PN-ACM-332

ANNUAL REPORT

Covering Period: 1.01.2000 - 31.12.2000

Submitted to the Office of Agriculture & Food Security
U.S. Agency for International Development

Protection of land and settlements in arid regions from contamination by atmospheric deposition

Principal Investigator:	Arieh Singer
Co-Investigators:	Yitzhak Mahrer and Amos Banin
Grantee Institution:	The Hebrew University of Jerusalem
Collaborators:	Dr. L. Poberezsky Dr. M. Gilenko
Institution:	Scientific Research Association "Waterproject", Victor Malaysov Str. 3 Tashkent 7000, Uzbekistan

Project Number:	
Grant Number:	TA-MOV-96-CA16-013
Grant Project Officer:	Mr. David Mulenex Science Attache, U.S. Embassy Tel-Aviv, Israel.
Project Duration:	January 1, 1997 - December 31, 2001

A

TABLE OF CONTENTS

	Page
Table of Contents	1
Executive Summary	2
SECTION I	
(A) Research Objectives	4
(B) Research Accomplishments	4
(1) Wind erosion potential of Amu Darya soils	4
Fig. 1 PM 850	5
(2) Friction velocity	7
Figs. 2-3 Wind tunnel	8
Friction velocity of Amu Darya soils	10
Figs. 4-7 Friction velocity data	11
(3) Threshold wind velocity	16
Threshold wind velocity of Amu Darya soils	19
Fig. 8 Threshold wind velocity data	21
(4) Moisture effects on threshold wind velocity	24
Fig. 9 Threshold wind velocity data	25
(5) Estimate of dust emission potential	28
Fig. 10 PM 10 determination equipment	
(C) Scientific Impact of Collaboration	30
(D) Description of Project Impact	30
(E) Strengthening of Developing Country Institution	30
(F) Future work	31
SECTION II	
A) and B)	31
D)	31

EXECUTIVE SUMMARY

The purpose of this research is to provide recommendations for the establishment of measures aimed at containing the process of salt transfer, propagation and deposition in the Amu Darai River delta, southern Aral Sea. A comprehensive approach has been taken so that the recommendations will be based on an analysis of ground data using the GIS system, on devising a mathematical model that would describe, quantify and predict the processes of atmospheric salt transport and on an examination of methods for the reduction of dust generation by soil surface stabilization.

During the fourth project year (2000), the emphasis was on the determination of the deflatability of the soils and on the ameliorating effect of treatments on the deflatability. The principal soil and wind erosion parameters were determined. Friction velocity and threshold wind velocity determinations were carried out in an open circuit wind tunnel of the suction type. Friction velocities were in the range normal for fine sandy soils. The relatively highest threshold wind velocity was determined for the salt crust of soil No. 1. This indicates that salt crusts are relatively more stable towards wind erosion, i.e. that stronger winds are required to deflate these soils. The most important finding in these experiments was that even low moisture contents (below field capacity) dramatically increase threshold wind velocity, implying that by keeping the surface soil moist, wind erosion can almost completely be avoided. Also soil crusts significantly reduce deflatability. An artificially simulated Takyr soil crust very strongly increased threshold wind velocity.

In a different aspect of studies, soil characteristics that could be used for a prediction of their wind erodibility, were examined. The soil size fraction of <850 eq. diameter is considered as a measure of the potential for wind erosion. The conclusion of this determination was that all soils examined have a very high potential for wind erosion. Again, the least endangered are soils with a salt crust. An additional characteristic determined was

PM 10, i.e. the proportion of particles equal to and smaller than 10 μm, generated by a simulation of a dust storm. This determination, carried out by Dr. T.Zobeck from the USDA in Lubbock, Texas, indicated that the Takyr soil, once the crust was fragmented and shattered, had the highest potential for suspended dust generation.

The two principal collaborators of the project from Uzbekistan visited Israel twice in the course of the year 2000 for discussions on the results so far obtained, and on plans for future work.

The plan for the year 2001 (project duration extension of a second year) consists in the examination of additional samples from Uzbekistan (including 2 from the desiccated and exposed Aral Sea bottom) that were brought to Israel in November 2000. The effect of chemical treatments on deflatability will be examined. Recommendations of treatments for the decrease in soil deflatability will be formulated.

SECTION I

SIGNIFICANT SCIENTIFIC RESULTS

A) Research Objectives

(a) To collect the data essential for an assessment of the phenomenon of atmospheric salt transfer and deposition in the Aral Sea area, and analyze the data using the GIS system.

(b) To assess the rate of mineral (aluminosilicates, soluble salts) matter deflation and deposition taking place in the specified area.

(c) To devise a meteorological model that would describe, quantify, and predict the processes of salt transport and deposition. To establish a salt balance for the region.

(d) To examine methods for the reduction of soil deflation and dust generation by soil surface stabilization, using treatments with soil stabilizers.

(e) To Provide recommendations for the establishment of measures aimed at containing the process of salt transfer, propagation and deposition. More specifically: (a) To provide recommendations related to plants for the construction of artificial water bodies/reservoirs, and predict their eventual effects on the process of dust transfer/deposition, using a numerical model; (b) To assess the effect of soil-surface stabilization on regional dust transfer.

B) Research Accomplishments

(1) Wind erosion potential of Amu Darya soils

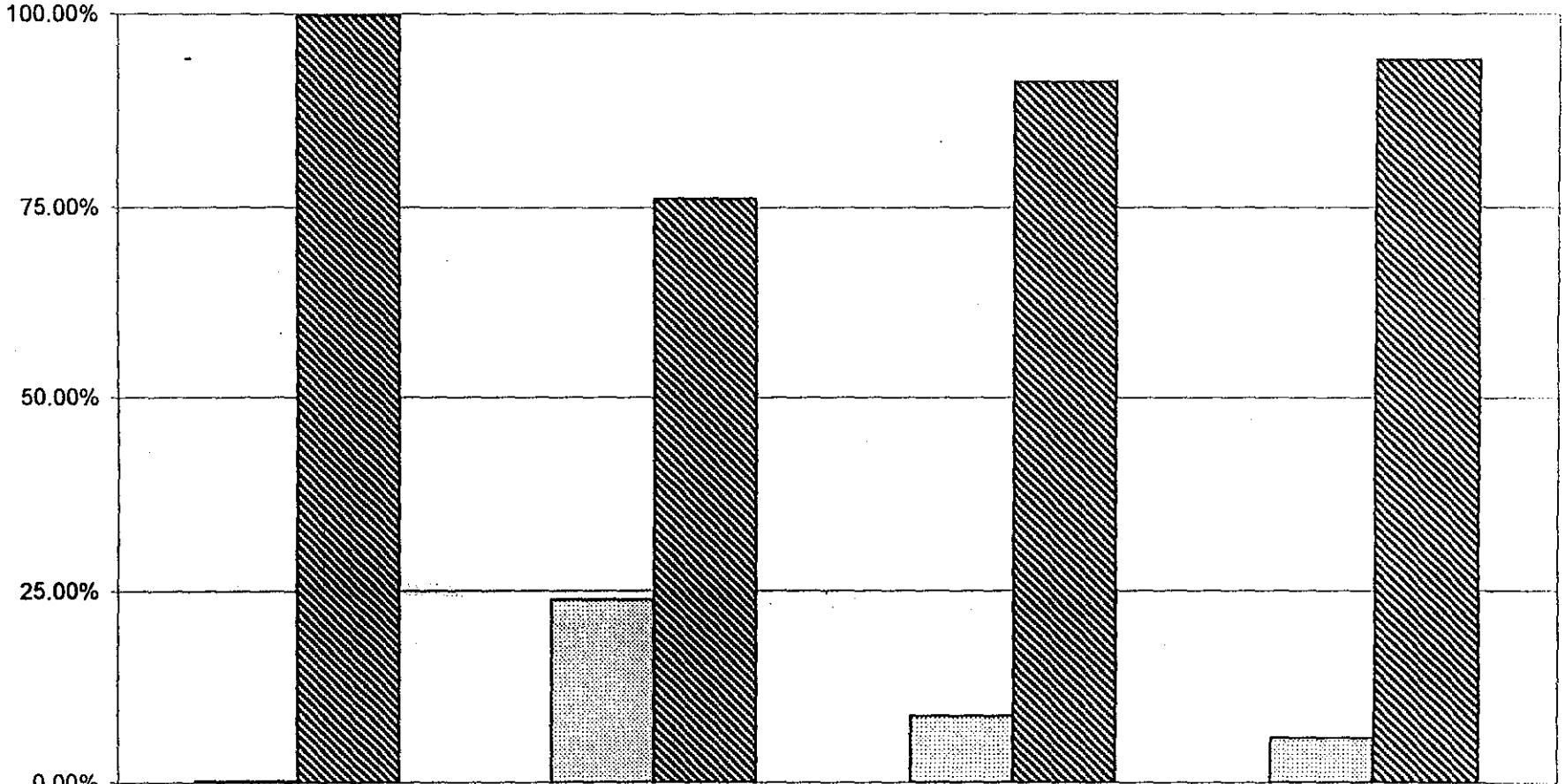
Research Objectives

To provide recommendations for the reduction of soil deflation in the Aral Sea Basin area.

Pm850.xls

Erosive Fraction

Pm 850



	no.1 (1-15)	no.1 (0-1)	no.2 top soil	no.3 top soil
>0.850	0.24%	23.82%	8.70%	5.86%
<0.850	99.76%	76.18%	91.30%	94.14%

soil sample

fig. 1. PM 850 of soils from the Amu Darya Delta

General

As a result of the accelerated desiccation of the Aral Sea, deflation (wind erosion) of some of the soils in the Aral Sea Basin and of the dry Aral Sea bottom, has created an ecological disaster of gigantic proportion. The dust, generated on various land surfaces, is being moved in enormous quantities and deposited in far away areas. Containing a host of noxious compounds, including salts and pesticide/herbicide residues, the dust, where deposited, pollutes the soils and water bodies. Where inhaled by living beings, it causes chronic maladies and even early death. Studies leading to an elimination, or at least reduction in the dust generating process, are therefore of utmost importance.

Estimate of wind erosion potential of the soils

The soil size fraction of <850 μm eq. diameter (PM 850) was considered as a measure of the potential for wind erosion of the soils. Fig. 1 gives the data for the 4 Amu Darya soils, obtained by dry-sieving of uncrushed soils. From this figure, it can be seen that all soils have a very high proportion of particles <850 μm, and thus a very high wind erosion potential. The least endangered is the salt crust in soils 1, that has the relatively highest proportion of >850 μm particles.

Wind erosion parameters

During wind erosion, soil is transported in various modes, and the transport mode for a particular size particle is controlled by windspeed. In the wind erosion process, eroded particles move in creep, saltation, or suspension. Creep particles roll along the ground and have a diameter of 1 to 2 mm. Saltating particles have a diameter of 0.1 to 1.0 mm, and depending on surface roughness, particle size, distribution, and wind speed, move in a series of short hops at heights generally below 1 m. The suspended particles range from <0.001 to 0.1 mm in diameter and are subject to long-range transport.

In the following, friction velocity, threshold wind velocity and the effects of treatments on threshold wind velocity were determined. The treatments were moisture content and crust formation.

Equipment

Friction velocity and threshold wind velocity determinations were carried out in an open circuit wind tunnel of the suction type (Fig.2). The wind tunnel had a working length of 9956 cm, and a height of 1200 cm (Fig. 3).

Friction velocity

Under normal atmospheric conditions on flat, unvegetated surfaces and in the absence of intense solar heating, the turbulent velocity profile plots as a straight line on a semi-logarithmic chart. The gradient of the semi-logarithmic profile is a result of the surface roughness producing a drag on the overlying airflow. If the gradient of the velocity profile is known, the shear stress at the surface can be determined. A common method for describing the gradient of the velocity profile is in terms of the friction velocity (u_*). The friction velocity is proportional to the velocity profile gradient and can be calculated from two velocities at known heights. Very close to the surface, the wind velocity is zero. The height of this zero-velocity region is termed the aerodynamic roughness length (z_0) and it is an important parameter for it is a function of the surface roughness and it partly controls the gradient of the velocity profile, and hence u_*. If friction velocities (u_*) increase, sediment transport would be likely to rise too.

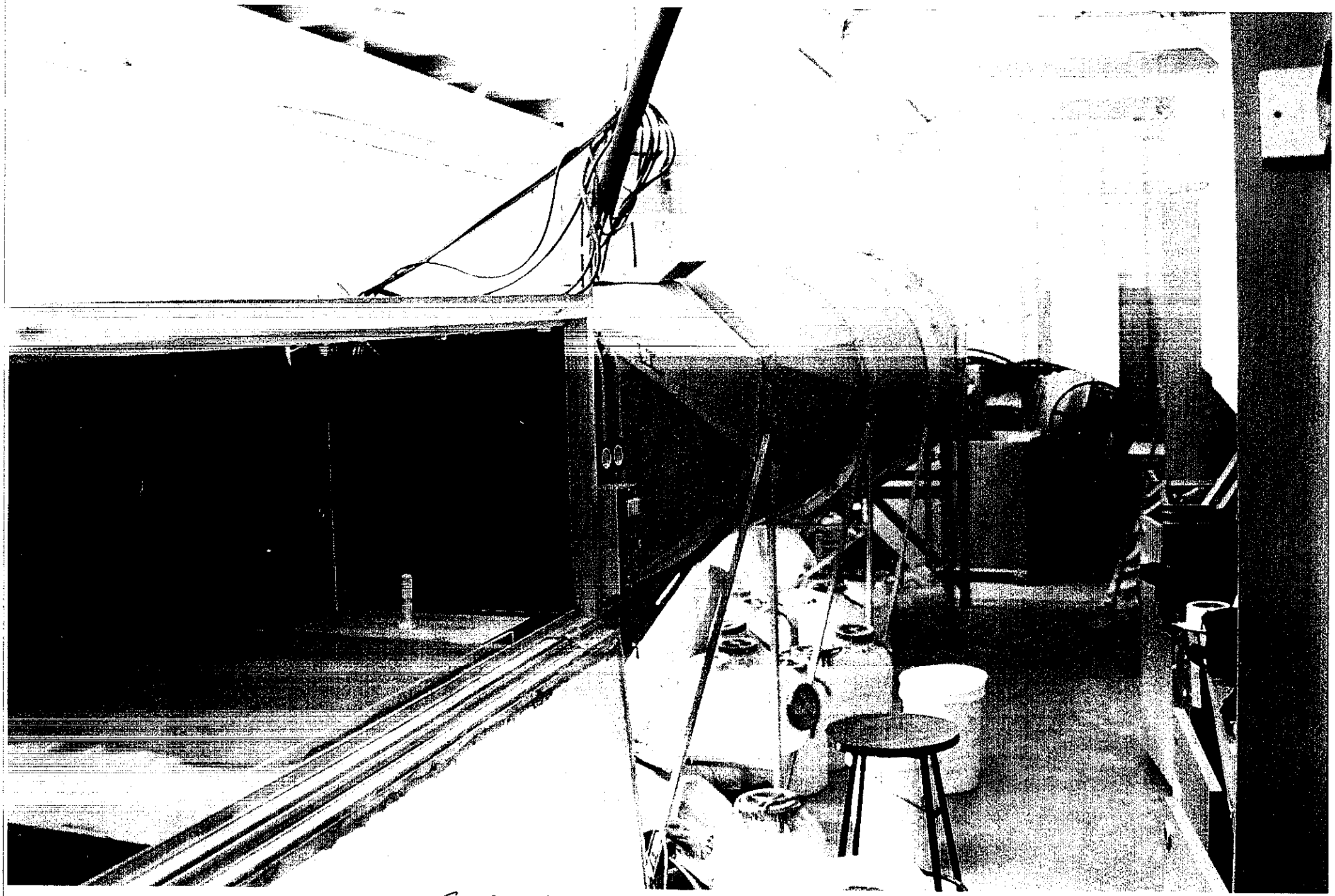


Fig. 2 Wind tunnel of the suction type

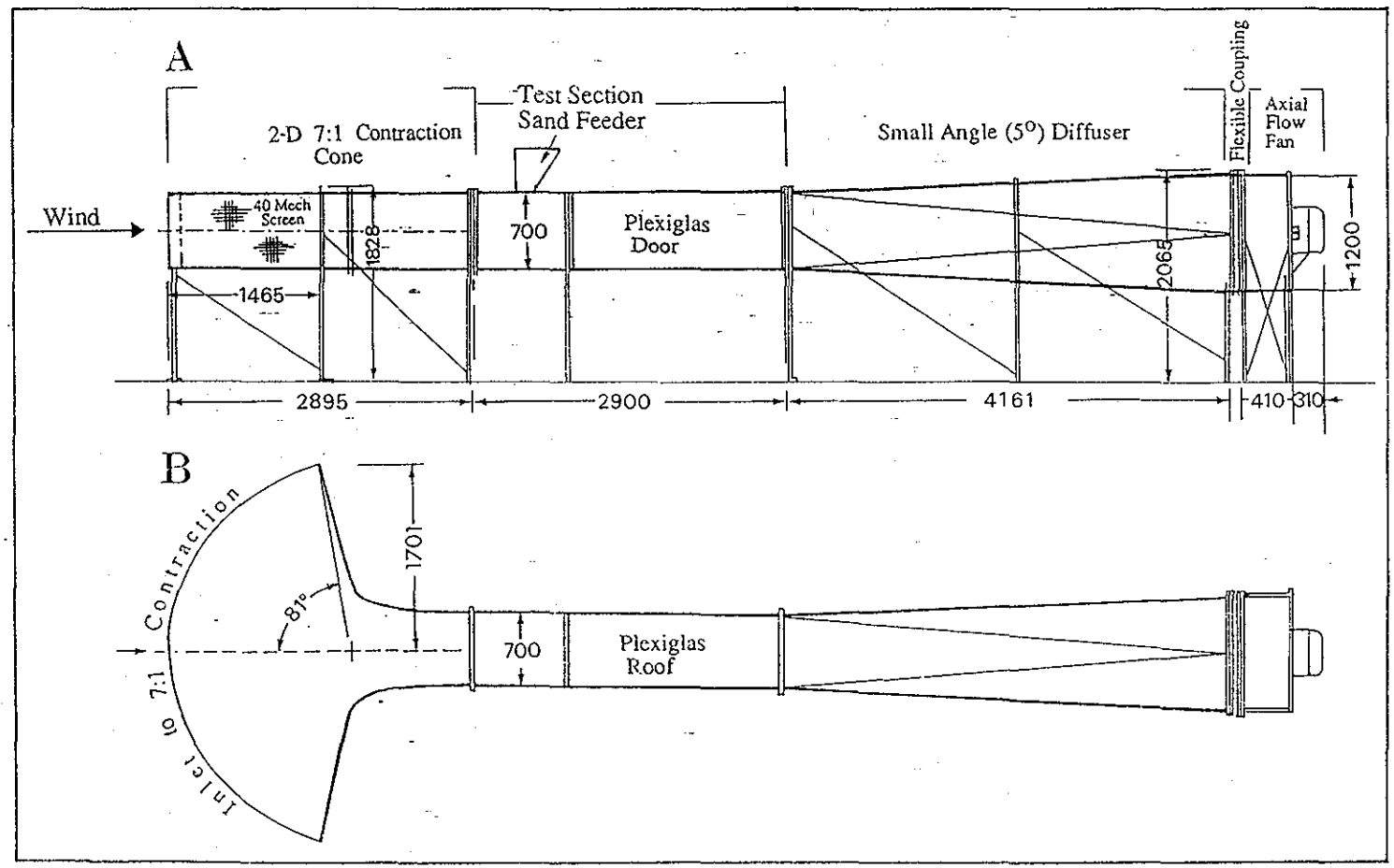


Figure 3 Schematic diagram of an open-circuit wind tunnel used at Ben-Gurion University of the Negev (designed by Prof. M. Cohen). Dimensions are in mm. A, side view; B, plan view.

The relationship between aerodynamic roughness (z_0), friction velocity (u_*) and wind velocity (u) at a height (z) are described by the Karman-Prandtl velocity distribution.

$$\frac{u}{u_*} = \frac{1}{\kappa} \ln \frac{(z-d)}{z_0}$$

where: κ = von Karman's constant ($\approx$0.4) and d=zero-plane displacement. Friction velocity (u_*) is commonly determined from regression analysis of time-averaged velocity measurements at several known heights.

Friction velocity summary of Amu Darya delta soils

The friction velocities results were obtained at the Ben-Gurion University wind tunnel (suction type). Soil moisture was measured for each soil sample on air-dry samples.

The friction velocity was determined by the Karman-Prandtl equation:

$$\boxed{u(z) = {u_*}/{k} \; ln \; {z}/{z_0}}$$

The wind velocities above soil surface were measured at 5-10 mm intervals, in order to receive a proper curve. For each wind velocity, three repetitions were made at each height above soil surface, for a minimum of 8 data points.

The conditions under which all the experiments were carried out were as follows:

- The soil surface was leveled by hand with a plastic roller, so that roughness varied only slightly, depending only on the size of the soil aggregates.
- The soil was uniformly mixed and free from visible organic residues.
- The soils, that had been passed through a 2.5 mm sieve, were air dried at the same conditions (humidity, temperature) and had the following moisture contents:

Fig. 4 Friction velocity data

11

soil no.1 (0-1) top soil																
	V1					V2					V3					
	1130700					2130700					3130700					
h	p1	p2	p3	P	U	p1	p2	p3	P	U	p1	p2	p3	P	U
0.012	0.38	0.40	0.40	0.393	2.536	0.43	0.45	0.42	0.433	2.661	0.61	0.62	0.60	0.610	3.158
0.017	0.42	0.43	0.45	0.433	2.661	0.52	0.52	0.50	0.513	2.897	0.65	0.68	0.68	0.670	3.308
0.022	0.56	0.53	0.53	0.540	2.971	0.58	0.59	0.60	0.590	3.105	0.75	0.77	0.77	0.763	3.532
0.027	0.55	0.57	0.58	0.587	3.043	0.61	0.63	0.65	0.630	3.209	0.82	0.83	0.81	0.820	3.661
0.032	0.59	0.60	0.61	0.600	3.132	0.70	0.67	0.68	0.683	3.342	0.85	0.86	0.88	0.863	3.757
0.037	0.60	0.61	0.62	0.610	3.158	0.77	0.73	0.75	0.750	3.501	0.90	0.90	0.92	0.907	3.850
0.042	0.66	0.65	0.62	0.643	3.243	0.75	0.78	0.78	0.770	3.548	0.95	0.97	0.97	0.963	3.968
0.047	0.67	0.65	0.65	0.657	3.276	0.80	0.78	0.80	0.793	3.601	0.98	0.98	1.00	0.987	4.016
0.052	0.68	0.72	0.68	0.693	3.366	0.81	0.80	0.80	0.803	3.624	0.98	1.00	1.00	0.993	4.030
0.057	0.73	0.75	0.70	0.727	3.446	0.80	0.82	0.81	0.810	3.639	1.00	1.02	1.02	1.013	4.070
0.062	0.76	0.73	0.70	0.730	3.454	0.85	0.84	0.86	0.850	3.727	1.03	1.06	1.05	1.047	4.136
0.067	0.75	0.77	0.78	0.767	3.540	0.87	0.90	0.88	0.883	3.800	1.05	1.05	1.07	1.057	4.156
0.072	0.77	0.78	0.77	0.773	3.555	0.88	0.88	0.90	0.887	3.807	1.08	1.06	1.10	1.080	4.202
0.077	0.79	0.77	0.77	0.777	3.563	0.90	0.92	0.90	0.907	3.850	1.10	1.07	1.09	1.087	4.215
0.082	0.79	0.78	0.77	0.780	3.571	0.90	0.90	0.92	0.907	3.850	1.10	1.10	1.09	1.097	4.234

exp	u 10	u 15	u 20	u 25	u 30	u 35	u 40	u 45	u 50	u 55	u 60	u 65	u 70	u 75	u 80	U*	z (mm)	k/U*	U*/u80
1130700	2.536	2.661	2.971	3.043	3.132	3.158	3.243	3.276	3.366	3.446	3.454	3.540	3.555	3.563	3.571	0.225	1.313	1.776	0.063
2130700	2.661	2.897	3.105	3.209	3.342	3.501	3.548	3.601	3.624	3.639	3.727	3.800	3.807	3.850	3.850	0.252	1.661	1.585	0.066
3130700	3.158	3.308	3.532	3.661	3.757	3.850	3.968	4.016	4.030	4.070	4.136	4.156	4.202	4.215	4.234	0.234	0.541	1.707	0.055
															avarage:		1.172		

soil no.1 U1-U3

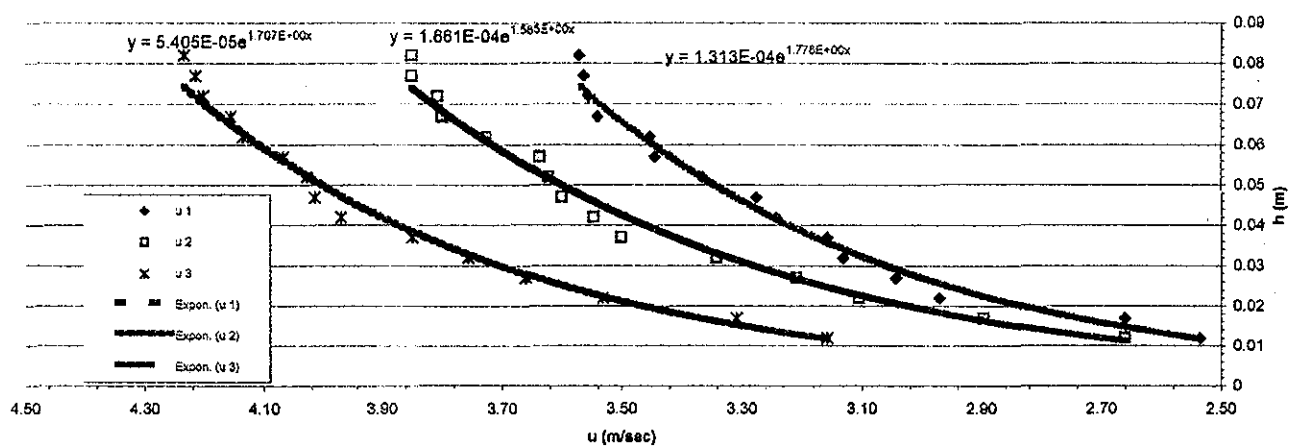


Fig. 5 Friction velocity data

12

soil no.1 (1-15)															
V1						V2					V3				
4030700						5030700					6030700				
h (m)	p1	p2	p3	P	U	p1	p2	p3	P	U	p1	p2	p3	P	U
0.012	0.38	0.37	0.35	0.367	2.448	0.39	0.40	0.39	0.393	2.536	0.56	0.55	0.57	0.560	3.026
0.022	0.40	0.42	0.41	0.410	2.589	0.42	0.44	0.45	0.437	2.672	0.60	0.61	0.61	0.607	3.149
0.032	0.42	0.41	0.42	0.417	2.610	0.50	0.53	0.52	0.517	2.906	0.62	0.64	0.66	0.640	3.234
0.042	0.43	0.45	0.45	0.443	2.692	0.54	0.55	0.58	0.557	3.016	0.75	0.78	0.79	0.773	3.555
0.052	0.50	0.52	0.51	0.510	2.887	0.61	0.60	0.60	0.603	3.140	0.79	0.80	0.81	0.800	3.616
0.062	0.55	0.53	0.55	0.543	2.980	0.60	0.61	0.61	0.607	3.149	0.80	0.81	0.81	0.807	3.631
0.072	0.58	0.57	0.58	0.577	3.070	0.63	0.62	0.62	0.623	3.192	0.82	0.83	0.85	0.833	3.691
0.082	0.61	0.60	0.60	0.603	3.140	0.64	0.65	0.65	0.647	3.251	0.93	0.92	0.92	0.923	3.885

		exp	u 12	u 22	u 32	u 42	u 52	u 62	u 72	u 81	U*	z (mm)	k/U*	U*/u82
half tray-b.g.u		4030700	2.448	2.589	2.610	2.692	2.887	2.980	3.070	3.14	0.163	0.415	2.453	0.052
		5030700	2.536	2.672	2.906	3.016	3.140	3.149	3.192	3.25	0.161	0.243	2.485	0.050
		6030700	3.026	3.149	3.234	3.555	3.616	3.631	3.691	3.88	0.191	0.282	2.091	0.049
										avarage:		0.313		

soil no.1 (1-15)

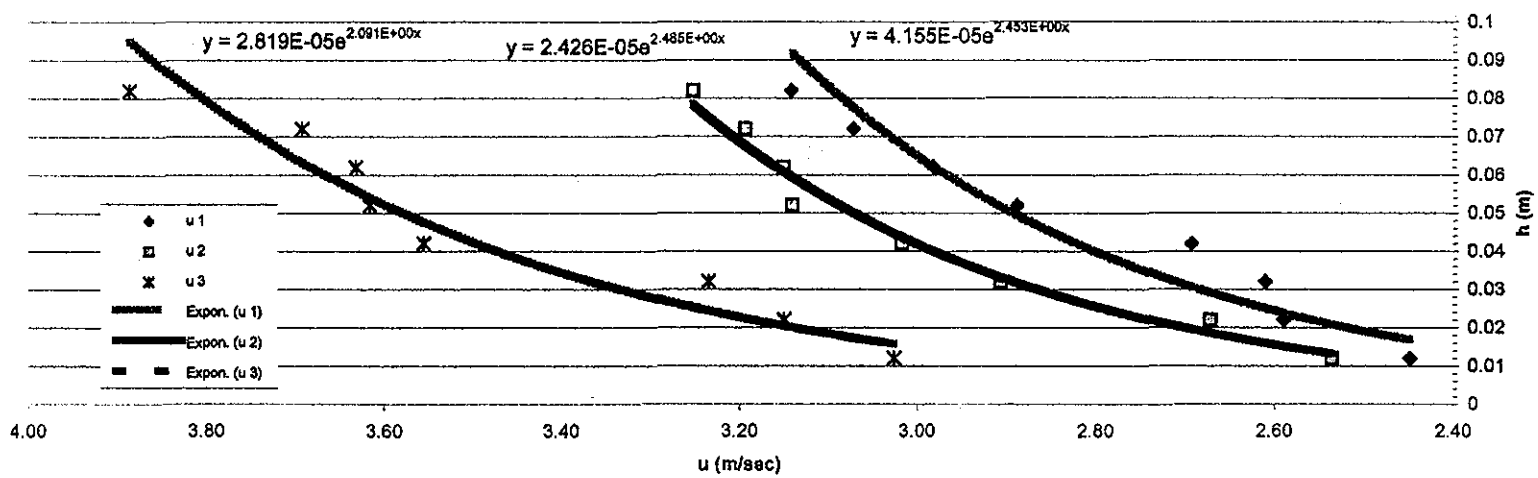


Fig. 6 Friction velocity data

13

soil no.3 takyr (0-15)															
V3						V4					V5				
1030700						2030700					3030700				
h (m)	p1	p2	p3	P	U	p1	p2	p3	P	U	p1	p2	p3	P	U
0.01	0.42	0.45	0.45	0.440	2.68	0.43	0.45	0.46	0.447	2.70	0.42	0.40	0.40	0.407	2.58
0.02	0.58	0.59	0.59	0.587	3.10	0.58	0.58	0.59	0.583	3.09	0.48	0.50	0.52	0.500	2.86
0.03	0.62	0.63	0.65	0.633	3.22	0.60	0.61	0.60	0.603	3.14	0.58	0.58	0.59	0.583	3.09
0.04	0.70	0.73	0.75	0.727	3.45	0.70	0.65	0.68	0.677	3.33	0.61	0.60	0.60	0.603	3.14
0.05	0.79	0.79	0.80	0.793	3.60	0.70	0.73	0.70	0.710	3.41	0.63	0.65	0.63	0.637	3.23
0.06	0.80	0.81	0.80	0.803	3.62	0.78	0.79	0.78	0.783	3.58	0.68	0.70	0.70	0.693	3.37
0.07	0.81	0.80	0.81	0.807	3.63	0.79	0.79	0.80	0.793	3.60	0.70	0.70	0.70	0.700	3.38
0.08	0.81	0.83	0.81	0.817	3.65	0.83	0.82	0.82	0.823	3.67	0.75	0.73	0.73	0.737	3.47

	exp	u 10	u 20	u 30	u 40	u 50	u 60	u 70	u 80	U*	z (mm)	k/U*	U*/u80
half tray-b.g.u	1030700	2.682	3.097	3.218	3.446	3.601	3.624	3.631	3.654	0.200	0.452	1.996	0.055
	2030700	2.702	3.088	3.140	3.326	3.407	3.578	3.601	3.669	0.187	0.313	2.141	0.051
	3030700	2.578	2.859	3.088	3.140	3.226	3.366	3.383	3.470	0.171	0.238	2.346	0.049
										avarage:	0.334		

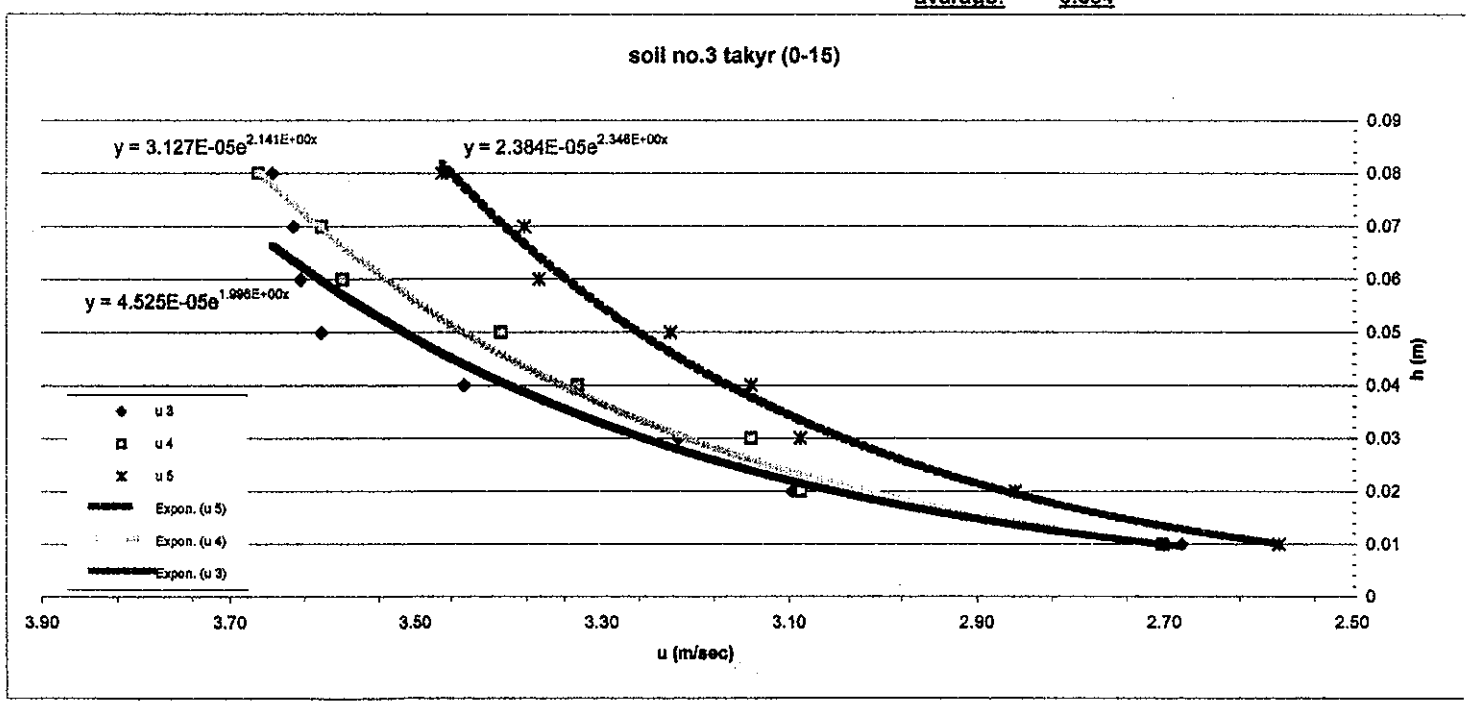
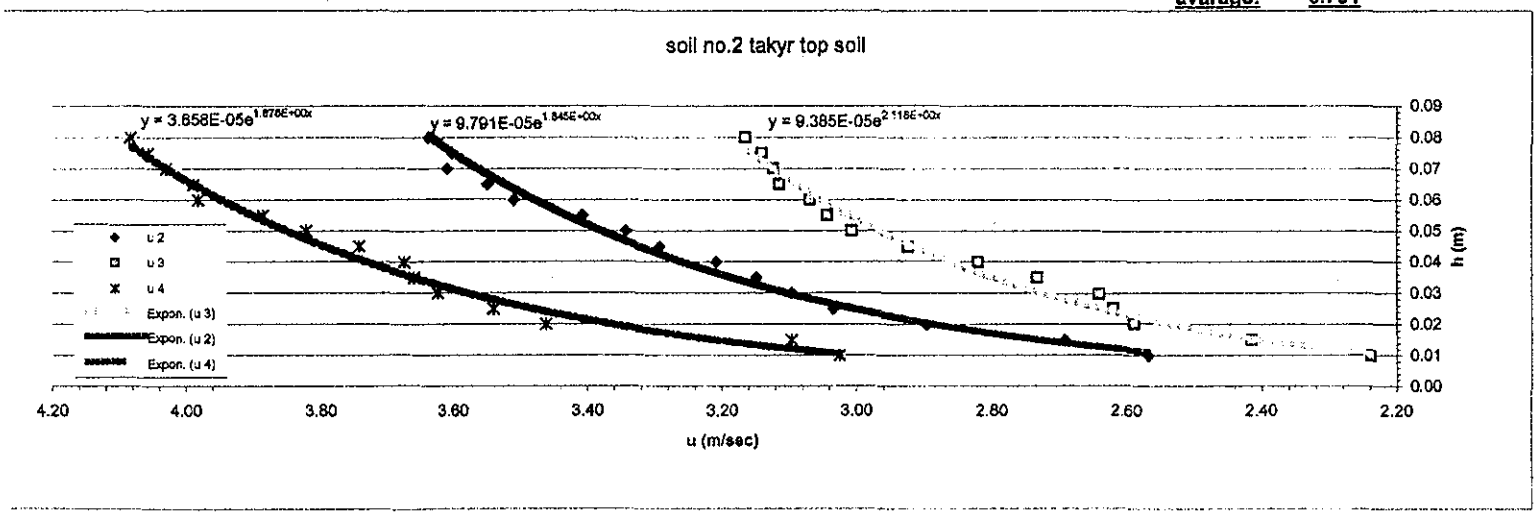


Fig. 7 friction velocity data

14

soil no.2 takyr top soil																
	V2						V3					V4				
	2060700						3060700					4060700				
h (m)	p1	p2	p3	P	U	p1	p2	p3	P	U	p1	p2	p3	P	U
0.010	0.40	0.40	0.41	0.403	2.568	0.30	0.32	0.30	0.307	2.239	0.58	0.55	0.55	0.560	3.026
0.015	0.43	0.45	0.45	0.443	2.692	0.35	0.35	0.37	0.357	2.415	0.60	0.58	0.58	0.587	3.097
0.020	0.53	0.48	0.53	0.513	2.897	0.41	0.41	0.41	0.410	2.589	0.73	0.74	0.73	0.733	3.462
0.025	0.55	0.56	0.58	0.563	3.034	0.42	0.42	0.42	0.420	2.620	0.77	0.76	0.77	0.767	3.540
0.030	0.57	0.60	0.59	0.587	3.097	0.42	0.43	0.43	0.427	2.641	0.80	0.81	0.80	0.803	3.624
0.035	0.60	0.61	0.61	0.607	3.149	0.45	0.45	0.47	0.457	2.732	0.81	0.83	0.82	0.820	3.661
0.040	0.62	0.63	0.64	0.630	3.209	0.48	0.50	0.48	0.487	2.820	0.82	0.83	0.83	0.827	3.676
0.045	0.66	0.68	0.65	0.663	3.293	0.50	0.52	0.55	0.523	2.925	0.86	0.85	0.86	0.857	3.742
0.050	0.68	0.67	0.70	0.683	3.342	0.54	0.55	0.57	0.553	3.007	0.90	0.90	0.88	0.893	3.821
0.055	0.71	0.70	0.72	0.710	3.407	0.57	0.56	0.57	0.567	3.043	0.92	0.92	0.93	0.923	3.885
0.060	0.73	0.77	0.76	0.753	3.509	0.58	0.57	0.58	0.577	3.070	0.98	0.96	0.97	0.970	3.982
0.065	0.75	0.77	0.79	0.770	3.548	0.59	0.59	0.60	0.593	3.114	0.96	0.98	0.98	0.973	3.989
0.070	0.80	0.79	0.80	0.797	3.609	0.60	0.59	0.60	0.597	3.123	0.98	1.00	1.00	0.993	4.030
0.075	0.79	0.79	0.80	0.793	3.601	0.60	0.60	0.61	0.603	3.140	1.00	1.02	1.00	1.007	4.056
0.080	0.81	0.81	0.81	0.810	3.639	0.61	0.61	0.62	0.613	3.166	1.03	1.01	1.02	1.020	4.083

exp	u 10	u 15	u 20	u 25	u 30	u 35	u 40	u 45	u 50	u 55	u 60	u 65	u 70	u 75	u 80	U*	z (mm)	k/U*	U*/u80
2060700	2.568	2.692	2.897	3.034	3.097	3.149	3.209	3.293	3.342	3.407	3.509	3.548	3.609	3.601	3.639	0.217	0.979	1.845	0.060
3060700	2.239	2.415	2.589	2.620	2.641	2.732	2.820	2.925	3.007	3.043	3.070	3.114	3.123	3.140	3.166	0.189	0.939	2.118	0.060
4060700	3.026	3.097	3.462	3.540	3.624	3.661	3.676	3.742	3.821	3.885	3.982	3.989	4.030	4.056	4.083	0.213	0.366	1.876	0.052
															avarage:		0.761		



- The soil samples were placed on a plastic tray having the following dimensions: 1200Lx650Wx10H (cm). The tray was positioned inside the test section of the wind tunnel.
- The wind tunnel test section is: 1900Lx700Wx700H (cm), with a Plexiglas roof and door.
- The relative air humidity during the tests was constant (Beer-Sheva in summer).
- The air flow within the tunnel was free from suspended particles, by working with a barred lab and air-conditioned system working during the tests.
- Pitot tubes measuring the wind velocity, were connected to a manometer (mm H_2O), and data logger.
- For each height above soil surface, the time for collecting data was at least three minutes, the first minute to stabilize wind velocity and the others to collect the data. The data were collected after the data logger, that was attached to the system, was showing a linear/parallel line on the computer screen (Figs. 4-7).

Three wind velocities were measured for each soil sample, below the saltation layer (at the range of 0-4.5 m/sec). The results for every soil sample are as follows:

With soil no.1 (crust) and soil no.2 it was clear that Z_0 was different at wind velocities greater than 4 m/sec. During the experiment, a creep motion of the soil surface was observed. This motion was not observed at smaller wind velocities or with the other soil samples at the wind velocities range that was measured.

The uncertainty of height measurement is +\- 1 mm.

Friction velocities (u*) and roughness height (z) of some Amu Darya soils.

Soil type	Friction velocity (m/sec) U*	Roughness height (mm) z
1 (crust)	0.225	1.313
	0.252	1.661
	0.234	0.541
1 (1-15)	0.163	0.415
	0.161	0.243
	0.191	0.282
2 (crust)	0.217	0.979
	0.189	0.939
	0.213	0.366
3	0.200	0.452
	0.187	0.313
	0.171	0.238

Threshold wind velocity

Sediment is entrained into the airflow when forces acting to move a stationary particle overcome the forces resisting sediment movement. Particles are subjected to three forces of movement: lift, surface drag and form drag. Lift is a result of the air flowing directly over the particle forming a region of low pressure. Surface drag is the shear stress on the particle provided by the velocity profile, and the form drag is also related to pressure differences around the particle. When these forces overcome the forces of particle cohesion, packing and weight, the particle tends to shake in place and then lift-off spinning into the airstream.

Aerodynamic entrainment is primarily a function of the mean grain size of the particles involved and the shear velocity of the wind. Bagnold (1941) studied these relationships and derived values of critical threshold friction velocity (u_{*ct}) for a wide range of particle sizes, with the principal determinant as the square root of grain diameter:

$$u_{*ct} = A\sqrt{\left[\frac{(\sigma-\rho)}{\rho}\right]gd}$$

where σ=particle density, g=acceleration due to gravity, d=grain diameter and A=constant dependent upon the grain Reynolds number ($\approx$0.1).

In general, larger particles have a higher threshold of entrainment. However, smaller particles (with diameters less than about 0.06 mm) also require higher shear velocities to entrain them. This is because particles in this size range and smaller tend to have additional molecular and electrostatic forces of cohesion. The most susceptible grain size for entrainment is seen to be between about 0.04 and 0.40 mm, i.e. sand-sized particles. The critical thresholds of motion on natural sediment beds are influenced by variations in factors such as sediment mixtures, surface crusting, surface slope, moisture and vegetation.

Moisture content

Although the potential influence of moisture content on the threshold of friction velocity has long been recognized, the exact physical nature of the relationship is still unknown. The theoretical basis for the available models are that the critical shear velocity increases as a function of the increased surface tension associated with pore moisture.

The Sensit

For the determination of the threshold wind velocity, a SENSIT instrument was used.

The Sensit Wind Eroding Mass Sensor gives researchers the ability to examine high-resolution erosion activity. The Sensit responds linearly to the impacting kinetic energy of wind blown particles. The Sensit output is representative of electrical charges produced by the deformation of the piezoelectric sensor. This charge is proportional to the energy of impacting particles.

The relationship of total charge (q), voltage (V) and capacitance (C) is expressed as q=CV. The voltage developed across the integrating capacitor represents the charge in the capacitor as V=q/C. The voltage waveform of the charging integrator capacitor resembles an

irregular stair step where each step represents a contribution of charge produced by the kinetic energy of individual impacting particles. When the voltage across the integrating capacitors exceeds an internal voltage reference, the capacitors are discharged allowing the process to repeat. The fast discharge pulse is stretched to become the kinetic energy output pulse representing a data value of one fixed unit of accumulated kinetic energy. A field calibration constant is obtained when the sum of output pulses from the sensor is referenced to the total collected mass from a sand catcher for an erosion event.

A minimum detectable particle diameter is difficult to estimate because of combined effects of mass, velocity and coefficient of drag. The sensor response drops off at roughly a 5th order function to particle diameter. This sharp cut-off function defeats response at approximately 50 to 75 microns for low velocity particles. The sensor does respond to high velocity particles from 10 to 50 micron in diameter. Particle diameters less than 10 microns tend to flow around the sensor due to the coefficients of drag.

The instrument has two data outputs. Kinetic energy and number of particle impacts. For reasons yet to be fully understood, the **kinetic energy** output has better than 0.997 r2 correlation to impacting mass and is used to measure saltating mass. The **particle impacts** output responds to individual impacting particles. All outputs are CMOS-TTL compatible (Q) pulses of 0› 5 volts having a pulse width of greater than 650 uS producing a maximum data rate of 1538 pulses per second. Data acquisition is accomplished by a data logger counting the number pulses of both outputs for a user selected sampling period.

The kinetic energy output is the primary output. Each time the capacitor is discharged, an output pulse is produced. One pulse represents a fixed amount of accumulated energy. When the mass collected by a catcher is divided by the total number of KE output pulses for an erosion event, a rudimentary mass calibration constant is obtained. Multiplying the KE count for each sampling period by this constant reconstructs an informative

high-resolution picture of the mass movement.

The kinetic energy signal is a continual background count for whatever data system sampling period is used. The background is the combination of a weak artificial current intentionally introduced into the integrator and natural electronic noise from the crystal sensor. All integrator current sources including electronic noise generated within electrical components contribute to the integration. This technique insure positive integration at all times and no threshold associated with the energy measurement.

The minimum detectable energy level is a function of the stability of background count. Detectivity and increased resolution is obtained by increasing the sampling time.

The second output is the number of particle impacts. Plotting this data as a function of shear stress (often synonymous with Friction Velocity (U^*) shows the threshold level of friction velocity where movement begins. Determining threshold is a valuable application of the Sensit since threshold changes as conditions change throughout an erosion event. Threshold depicts the minimum wind energy required to cause moment. Internally, this output does have an electrical trigger level. One pulse is produced for every particle impact of sufficient energy to trigger the particle count output circuitry.

Threshold wind velocity summary of Amu-Darya river delta soils

Working method:

The wind velocity at the wind tunnel was determined by a resistor, and was measured at the center of the wind tunnel, out of the boundary layer, in order to obtain real velocity values without influence of the tunnel boundaries. The pitot tubes were calibrated by a differential pressure manometer (mmH_2O) in the range of 0-10 m/sec.

The values of the initial velocity were determined by pre-experiments that were carried out on local soils (Gilat, Nirim, Rehovot) with a soil texture similar to that of the Amu-Darya soils (with the exception of Rehovot soil). These soils gave us the ranges for the expected threshold wind velocities.

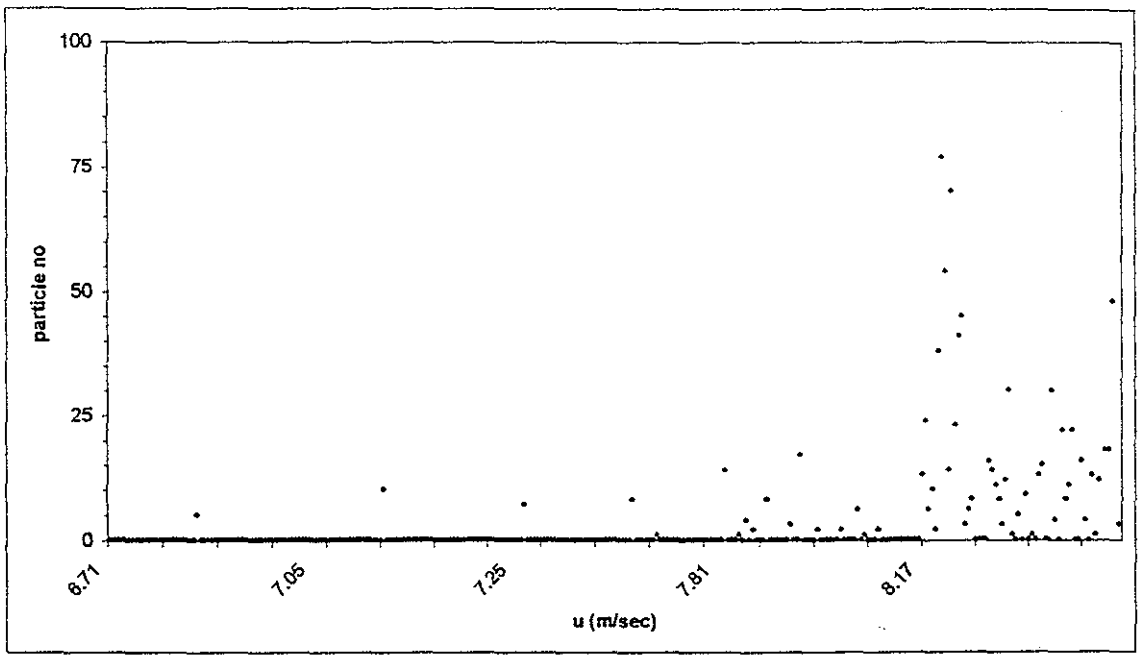
With the help of the computerized system it was possible to determine the velocity at which particle movement started.

The frequency of the measurement was 16 Hz (16 readings per second). The wind velocity and the particles impact are averages of 960 data points that were measured during the experiments (60 sec for each wind velocity level). That, in order to reduce the variance between the repetitions and to increase the resolution of the data points. The 16 Hz frequencies were determined by early experiments that were carried out. Since the experiments were controlled at lab conditions, we were able to measure with a high resolution compared to experiments carried out in the field.

The soil sample was placed 18 cm ahead of the "SENSIT" system. At any other distances, we noticed disturbances that the system caused, expressed by the large variance between the repetitions at the same wind velocity (Figs. 8a, b, c, d).

The results of the experiments for Amu-Darya river delta soil samples

Soil no.1 (crust):



Soil no.1 (1-15):

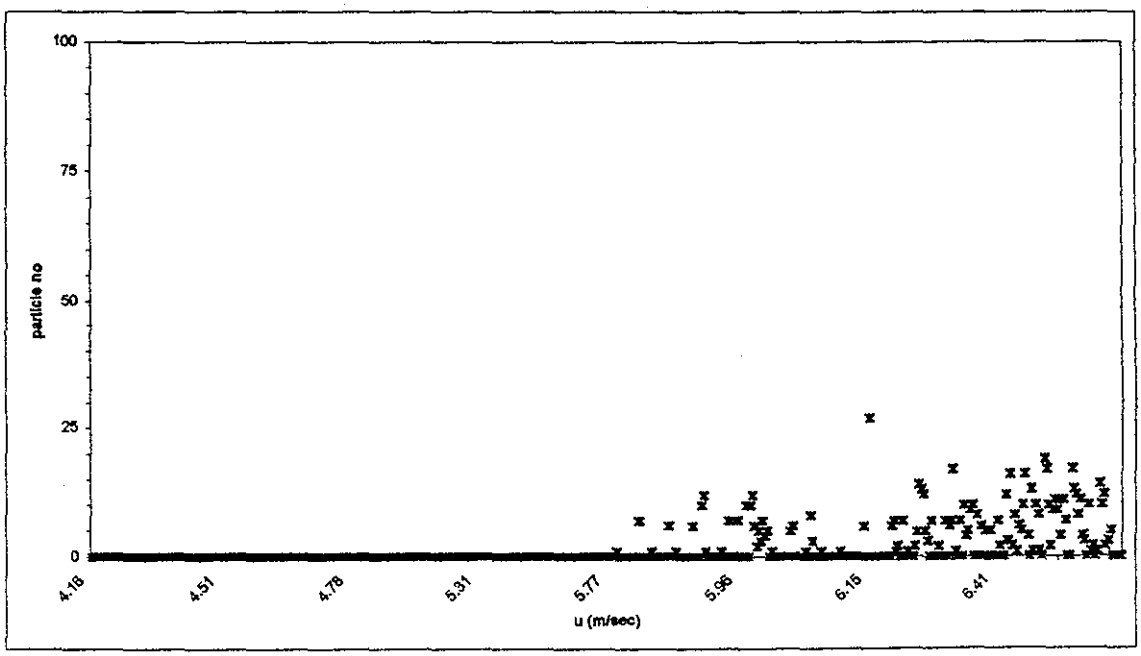
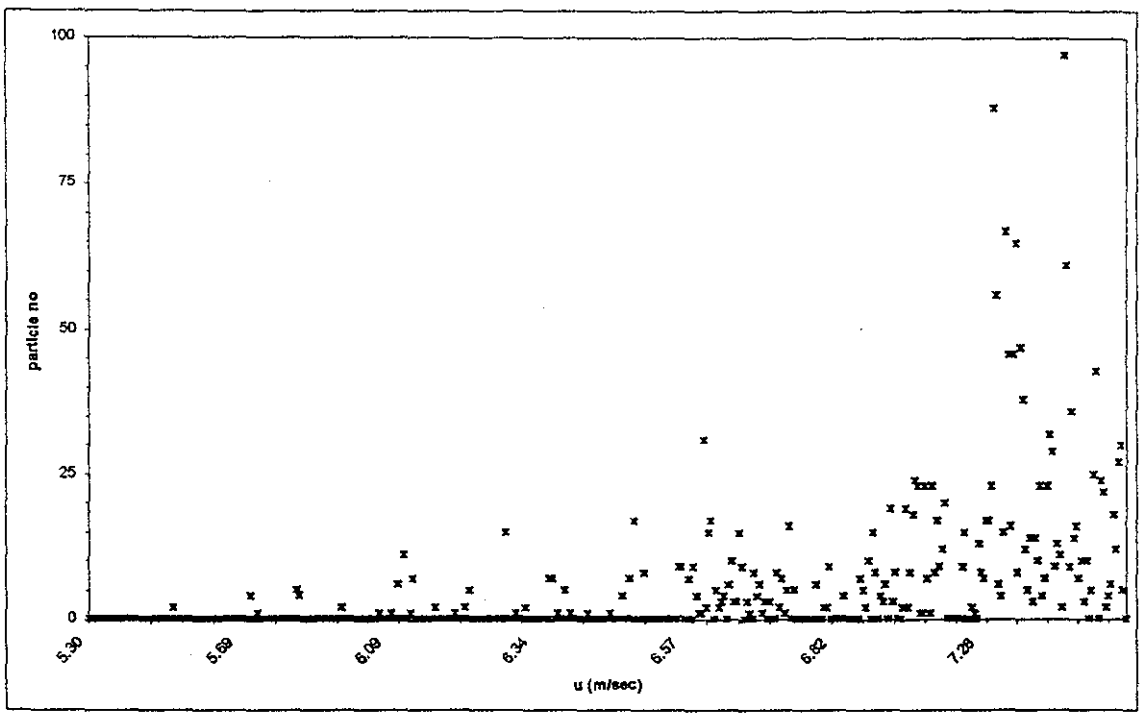


Fig. 8 a, b. Threshold friction velocity determinations

Soil no.2 (crust):



Soil no.3:

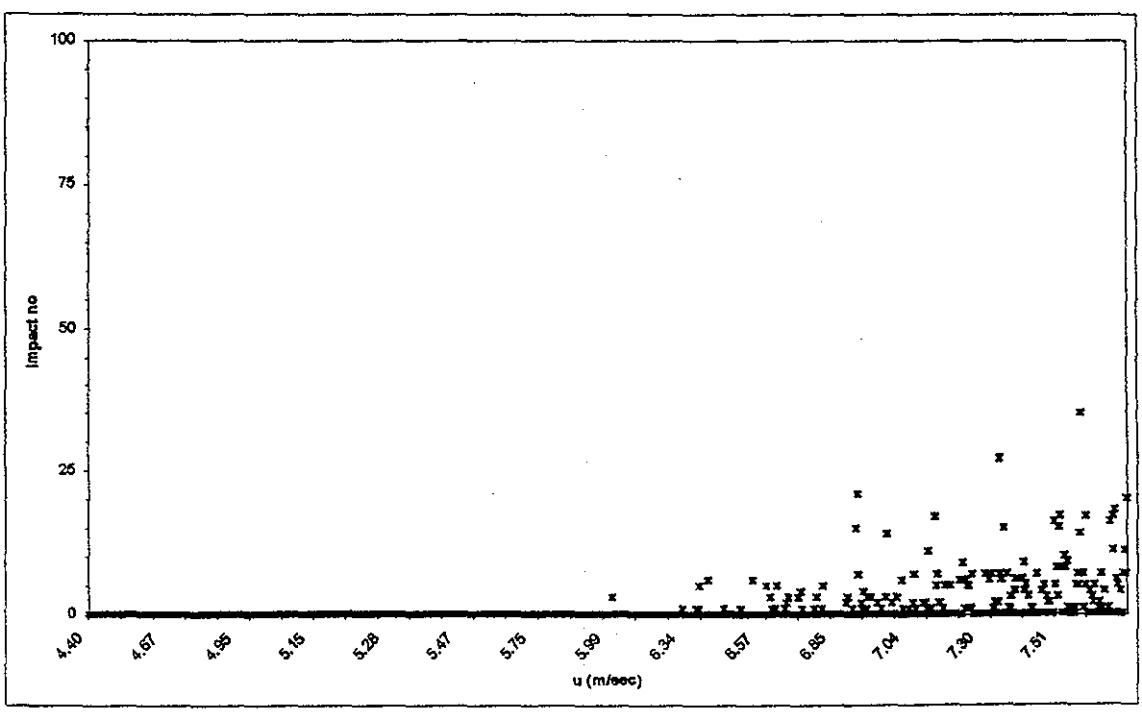


Fig 8 b, c Treshold friction velocity determinations

The results of the experiments for Amu-Darya soils

All the results were taken at frequency of 16 Hz (the wind velocity and particle impact).

Soil type	Repitition	U_{*t} (m/sec)	Average	Std	Var
Soil no.1 (top soil)	1	7.25	7.07	0.606	0.440
	2	6.11			
	3	7.03			
	4	7.84			
	5	7.67			
	6	6.53			
Soil no.1 (1-15)	1	5.77	5.72	0.085	0.011
	2	5.79			
	3	5.6			
Soil no.2	1	5.69	5.58	0.077	0.009
	2	5.55			
	3	5.51			
Soil no.3	1	6.34	6.50	0.161	0.039
	2	6.44			
	3	6.72			

Column no.3 represent the TWV (Threshold Wind Velocity) of each experiment with deduction of values that were larger then 30 sec intervals between impacts.

- **For soil no.1 (crust) we made six repetitions, because of the large variance at the results.**

Humidity of air dry- soils

Air dry humidity	
Soil type	**Humidity**
Soil no.1 (crust)	2.823%
Soil no.1 (1-15)	0.798%
Soil no.2 (crust)	2.873%
Soil no.3	0.686%

Moisture effects on TWV of Amu-Darya soils

Three moisture levels were measured for all soil samples. At each level we measured the threshold wind velocity, comparing to the original test when the soil sample was air-dry.

Working method:

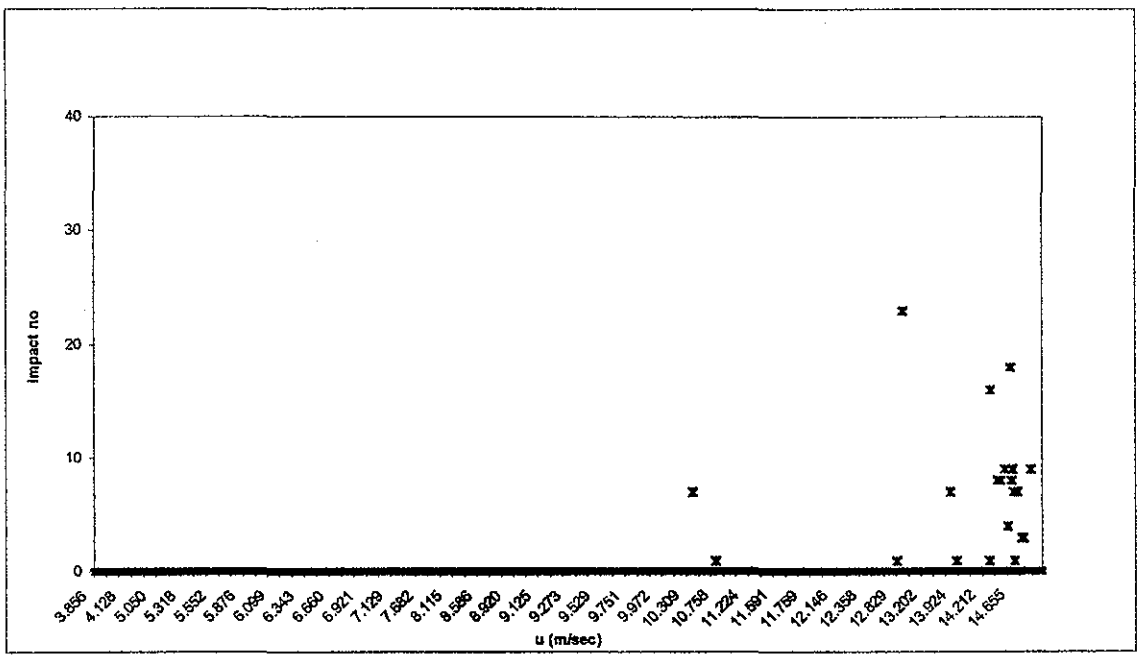
The wind velocity was determined in the same way as at the TWV experiments. All soils were oven dried (64°C) for a minimum of 24 hours, stirred, passed through a 2.5 mm diameter sieve and then exposed to air at least 24 hours before every moisture experiment.

The tray was filled to a depth of 10 mm with each soil type. A very fine film of distilled water mist, at a constant weight was sprayed up on the soil surface; the amount of water that we sprayed was 50 gr., 100 gr., and 200 gr. for moisture levels 1-3 respectively, for all soil types. This wetting method was adapted in order to receive consistent repetitions. The test began after all the water had infiltrated (minimum of 60 sec after the end of infiltration). Prior to every repetition, a soil sample was taken for the determination of air-dry moisture.

During the test, wind velocity was increased every 60 sec, up to the point that we were able to determine as the threshold wind velocity. At the end of each test, a soil sample from the upper 1 mm layer was taken to determine soil humidity after exposure in the wind tunnel. The average of these 2 values was taken as soil humidity (Figs. 9a, b, c, d).

Soil no.1 (crust):

Relative humidity 4.796%



Soil no.1 (1-15):

Relative humidity 4.483%

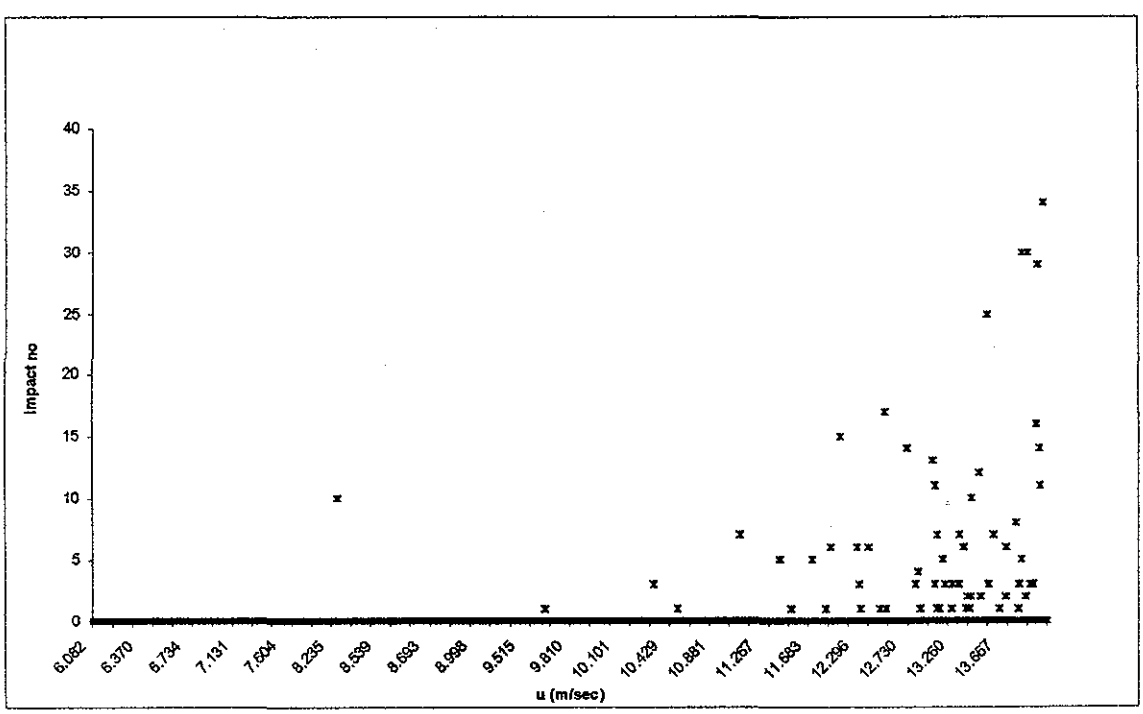
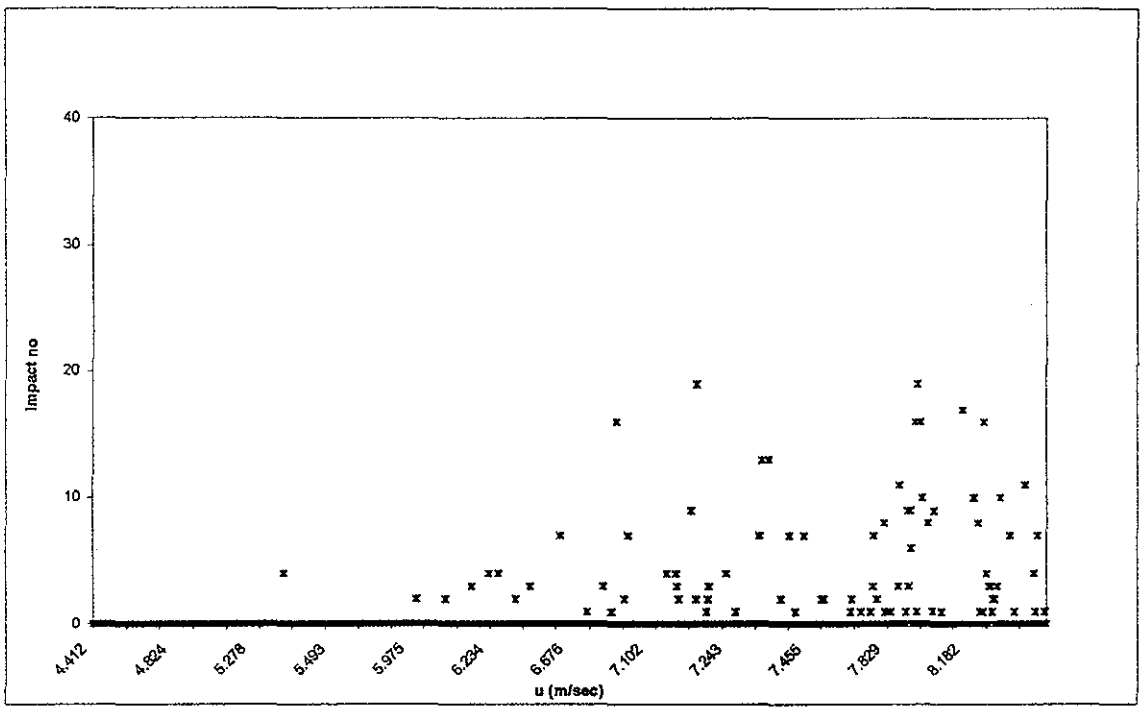


Fig. 9 a, b Moisture effects on threshold wind velocity

Soil no.2 (crust):

Relative humidity 7.309%



Soil no.3:

Relative humidity 4.985%

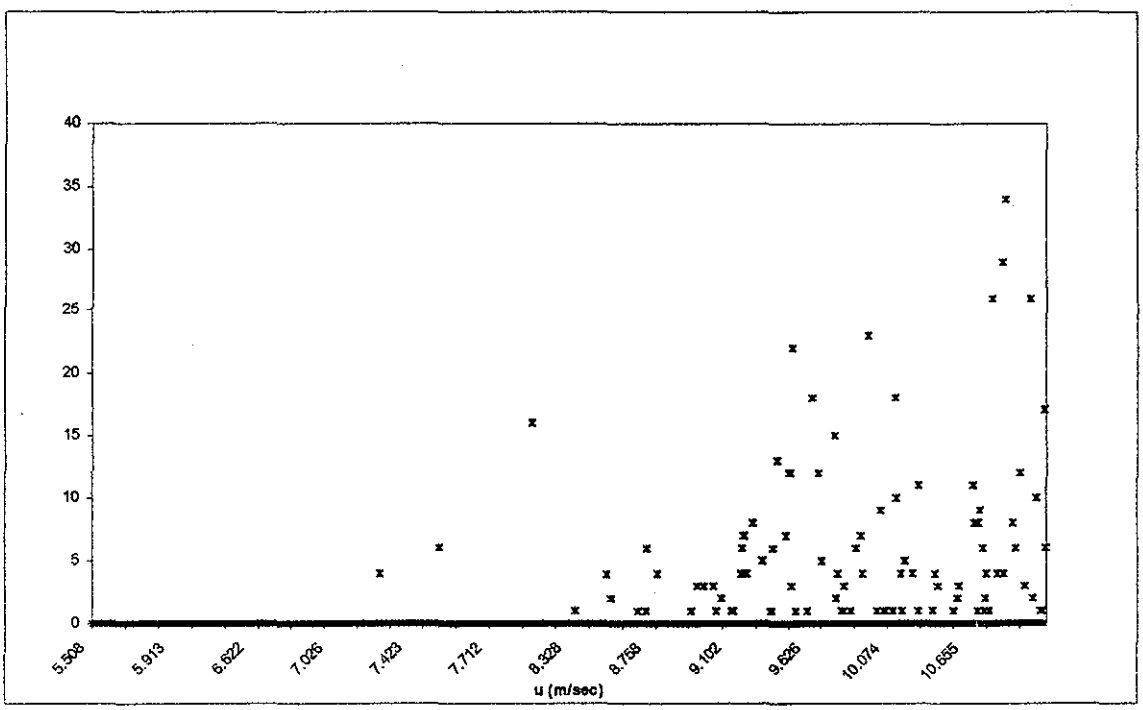


Fig. 9 c, d. Moisture effects on threshold wind velocity

Moisture effects on TWV of Amu Darya soils

layer thickness (mm)	critical wind velocity (m/sec)	moisture level	relative humidity	soil type	repetition	exp
1	10.429	level 1	4.883%	soil no.1 (1-15)	1	1191000
	10.288		2.955%		2	4051100
1	12.247	level 2	3.590%		1	2191000
	12.548		4.894%		2	5051100
1	15.821	level 3	5.903%		1	3191000
	14.416		5.706%		2	6051100
1	12.83	level 1	4.796%	soil no.1 (crust)	1	4161000
	12.44		5.844%		2	7051100
1	14.712	level 2	7.125%		1	5161000
	12.701		7.551%		2	8051100
1	16.263	level 3	11.974%		1	6161000
	15.47		8.942%		2	9051100
1	5.975	level 1	7.309%	soil no.2	1	1161000
	6.666		5.741%		2	1051100
1	8.872	level 2	10.852%		1	2161000
	11.431		9.556%		2	205110
1	12.147	level 3	12.701%		1	3161000
	14.169		12.086%		2	3051100
1	7.712	level 1	4.985%	soil no.3	1	4191000
	6.869		9.759%		2	3271000
1	11.915	level 2	4.960%		1	5191000
	15.016		11.185%		2	4271000
1	14.639	level 3	7.010%		1	6191000
	15.912		11.474%		2	5271000

Estimate of dust emission potential of the soil materials

Small particles (of less than 0.06 mm) whose settling velocity may be very small in comparison to the combined effects of wind lift and drag might be transported in suspension and thus are the potential sources for dust emission.

Dust emissions from wind erosion on disturbed soils are very common in many regions around the world. Recently, concern for the health and climatic impact of dust aerosols has produced increased interest in this subject. A wide variety of devices have been proposed in the past to evaluate sediment or fugitive dust in the laboratory. A rotating drum-type device was recently developed by Zobeck and Amante-Orozeo (1999) from the USDA-Agricultural Research Service, Lubbock, Texas, to create and perform *in situ* analysis of dust (Fig. 10).

The entire system consists of a dust aerosol generating tube, laser particle size analyzer, and dust settling chamber containing other dust aerosol monitoring and sampling devices. Source samples are placed in a one meter long, 0.07 meter-square tube. The tube is started with the long axis perpendicular to the floor and inverted approximately every 3 seconds, dropping the sample one meter and generating dust by the impact. The dust is conveyed through a laser particle analysis system and then to a settling chamber. In the settling chamber, the dust is sampled by a Mini-Vol sampler to determine mean particle concentration, DataRam nephelometers to determine *in situ* PM_{10} and $PM_{2.5}$ during the run, the Grimm Particle Sizer to determine *in situ* particle size distribution and mass. PM_{10} and $PM_{2.5}$ materials are particulate matter having aerodynamic diameters less than or equal to 10 or 2.5 microns, respectively. The determinations were carried out by Dr. T.M. Zobeck, USDA-Agricultural Research Service, Lubbock, Texas, U.S.A.

Fig. 10 PM10 determination equipment

PM-10, LUBBOCK

28A

Table : PM-10 in 3 soil samples from the Amu Darya Delta Region.

Sampler							
Data Ram							
	Sampled	**F. weight**	**F+dust**	**Dust w.**	**E. time**	**Air flow**	**Dust conc.**
Sample Id	**Dust**	----------	**mg**	----------	**(min)**	**(l/min)**	**(mg/m^3)**
Soil 1- crust Rep 1	PM10	10.041	10.89	0.849	30	2.01	14.08
Rep 2	PM10	9.911	13.00	3.089	30	2.01	51.23
Rep 3	PM10	10.215	13.305	3.090	30	2.01	51.24
Soil 2-Takyr Rep 1	PM10	10.192	15.542	5.350	30	2.01	88.72
Rep 2	PM10	9.990	16.202	6.212	30	2.01	103.02
Rep 3	PM10	10.129	16.632	6.503	30	2.01	107.84
Soil 3- crust Rep 1	PM10	10.147	13.185	3.038	30	2.01	50.38
Rep 2	PM10	10.050	12.635	2.585	30	2.01	42.87
Note:	*Soil 1 Rep 1 had a bad seal, data is no good.						
	** No data						
Sampler							
MiniVol							
	Sampled	**F.weight**	**F+dust**	**Dust w.**	**E. time**	**Air flow**	**Dust conc.**
Sample Id	**Dust**	----------	**mg**	----------	**(min)**	**(l/min)**	**(mg/m^3)**
Soil 1 Rep 1	PM10	16.282	30.470	14.188	30	4.98	94.97
Soil 1 Rep 2	PM10	16.801	28.412	11.611	30	4.98	77.72
Soil 1 Rep 3	PM10	16.228	28.832	12.604	30	4.98	84.36
Soil 2 Rep 1	PM10	16.080	38.905	22.825	30	4.98	152.78
Soil 2 Rep 2	PM10	16.611	41.131	24.520	30	4.98	164.12
Soil 2 Rep 3	PM10	16.361	44.998	28.637	30	4.98	191.68
Soil 3 Rep 1	PM10	16.340	31.529	15.189	30	4.98	101.67
Soil 3 Rep 2	PM10	16.861	28.805	11.944	30	4.98	79.95
Notes:							
Sample Id							
1	Top Soil (0-1 cm)						
2	Soil (0-1 cm)						
3	Top Soil (0-1 cm)						

C) Scientific Impact of Collaboration

Scientific collaboration during the fourth project year was reflected in two visits of the collaborating partners from Uzbekistan in Israel. The visits of the Uzbek partners in Israel had as their purpose discussions of the results obtained to date and of the plans for further work. For their second visit, the Uzbek partners brought to Israel additional soil samples from the Kungrad area in the Amu Darya Delta, where a large industrial complex is endangered by dust storms. Means for amelioration of this problem are a major concern of the administration in the area. During their visit in Israel, the Uzbek partners followed the experimental work on wind erosion at the wind-tunnel in Beer-Sheva.

D) Description of Project Impact

From the first results obtained on the effect of soil treatments on dust generation, it appears that some useful and practical recommendations will evolve for the reduction of the dust load at some key locations in the Amu Darya Delta.

As a result of the cooperation with the Wind Erosion and Water Conservation Research Unit, USDA, in Lubbock, Texas, for the first time it will be possible to assess the dust generation potential of the desiccated and exposed Aral Sea bottom, and of the various soils in the Amu Darya River delta. Moreover, it will be possible to single out the surface materials (soils, sediments) with the largest dust generating potential.

E) Strengthening of Developing Country Institutions

"Waterproject", the partner institute in Tashkent, has never in the past been involved in wind erosion studies. With studies carried out at present in Israel, the Uzbek partners are for the first time becoming exposed to this field of study. Considering that wind erosion is a major problem in Central Asia, it is likely that the study carried out now will serve as a stimulator and basis for the development of this research direction.

F) **Future Work**

In the fifth research year, the studies on the erodibility of the soils of the Amu Darya Delta and of the exposed Aral Sea sediments, will be continued and brought to completion. Specifically, the four additional samples brought to Israel in November 2000 will be analyzed. Emphasis will be placed on the study of the effects of treatments on the deflatability of the soils/sediments. The treatments include crust formation, wetting, and chemical soil stabilizers. As a result of these studies, recommendations will be formulated for treatments intended to reduce dust generation.

Section II

A) and B)

Difficulties in the transfer of funds to the Uzbek partner have abated, principally because most of the funds have been exhausted. By a complicated chain of helpers, the desiccated and exposed Aral Sea bottom near the inlet of the Amu Darya River into the Sea, had been sampled, and the samples brought to Israel. It is anticipated that severe logistic problems, as well as health problems of the principal investigator, will prevent the operation of the field trials in the Aral Sea area.

D) Collaboration during 2000

Collaboration with the partner institute in Uzbekistan in 2000 consisted primarily of two visits of the principal investigator from Tashkent in Israel. During the visits, in February and November, the methods for the determination of the deflatability of the soils were discussed. The operation of the equipment, and principally that of the wind tunnel, was demonstrated.