ASSESSMENT THE HAZARD OF SAND DUNE MOVEMENTS ON THE IRRIGATION CANALS, TOSHKA PROJECT

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ABSTRACT

The south valley project (Toshka) is considered as one of the most challenging and promising developing projects in Egypt. Due to the huge longitudinal dune belt and the arid climate conditions, a big amount of sand dunes in the region moved towards the watercourses resulted in filling the watercourses and consequently decreasing the canals efficiency and enhancing the growth of aquatic weeds. Hence, the objective of this research paper is to investigate the quantity of blown sand that precipitated inside the watercourses by conducting an extensive field data measurement in a period of one year around (June 2007 – June 2008). About 20 actual cross-sections located in El-Sheikh Zayed canal, Branch1 canal, and branch 2 canal are conducted. In addition, about 74 sand collectors and 48 sticks were fixed around the studied canals and the readings were monthly recorded. The results have shown that some reaches of the studied canals are exposed to the risks of sand dunes movements and consequently the growth of aquatic weeds and alga. The expected amounts of sand that fill in the watercourses are ranged between 150 and 4450 m^3/year with sand depths up to 20 cm. The sticks revealed that the last reach of main canal (km 35- km 45) and Branch 3 are the most regions exposed to active sand dunes. Based upon the obtained results, a preventive maintenance program for controlling sand movement towards lined canals are proposed and presented herein.

Keywords: Sediment Transport, Canal Efficiency, Active Sand Dunes

1. INTRODUCTION

In Egypt, the majority of population, 65 millions capita, is concentrated on about 4% of the land, primarily along the banks of the river and the delta. This population is growing at 3.2% annually with the same amount of allocated fresh water (56 milliard cubic meters a year) since the agreement in 1959 between Egypt and Sudan. Therefore, the government has been imposed to construct new Barrages and national projects for optimum use of the limited water resources. One of these projects is the south valley project at Toshka aiming to: i) establish new developed agricultural

society with a total of two millions feddan, ii) relieve population pressure from the delta; and iii) open new working opportunities.

The project comprises a huge pumping station constructed on the left bank of Lake Nasser 8 km North of Toshka to supply the main lined canal (El-Sheikh Zayed) and its four main branches with water as well. The station was designed to have a maximum static lifting of abut 52.5 meters and discharge of about 300 m^3/sec (25 million m^3/day). The main canal runs towards the west for 70 km and the first branch takes its water 29.35 km from the head. Another three branches are taking their water from the end of the main canal. Branch 1, branch 2, branch 3, and branch 4 serve 180, 80, 100, and 180 thousands feddan respectively. Since the area of the projects is lying in sandy soils with high tendency for water seepage, numbers of irrigation canals have been lined with concrete overlying impermeable membranes.

The movement of sand dunes has been investigated by many investigators. N.S. Imbabi (1981) studied the Barchans of the Kharga depression. He revealed that the dune belts of Kharga depression are oriented parallel to the long axis of the depression and are divided into three belts; the western belt consists of simple and compound barchans that extend from the Abu Muharik dune belt. The middle belt of barchans is smaller, but of great economic importance since it crosses the Kharga-Asyut highway. The eastern barchan belts parallel the eastern scarp of the depression and consist of 261 barchans of various sizes. Analysis of barchan shape parameters indicates that the shape of the dunes remains essentially constant as growth takes place, although the degrees of association of the parameters decreases as the dunes increase in size. The rate of barchan movement varies between 20 and 100 m/year, and exhibits strong correlation with effective winds, dune size, ground length of the windward side and mean slope angle of the windward side. Wind data of the Kharga station indicates that about 95% of the effective winds (20 km/hr) are blown from the northern direction and smaller dunes move faster than larger ones because the sand mass transported decreases, as the dune gets smaller.

The active sand dunes and the amount of blown sand are based upon wind velocity & direction, plant cover, height and grain size of the dunes,…etc. Bagnold (1941), Kawamura (1951), and Lettau (1975). Rubin (1982) and Hunter (1983) have studied various sedimentary structures in Aeolian deposits and have derived criteria to interpret the processes of sedimentation and the geometry of the bed forms involved in their formation. Their models were derived primarily from study of active sand waves and were then applied to ancient sediments. By knowing the shear velocity, a number of weighting formulas were developed. These equations are as follows:

Lettau's eq. $$q.g / \rho = 6.5\ v^{*2} (v^* - 2.5) \quad (1)$$

Bagnold's eq. $$q.g/ \rho = 3.33\ v^{*3} \quad (2)$$

Kawamura's eq. $$q.g/ \rho = 3.1\ (v^* + 30)^2 (v^* - 30) \quad (3)$$

in which q is the rate of sand drift, g is the gravity acceleration, ρ is the density of air, v^* is the shear velocity of sand drift. All units are c.g.s (centimeter-gram-second).

In the project area, Toshka depression which lies in South-East part of the Western Desert of Egypt is characterized by the presence of numerous moving dunes organized by several groups. Its altitude floors of about 90 m a.s.l., slopes gradually take place from all direction to the depression from altitudes more than 300 m a.s.l. The Toshka depression is surrounded from the north by the vast plateau called Sinn EL-Kaddab plateau which are capped by Paleocene and Eocene limestone and chalk. On this plateau, there are two Aeolian features of great importance to the dunes of the depression. The first feature is the huge longitudinal dune belt which enters Toshka area from the North and spills dawn its northern scarp to west part of the area. The second feature is small sand dues area which lies on the plateau surface and extend south to Toshka area. The climate conditions in Toshka play an important role in shaping the landscape and the ecology of the region. The area has a dry arid climate with very restricted annual rainfalls (the dry period may extend for more than two years). It is expected that moving sand dunes will create a serious problem for economic development of Toshka project in case of no action taken place.

Therefore, the objectives of this research paper are to quantify the amount of sediment accumulation inside the watercourses and introduce the means of protection against the sand movement as well as proposing the more feasible vainest maintenance program for removing the sand from the lined canals.

2. DATA COLLECTION AND ANALYSIS

In order to achieve the goals of this research, an intensive field data measurement were performed. A group of 19 cross-section allocated allover the selected reaches of the canals were measured twice throughout the year around by using a total station survey and echo sounder devices. The actual cross-sections were compared with the design ones and the depth of sand depositions were determined and presented in Table 1. Figures 1, 2, and 3 present the actual and design cross section as a representative for El-Sheikh Zayed canal, conductor (1&2) and branch 2 canals, respectively.

Table (1) Depths of Sand Accumulations along the cross- sections of the Studied Canals

Canal name	Location (km)	Deposition depth (cm)		Annual deposition rates (cm/year)
		June 07	April 08	
Main Canal	20.000	0.63	1.20	0.67
	25.000	7.53	2.83	0.00
	27.500	3.43	4.53	1.30
	30.000	3.30	4.67	1.63
	32.500	2.34	3.50	1.40
	35.000	1.68	5.00	3.97
	37.500	0.63	5.90	6.30
	40.000	4.93	11.33	7.67
	45.000	1.93	4.43	3.00
Conductor 1&2	55.000	4.05	6.35	2.75
	60.000	3.25	4.20	1.15
	65.000	2.60	5.05	2.95
	70.000	18.65	28.65	12.00
Branch2	0.500	7.38	15.38	18.38
	3.000	8.88	9.38	0.63
	5.500	10.50	10.75	0.25
	8.000	17.88	22.13	5.13
	11.000	34.88	41.38	7.75
Branch1	1.500	6.25	9.63	4.00

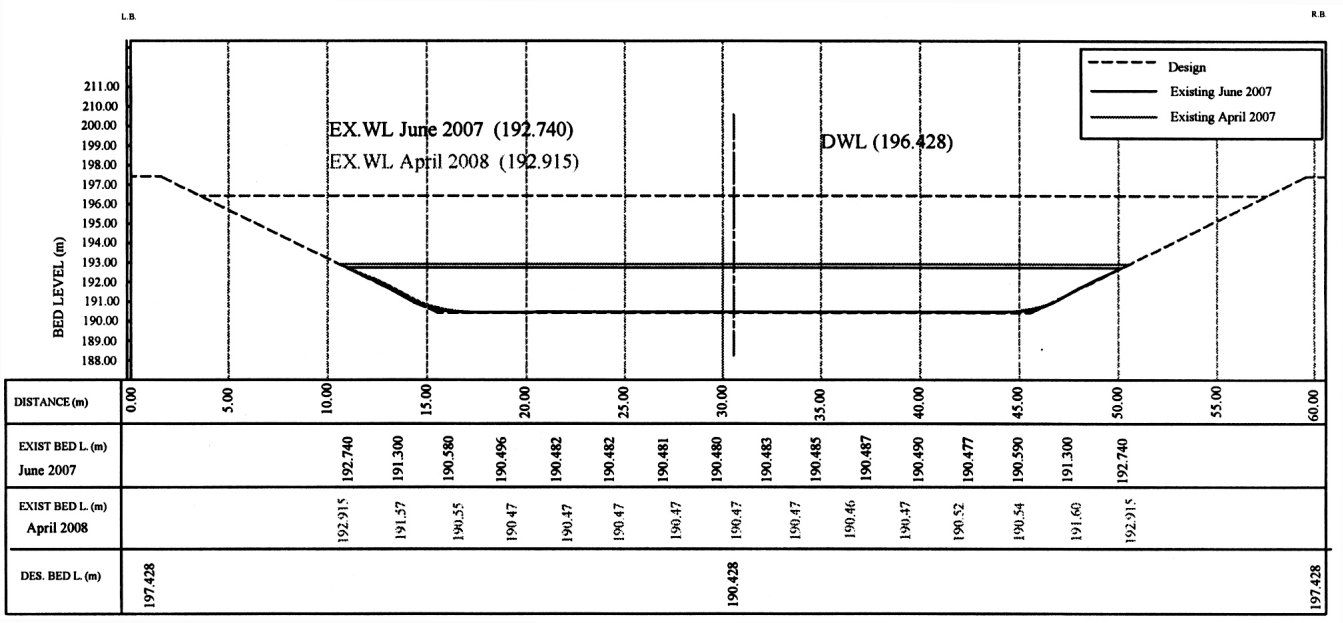

Fig. (1) Actual and design cross sections for main canal at km 40.000

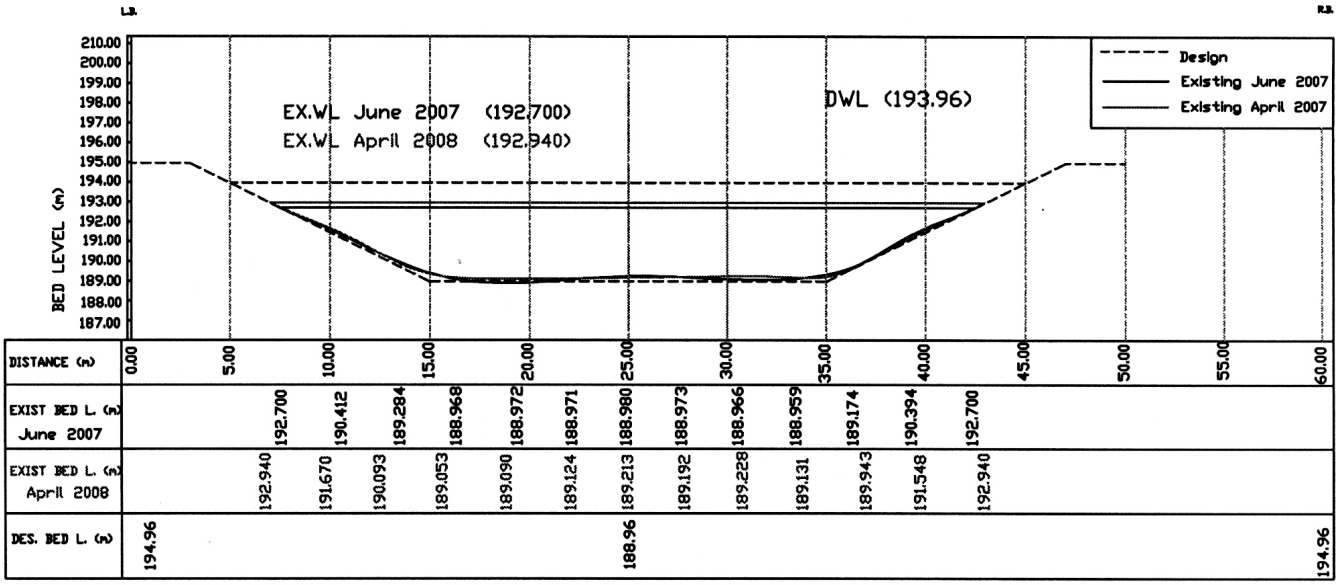

Fig. (2) Actual and design cross sections for conductor 1&2 at km 70.000

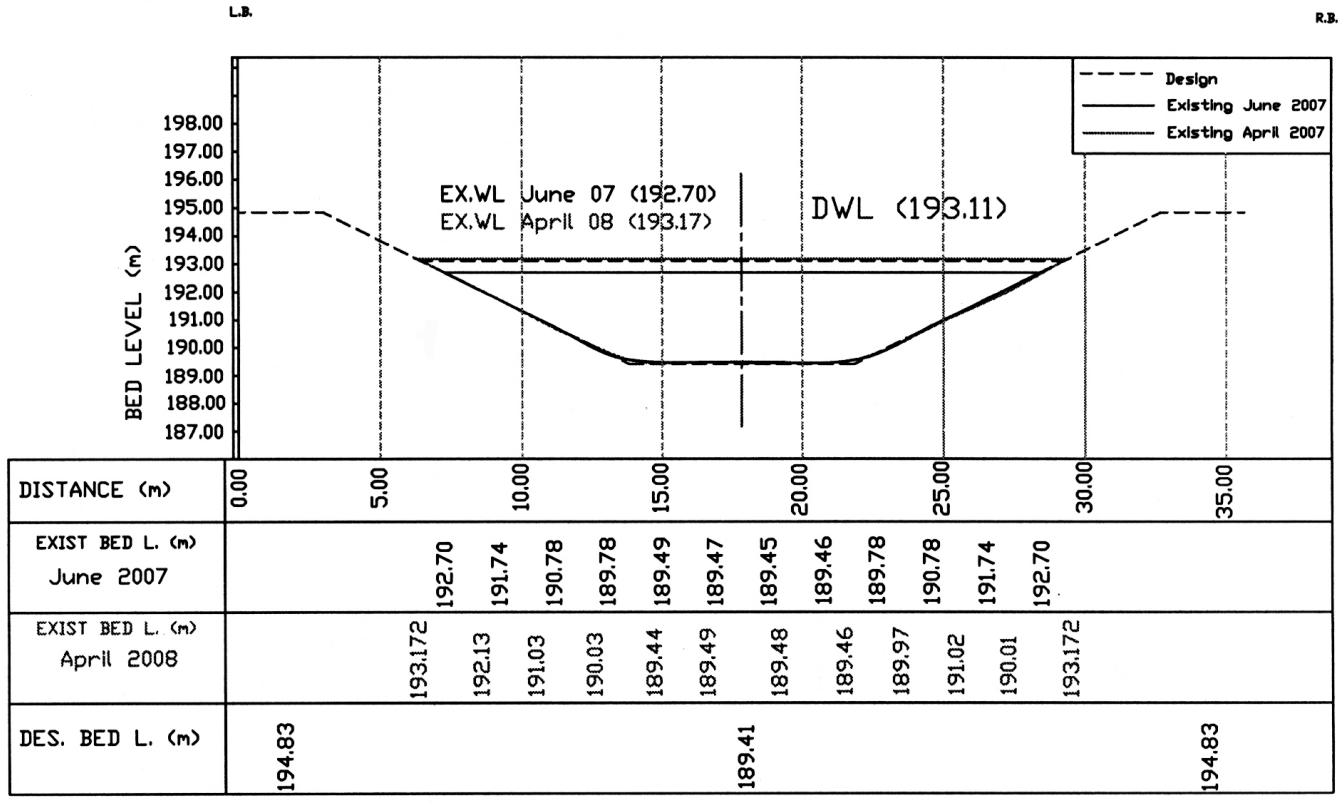

Fig. (3) Actual and design cross sections for branch 2 at km 3.000

Presently, the results revealed that the sediment accumulation in some watercourses is ranged from 0.63 cm to 41.38 cm. In El-Sheikh Zayed canal, the deposited sediment from km 3.350 to km 14 is due to the suspended materials, while the active sand dunes threaten the reach from km 26.5 to the tail end with maximum accumulative depth of 7.67 cm/ year at km 40. The conductors (1, 2) is suffering from the active sand dunes especially the last reach from km 71 till km 72.8 with an average accumulative depth

of 12 cm/year. Branch 2 suffers from sand dunes movement especially from the intake until km 4 with maximum value of 18.38 cm/year at km 0.500. Generally, the sediment depositions are concentrated on the sides of the bed.

About 74 sand collectors and 48 sticks have been fixed in varies locations around the studied reaches as shown in Fig. 4. The measurements were monthly collected and presented in Tables 2-a, 2-b and 3. The sand collectors revealed that the rate of sand accumulations within the main canal ranges between 25.48 gm/year for collector No. 25 at km 50 and 28218.25 gm/year for collector No. 22 at km 40. While in conductor (1&2), the rate of sand movement ranges between 67.20 gm/year for collector No. 31 at km 65 and 406.25 gm/year for collector No. 30 at km 60. While in branch 2, it ranges between 96.73 gm/year for collector No. 45 at km 14 and 42387.26 gm/year for collector No. 42 at km 8. In branch 1, it ranges between 77.92 gm/year for collector No. 61 at km 22.5 and 15882.39 gm/year for collector No. 56 at km 13.5. In branch 3, the rate of sand accumulation ranges between 104.47 gm/year for collector No. 69 at km 10.5 and 2850.29 gm/year for collector No. 66 at km 4.50. The quantities of sand expected to fall in the project watercourses are 4415 m^3/year for main canal, 154 m^3/year for conductor (1&2), 1837 m^3/year for branch 2, 2185 m^3/year for branch 1, and 2515 m^3/year for branch 3.

The measurements of Sticks show changes in values due to sand dunes accumulation or displacement. These changes range between 44 cm for stick No. 17 and -43 cm for stick No. 37. The predicted sand dunes displacement is ranged between 15 m/year and 100 m/year based on many parameters such as barchans shape, region characteristics, wind ……etc. It can be concluded that the last reach of main canal (km 35- km 45) and Branch 3 are the most regions exposed to active sand dunes movement.

3. PROPOSED MAINTENANCE PROGRAM

Based on the obtained results, the sediment depositions could be removed once every four years from the most exposed reaches to the active dunes (as mentioned) by utilizing:

- Long Boom Excavator with suitable desalting bucket.
- Hydraulic Excavator with rotor dredger bucket and suction system.
- Amphibious Mounted long reach excavator with pontoon.

While for controlling the active sand dune movement and reducing the blown sand that precipitated inside the canals, the following scenarios could be applied:

- Construction of Trenches are recommended around some reaches.
- Fixation of those dunes whose potential hazard is high by the most suitable method for the locality, such as spraying surface with the coarser limestone that available in Toshka depression.
- Vegetation protection around the affected reaches of canals by planting rows of trees of types Gatarova and Casoriana which can sustain the shortages of water and high temperature.

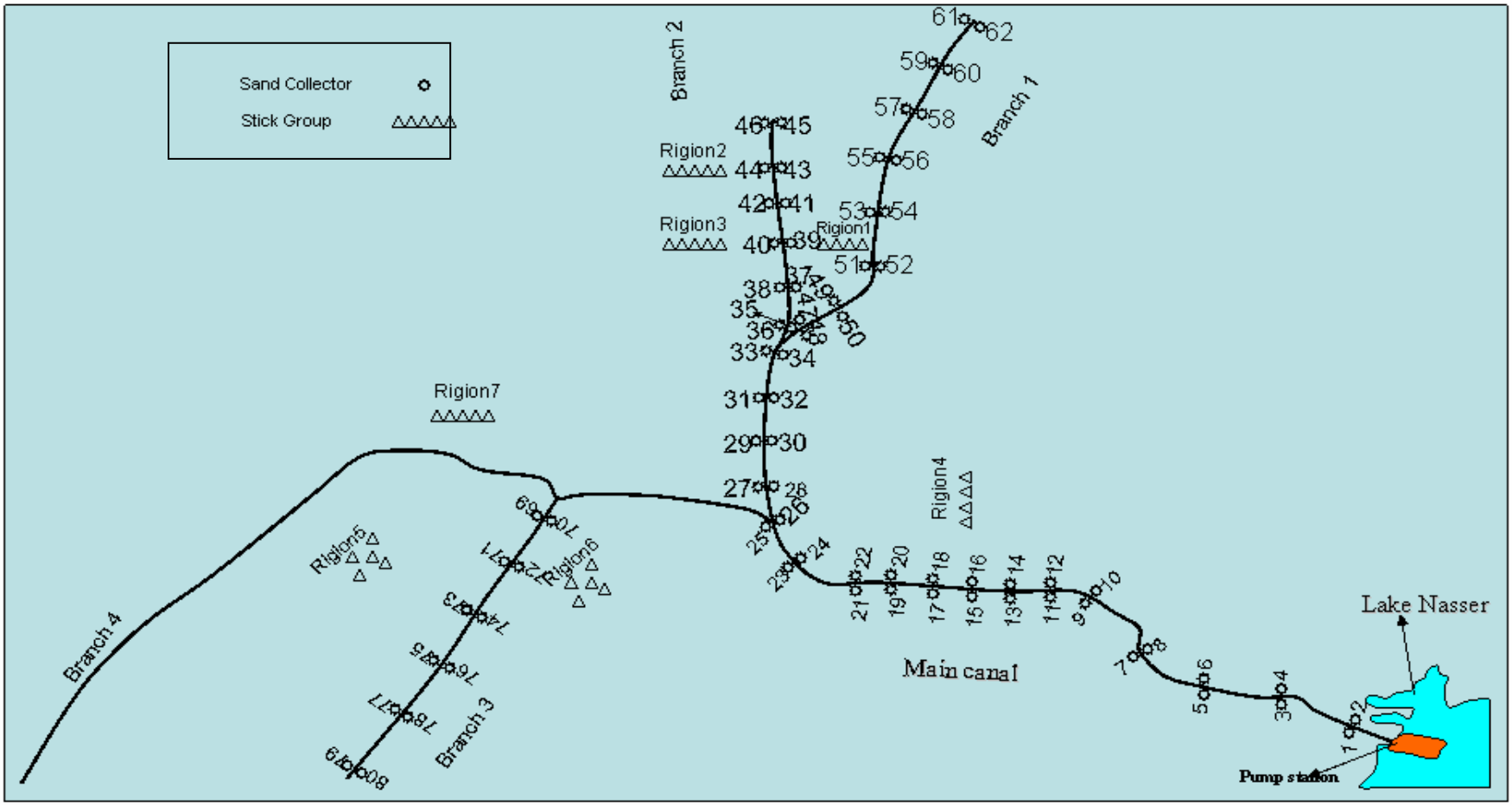

Fig. (4) The location of sand collectors and stick groups in the study area

Table (2-a) Quantities of Sand Accumulations within the fixed Sand Collectors

Sand collector No.	Canal name	Location (km)	Collected sand (gm/year)	Angle of inclination	Correction factor	Corrected Quantity (gm/year)
1	Main Canal	5.000	46.96	43.12	1.46	54.16
2		5.000	118.48	43.12	1.46	136.65
3		10.000	64.92	59.86	1.16	68.38
4		10.000	170.26	59.86	1.16	179.34
5		15.000	48.28	45.91	1.39	54.56
6		15.000	244.36	45.91	1.39	276.13
7		20.000	43.6	3.94	14.56	240.67
8		20.000	148.62	3.94	14.56	820.38
9		25.000	63.06	21.48	2.73	99.42
10		25.000	1374.66	21.48	2.73	2167.38
11		27.500	72.8	57.79	1.18	77.17
12		27.500	188.56	57.79	1.18	199.87
13		30.000	79.86	57.79	1.18	84.65
14		30.000	1271.04	57.79	1.18	1347.30
15		32.500	83.1	57.79	1.18	88.09
16		32.500	1006.86	57.79	1.18	1067.27
17		35.000	94.14	64.49	1.11	97.59
18		35.000	1706.62	64.49	1.11	1769.20
19		37.500	86.06	64.49	1.11	89.22
20		37.500	9144.64	64.49	1.11	9479.94
21		40.000	127.8	64.49	1.11	132.49
22		40.000	27220.18	64.49	1.11	28218.25
23		45.000	96.74	20.23	2.89	157.69
24		45.000	4840.78	20.23	2.89	7890.47
25		50.000	1	0.77	74.45	25.48
26		50.000	1	0.77	74.45	25.48
27	Conductor 1&2	55.000	125.68	30.17	1.99	167.15
28		55.000	151.22	30.17	1.99	201.12
29		60.000	86.54	59.88	1.16	91.16
30		60.000	385.68	59.88	1.16	406.25
31		65.000	63.8	59.88	1.16	67.20
32		65.000	227.7	59.88	1.16	239.84
33		70.000	124.12	59.88	1.16	130.74
34		70.000	212.66	59.88	1.16	224.00

Table No. (2-b) Quantities of Sand Accumulations within the fixed Sand Collectors

Sand collector No.	Canal name	Location (km)	Collected sand (gm/year)	Angle of inclination	Correction factor	Corrected Quantity (gm/year)
35	Branch 2	0.500	227.22	30.91	1.95	299.17
36		0.500	3907.34	30.91	1.95	5144.66
37		3.000	147.04	19.90	2.94	242.13
38		3.000	5627.18	19.90	2.94	9266.09
39		5.500	98.18	19.90	2.94	161.67
40		5.500	1113.34	19.90	2.94	1833.30
41		8.000	200.90	31.17	1.93	263.37
42		8.000	32332.39	31.17	1.93	42387.26
43		11.000	100.58	31.17	1.93	131.85
44		11.000	632.53	31.17	1.93	829.24
45		14.000	73.78	31.17	1.93	96.73
46		14.000	612.86	31.17	1.93	803.45
47	Branch 1	1.500	75.34	33.40	1.82	95.87
48		1.500	112.80	33.40	1.82	143.54
49		4.500	184.56	33.40	1.82	234.84
50		4.500	202.28	33.40	1.82	257.39
51		7.500	105.49	33.40	1.82	134.23
52		7.500	448.40	33.40	1.82	570.58
53		10.500	181.40	88.46	1.00	181.42
54		10.500	8580.54	88.46	1.00	8581.64
55		13.500	145.87	88.46	1.00	145.89
56		13.500	15880.36	88.46	1.00	15882.39
57		16.500	186.17	88.46	1.00	186.20
58		16.500	9030.78	88.46	1.00	9031.93
59		19.500	428.68	62.71	1.13	446.62
60		19.500	14615.71	62.71	1.13	15227.45
61		22.500	71.50	52.00	1.27	77.92
62		22.500	413.07	52.00	1.27	450.17
63	Branch 3	1.500	397.46	23.73	2.49	594.35
64		1.500	111.72	23.73	2.49	167.06
65		4.500	112.60	42.16	1.49	131.01
66		4.500	2449.78	42.16	1.49	2850.29
67		7.500	116.32	70.67	1.06	118.64
68		7.500	1055.98	70.67	1.06	1077.09
69		10.500	102.42	70.67	1.06	104.47
70		10.500	1079.82	70.67	1.06	1101.41
71		13.500	181.15	83.66	1.01	181.52
72		13.500	55898.39	83.66	1.01	56014.59
73		16.500	40.10	39.12	1.59	47.93
74		16.500	311.55	39.12	1.59	372.37

Table (3) Reading of Fixed Sticks around the Project Area

Region	Stick No.	Stick Length (cm)			
		12/12/2007	28/02/2008	01/04/2008	07/05/2008
1	1	75	75	75	75
	2	50	48	50	49
	3	50	37	35	34
	4	50	49	50	30
	5	50	68	60	63
	6	50	59	54	52
2	7	60	61	60	61
	8	60	60	58	61
	9	60	60	59	61
	10	60	62	61	62
	11	60	62	63	64
	12	60	63	64	65
3	13	60	60	60	60
	14	60	61	63	62
	15	60	60	60	61
	16	60	62	64	64
4	17	60	33	30	16
	18	50	41	38	30
	19	50	77	77	79
	20	75	52	42	38
	21	45	51	54	55
	22	40	50	52	51
5	23	50	61	60	58
	24	50	63	66	68
	25	50	58	54	50
	26	50	64	51	50
	27	40	42	67	67
	28	40	53	45	44
	29	60	45	57	62
	30	60	47	46	45
	31	45	45	46	46
	32	45	52	55	57
	33	45	56	58	59
	34	45	63	66	68
6	35	45	65	45	68
	36	45	75	62	88
	37	45	72	80	88
	38	45	52	80	67
	39	45	70	66	39
	40	45	20	18	15
	41	45	51	54	55

Cont. Table (3)

7	42	45	38	37	22
	43	45	66	69	70
	44	45	68	58	64
	45	45	55	55	54
	46	45	71	74	74
	47	60	53	61	61
	48	50	62	52	52

4. CONCLUSION

As the project lies in area characterized by the presence of numerous moving dunes, the sand driven and precipitated inside the watercourses threaten the canal capacity and create suitable environment for growing the aquatic weeds. The results revolted that the sediment accumulation in some watercourses at the present time ranged from 0.67 to 18.38 cm; the predicted sand dunes displacement is ranged between 15 m/year and 100 m/year and the last reach of the main canal (km 35- km 45) and Branch 3 are the most regions exposed to active sand dunes. The most threaten reaches of watercourses have been assigned in order to be protected by means of spraying surface with a thin veneer of granule – size grains that available in Toshka depression close to the project area. Other reaches could be protected by planting some types of trees such as Gatarova and Casoriana. The proposed maintenance program for sand removal (frequency, types of Equipments) could be implemented as presented herein.

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