orientation of the tidal channels, seem to suggest that the transport directions have not been misinterpreted.

3.2 Mixed (Bimodal) Sediment Transport

Bimodal sediments containing a mixture of sand and mud are relatively uncommon in the outer estuary but become more common towards its head, particularly on the west side of the Hundpaapzand (Fig.2). Transport of the bimodal sediments could be described on 20 lines of samples which are contained in three groups (numbered 8 to 10; Fig.12). The patterns of transport are shown in Figure 13 and the statistics for each line are contained in Table 1 (starting with Line 8A). The results of the trend analysis are as follows:

Lines 8A to 8C

These lines correspond well with the sand transport paths defined in Lines 1 and 2A, 2B which indicated an ebb-dominated regime from the River Eems onto the Rysumer Nacken tidal flats. The trend statistics suggest both Case B and Case C transport are occurring and examination of the X-distribution for each case shows net accretion for Case B (Fig.14) and dynamic equilibrium for Case C (Fig.15).

Lines 9A to 9C

Also similar to the sand transport regime (ie. Lines 5A to 5M), this group of lines shows flood-dominated transport from the Randzelgat Channel onto the Randzel intertidal flats. The R^2 values are all exceptionally high (0.97) and the X-distributions are indicative of accretion.

Lines 10A to 10N

This important group of lines completes the pattern of sediment transport in the vicinity of the Hundpaapzand. Lines 10A to 10C show flood-dominated transport down the Ostfriesisches Gatje and into the Dollard which agrees well with the sand transport regime in the same area (Lines 3K to 3M). It is interesting to note that despite Case C trends (sediments coarsening), the X-distributions indicate net accretion (Fig.16).

Line 10D provides a link between the flood transport regime in the channel with the mixed sediments found in Delfzijl harbour and Lines 10E to 10N demonstrate a clockwise pattern of transport around the southern end of the Hundpaapsand with deposition occurring on the west half of the shoal. The R^2 values are all exceptionally high and Case C is the dominant trend although the X-distribution shows that there is net accretion of sand occurring.

3.3 Mud Transport

The areas of mud in the Eems estuary are limited principally to the harbours of Emshaven and Delfzijl as well as the upper reaches of the Dollard (Fig.2). In the river Ems mud deposits are found at random among the sand and mixed sediments. The lack of mud samples enabled only several lines of samples to be analysed. These are shown on Figure 17 and the statistics given in Table I (Lines 11 to 13). Figure 18 provides the pattern of sediment transport.

Line 11A produces a transport direction up the River Ems, a direction opposite to that of either the sand or bimodal sediments. The trend is particularly good (R^2 = 0.92) and the X-distribution indicates net accretion (Fig.19).

Line 11B follows the same transport into the Port of Delfzijl as the mixed sediments. The X-distribution clearly defines an accreting environment (Fig.20). Lines 11C and 11D also follow the same direction as the mixed sediments which shows transport out of the Ostfriesisches Gatje and into the Bocht Van Watum (ie. a clockwise circulation around the Hundpaapzand). The Final two lines (12 and 13) indicate that muds are accreting into the Dollard and also farther up the river as far as Jemgum.

4.0 DISCUSSION

4.1 General

The transport pathways for the three facies (sand, bimodal and mud) as depicted in Figures 4, 13 and 18 are, with the exception of mud transport up the River Ems, mutually supportive in their overall patterns. This provides considerable support to their validity. The sediment trend analysis demonstrates that the whole estuary is influenced by a complex "mix" of ebb and flood dominated transport paths. The ebb-regime is controlled largely by the outflow from the River Ems which initially favours the north and west side of the estuary. Following the smaller channel between the Dukegatplate and the Emshörnplate, the ebb regime crosses the main channel into the Alte Ems and continues past the barrier islands and into the Hubertgat.

The flood regime in the outer estuary is predominantly confined to the main channels of the Westerems and Randzelgat, although there is some evidence of a flood transport regime on the south side of the Hubergat. The area between the Alte Ems and the Dukegat is where the ebb and flood converge with the result that the flood transport is deflected to the east and ebb transport to the west. In the middle and inner portions of the estuary, the flood regime is confined principally to the east side, with transport of sediment reaching the Dollard. The marine origin of sediments in the Dollard has been determined in previous studies (eg: Favejee, 1960).

The pattern of sediment transport is further validated by the relationship between the ebb/flood regimes and the location of the numerous shoals. Each shoal divides the ebb and flood dominated transport paths as seen, for example, in the Dukegatplate, the Mowen Steert, the Horsbornplate and the Ballonplate. The Hundpaapzand is also located between an ebb-directed regime on the west side and a flood directed regime in the Ostfriesisches Gatje on its east side. The Shoal itself is being built up by sediment in both regimes.

The one anomaly concerning mud transport up the River Ems when both sand and mixed sediments appear to be influenced by ebb transport is possibly due to the cohesive properties of mud. As noted earlier, the marine origin of the mud sediments has been described in previous work. It is suggested that mud is carried into the river on the flood tide and deposited during the high water slack. Once deposited, its cohesivness does not allow it to be resuspended and transported on the ebb-flow. Sand and mixed deposits, on the other hand, are able to join the ebb transport regime.

4.2 Implications for Dredging Operations

Although the purpose of this report is not to advise specifically on the present dredged channel, the patterns of sediment transport do allow several observations to be made. In general, a dredged channel oriented transversely or across the pathway of net sediment transport can be expected to act as a sediment trap. Material, in attempting to cross the channel, will become deposited and, until infilling is complete, will be unable to continue its movement on the further side. When a dredged channel is parallel to the natural transport path, deposition can, and probably will occur; however there is a greater probability of natural flushing of sediment in the direction of net transport. As a result, dredging requirements may be less when channel and transport path are parallel compared to when they are not. It is also reasonable to suppose that dredging requirements will be further lessened when the dredged channel follows an ebb transport path as opposed to a flood transport path. While the former may or may not contain less sediment the tendency for the seaward removal of material is clearly more desirable than landward (and hence estuary infilling) movement. Following a sediment trend analysis such as this study, further process studies could be undertaken in the ebb and flood dominated channels to determine which maintains the higher sediment flux.

The present dredged channel (Fig.1) leaves the River Ems on the ebb-dominated transport path. However, immediately west of the training wall it crosses into the flood dominated regime of the Ostfriesisches Gatje . In the "cross-over" region (Fig.21) higher than average dredging could be expected. The dredged channel then follows a flood-dominated transport path through the Ostfriesisches Gatje and into the Dukegat channel. At the north end of the Dukegatplate, it crosses the ebb regime which emerges from the channel lying between the Dukegatplate and the Emshörnplate en route to the ebb-dominated Alte Ems Channel. Once again higher than average dredging is predicted in this cross-over region (Fig.21). The validity of the derived sediment trends is greatly enhanced by the fact that both areas identified in Figure 21 do require greater removal of material than elsewhere in the channel (Rijkswaterstaat, pers.comm). Once in the Randzelgat, the dredged channel continues in a flood oriented transport regime all the way to the mouth of the estuary where it exits through the Westerems Channel.

It is interesting to note that the present dredged channel nearly everywhere follows the flood-dominated transport pathways. The exception is in the River Ems itself and this is the locality where muds are deposited on the flood. On the basis of the sediment trend analysis alone, a possible route that may minimize the dredging requirements would follow only the ebb transport paths. Such a route is illustrated in Figure 21.

The sediment trend analysis also establishes the probable fate of dredged material at the two disposal sites shown on Figure 1. Material from the harbour of Delfzijl is dumped in the channel south of the Hundpaapsand. There is no evidence to suppose it is transported either into the Dollard or towards the River Ems. Rather it appears to travel north into the Bocht van Watum and onto the west side of the Hundpaapsand. It appears likely that the dredged material is responsible for the large amount of mixed sediments in this area.

The second disposal site for dredged material out of Emshaven is in the channel south of the Alte Ems Reede shoal. This is a region dominated by flood transport which is likely to return the sediment into Emshaven. Although there are insufficient samples in Emshaven to provide meaningful trends, the few samples available suggested transport into the port.

5.0 SUMMARY AND CONCLUSIONS

1. A sediment trend analysis was performed on about 668 grain-size distributions taken from the Ems Estuary. The technique enabled patterns of net sediment transport to be determined for three facies consisting of sand, bimodal or mixed sediments and mud.

2. The trends for the three facies essentially agreed with each other thereby mutually supporting their validity. The only exception occurred in the River Ems where mud is evidently transported up-river, whereas sand and mixed sediments appear to be ebb-dominated (ie. down- river). The possible explanation for this finding is that mud is transported within the intruding salt-water wedge and deposited at high water slack. The cohesive properties do not allow the mud to be re-suspended and transport on the ebb.

3. The trend analysis clearly defined a complicated pattern of ebb and flood-dominated transport paths. The numerous shoals in the estuary separate the two regimes. All transport paths showed net accretion indicating that, as a whole, the estuary is infilling.

4. The present dredged channel crosses the natural pathways of sediment movement in two locations, and higher than average dredging is predicted. These areas are in the narrows between the end of the training wall and the Ostfriesisches Gatje channel, and in the region between the Alte Ems and Dukegat channels.

5. On the basis of the sediment trends, a possible route for the dredged channel is described which takes into account the natural ebb transport regime. In following this route, maintenance dredging may be minimized because (i) it parallels the transport pathways and (ii) the ebb flow will help to keep the channel flushed.

6. Dredged material currently taken from the Port of Delfzijl and disposed of in the adjacent channel is being dispersed into the Bocht Van Watum and onto the western half of the Hundpaapsand.

7. The present dredged material disposal site in the channel south of the Alte Reede shoal is located in a flood-dominated transport regime. For this reason, some sediment will be returned to the Port of Emshaven.

6.0 ACKNOWLEDGEMENTS

Special thanks are expressed to Dr. Tjark van Heuvel of the Rijkswaterstaat for his instigation and support for this study. The efforts and help of Dr. Rudi Spanhoff, also of the Rijkswaterstaat, in supporting the concepts of the approach used in this study are gratefully acknowledged. Special thanks are also extended to the Rijkswaterstaat staff and crew in Delfzijl for their work in the field programme. Field planning, grain-size analyses and preliminary interpretations were carried out by Richard Powys of GeoSea Consulting. The help of Pat Hancock (typing) and Sheila Ripper (drafting) has been very much appreciated.

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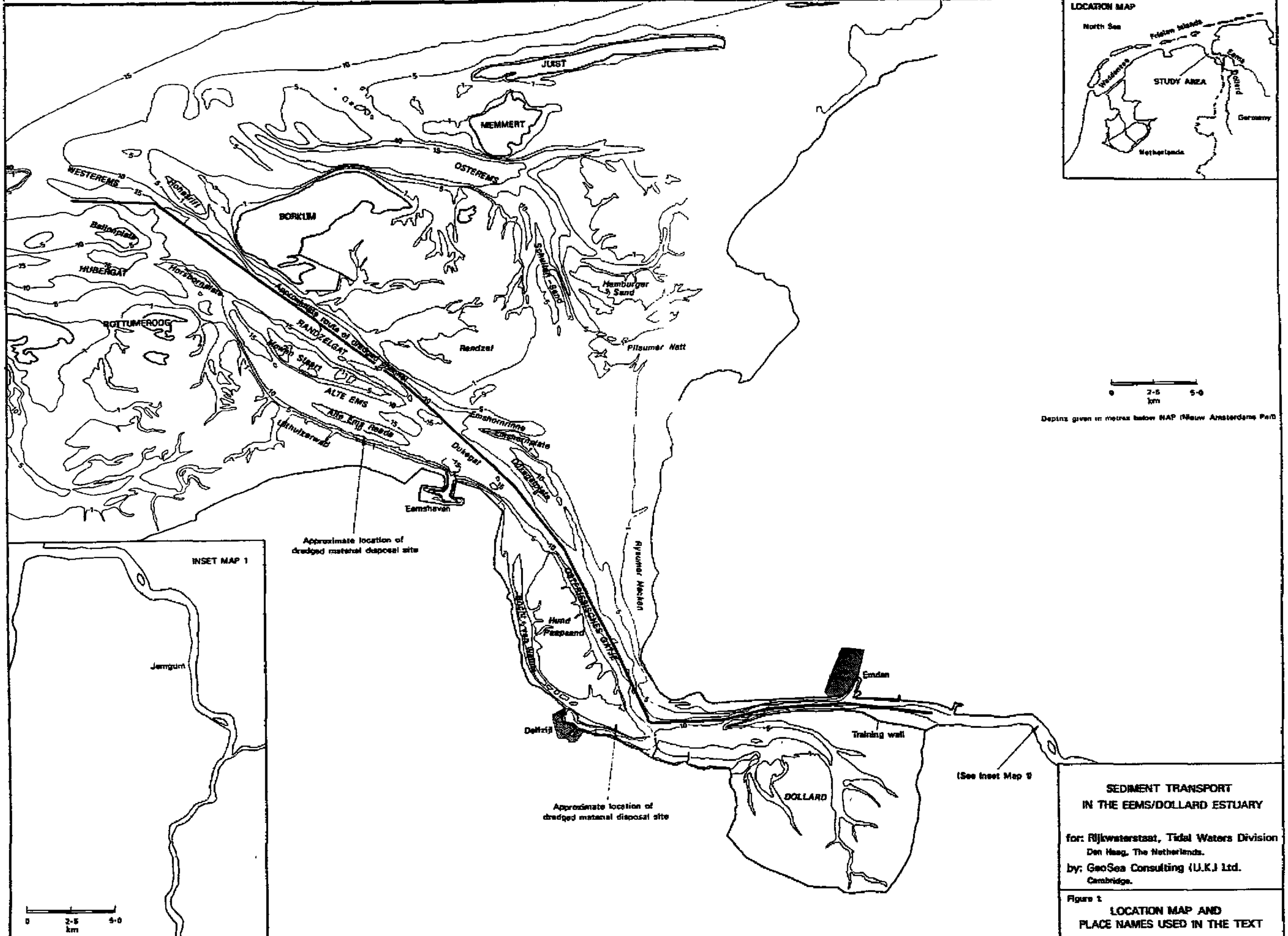


SEDIMENT TRANSPORT
IN THE EEMS/DOLLARD ESTUARY

for: Rijkwaterstaat, Tidal Waters Division
Den Haag, The Netherlands.
by: GeoSea Consulting (U.K.) Ltd.
Cambridge.

Figure 1
LOCATION MAP AND
PLACE NAMES USED IN THE TEXT

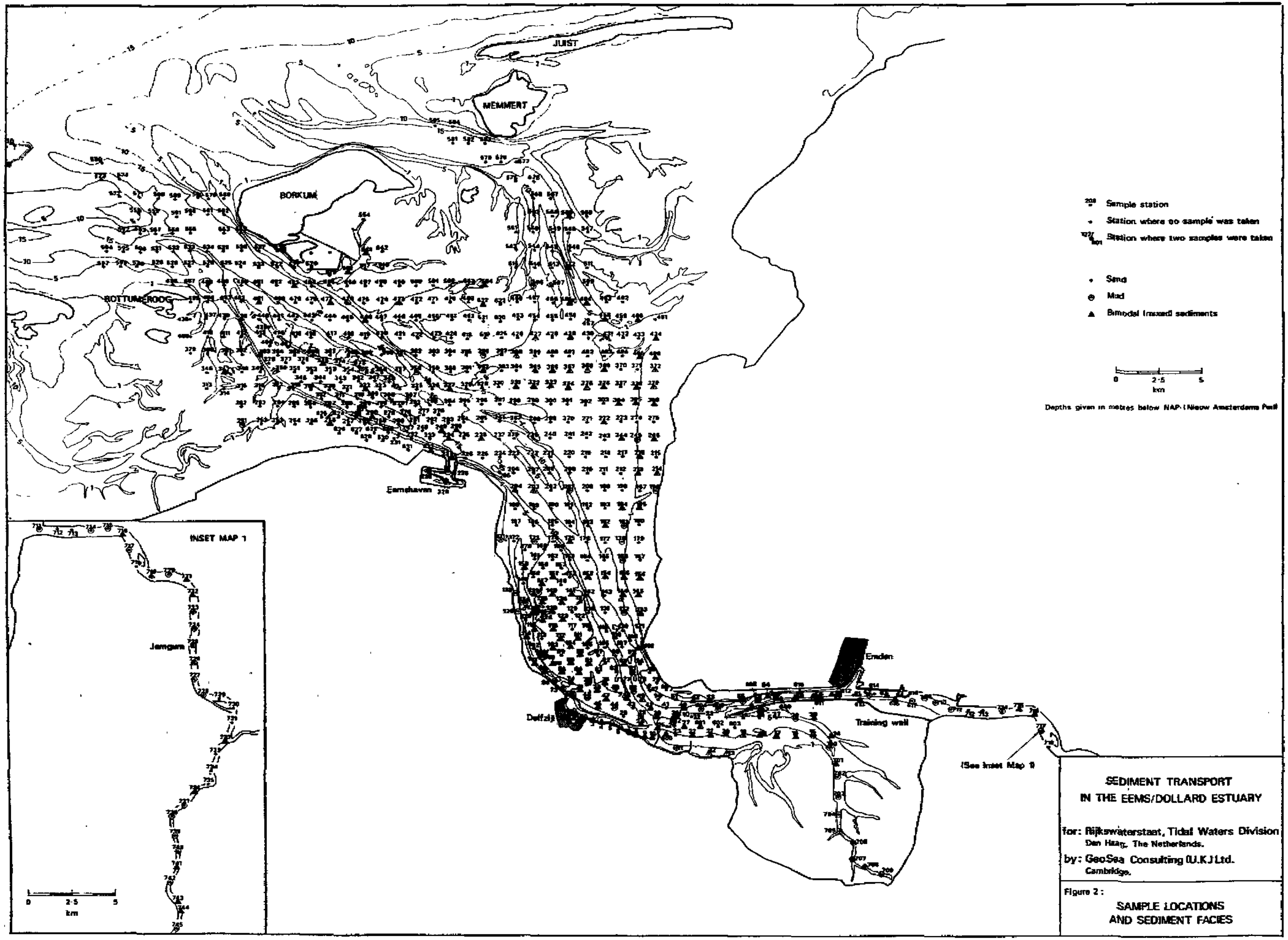


Figure 2 :

SAMPLE LOCATIONS
AND SEDIMENT FACIES

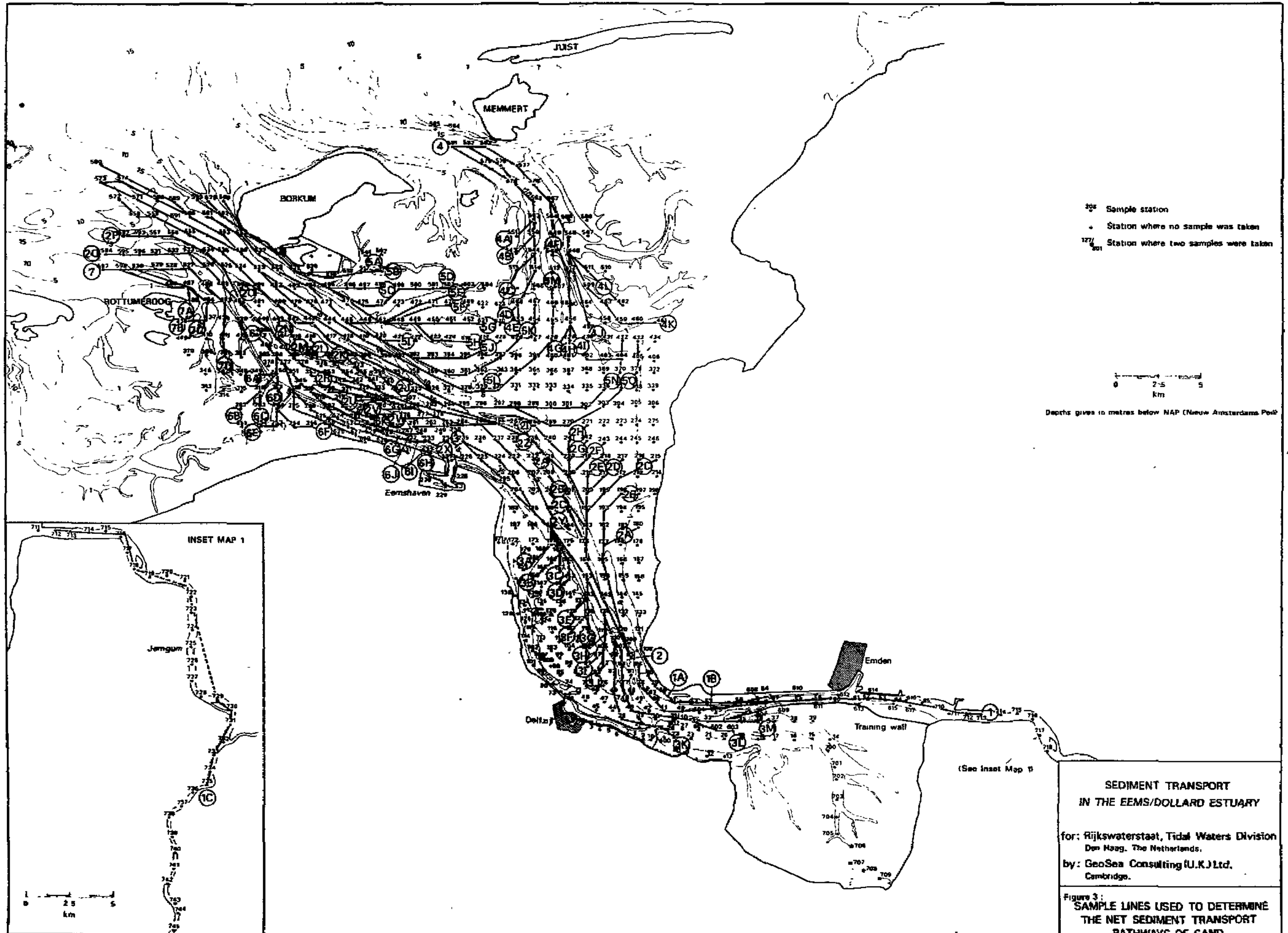
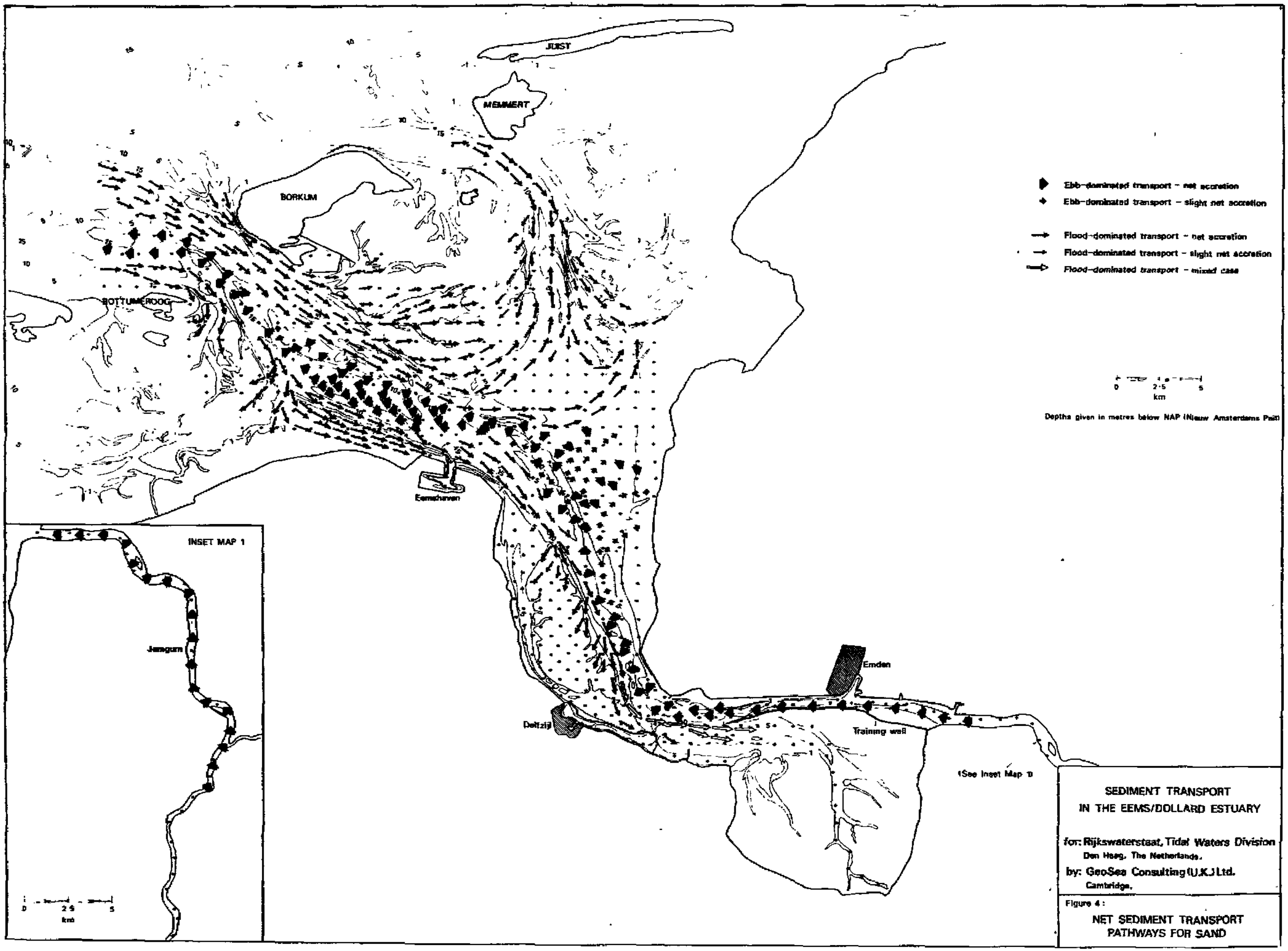


Figure 3 : SAMPLE LINES USED TO DETERMINE THE NET SEDIMENT TRANSPORT PATHWAYS OF SAND



SEDIMENT TRANSPORT
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Figure 4:

NET SEDIMENT TRANSPORT PATHWAYS FOR SAND

	D1	D2	X
MEAN	2.77	2.94	3.03
SORTING	0.51	0.44	0.84
SKEWNESS	-0.36	-0.36	-0.82

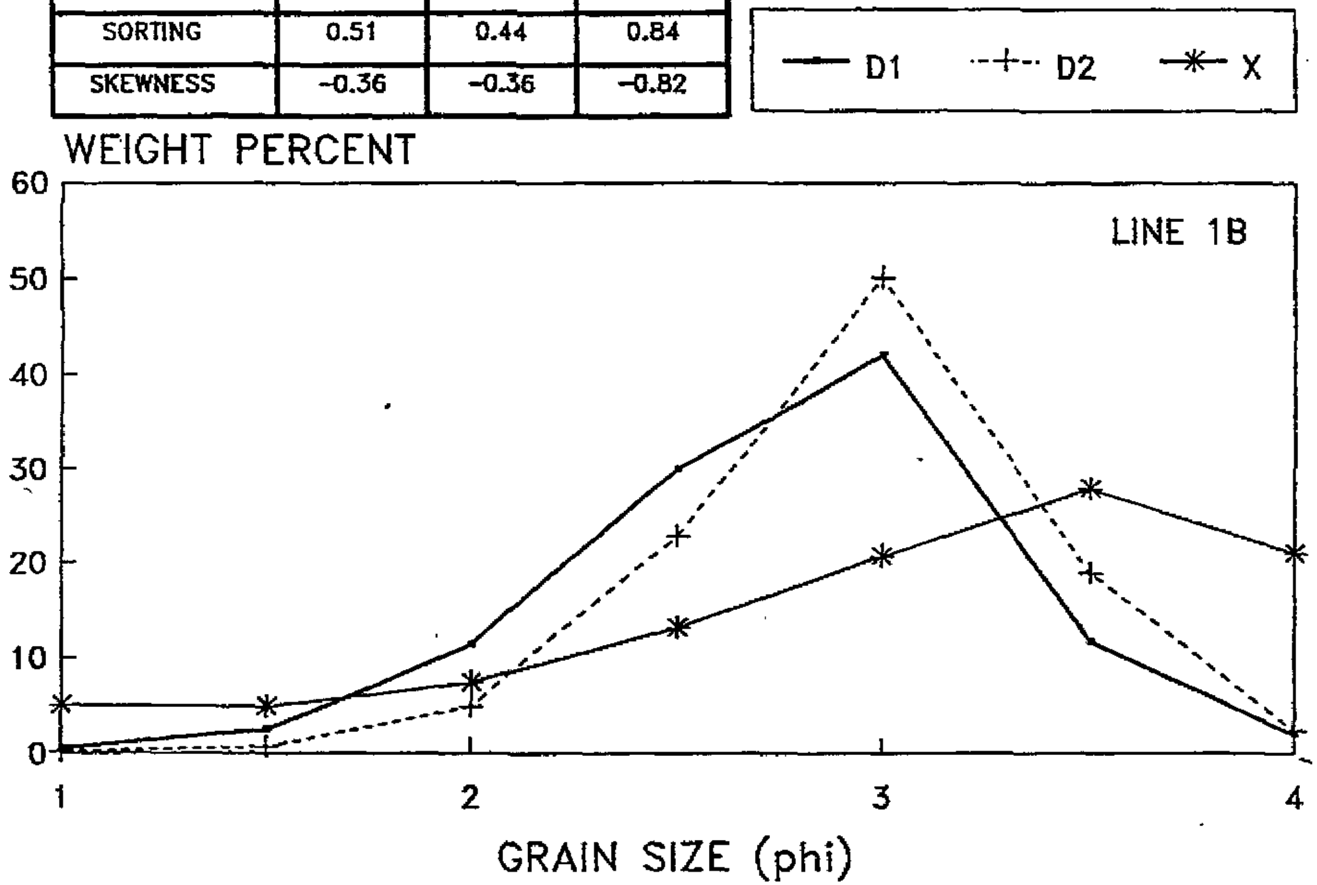


Figure 5: D_1, D_2 and X for Line 1B. The X-distribution is indicative of net accretion and its mode at 3.5 phi is the size most easily eroded and deposited.

	D1	D2	X
MEAN	2.38	2.64	2.86
SORTING	0.73	0.64	0.83
SKEWNESS	0.06	-0.21	-0.48

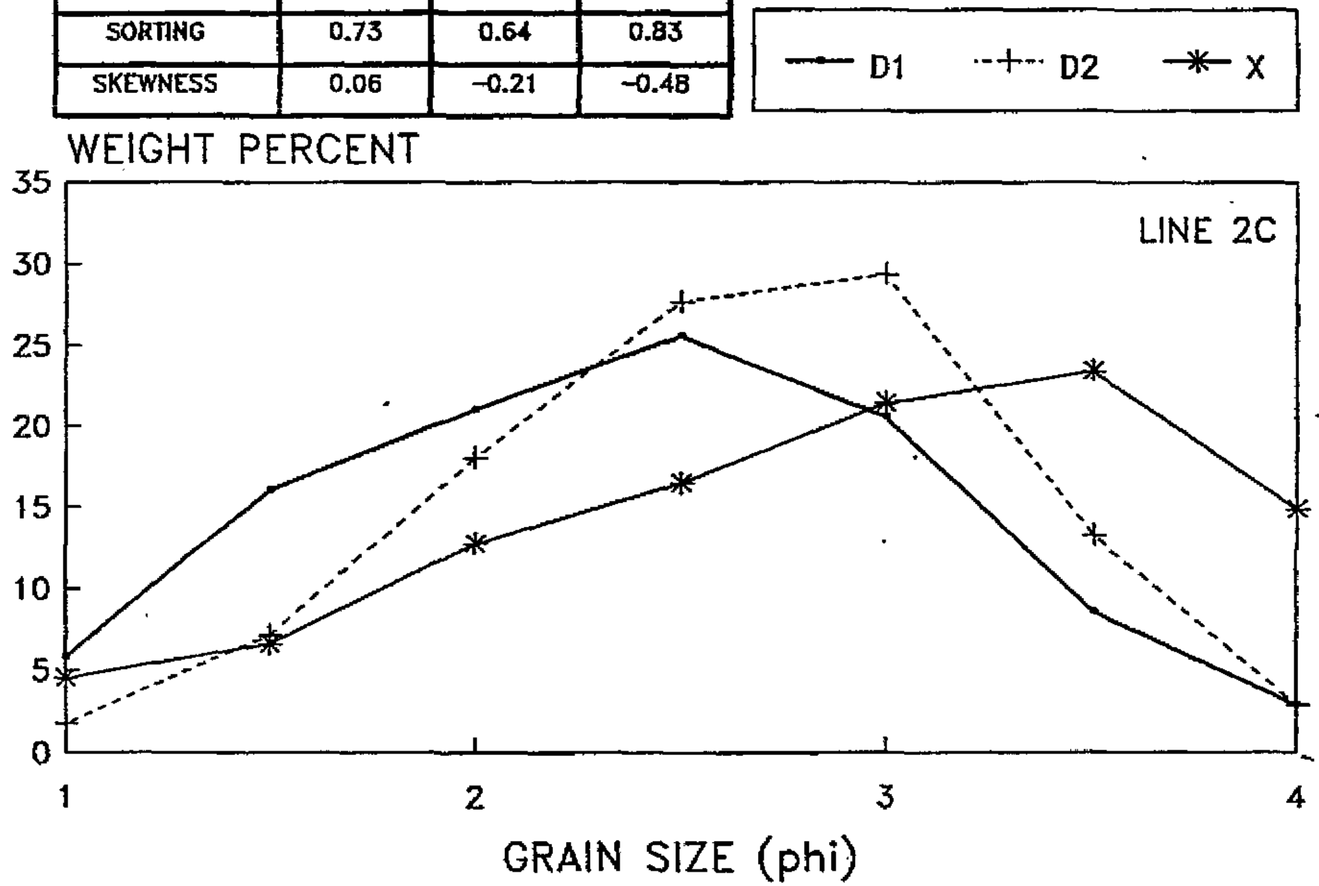


Figure 6: D_1, D_2 and X for Line 2C. The X-distribution clearly shows accretion from the main channel onto the eastern tidal flats (compare with Figure 7 which is interpreted as slight net accretion.

	D1	D2	X
MEAN	2.34	2.6	2.83
SORTING	0.73	0.61	0.78
SKEWNESS	0.15	-0.16	-0.42

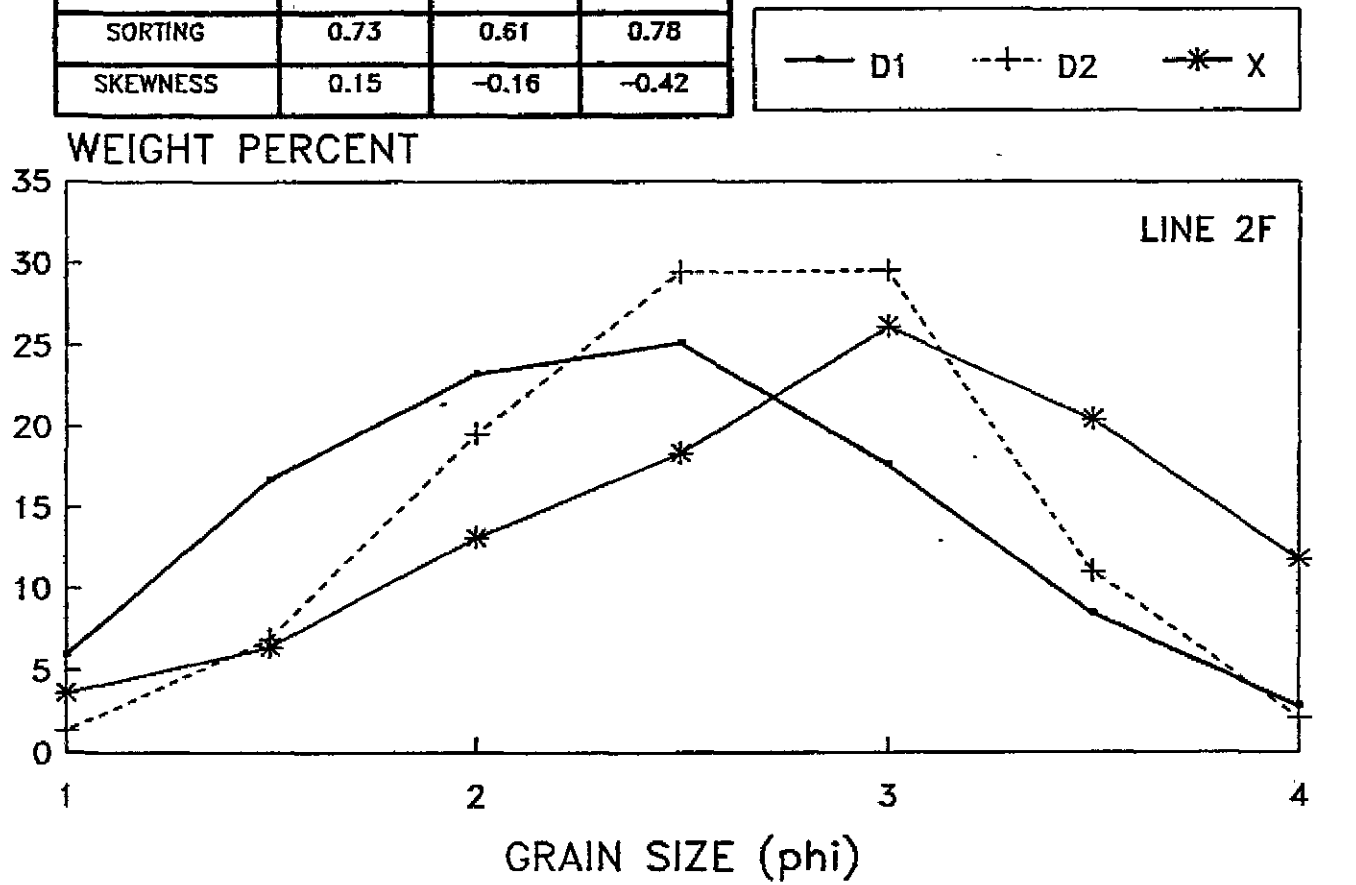


Figure 7: D_1, D_2 and X from Line 2F. Note how the X-distribution falls inside the D_2 distribution. It is interpreted as "slight net accretion".

	D1	D2	X
MEAN	2.48	2.68	2.86
SORTING	0.64	0.54	0.8
SKEWNESS	-0.16	-0.26	-0.47

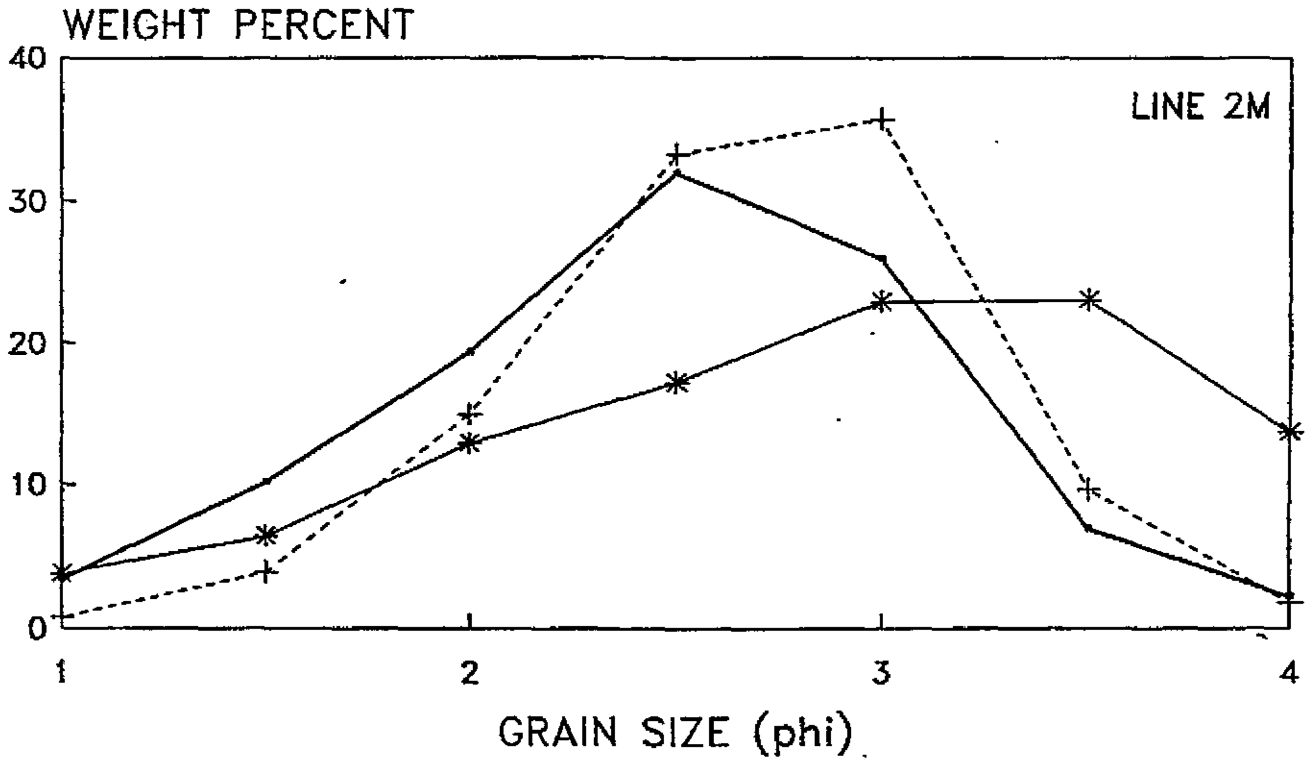


Figure 8: D_1, D_2 and X for Line 2M showing net accretion onto the Mowen Steert shoal.

	D1	D2	X
MEAN	2.23	2.98	3.26
SORTING	0.78	0.55	0.59
SKEWNESS	0.31	-0.69	-0.89

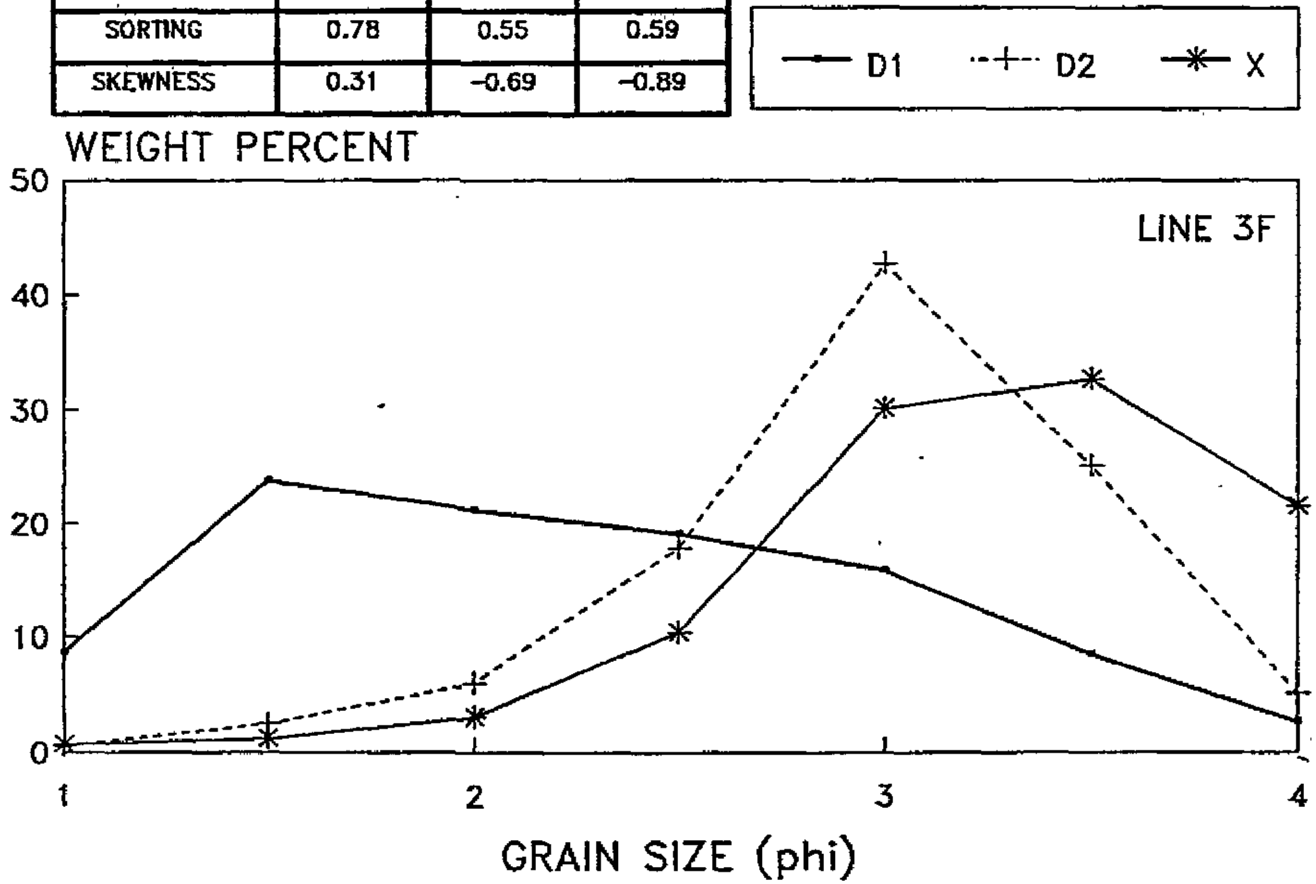


Figure 9: D_1, D_2 and X for Line 3F showing net accretion onto the Hund Paapsand.

	D1	D2	X
MEAN	2.21	2.83	3.18
SORTING	0.59	0.48	0.49
SKEWNESS	0.38	-0.44	-0.98

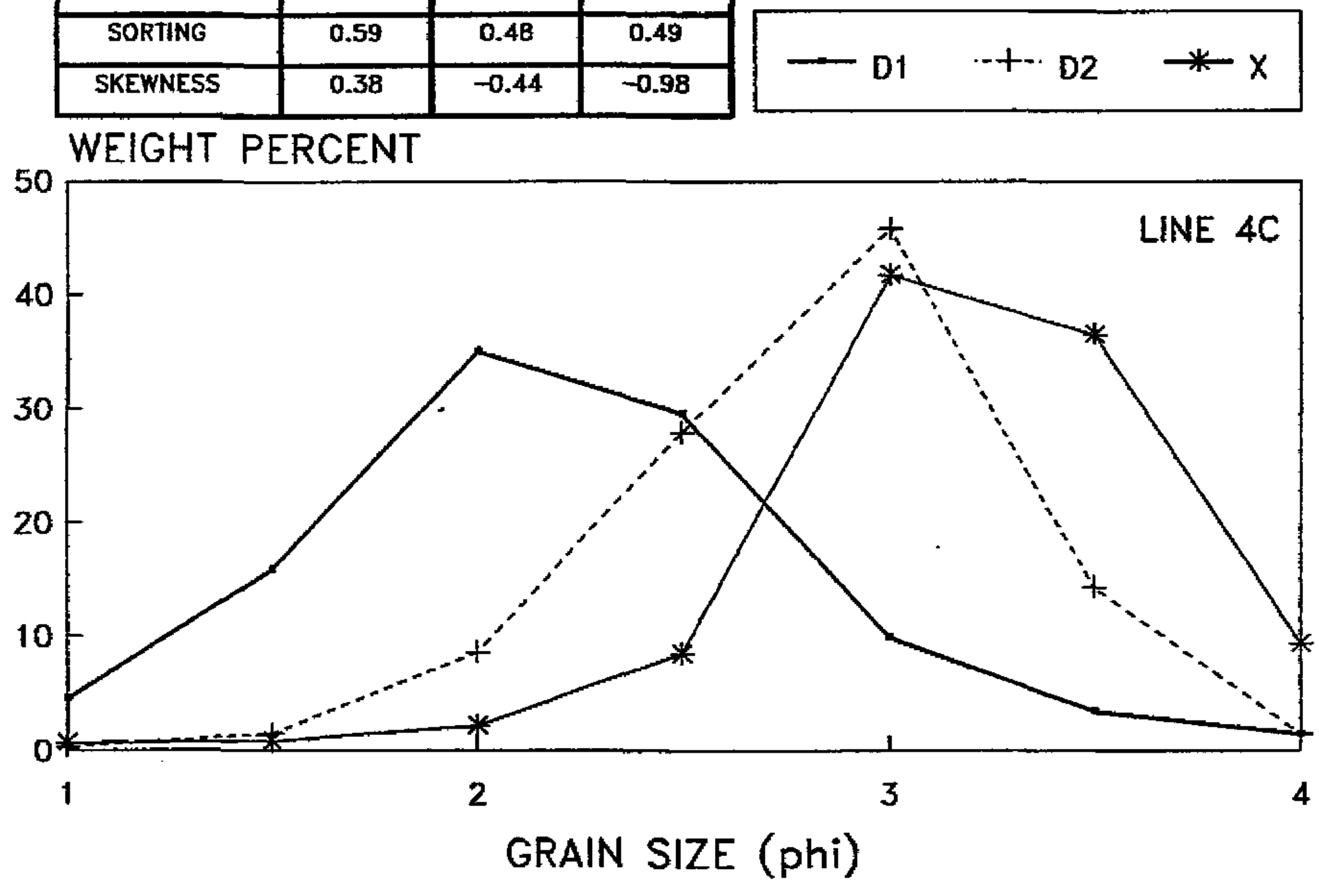


Figure 10: D_1, D_2 and X for Line 4C showing slight net accretion. Compare with Figure 11.

	D1	D2	X
MEAN	2.18	2.80	3.30
SORTING	0.57	0.53	0.60
SKEWNESS	0.34	−0.55	−1.21

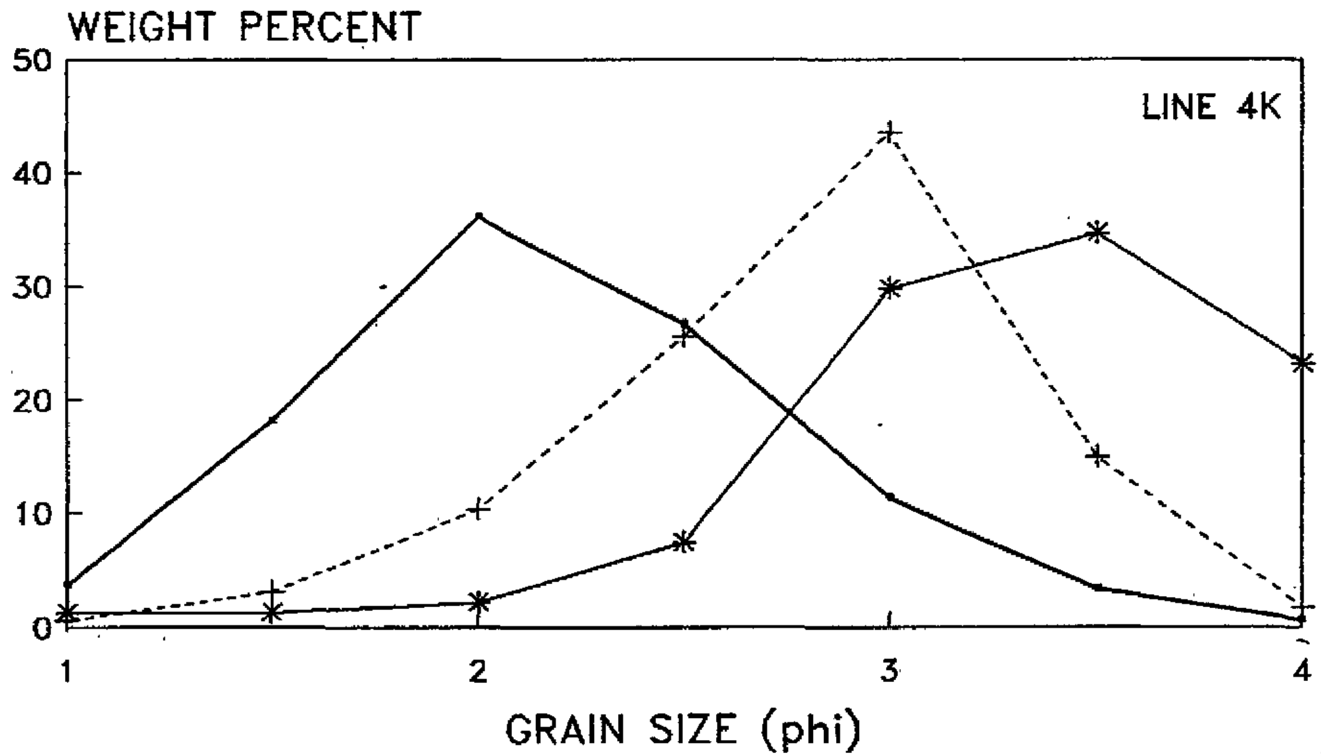


Figure 11: D_1, D_2 and X for Line 4K showing net accretion.

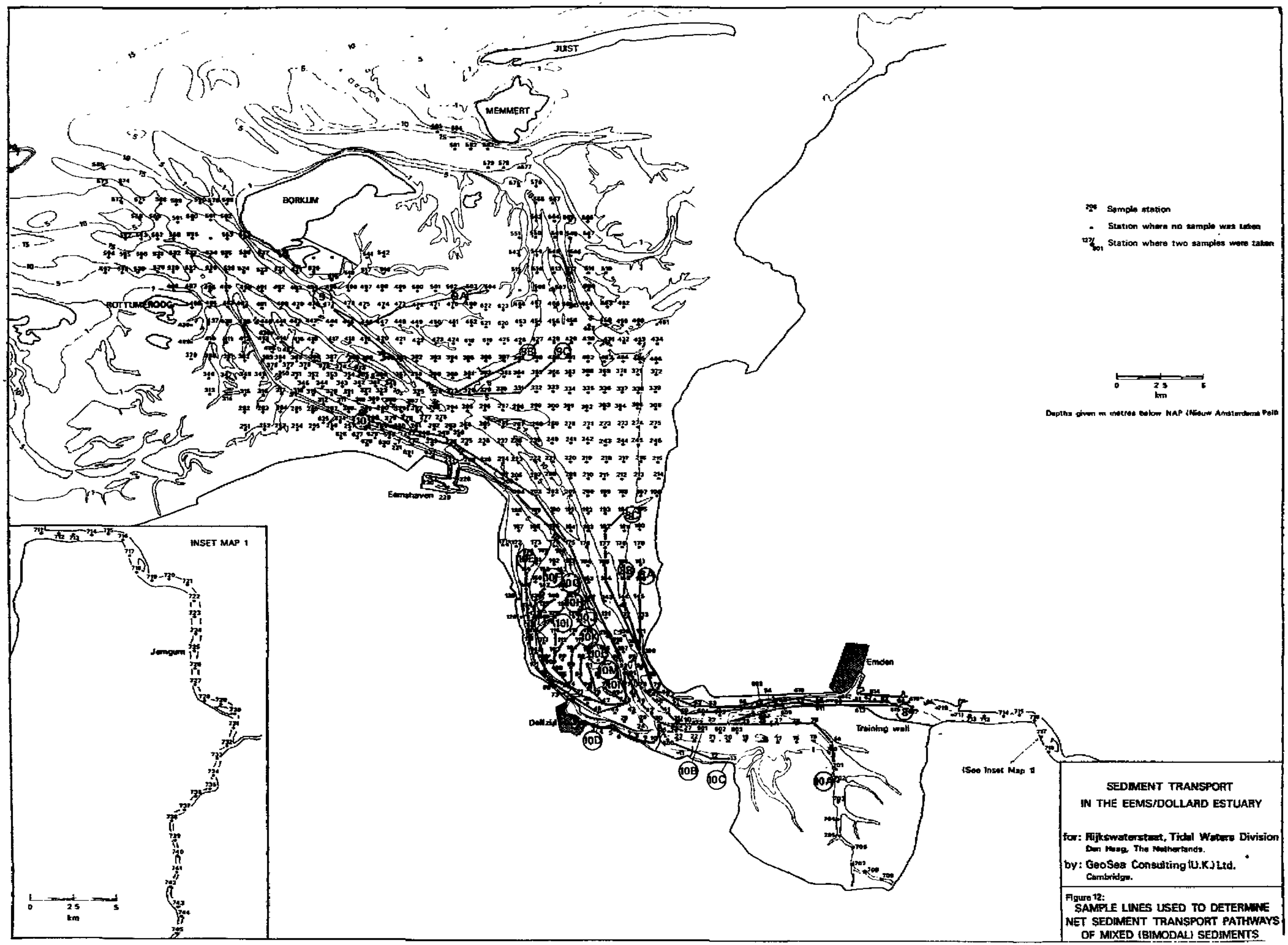
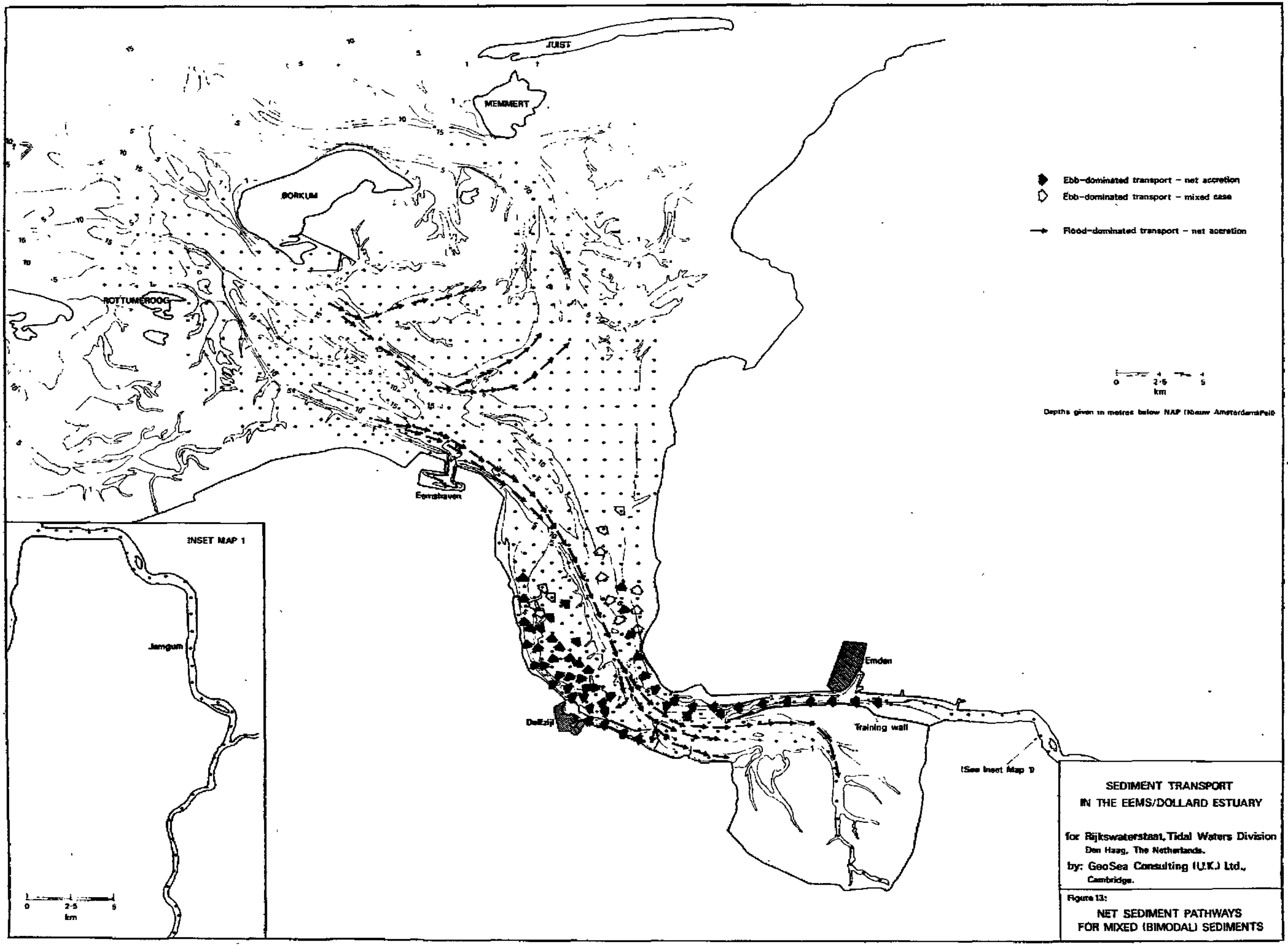


Figure 12:
SAMPLE LINES USED TO DETERMINE NET SEDIMENT TRANSPORT PATHWAYS OF MIXED (BIMODAL) SEDIMENTS



SEDIMENT TRANSPORT
IN THE EEMS/DOLLARD ESTUARY

for Rijkswaterstaat, Tidal Waters Division
Den Haag, The Netherlands.

by: GeoSea Consulting (U.K.) Ltd.,
Cambridge.

Figure 13:
NET SEDIMENT PATHWAYS
FOR MIXED (BIMODAL) SEDIMENTS

	D1	D2	X
MEAN	4.86	5.50	6.28
SORTING	2.04	1.86	2.06
SKEWNESS	0.29	0.08	-0.25

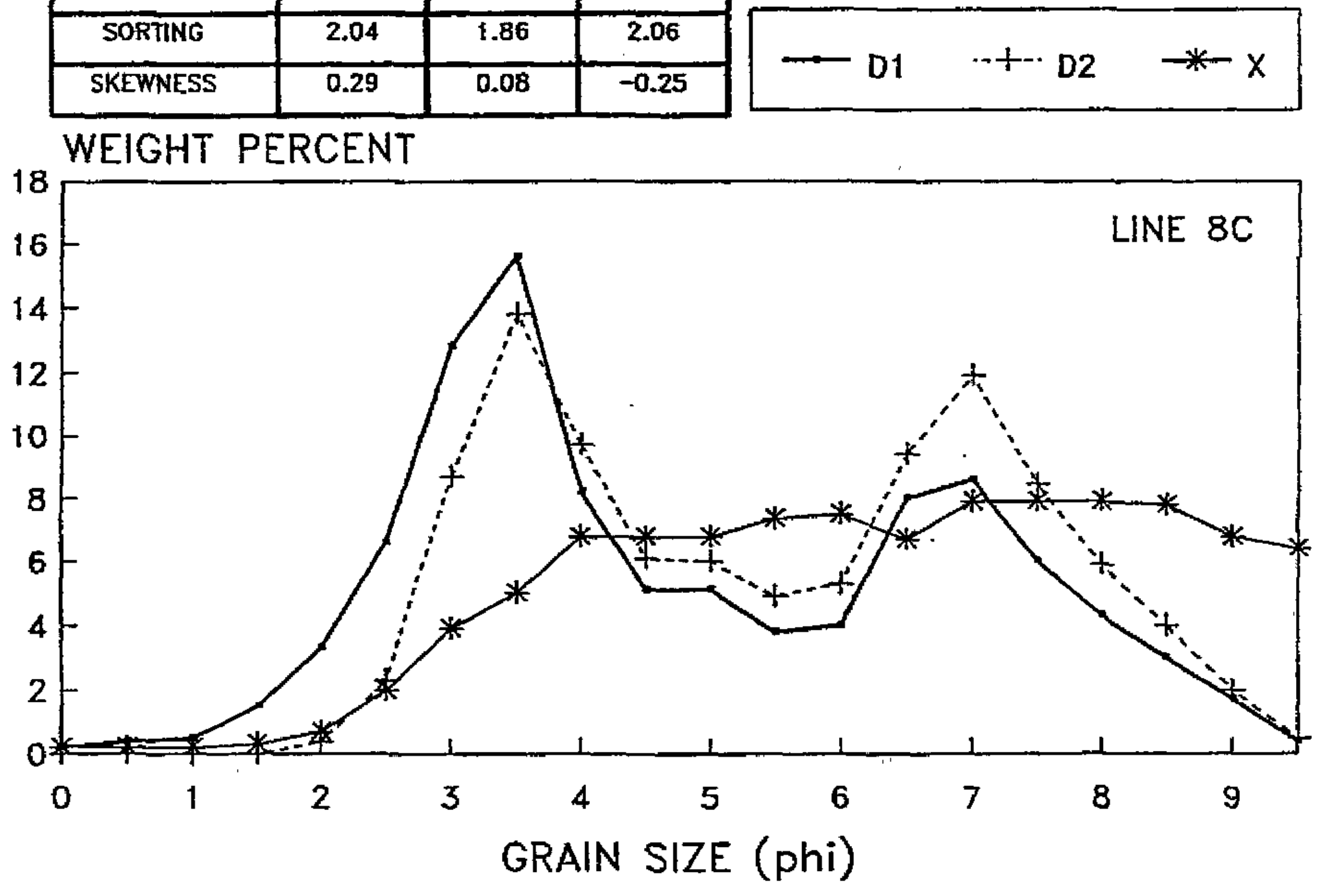


Figure 14: D_1, D_2 and X for Line 8C. (Case B transport) The rising X-distribution indicates net accretion is occurring in the Rysumer Nacken tidal flats.

	D1	D2	X
MEAN	5.02	4.83	5.45
SORTING	2.03	1.88	2.37
SKEWNESS	0.19	0.58	0.06

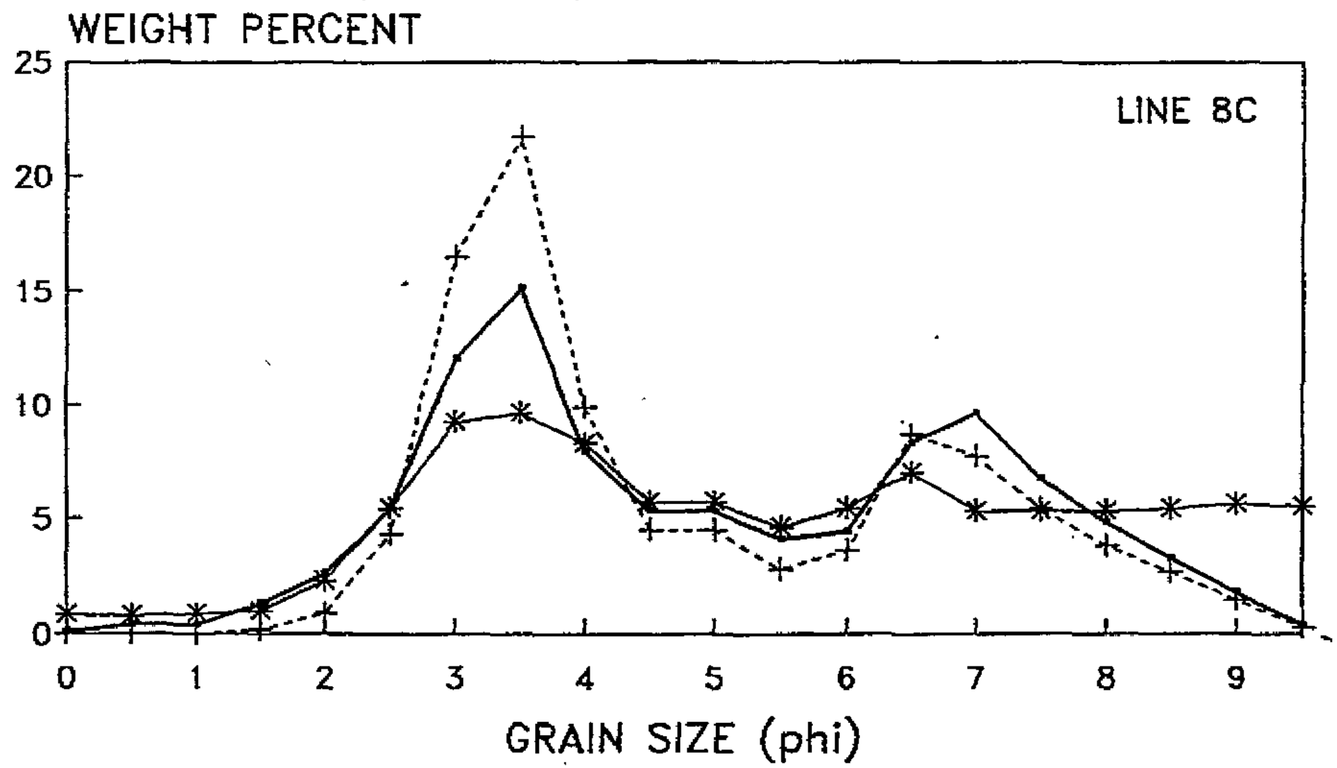


Figure 15: D_1, D_2 and X for Line 8C (Case C transport). The sand and mud modes of the X-distribution correspond closely with the modes of D_1 and D_2 indicating dynamic equilibrium.

	D1	D2	X
MEAN	5.02	4.29	4.64
SORTING	2.23	1.92	2.25
SKEWNESS	0.08	0.81	0.65

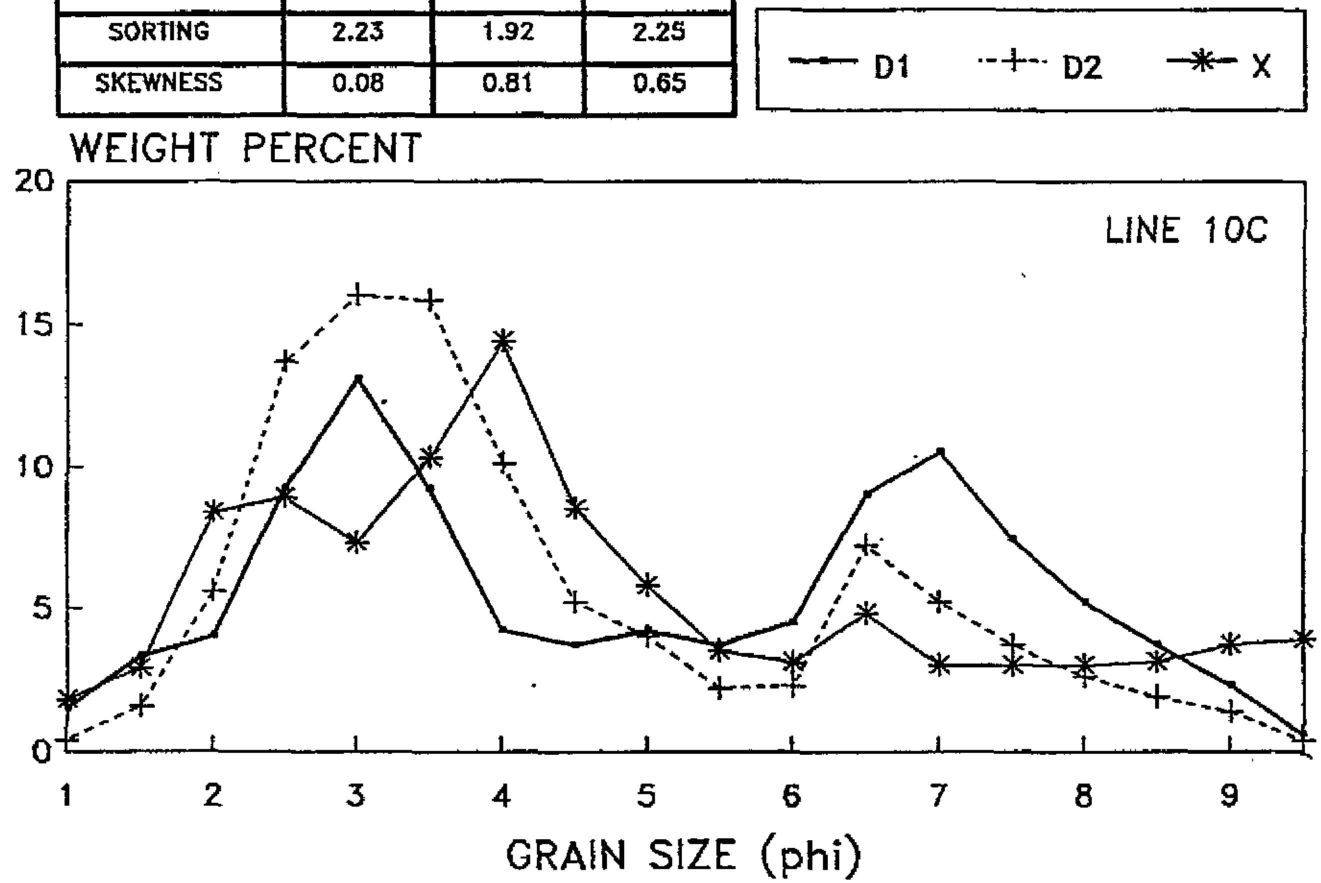
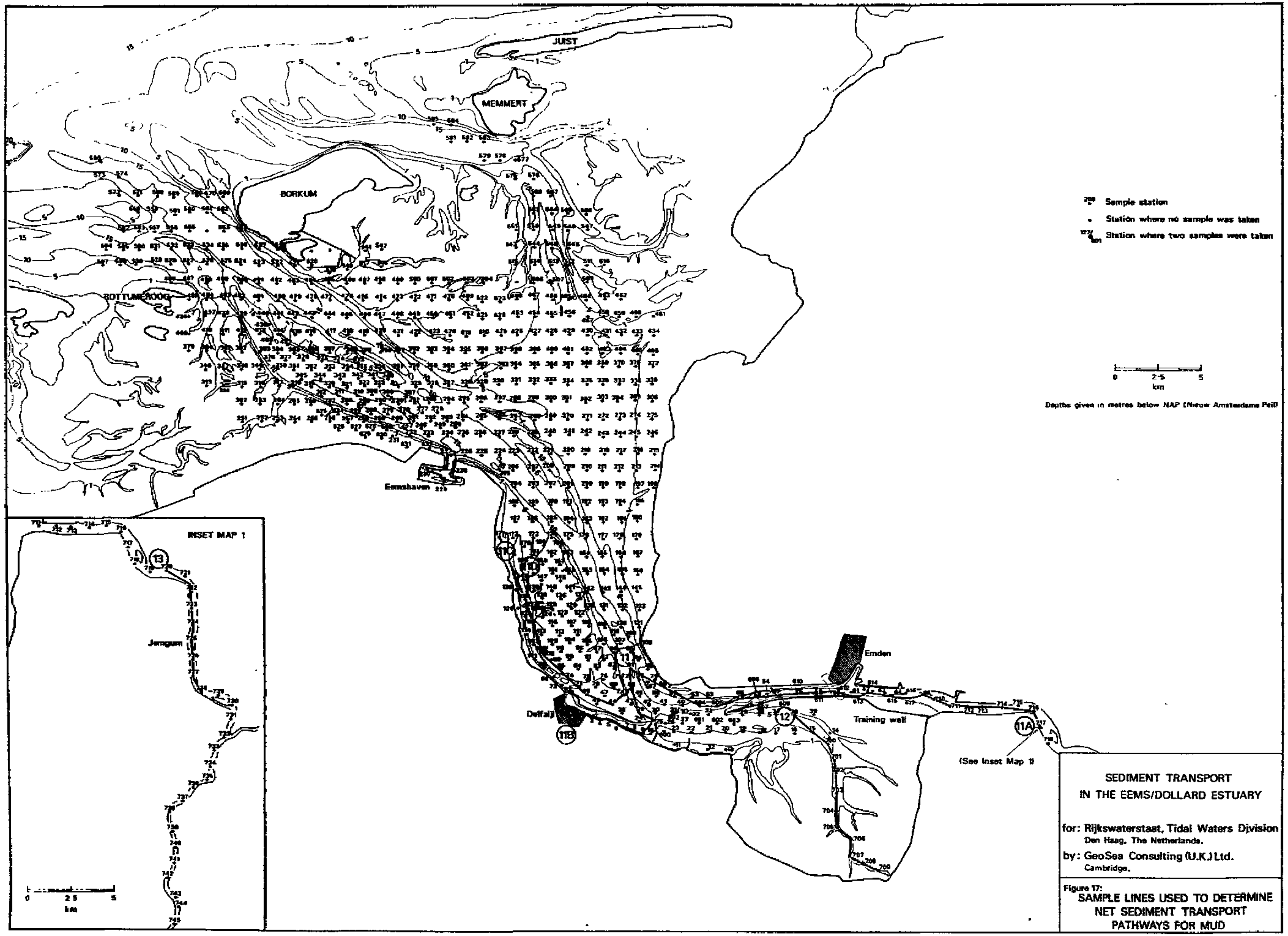


Figure 16: D_1, D_2 and X for Line 10C. Note the sand mode of the X-distribution indicating net accretion.



SEDIMENT TRANSPORT
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by: GeoSea Consulting (U.K.) Ltd.
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Figure 17:
SAMPLE LINES USED TO DETERMINE NET SEDIMENT TRANSPORT PATHWAYS FOR MUD

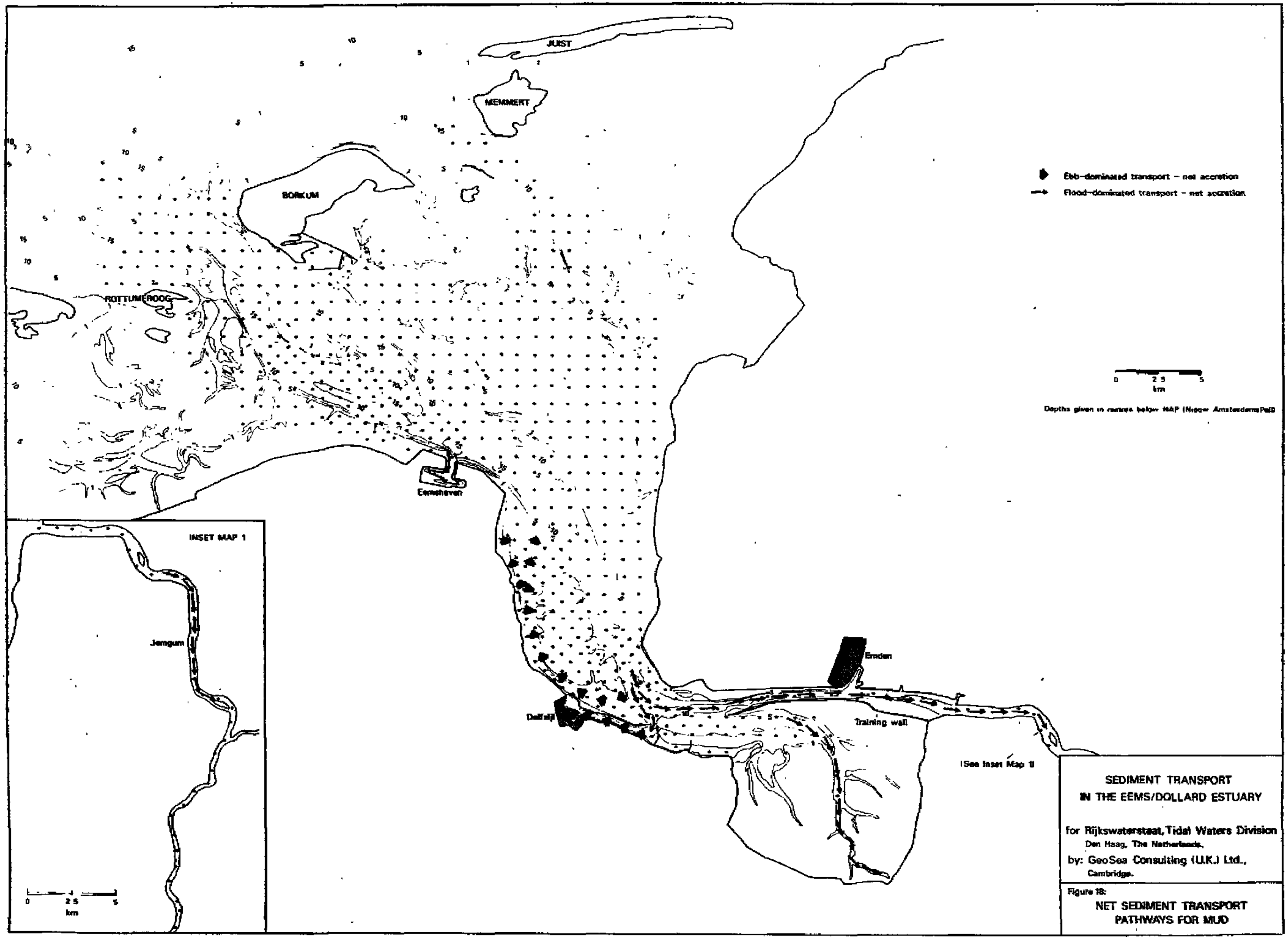


Figure 18:
NET SEDIMENT TRANSPORT PATHWAYS FOR MUD

	D1	D2	X
MEAN	6.32	6.48	6.24
SORTING	1.54	1.48	2.10
SKEWNESS	-0.32	-0.45	-0.17

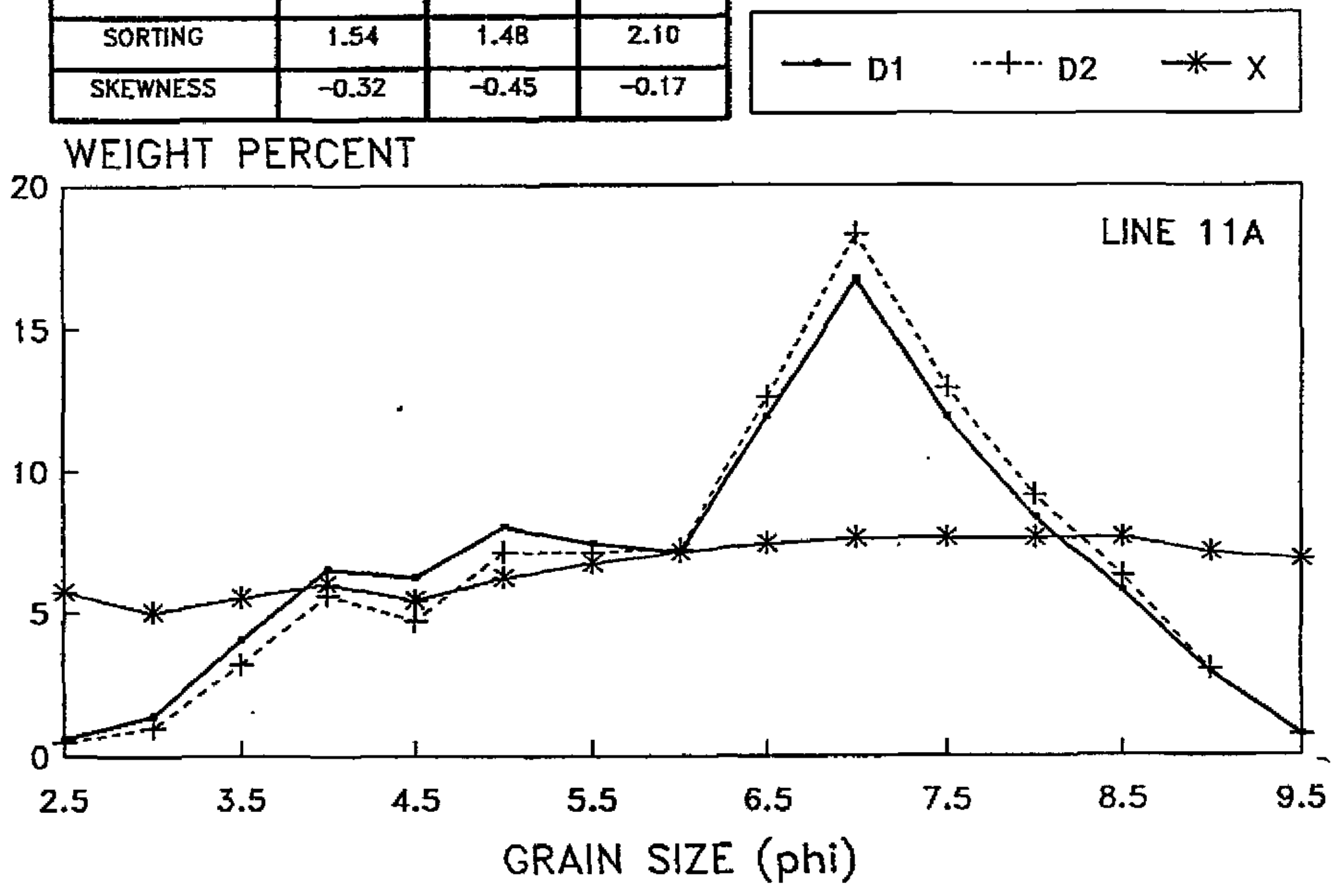


Figure 19: D_1, D_2 and X for Line 11A showing accretion for the mud deposits in the River Ems.

	D1	D2	X
MEAN	5.66	6.54	6.74
SORTING	1.95	1.52	1.86
SKEWNESS	-0.19	-0.62	-0.54

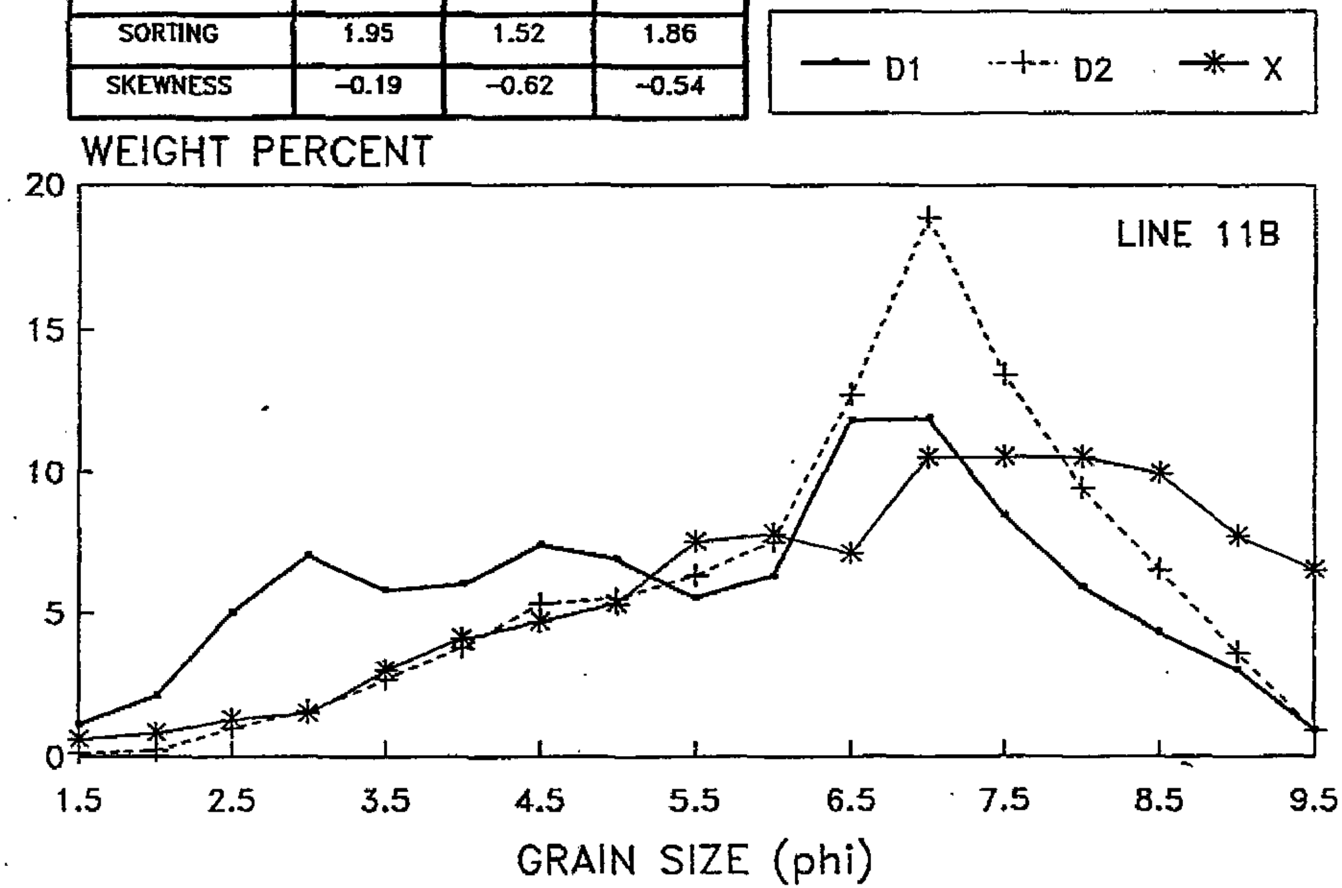
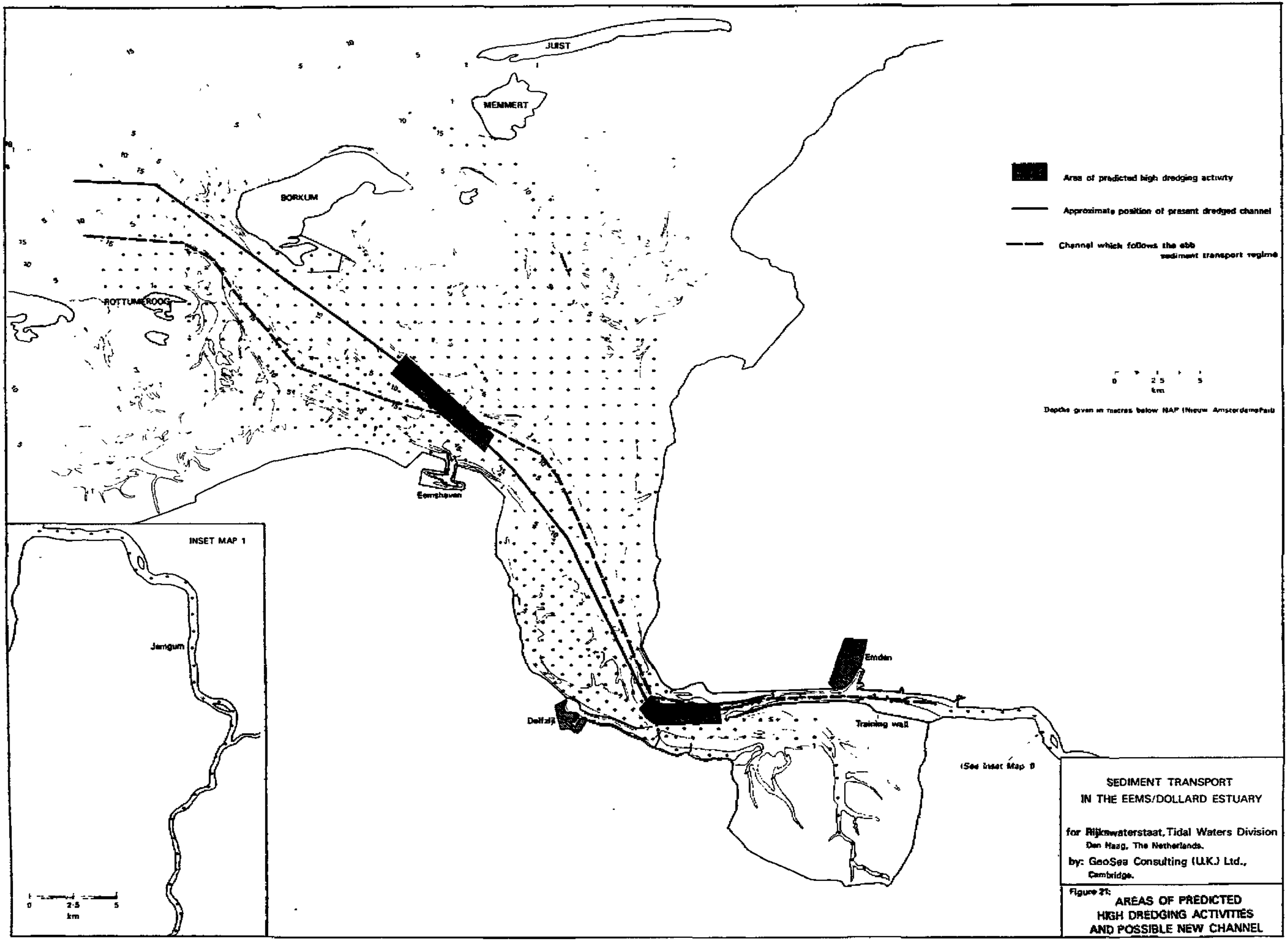


Figure 20: D_1, D_2 and X for Line 11B showing net accretion of mud into the Port of Delfzijl.



SEDIMENT TRANSPORT
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Figure 21: AREAS OF PREDICTED HIGH DREDGING ACTIVITIES AND POSSIBLE NEW CHANNEL

TABLE 1

Sediment trend statistics for all lines of samples

(see Figures 3,10 and 14)

Definitions

1. **R^2** = multiple correlation coefficient derived from the mean, sorting and skewness of each sample distribution along the line. This is a relative indication of how well the samples are related by transport.

2. **Case B**: Sediments becoming finer, better sorted and more negatively skewed in the direction of transport.

3. **Case C**: Sediments becoming coarser, better sorted and more positively skewed in the direction of transport.

4. **N** = number of possible pairs in the line of samples.

5. **x** = number of pairs making a particular trend in a specific direction.

6. **Z** = Z-score statistic: ** are those samples significant at the 99% level. * are those trends significant at the 95% level.

7. Down = transport in the down-estuary direction

   Up = transport in the up-estuary direction

8. Status (i.e. net erosion, accretion or dynamic equilibrium) is determined by the shape of the X-distribution (for a complete explanation see: The sediment transport regime in the Mond Haringvliet; report by GeoSea Consulting for the Rijkswaterstaat, July 1988).

SAND SAMPLES

Line	Case	R^2	Direction	N	x	Z	Status
1A	B		Up		5	-0.28	
			Down		12	2.87**	Net accretion
		0.28		45			
	C		Up		7	0.62	
			Down		1	-2.08	
1B	B		Up		6	-0.36	Net accretion
			Down		21	5.76**	
		0.43		55			
	C		Up		0	-2.80	
			Down		0	-2.80	
1C	B		Up		3	-0.756	Net accretion
			Down		17	6.299**	
		0.58		36			
	C		Up		7	1.260	
			Down		4	0.252	
2A	B		Up		0	-0.93	Slight net
			Down		4	4.01**	accretion
		0.97		6			
	C		Up		1	0.31	
			Down		0	-0.93	
2B	B		Up		2	0.10	Slight net
			Down		8	4.78**	accretion
		0.98		15			
	C		Up		3	0.88	
			Down		1	-0.68	
2C	B		Up		2	-1.26	Net accretion
			Down		24	9.83**	
		0.95		36			
	C		Up		4	-0.25	
			Down		5	0.25	
2D	B		Up		0	-2.27	Net accretion
			Down		29	12.35**	
		0.97		36			
	C		Up		2	-1.26	
			Down		5	0.25	
2E	B		Up		0	-2.27	Slight net
			Down		29	12.35**	accretion
		0.88		36			
	C		Up		1	-1.76	
			Down		5	0.25	

SAND SAMPLES

Line	Case	R^2	Direction	N	x	Z	Status
2F	B		Up		0	-2.27	Slight net
			Down		27	11.34**	accretion
		0.97		36			
	C		Up		1	-1.76	
			Down		6	0.76	
2G	B		Up		0	-2.27	Slight net
			Down		25	10.33**	accretion
		0.84		36	2	-1.26	
	C		Up		6	0.76	
			Down				
2H	B		Up		0	-2.54	Net accretion
			Down		32	11.89**	
		0.79		45			
	C		Up		2	-1.63	
			Down		6	0.17	
2I	B		Up		0	-2.80	Net accretion
			Down		39	13.10**	
		0.63		55			
	C		Up		2	-1.99	
			Down		6	-0.36	
2J	B		Up		5	-1.63	Net accretion
			Down		42	11.04**	
		0.75		78			
	C		Up		4	-1.97	
			Down		16	2.14*	
2K	B		Up		19	0.52	Net accretion
			Down		72	14.26**	
		0.76		136			
	C		Up		7	-2.59	
			Down		15	-0.52	
2L	B		Up		25	2.07*	Net accretion
			Down		65	12.45**	
		0.72		136			
	C		Up		1	-4.15	
			Down		21	1.04	
2M	B		Up		12	-1.74	Net accretion
			Down		97	19.04**	
		0.73		153			
	C		Up		1	-4.43	
			Down		15	-1.01	

SAND SAMPLES

Line	Case	R^2	Direction	N	x	Z	Status
2N	B		Up		26	0.49	Slight net accretion
			Down		113	19.58	
		0.72		190			
	C		Up		2	-4.77	
			Down		15	-1.92	
2"O"	B		Up		32	0.07	Net accretion
			Down		145	21.55**	
		0.73		253			
	C		Up		1	-5.82	
			Down		29	-0.50	
2P	B		Up		52	1.31	Net accretion
			Down		198	24.87**	
		0.73		351			
	C		Up		6	-6.11	
			Down		33	-1.76	
2Q	B		Up		70	2.27*	Net accretion
			Down		230	25.46**	
		0.70		435			
	C		Up		4	-7.30	
			Down		49	-0.78	
2R	B		Up		10	-1.38	Net accretion
			Down		75	16.56**	
		0.95		120			
	C		Up		2	-3.59	
			Down		21	1.66	
2S	B		Up		15	-0.52	Net accretion
			Down		87	18.15**	
		0.90		136			
	C		Up		3	-3.63	
			Down		19	0.52	
2T	B		Up		15	-0.52	Net accretion
			Down		89	18.67**	
		0.95		136			
	C		Up		2	-3.89	
			Down		20	0.78	
2U	B		Up		8	-1.51	Net accretion
			Down		74	17.96**	
		0.93		105			
	C		Up		1	-3.58	
			Down		12	-0.33	

SAND SAMPLES

Line	Case	R^2	Direction	N	x	Z	Status
2V	B		Up		13	-0.55	Net accretion
			Down		86	19.60**	
		0.94		120			
	C		Up		1	-3.86	
			Down		11	-1.10	
2W	B		Up		11	-0.12	Net accretion
			Down		60	15.41**	
		0.91		91			
	C		Up		3	-2.65	
			Down		9	-0.75	
2X	B		Up		17	0.55	Net accretion
			Down		59	12.15**	
		0.94		120			
	C		Up		17	0.55	
			Down		16	0.28	
2Y	B		Up		22	1.93*	Slight net accretion
			Down		63	13.25**	
		0.92		120			
	C		Up		2	-3.59	
			Down		19	1.10	
2Z	B		Up		1	-2.08	Slight net accretion
			Down		33	12.34**	
		0.96		45			
	C		Up		2	-1.63	
			Down		6	0.17	
2A'	B		Up		0	-2.27	Net accretion
			Down		27	11.34**	
		0.93		36			
	C		Up		1	-1.76	
			Down		7	1.26	
2B'	B		Up		0	-1.46	Net accretion
			Down		9	5.56**	
		1.00		15			
	C		Up		1	-0.68	
			Down		5	2.44**	
2C'	B		Up		0	-1.46	Net accretion
			Down		10	6.34**	
		0.98		15			
	C		Up		1	-0.68	
			Down		4	1.66*	

SAND SAMPLES

Line	Case	R^2	Direction	N	x	Z	Status
3A	B		Up		13	5.43**	Net accretion
			Down		2	-0.86	
		0.53		28			
	C		Up		4	0.29	
			Down		2	-0.86	
3B	B		Up		24	9.83**	Slight net accretion
			Down		0	-2.27	
		0.66		36			
	C		Up		3	-0.76	
			Down		3	-0.76	
3C	B		Up		13	6.85**	Slight net accretion
			Down		0	-1.73	
		0.87		21			
	C		Up		3	0.25	
			Down		3	0.25	
3D	B		Up		17	7.71**	Net accretion
			Down		0	-2.00	
		0.71		28			
	C		Up		3	-0.29	
			Down		3	-0.29	
3E	B		Up		16	7.14**	Net accretion
			Down		1	-1.43	
		0.91		28			
	C		Up		5	0.86	
			Down		4	0.29	
3F	B		Up		26	9.18**	Net accretion
			Down		1	-2.08	
		0.80		45			
	C		Up		5	-0.28	
			Down		3	-1.18	
3G	B		Up		21	8.32**	Net accretion
			Down		1	-1.76	
		0.81		36			
	C		Up		5	0.25	
			Down		3	-0.76	
3H	B		Up		15	5.29**	Net accretion
			Down		2	-1.26	
		0.81		36			
	C		Up		9	2.27	
			Down		7	1.26	

SAND SAMPLES

Line	Case	R^2	Direction	N	x	Z	Status
3I	B		Up		24	8.28**	Net accretion
			Down		2	-1.63	
		0.93		45			
	C		Up		9	1.52	
			Down		8	1.07	
3J	B		Up		31	9.84**	Slight net accretion
			Down		2	-1.99	
		0.82		55			
	C		Up		9	0.87	
			Down		8	0.46	
3K	B		Up		53	13.19**	Net accretion
			Down		4	-2.34	
		0.86		91			
	C		Up		8	-1.07	
			Down		11	-0.12	
3L	B		Up		38	8.44**	Mixed case
			Down		11	-0.12	
		0.81		91			
	C		Up		20	2.73**	
			Down		6	-1.70	
3M	B		Up		40	7.93**	Mixed Case
			Down		15	0.55	
		0.87		105			
	C		Up		23	2.91**	
			Down		12	-0.33	
4A	B		Up		10	6.34**	Slight net accretion
			Down		1	-0.68	
		0.50		15			
	C		Up		0	-1.46	
			Down		1	-0.68	
4B	B		Up		15	6.57**	Slight net accretion
			Down		2	-0.86	
		0.92		28			
	C		Up		0	-2.00	
			Down		6	1.43	
4C	B		Up		27	9.63**	Slight net accretion
			Down		5	-0.28	
		0.89		45			
	C		Up		0	-2.54	
			Down		6	0.17	

SAND SAMPLES

Line	Case	R^2	Direction	N	x	Z	Status
4D	B		Up		34	11.06**	Net accretion
			Down		4	-1.17	
		0.83		55			
	C		Up		1	-2.40	
			Down		8	0.46	
4E	B		Up		34	11.06**	Net accretion
			Down		4	-1.17	
		0.91		55			
	C		Up		2	-1.99	
			Down		8	0.46	
4F	B		Up		18	6.80**	Net accretion
			Down		4	-0.25	
		0.58		36			
	C		Up		2	-1.26	
			Down		6	0.76	
4G	B		Up		25	8.73**	Slight net accretion
			Down		3	-1.18	
		0.60		45			
	C		Up		2	-1.63	
			Down		7	0.62	
4H	B		Up		25	8.73**	Slight net accretion
			Down		4	-0.73	
		0.93		45			
	C		Up		3	-1.18	
			Down		6	0.17	
4I	B		Up		41	10.70**	Net accretion
			Down		5	-1.63	
		0.92		78			
	C		Up		5	-1.63	
			Down		15	1.80*	
4J	B		Up		27	9.63**	Slight net accretion
			Down		5	-0.28	
		0.97		45			
	C		Up		3	-1.18	
			Down		6	0.17	
4K	B		Up		38	11.07**	Net accretion
			Down		8	-0.09	
		0.96		66			
	C		Up		3	-1.95	
			Down		9	0.28	

SAND SAMPLES

Line	Case	R^2	Direction	N	x	Z	Status
4L	B	0.91	Up	45	27	9.63**	Slight net accretion
			Down		4	-0.73	
	C		Up		3	-1.18	
			Down		7	0.62	
5A	B	0.80	Up	15	6	3.22**	Slight net accretion
			Down		4	1.66	
	C		Up		2	0.10	
			Down		0	-1.46	
5B	B	0.87	Up	21	9	4.21**	Net accretion
			Down		5	1.57	
	C		Up		4	0.91	
			Down		0	-1.73	
5C	B	0.79	Up	28	12	4.86**	Slight net accretion
			Down		6	1.43	
	C		Up		2	-0.86	
			Down		2	-0.86	
5D	B	0.72	Up	55	27	8.21**	Slight net accretion
			Down		2	-1.99	
	C		Up		2	-1.99	
			Down		5	-0.76	
5E	B	0.93	Up	28	14	6.00**	Slight net accretion
			Down		5	0.86	
	C		Up		4	0.29	
			Down		3	-0.29	
5F	B	0.79	Up	45	22	7.38**	Net accretion
			Down		3	-1.18	
	C		Up		4	-0.73	
			Down		9	1.52	
5G	B	0.45	Up	78	27	5.91**	Net accretion
			Down		1	-3.00	
	C		Up		5	-1.63	
			Down		10	0.09	

SAND SAMPLES

Line	Case	R^2	Direction	N	x	Z	Status
5H	B		Up		26	5.56**	Net accretion
			Down		6	-1.28	
		0.36		78			
	C		Up		6	-1.28	
			Down		10	0.09	
5I	B		Up		17	6.30**	Net accretion
			Down		4	-0.25	
		0.81		36			
	C		Up		4	-0.25	
			Down		5	0.25	
5J	B		Up		24	5.86**	Net accretion
			Down		2	-2.33	
		0.60		66			
	C		Up		6	-0.84	
			Down		11	1.02	
5K	B		Up		33	6.85**	Net accretion
			Down		2	-2.97	
		0.64		91			
	C		Up		5	-2.02	
			Down		16	1.47	
5L	B		Up		28	6.25**	Net accretion
			Down		4	-1.97	
		0.48		78			
	C		Up		9	-0.26	
			Down		15	1.80*	
5M	B		Up		117	20.46**	Net accretion
			Down		11	-2.80	
		0.80		190			
	C		Up		13	-2.36	
			Down		22	-0.38	
5N	B		Up		144	19.93**	Net accretion
			Down		19	-2.82	
		0.42		276			
	C		Up		14	-3.73	
			Down		26	-1.55	
5"O"	B		Up		136	18.47**	Net accretion
			Down		39	0.82	
		0.73		276			
	C		Up		20	-0.46	
			Down		32	-2.64	

SAND SAMPLES

Line	Case	R^2	Direction	N	x	Z	Status
6A	B		Up		6	4.54**	Net accretion
			Down		0	-1.20	
		0.97		10			
	C		Up		2	0.72	
			Down		0	-1.20	
6B	B		Up		9	5.56**	Net accretion
			Down		0	-1.46	
		0.92		15			
	C		Up		3	0.88	
			Down		0	-1.46	
6C	B		Up		9	5.56**	Net accretion
			Down		0	-1.46	
		0.96		15			
	C		Up		3	0.88	
			Down		0	-1.46	
6D	B		Up		6	4.54**	Net accretion
			Down		1	-0.24	
		0.97		10			
	C		Up		2	0.72	
			Down		0	-1.20	
6E	B		Up		20	9.43**	Net accretion
			Down		0	-2.00	
		0.64		28			
	C		Up		3	-0.29	
			Down		1	-1.43	
6F	B		Up		28	10.09**	Net accretion
			Down		2	-1.63	
		0.78		45			
	C		Up		2	-1.63	
			Down		3	-1.18	
6G	B		Up		33	12.34**	Net accretion
			Down		1	-2.08	
		0.82		45			
	C		Up		2	-1.63	
			Down		2	-1.63	
6H	B		Up		28	10.09**	Net accretion
			Down		9	1.5	
		0.93		45			
	C		Up		2	-1.63	
			Down		3	-1.18	

SAND SAMPLES

Line	Case	R^2	Direction	N	x	Z	Status
6I	B		Up		48	11.61**	Net accretion
			Down		16	1.47	
		0.80		91			
	C		Up		2	-2.97	
			Down		8	-1.07	
6J	B		Up		40	11.82**	Net accretion
			Down		5	-1.21	
		0.72		66			
	C		Up		3	-1.95	
			Down		3	-1.95	
6K	B		Up		34	12.79**	Net accretion
			Down		0	-2.54	
		0.90		45			
	C		Up		4	-0.73	
			Down		0	-2.54	
7A	B		Up		4	2.63**	Net accretion
			Down		2	0.72	
		0.64		10			
	C		Up		1	-0.24	
			Down		0	-1.20	
7B	B		Up		4	2.63**	Net accretion
			Down		3	1.67*	
		0.79		10			
	C		Up		1	-0.24	
			Down		1	-0.24	
7C	B		Up		4	2.63**	Net accretion
			Down		1	-0.24	
		0.77		10			
	C		Up		1	-0.24	
			Down		2	0.72	
7D	B		Up		16	3.72**	Net accretion
			Down		9	0.87	
		0.45		55			
	C		Up		3	-1.58	
			Down		11	1.68*	

MIXED (BIMODAL) SEDIMENT SAMPLES

Line	Case	R^2	Direction	N	x	Z	Status
8A	B		Up		10	0.65	Mixed case
			Down		15	2.51**	
		0.99		66			
	C		Up		10	0.65	
			Down		25	6.23**	
8B	B		Up		9	2.27*	Net accretion
			Down		10	2.77**	
		0.99		36			
	C		Up		6	0.76	
			Down		8	1.76*	
8C	B		Up		14	0.83	Mixed case
			Down		20	2.73**	
		0.98		91			
	C		Up		14	0.83	
			Down		29	5.59**	
9A	B		Up		1	0.31	Net accretion
			Down		3	2.78**	
		1.00		6			
	C		Up		0	-0.93	
			Down		1	0.31	
9B	B		Up		0	-1.46	Net accretion
			Down		1	-0.68	
		0.92		15			
	C		Up		3	0.88	
			Down		5	2.44**	
9C	B		Up		0	-1.46	Net accretion
			Down		0	-1.46	
		0.98		15			
	C		Up		2	0.10	
			Down		6	3.22**	
10A	B		Up		5	-0.28	Net accretion
			Down		14	3.78**	
		0.81		45			
	C		Up		7	0.62	
			Down		10	1.97	
10B	B		Up		9	1.52	Net accretion
			Down		6	0.17	
		0.93		45			
	C		Up		3	-1.18	
			Down		19	6.03**	

MIXED (BIMODAL) SEDIMENT SAMPLES

Line	Case	R^2	Direction	N	x	Z	Status
10C	B	0.91	Up	55	7	0.05	Net accretion
			Down		9	0.87	
	C		Up		3	-1.58	
			Down		17	4.13**	
10D	B	0.92	Up	78	11	0.43	Net accretion
			Down		26	5.56**	
	C		Up		13	1.11	
			Down		16	2.14	
10E	B	0.94	Up	55	11	1.68*	Net accretion
			Down		16	3.72**	
	C		Up		9	0.87	
			Down		9	0.87	
10F	B	0.95	Up	78	10	0.09	Mixed case
			Down		18	2.82**	
	C		Up		8	-0.60	
			Down		28	6.25**	
10G	B	0.96	Up	78	11	0.43	Mixed case
			Down		18	2.82**	
	C		Up		11	0.43	
			Down		27	5.91**	
10H	B	0.96	Up	105	12	-0.33	Net accretion
			Down		20	2.03*	
	C		Up		14	0.25	
			Down		44	9.11**	
10I	B	0.94	Up	91	14	0.83	Net accretion
			Down		16	1.47	
	C		Up		8	-1.07	
			Down		36	7.81**	
10J	B	0.93	Up	78	12	0.77	Net accretion
			Down		14	1.46	
	C		Up		8	-0.60	
			Down		27	5.91**	

MIXED (BIMODAL) SEDIMENT SAMPLES

Line	Case	R^2	Direction	N	x	Z	Status
10K	B		Up		8	-0.60	Net accretion
			Down		16	2.14*	
		0.96		78			
	C		Up		11	0.43	
			Down		28	6.25**	
10L	B		Up		6	-0.36	Net accretion
			Down		12	2.09*	
		0.95		55			
	C		Up		8	0.46	
			Down		15	3.31**	
10M	B		Up		4	-0.25	Net accretion
			Down		7	1.26	
		0.95		36			
	C		Up		7	1.26	
			Down		11	3.28**	
10N	B		Up		4	0.91	Net accretion
			Down		2	-0.41	
		0.93		21			
	C		Up		0	-1.73	
			Down		8	3.55**	

MUD SAMPLES

Line	Case	R^2	Direction	N	x	Z	Status
11A	B		Up		46	12.41**7	Net accretion
			Down		12	0.77	
		0.92		78			
	C		Up		4	-1.97	
			Down		7	-0.94	
11B	B		Up		12	3.78**	Net accretion
			Down		3	-0.76	
		0.85		36			
	C		Up		1	-1.76	
			Down		4	-0.25	
11C	B		Up		3	0.25	Net accretion
			Down		9	4.21**	
		0.93		21			
	C		Up		5	1.57	
			Down		0	-1.73	
11D	B		Up		3	0.25	Net accretion
			Down		8	3.55**	
		0.86		21			
	C		Up		4	0.91	
			Down		0	-1.73	
12	B		Up		18	4.54**	Net accretion
			Down		5	-0.76	
		0.49		55			
	C		Up		3	-1.58	
			Down		0	-2.80	
13	B		Up		1	-1.07	Net accretion
			Down		9	4.21**	
		0.45		21			
	C		Up		3	0.25	
			Down		0	-1.73	

APPENDIX II

SEDIMENT TRANSPORT MODEL

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1.0 SEDIMENT TRANSPORT MODEL

The following is a brief review of the transport model, a detailed analysis of which is contained in McLaren and Bowles (1985).

1.1 Case A (development of a lag deposit)

Consider a sedimentary deposit which has a grain-size distribution denoted by the function g(s) (Fig. A -1). where 's' is grain size in phi units. If eroded, the sediment that goes into transport has a new distribution, r(s), which is derived from g(s) according to the function t(s) so that:

$$r(s_i) = kg(s_i)\,t(s_i) \qquad (1)$$

or

$$t(s_i) = \frac{r(s_i)}{kg(s_i)}$$

where $g(s_i)$ and $r(s_i)$ define the proportion of the sediment in the i^{th} grain-size class interval for each of the sediment distributions.

k is a scaling factor that normalizes r(s) so that:

$$\sum_{i=1}^{N} rs_i = 1$$

thus

$$k = \frac{1}{\sum_{i=1}^{N} g(s_i)\,t(s_i)}$$

With the removal of r(s) from g(s) the remaining sediment (a lag) has a new distribution denoted by d(s) (Fig. A -1) where :

$$d(s_i) = kg(s_i)[1 - t(s_i)]$$

or

$$t'(s_i) = \frac{d(s_i)}{k'g(s_i)}$$

where

$$t'(s_i) = 1 - t(s_i)$$

and

$$k' = \frac{1}{\sum_{i=1}^{N} g(s_i)[1 - t(s_i)]}$$

The function, t(s), is defined as a sediment transfer function and is described in exactly the same manner as a grain-size distribution function. It may be thought of as a function that incorporates all sedimentary and dynamic processes that result in initial movement and transport of particular grain sizes during a unit of time.

Data from flume experiments show that distributions of transfer functions change from having a high negative skewness to being nearly symmetrical (although still negatively skewed) as the energy of the eroding/transporting process increases. These two extremes in shape are termed low energy and high energy transfer functions respectively (Fig. A -2). The shape of t(s) is also dependent, not only on changing energy levels of the process involved in erosion and transport, but also on the initial distribution of g(s) (Fig. A -1). The coarser g(s) is, the less likely it is to be acted upon by a high energy transfer function. Conversely, the finer g(s) is, the easier it becomes for a high energy transfer function to operate on it. In other words, the same process may be represented by a high energy transfer function when acting on fine sediments, and by a low energy transfer function when acting on coarse sediments. The terms, high and low energy are, therefore, relative to the distribution of g(s).

The fact that t(s) appears to be mainly a negatively skewed function results in r(s), the sediment in transport, always becoming finer and more negatively skewed than g(s) (Fig. A -1). The function 1 - t(s) is, therefore, positively skewed, with the result that d(s), the lag remaining after r(s) has been removed, will always be coarser and more positively skewed than the original source sediment.

If t(s) is applied to g(s) an infinite number of times (i.e. 'n' times), then the variance of both g(s) and d(s) will approach zero (i.e. sorting will become better). However, depending on the initial distribution of g(s), it is possible for variance to become greater before eventually decreasing. Because the phi scale produces approximately Gaussian or normal distributions which are symmetrical, it is probable that an increasing variance will rarely be observed.

Given two sediments, $d_1(s)$ and $d_2(s)$, and $d_2(s)$ is coarser, better sorted and more positively skewed than $d_1(s)$, it may be possible to conclude that $d_2(s)$ is a lag of $d_1(s)$ and that the two distributions were originally similar (Case A; Table A -1).

1.2 Case B (Sediments becoming finer in the direction of transport)

Consider a sequence of deposits [$d_1(s)$, $d_2(s)$, $d_3(s)$] that follows the direction of the sediment in transport (Fig. A -3). Each deposit is derived from its corresponding sediment in transport, and according to the '3-box' model shown in Figure A -1, each $d_n(s)$ can be considered a lag of each $r_n(s)$. Thus $d_n(s)$ will be coarser, better sorted and more positively skewed than $r_n(s)$. Similarly, each $r_n(s)$ is acted upon by its corresponding $t_n(s)$ with the result that the sediment in transport becomes progressively finer, better sorted and more negatively skewed.

Any two sequential deposits [e.g. $d_1(s)$ and $d_2(s)$] may be related to each other by a function X(s) so that :

$$d_2(s) = kd_1(s)X(s)$$

where $$k = \frac{1}{\sum_{i=1}^{N} d_1(s_i)X(s_i)}$$

or $$X(s) = \frac{d_2(s)}{kd_1(s)}$$

As illustrated in Figure A-3, $d_2(s)$ can also be related to $d_1(s)$ by:

$$d_2(s) = \frac{kd_1(s)t_1(s)[1-t_2(s)]}{1-t_1(s)}$$

$$= kd_1(s)X(s) \qquad (2)$$

where $$X(s) = \frac{t_1(s)[1-t_2(s)]}{1-t_1(s)} \qquad (3)$$

The function X(s) combines the effects of two transfer functions $t_1(s)$ and $t_2(s)$ (Equation 3). It may also be considered as a transfer function in that it provides the statistical relationship between the two deposits and it incorporates all of the processes responsible for sediment erosion, transport and deposition over the period of time represented by the samples. The deposit $d_2(s)$ will, therefore, change relative to $d_1(s)$ in accordance to the shape of X(s) which, in turn, is derived from the combination of $t_1(s)$ and $t_2(s)$ as expressed in Equation 3. It is important to note that X(s) can be derived from the deposits themselves (Equation 2) and it provides the relative probability of any particular sized grain being moved.

Using empirically derived $t(s)$ functions it can be shown that when energy is decreasing in the direction of transport [i.e. $t_2(s) < t_1(s)$] and both are low energy functions (Fig.A-4), then $X(s)$ is always a negatively skewed distribution. This will result in $d_2(s)$becoming finer, better sorted and more negatively skewed than $d_1(s)$. Therefore, given two sediments, $d_1(s)$ and $d_2(s)$ and $d_2(s)$ is finer, better sorted and more negatively skewed than $d_1(s)$, it may be possible to conclude that the direction of sediment transport is from d_1 to d_2 (Table A -1).

1.3 Case C (Sediments becoming coarser in the direction of transport)

In the event that $t_1(s)$ is a high energy function (Fig. A-2), and $t_2(s) < t_1(s)$ (i.e. energy is decreasing in the direction of transport), the result of Equation 3 will produce a positively skewed $X(s)$ distribution (Fig. A-4). Therefore, $d_2(s)$ will become coarser, better sorted and more positively skewed than $d_1(s)$ in the direction of transport, and should this relationship be observed, it may be possible to conclude that the direction of sediment transport is from d_1 to d_2 (Table A -1).

It is interesting to note that sediments cannot become coarser forever, because, with coarsening it becomes less and less likely that the transport processes will maintain high energy characteristics. As the deposits become coarser, the transfer function describing the processes will revert to a low energy function with the result that the sediment must become finer again.

Cases A and C produce identical grain-size changes between d_1 and d_2 (Table A-1). Generally, however, the geological interpretation of the environments being sampled will clearly differentiate between the two Cases.

2.0 METHOD TO DETERMINE TRANSPORT DIRECTION FROM GRAIN-SIZE DISTRIBUTIONS

Clearly the model presented above does not result in perfect sequential changes of grain-size distributions in the direction of sediment transport, although numerous authors have recognized general changes in specific parameters (e.g. mean grain size or sorting). The model demands specific changes in all three parameters (mean, sorting and skewness) to suggest a transport direction. Given such complicating factors as variability in 'original source', probable local and temporal variability in the transfer functions, and variable time intervals represented by the samples themselves, it is not surprising that sequential changes in grain-size distributions are seldom recognized.

One approach that appears to be successful in recognizing trends is a simple statistical method whereby the Case (Table A -1) is determined among all possible pairs in a sample sequence. Given a sequence of 'n' samples, there are $\frac{n^2-n}{2}$ directionally-orientated pairs that may exhibit a transport trend in one direction, and an equal number of pairs in the opposite direction. When any two samples are compared with respect to their mean size, sorting and skewness, 8 possible trends exist; compared to d_1, d_2 may be: (i) finer (F), better sorted (B) and more negatively skewed (-); (ii) coarser (C), more poorly sorted (P) and more positively skewed (+); (iii) C, B, -; (iv) F, P, -; (v) C, P, -; (vi) F, B, +; (vii) C, B, +; or (viii) F, P +. Of these trends, only two are of interest, namely F, B, - (Case B) and C, B, + (Case A or C), for which there is a 1/8 probability of either occurring at random ($p = 0.125$). To determine if the number of occurrences that a particular Case exceeds the random probability of 0.125 the following two hypotheses are tested :

H_0 : $p<0.125$ and there is no preferred direction; and
H_1 : $p>0.125$ and transport is occurring in a preferred direction.

Using the Z-score in a one-tailed test, H is accepted if:

$$Z=\frac{x-Np}{\sqrt{Npq}} >1.645 \text{(0.05 level of significance)}$$

or >2.33 (0.01 level of significance)

where: x = observed number of pairs representing a particular Case in one of the two opposing directions; N = total number of possible undirectional pairs.

$N = \frac{n^2-n}{2}$ where n = number of samples in sequence
$p = 0.125$; and
$q = 1.0 - p = 0.875$

The Z statistic is considered valid for N>30 (i.e. a large sample). Thus, for this application, a suite of 8 or 9 samples is the minimum required to evaluate adequately a transport direction

$$\text{ie. } \frac{9^2 - 9}{2} = 36 \text{ (the total possible pairs in one direction)}$$

3.0 INTERPRETATION OF THE X-DISTRIBUTION

Empirical examination of X-distributions from a large number of different environments has shown that there are four basic shapes that the distributions can take relative to the distributions of D_1 and D_2 deposits (Fig. A -5). These are as follows:

(1) The shape of the X-distribution resembles the D_1 and D_2 distributions, and the modes of all three distributions are similar (Fig. A -5A). In this situation, the relative probability of grains being transported produces a similar distribution to the actual deposits. This suggests that the environment is in dynamic equilibrium and for every grain in the deposit, there is an equal probability that it will be transported and re-deposited (i.e. there is a grain by grain replacement along the transport path).

(2) The shapes of the three distributions are similar, but the mode of X is finer than the modes of D_1 and D_2 (Fig. A -5B). In this situation, more fine grains are being deposited than are being eroded and transported; thus the environment is undergoing net accretion.

(3) The shapes of the three distributions are similar, but the mode of X is coarser than the modes of D_1 and D_2 (Fig. A -5C). Thus, more grains are being eroded than being deposited and the environment is undergoing net erosion.

(4) Regardless of the shapes of D_1 and D_2, the X-distribution more or less increases monotonically over the complete size range of the deposits (Fig. A -5D). This occurs when sediment, once deposited, undergoes no further transport. The environment, therefore, is undergoing total deposition and further erosion and transport of sediment ceases.

TABLE A-1: Summary of the interpretations with respect to sediment transport trends when one deposit is compared to another

CASE	RELATIVE CHANGE IN GRAIN-SIZE DISTRIBUTION BETWEEN DEPOSIT d_2 AND DEPOSIT d_1	INTERPRETATION
A	coarser better sorted more positively skewed	d_2 is a lag of d_1 (No direction of transport can be determined)
B	finer better sorted more negatively skewed	(i) The direction of transport is from d_1 to d_2 (ii) The energy regime is decreasing in the direction of transport (iii) t_1 and t_2 are low energy transfer functions (Figure A-5)
C	coarser better sorted more positively skewed	(i) The direction of transport is from d_1 to d_2 (ii) the energy regime is decreasing in the direction of transport (iii) t_1 is a high energy transfer function (Figure A-5) (iv) t_2 is a high or low energy transfer function

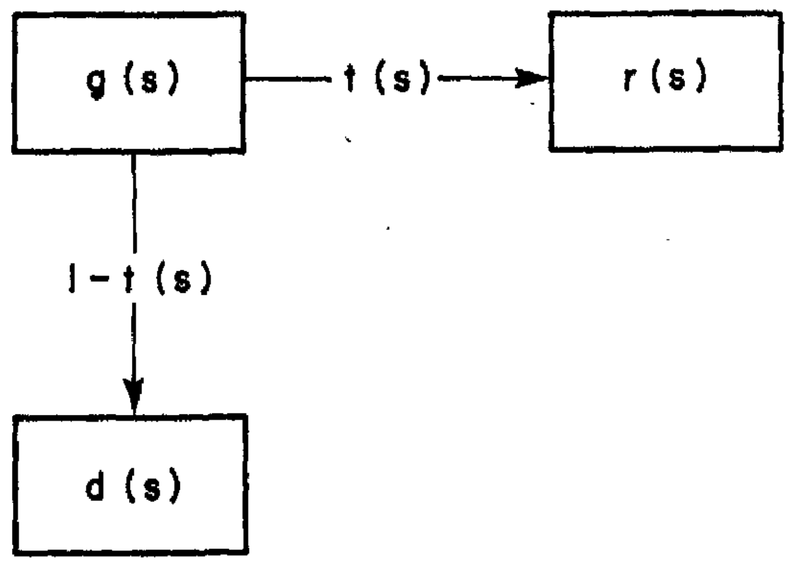


Figure A-1 : Sediment transport model to develop a lag deposit (see Appendix II for definition of terms).

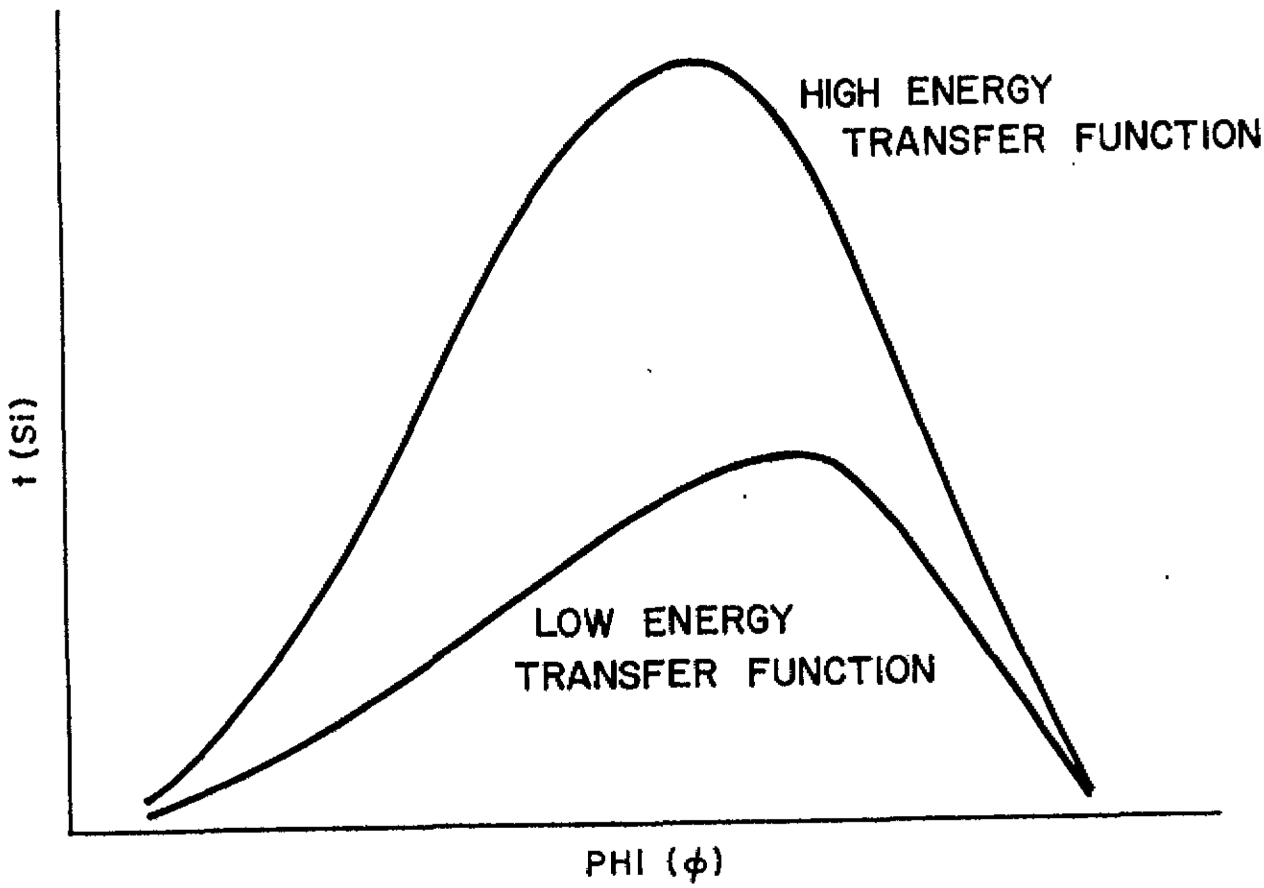


Figure A-2 : Diagram showing the extremes in shape of transfer functions (t(s)).

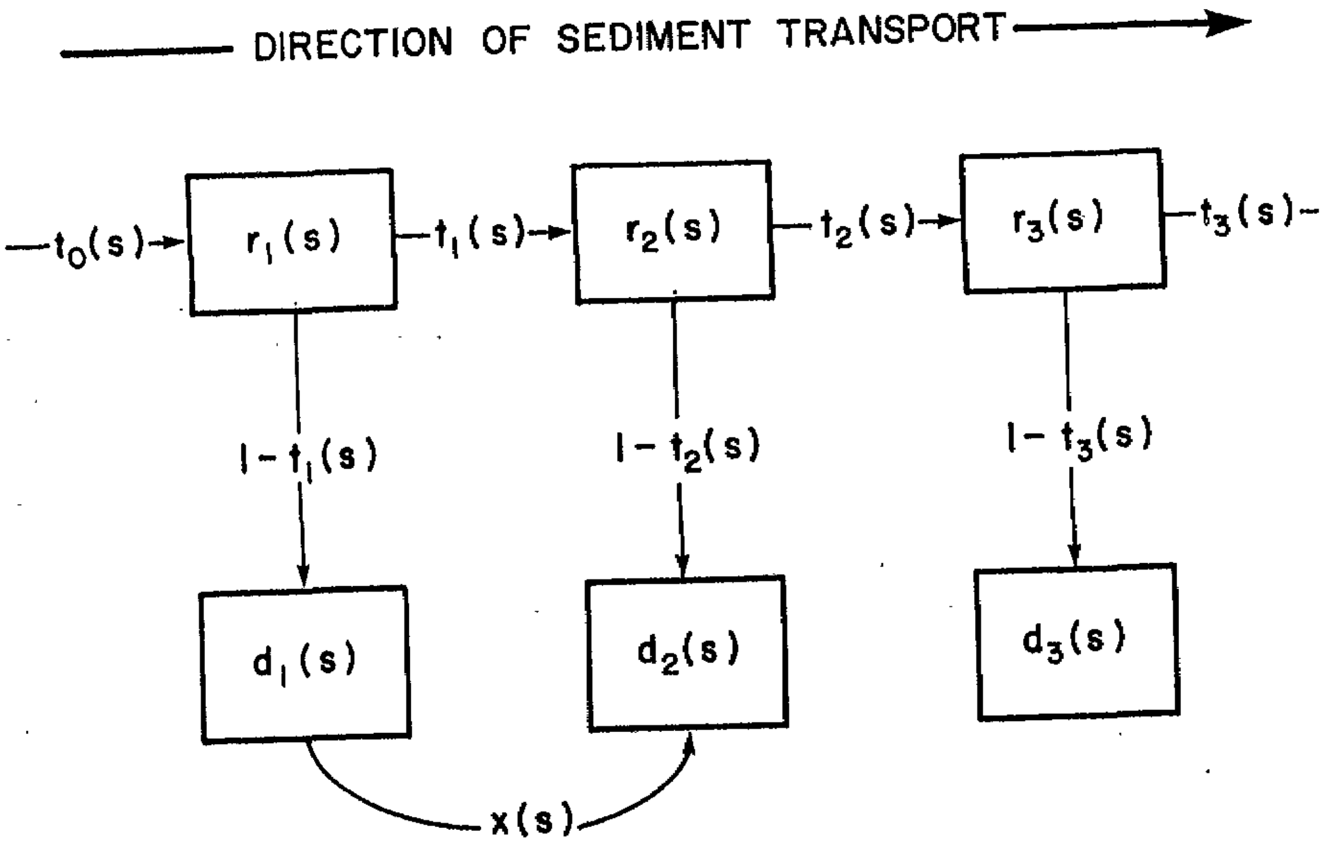
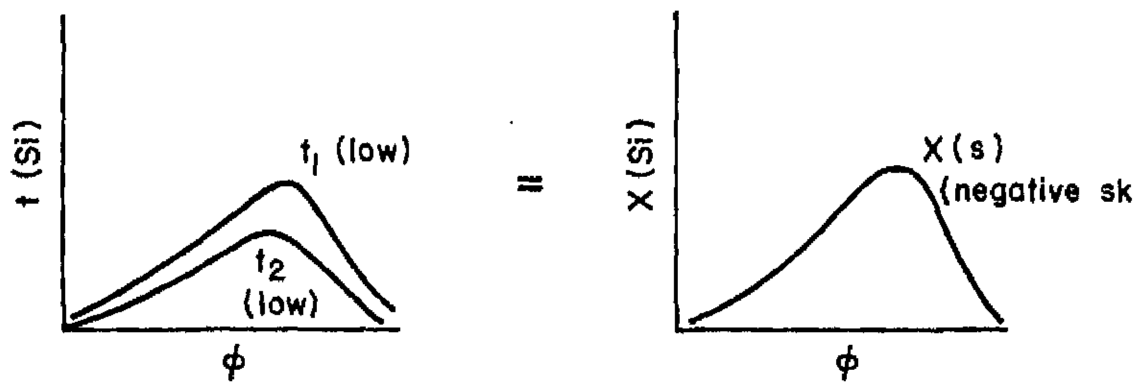


Figure A-3 : Sediment transport model relating deposits in the direction of transport (see Appendix I for definition of terms).

CASE B: $t_2 < t_1$; both low energy functions



CASE C: $t_2 < t_1$; t_1 is a high energy function; t_2 is high or low

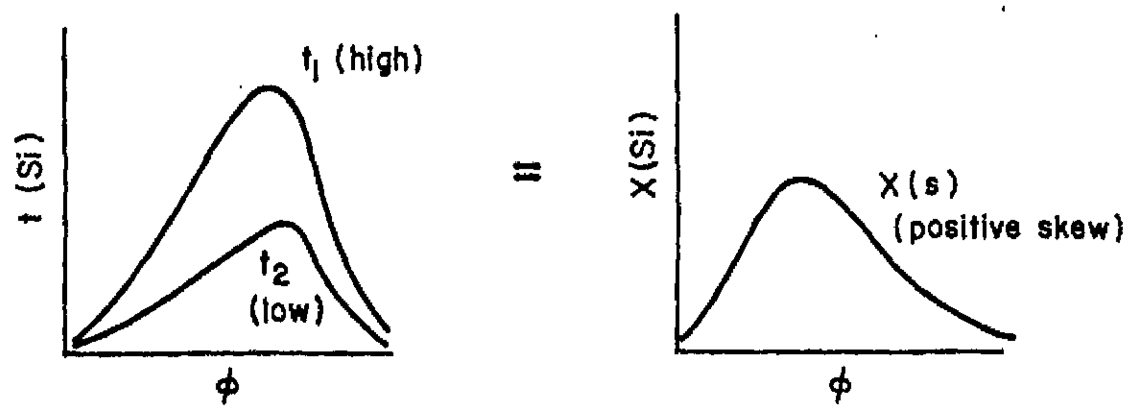


Figure A-4 : Summary diagram of t_1 and t_2 and corresponding X-distributions (equation 3) for Cases B and C (Table A-1).

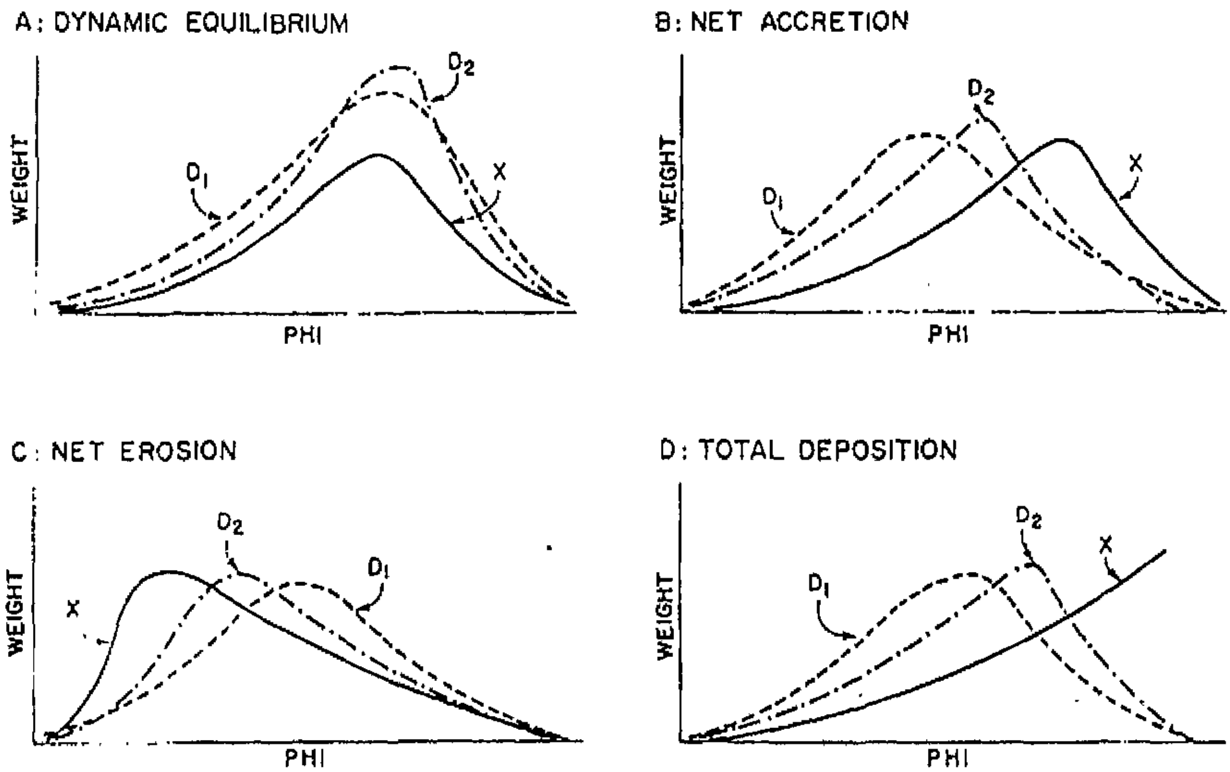


Figure A-5: Summary of the interpretations given to the shapes of X-distributions relative to the D_1 and D_2 deposits.