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A COMPARATIVE STUDY OF CONVENTIONAL REGIME EQUATIONS

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ABSTRACT:

When any one of the alluvial canal parameters such as width, depth, slope or velocity is affected all other parameters are uniquely determined and independtly adjusted, thus creating a new canal regime. Many formulae of canal regime have been presented, the best well known regime equations are those given by Lacey (1929, 1930, 1953), Blench (1957, 1966) and Simons-Albertson (1963).

Deviations of the observed canal dimensions of some cohesive canals located in El-Fayoum governorate, the eastern region of Delta in addition to Damietta branch, from those given by Lacey, Blench, and Simons, et al. are investigated.

INTRODUCTION:

The regime equations related to sediment transport is a purely empirical approach developed originally by British engineers working in India and Egypt. It is not a theory in the accurate sence, for it does not give a physical explanation for its findings. The regime theory has in its bases the concept of a channel that may scour or deposit at times but over the climatic cycle the net result is zero. Inglis Ref.(3) stated that channels which not alter appreciably from year to year although they may vary during the year are said to be in regime.

Some misconceptions about the meaning of the term regime exist. Frequently it has come to mean in equilibrium, but it must be stressed that the equilibrium of a transient nature. According to Blench to declar that a river in regime is comparable in the general sense to state that a country acquired a climate.

REGIME EQUATIONS:

It could be said that the regime method started with Kennedy in 1895. For twenty two canals in the upper Bori Doab of Punjab, Kennedy derived an expression in terms of velocity and depth.

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$$V = 0.55\ D^{0.64} \quad \text{m/sec.} \qquad .....(1)$$

where, V is the critical mean velocity at which for a given mean water depth D silting is just prevented.

Lacey's Equations:

The Lacey's equations are given as follows Ref.(10).

$$P = 4.8326\ Q^{1/2} \qquad .....(2)$$

$$d_{mm} = f^2/2.52 \qquad .....(3)$$

$$A = 2.282\ Q^{5/6}/f^{1/3} \qquad .....(4)$$

$$R = 0.4725\ Q^{1/3}/f^{1/3} \qquad .....(5)$$

$$V = 0.4382\ Q^{1/6}\ f^{1/3} \qquad .....(6)$$

in which;

V = critical mean velocity;
f = silt factor;
d = d_{50} = median particle size in mm;
R = hydraulic radius;
S = bed slope;
Q = water discharge; and
P = channel wetted perimeter; after making the substitution.
V = Q/PR; it is possible to eliminate P and R from (2) through (5) with the result.

$$S = \frac{f^{5/3}}{3169.8\ Q^{1/6}} \qquad .....(7)$$

The silt factor is poorly defined in equation (3) it must be determined by other factors beside the particle size, notably the sediment concentration which was made by Blench.

Blench's Equations:

The regime equations by Blench seem to have more generality than those given by Lacey Ref.(3). They are based on majority of field observations occured in Pakistan, India, and some data from Egypt in addition to laboratory data. Inglis (1948) Ref.(3) gave a set of regime equations similar to those given by Blench.

Blench presented three equations based on two silt factors, a bed factor f_b and side factor f_s. The two factors are defined in the following way

$$f_b = \frac{V^2}{D} \qquad \text{.....(8)}$$

$$f_s = \frac{V^3}{B} \qquad \text{.....(9)}$$

in which;

V = mean velocity;
B = mean width; and
D = mean water depth.

The three independent regime equations are

$$B = (f_b \; Q/f_s)^{1/2} \qquad \text{.....(10)}$$

$$D = (f_s . Q/f_b^2)^{1/3} \qquad \text{.....(11)}$$

$$S = \frac{f_b^{5/6} \; . \; f_s^{1/2} \quad y^{1/4}}{3.63 \; (1 + \frac{c}{233}) \; .g.Q^{1/6}} \qquad \text{.....(12)}$$

Where, y is the kinematic viscosity of water and c is the sediment concentration in parts per million by weight (p.p.m.).

The value of side factor varies from 0.1 to 0.3 depending on the cohesiveness of the bank material Ref.(5).

The recommended value of bed factor is;

$$f_b = 0.579 \; \sqrt{d} \;\; (1 + 0.12 \; c) \qquad \text{.....(13)}$$

The indian canals which supplied much of the data for Lacey and Blench equations have a sand bed of particle 0.1 mm $< d_{50} <$ 0.6 mm and slightly cohesive to cohesive banks. A typical canals is trapezoidal with side slope of about two horizontal to one vertical. The breadth depth ratio 4 $< B/D <$ 30 and discharge 0.03 $< Q < 300$ m^3/sec. A further limitation of indian data is that they came from canals whose sediment is usually controlled. It is usually less than 500 p.p.m. Ref.(4).

Simons-Albertson's Equations:

Based on the lack of application of the regime equations in the United States, Simons and Albertson made a collection of field data from north american sources and using the indian data, Table (1). They gave the following equations:

$$P = K_1 \, Q^{1/2} \qquad \text{.....(14)}$$

$$B = 0.9 \, P \qquad \text{.....(15)}$$

$$B = 0.92 \, B_s - 0.61 \qquad \text{.....(16)}$$

$$R = K_2 \, Q^{0.36} \qquad \text{.....(17)}$$

$$Y = 1.21 \, R \text{ for } R < 2.1 \text{ m.} \qquad \text{.....(18)}$$

$$Y = 0.61 + 0.93 \, R \text{ for } R > 2.1 \text{ m.} \qquad \text{.....(19)}$$

$$V = K_3 \, (R^2.S)^n \qquad \text{.....(20)}$$

$$\frac{C^2}{g} = \frac{V^2}{gYS} = K_4 \left(\frac{V.B}{y}\right)^{0.37} \qquad \text{.....(21)}$$

in which;

C = Chezy's roughness coefficient;
B = mean width;
B_s= surface width;
Y = depth of flow; and
y,P,R, and S have their usual meaning values of coefficients K_1, K_2, K_3, K_4 and n depend on the type of canal as in Table (2).

Limitations:

The regime methods were generally derived for bed load estimation with little account being given to the effect of suspended load or wash load. The equations are generally developed for steady state conditions, where the discharges are steady and the sediment loads are steady; and for canals which have adjusted their width, depth and slope to final values. The developments of the equations have largely for straight channels in alluvium, little account was made for the effect of meandering.

ble (1): Range of Data used by Simons & Albertson (After Raudikvi 1976).

	Number	Discharge m^3/sec.		Slope x 10^3		Average sediment concentration p.p.m.	d mm
		Min.	Max.	Min.	Max.		
an luis alley Color.	15	0.48	42.5	0.79	9.70	-	20 - 80
unjab India	42	0.14	254.9	0.12	0.34	238	0.43
ind India	28	8.81	256.5	0.059	0.100	156-3590	0.0346 - 0.1642
mperial alley Calif.	4	-	-	-	-	2500-8000	-
rrigation anwy Col. Neb.	24	1.22	29.4	0.058	0.387	-	0.028-7.6

able (2): Coefficients for Simon and Albertson's Eqns.in Metric System (After Henderson, 1970).

Type of Material	K_1	K_2	K_3	K_4	n
Sand bed and banks	6.34	0.572	9.28	0.33	0.33
Sand bed and cohesive banks	4.71	0.484	10.67	0.54	0.35
Cohesive bed and banks	3.98	0.407	-	0.87	-
Coarse non cohesive material	3.17	0.253	10.67	-	0.29
Sand bed and cohesive banks with heavy sediment load.	3.08	0.374	9.71	-	0.29

Table (3): Bahr Yusuf Distributaries (1980).

Name	Max. Q m^3/sec.	Average Q m^3/sec.	Standard deviation m^3/sec.	Coefficient of variation C_v	Frequency of max Q (36)
Sennoures	5.630	3.890	1.260	0.324	2
El-Zawya	1.792	1.343	0.354	0.264	2
Senrou	2.350	1.404	0.523	0.373	5
Talat	2.980	2.190	0.785	0.359	4
Wahby	14.780	10.770	3.706	0.344	2
Abou Seer	0.630	0.344	0.118	0.344	3
Aroose	1.921	1.565	0.513	0.330	13
El-Mahgara	0.1302	0.078	0.026	0.330	1
Kohafa	0.1206	0.081	0.0314	0.387	6
El-Aalam	1.934	1.480	0.500	0.337	3
Tanhala	4.220	3.070	1.072	0.349	3
Dar El Ramad	0.1353	0.0968	0.0348	0.361	6
Hawwara	0.2851	0.232	0.073	0.312	19
Baga	0.1096	0.1096	zero	zero	36
El-Agoose	0.246	0.201	0.053	0.265	15
Bahr Yusuf (1980)	66.90	47.81	14.34	0.30	2
Bahr Yusuf (1981)	61.23	47.41	12.74	0.27	2
Bahr Yusuf (1982)	59.93	46.55	12.74	0.274	2

Table (4): Damietta Branch (1976).

Frequency of max. discharge	Chainage K.M.	Max. Q m^3/sec.	Average Q m^3/sec.	Standard deviation m^3/sec.	C_v	Name
1/30	89.00	132.52	73.49	33.28	0.45	Zefta barrge
1/30	143.50	132.52	73.50	33.29	0.453	Mansoura lock
1/30	171.00	132.52	69.19	33.36	0.48	Bosat stn
1/30	201.00	128.93	58.18	30.78	0.53	Kafr Saad stn
1/30	212.80	123.72	56.02	30.08	0.54	El-Rassasy feeder
1/30	221.5	105.2	48.60	29.87	0.615	El-Enania lock
1/20	89.00	109.20	63.81	32.09	0.50	Ten days average discharge
1/20	143.50	109.20	64.67	30.76	0.48	
1/20	171.00	98.78	59.10	29.15	0.491	
1/20	201.00	79.43	46.04	22.91	0.50	
1/20	212.80	78.27	42.99	21.82	0.51	
1/20	221.50	77.12	33.28	26.96	0.81	

able (5) Actual Measurements
(Mean values of three successive cross sections)

ghlola 1977/1978.

c. No.	A m^2	Y m	B_s m	P m	B m	D m	R m	S $\times10^5$
1	15.00	1.98	10.10	11.30	7.53	1.48	1.33	-
2	12.17	1.65	10.13	11.37	7.45	1.22	1.07	6.67
3	8.33	1.60	6.97	8.40	5.22	1.20	0.994	-
4	8.17	1.50	7.73	8.94	5.44	1.057	0.91	4.40
5	6.23	1.35	5.80	7.30	4.61	1.077	0.85	7.50
6	4.50	1.283	5.63	6.53	3.50	0.80	0.68	1.90
7	5.15	1.27	6.07	6.63	4.09	0.847	0.773	10.33

-Zahaira 1976/1977

c. No.	A m^2	Y m	B_s m	P m	B m	D m	R m	S $\times10^5$
1	21.33	2.233	12.77	14.70	9.55	1.67	1.453	9.30
2	13.83	1.833	8.27	12.40	7.55	1.293	1.133	2.30
3	6.20	1.475	9.50	10.15	6.43	1.04	0.935	-
4	5.67	1.200	6.367	7.23	4.723	0.89	0.783	3.20
5	2.50	0.967	3.700	4.533	2.56	0.67	0.547	-

oha 1978/1979.

c. No.	A m^2	Y m	B_s m	P m	B m	D m	R m	S $\times10^5$
1	10.83	1.85	8.90	10.13	5.77	1.20	1.05	9.75
2	3.25	0.87	4.67	5.27	3.70	0.69	0.607	11.70
3	2.50	0.70	4.70	5.033	3.58	0.533	0.497	5.40

oha 1957/1958.

c. No.	A m^2	Y m	B_s m	P m	B m	D m	R m	S $\times10^5$
1	8.633	1.500	7.50	8.433	5.793	1.153	1.021	8.80
2	3.82	1.233	5.467	6.067	3.097	0.693	0.627	8.50
3	3.00	0.830	4.57	4.97	3.607	0.653	0.600	7.71

Table (6): Actual Measurements.
(Mean values of three successive cross sections)

Bahr Yusuf Distributaries. (1980)

Name of canal	A m^2	Y m	P m	B_s m	B m	R m	D m	S $\times10^5$
Sennoures	4.50	0.85	8.60	8.20	5.29	0.526	0.55	-
El-Zawya	9.25	1.33	10.13	9.07	6.93	0.913	1.02	-
Senro	9.75	0.98	12.57	11.57	9.98	0.778	0.84	-
Talat	8.85	1.19	11.16	10.52	7.46	0.793	0.84	-
Wahby	28.5	1.90	21.40	20.45	15.00	1.330	1.39	-
Abouseer"	6.13	1.10	8.13	7.77	5.58	0.760	0.79	-
Aroose	13.1	1.63	12.57	11.83	7.98	1.042	1.11	-
El-Mahgara	1.75	0.60	4.27	3.77	2.99	0.406	0.46	35.71
Kohafa	0.68	0.38	2.73	2.47	1.94	0.250	0.28	31.15
El-Aslam	13.5	1.62	12.07	10.63	8.35	1.120	1.27	31.00
Tanhala	16.13	1.83	15.23	14.10	8.95	1.055	1.14	74.60
Dar ElRamad	1.25	0.30	0.40	4.30	4.17	0.326	0.29	16.60
Hawwara	2.42	0.73	4.10	3.80	3.33	0.573	0.64	-
Baga	1.60	0.60	4.16	3.63	2.67	0.384	0.44	41.06
El-Agoose	2.45	0.63	5.50	5.00	3.98	0.441	0.49	-

Table (7): Median Particle Sizes, Side Factors and Bed Factors For Canals Under Study.

	Damietta Branch c=0.0		Damietta Branch c=500p.p.m		Zaghlola	El-Zahiara	Shoha		Bahr Yusuf Distributaries
	K.M. 171.0	K.M 221.5	K.M 171.0	K.M 221.5			c=0.0 p.p.m	c=500 p.p.m	
d_{50} mm	0.06	0.06	0.06	0.06	0.002	0.006	0.05	0.05	0.05
f_s	0.10	0.10	0.10	0.10	0.300	0.300	0.30	0.30	0.20
f_b	0.14	0.14	15.25	15.25	0.026	0.045	0.13	7.93	0.13

Available actual bed slopes were caluclated from the actual bed levels, obtained from the longitudinal sections. This calculation was based on the method of least square. Table (5) gives the actual section properties for Zaghlola 1977/1978, El-Zahiara 1976/1977, Shoha 1978/1979, and Shoha 1957/1958. The observed section properties of Bahr Yusuf's distributaries, 1980, are given in Table (6).

Soil samples were collected and analysed mechanically. The median particle size for each sample was obtained. Zaghlola, El-Zahiara and Shoha were found to have cohesive bed and banks. Bahr Yusuf and its distributaries; at the selected sections, were considered to have a sand bed and cohesive banks. Table (7) gives the median particle size and the proposed coefficients for every type of soil under investigation. The sediment load before the erection of Aswan High Dam was considered to have the value of 500 p.p.m. in average, during the year Ref.(12).

Generally, for canals under investigations Lacey's equations provided higher values for the wetted perimeter, hydraulic radius, consequently water area, and also smaller values of bed slopes, than those given by Simons-Albertson's equations. The values of bed slope given by Simons-Albertson's equations are bigger than the corresponding values given by the two other approaches.

The values of velocity given by Simons Albertson's equations of Dakahlia region (Zaghlola, El-Zahiara and Shoha) were bigger than those given by both Lacey and Blench's equations. In El-Fayoum region Blench's equations provided higher values of velocity than the corresponding values given by the other two approaches.

Equation (2) of Lacey shows that the wetted perimeter of stable channel is constant for a given discharge and independent of the finess of silt which is not true. However it is well known that the silt size influence the shape of cross sections. Coarse material will exhibit larger value of B_s (B_s=P for wide rivers). Lacey advocated use of only wetted perimeter for rivers. Even this formula was shown to apply to rivers on the basis of limited data comprising only seven observations Ref.(2). Therefore it was considered to examine the fitness of Lacey's equations to more extensive data.

Blench's equations do allow for varying of bank cohesion although these equations show that B and D are very sensitive to errors in bed and side factors which could be estimated arbitrary; the engineer might be advised to select a test reach of the canals and investigate both the side factor f_s and bed factor f_b by himself.

RESULTS AND ANALYSES:

Parallel with the development of regime equations in India similar work was going in Egypt, Molesworth, et al. (1917), Buckley (1919), Kinder (1919) and Chaleb (1929 - 1930) Ref.(3). All of them have in common a Kennedy type relationship and breadth slope relationship. An account of these formulae is given in Leliavsky Ref.(6).

The regime equations under study were applied to two types of irrigation canals; canals subjected to the system of irrigation turns which are Zaghlola, El-Zahiara and Shoha, and those which are used as carriers such as Bahr Yusuf's distributaries. Also the different approaches were applied to some sections along Damietta branch of the river Nile and Bahr Yusuf downstream El-Lahoun regulator.

Water discharges at the selected cross sections for Zaghlola, El-Zahiara and Shoha were based on the water duty and area served. Water losses should be considered in estimating the actual discharge at every particular section; for main and secondary canals, losses vary between 10% during winter and 20% during summer. These losses are in the form of seepage losses, evaporation from water surface, transpiration of aquatic plants and intake leaks Ref.(11). However the actual water duty was considered to be 60 m^3/fedd./day.

Discharges of Bahr Yusuf just downstream El-Lahoun regulator, its distributaries and Damietta branch were obtained from Ministry of Irrigation Refs.(7, 8). The average discharges during the year, standard deviations, and coefficients of variation for Bahr Yusuf and most of its distributaries are given in Table (3) and for Damietta branch are given in Table (4). A comparison between the coefficients of variation in the two tables demonstrates that the discharge of Damietta branch is more variable than the discharge of Bahr Yusuf or its distributaries, during the year.

The canal cross sections were chosen in straight reaches and being in their natural conditions, with the possible minimum influences of any hydraulic structures.

Section properties at each location were represented by the arithmetic mean of the properties of three successive cross sections each of about 200 m apart.

The water area of every natural cross section was planimetred, using a planimeter having an accuracy of 0.1 m^2.

These equations overestimated the water depth and underestimated the mean depth Tables (8, 12 and 13). This result implies a serious drawback in Blench's approach. Increasing the sediment concentration decreased the water depth and water area; increased the critical mean velocity, bed slope and mean width of the channel Table (12).

Due to the approximate nature of Simons-Albertson's equations, there are minor geometrical incompatabilities in the results given by these equations. One of them has already been shown in this research R.P $<$ B.Y, Tables (9 & 10), although the two values should be equal giving the water area. Also P $< B_s$, although P should be greater than B_s. None of these errors are serious as they are no larger than 12% which could be accepted in this type of work.

For good results of Simons-Albertson's equations the bed load concentration should be less than 500 p.p.m. Ref. (3). No account was made, by Simons-Albertson's equations, for varying the sediment concentration. Also the equation did not allow for the variations of the median particle size inside any particular type of soil.

For Damietta branch, the computed section properties, using the different approaches, deviate radically from the actual properties, both before and after the erection of Aswan High Dam Table (13). This could be due to a more variable discharge than the case of canals. Blench's equations underestimated the mean width and over estimated the mean water depth and bed slope. Also Lacey's approach underestimated the wetted perimeter, hydraulic radius and water area. All section properties were underestimated by using Simons-Albertson's method. However little contribution have been made for the regime equations in rivers as an accurate data are usually not available.

In case of Bahr Yusuf, Blench's equations underestimated the mean width and water area and over estimated the mean water depth. Lacey's equations may provide acceptable results for hydraulic radius, wetted perimeter and water area. Simons-Albertson's approach could also provide acceptable results for more section properties as given in Table (13). It may be said better results could be achieved in case of Bahr Yusuf as its discharge is less variable than the discharge of Damietta branch Tables (3 & 4).

Table (8): Bahr Yusuf Distributaries (1980).

Name	Blench's Equations					Lacey's Equations				
	B m	D m	A = B.D m^2	V m/sec.	S $x10^5$	P m	A m^2	R m	V m/sec.	S $x10^5$
Sennoures	1.92	4.06	7.80	0.72	10.64	11.47	13.617	1.187	0.414	4.21
El-Zawya	1.08	2.77	2.99	0.60	12.88	6.47	5.173	0.800	0.342	5.55
Senro	1.24	3.03	3.76	0.63	12.32	7.41	6.574	0.887	0.358	4.87
Talaat	1.40	3.28	4.59	0.65	11.84	8.34	8.01	0.960	0.372	4.68
Wahby	3.11	5.60	17.42	0.85	9.06	18.58	30.43	1.638	0.486	3.57
Abouseer	0.64	1.96	1.25	0.50	15.34	3.84	2.20	0.572	0.287	6.04
Aroose	1.12	2.83	3.17	0.61	12.74	1.921	1.59	0.830	0.346	5.04
El-Mahgara	0.29	1.16	0.34	0.38	19.95	1.74	0.59	0.338	0.221	7.89
Kohafa	0.28	1.13	0.32	0.38	20.20	1.68	0.55	0.330	0.218	7.99
El-Aalam	1.13	2.84	3.21	0.60	12.72	6.72	5.58	0.830	0.346	5.03
Tanhala	1.66	4.69	7.79	0.54	11.17	9.93	10.71	1.078	0.394	4.42
Dar El-Ramad	0.30	1.17	0.35	0.39	19.82	1.78	0.61	0.343	0.222	7.84
Hawwara	0.43	1.50	0.65	0.44	17.50	2.58	1.13	0.439	0.252	6.92
Baga	0.27	1.09	0.29	0.38	20.53	1.60	0.51	0.319	0.215	8.11
Aroose	0.40	1.43	0.57	0.43	17.94	2.40	1.00	0.418	0.246	7.09

Table (9): Simons-Albertson Equations.

Bahr Yusuf Distributaries (1980).

Name	P m	B m	B_e m	R m	Y m	$A_1 = P.R$ m^2	$A_2 = B.Y$ m^2	$A_{av.}$ m^2	V m/sec.	S_1 $x10^4$	S_2 $x10^4$	$S_{av.}$ $x10^4$
Sennoures	11.18	10.06	11.60	0.90	1.09	10.62	10.97	10.80	0.52	1.43	1.54	1.49
El-Zawya	6.31	5.68	6.84	0.60	0.73	3.79	4.15	3.97	0.45	2.08	2.22	2.15
Sanrou	7.22	6.50	7.73	0.66	0.80	4.77	5.20	4.99	0.47	1.96	2.07	2.02
Talat	8.13	7.32	8.62	0.72	0.87	5.85	6.37	6.11	0.49	1.88	1.96	1.92
Wahby	18.11	16.30	18.38	1.28	1.55	23.18	25.27	24.23	0.61	1.14	1.17	1.16
Abouseer	3.74	3.37	4.33	0.41	0.60	1.53	1.69	1.61	0.39	2.89	3.04	2.97
Aroose	6.53	5.88	7.05	0.61	0.74	3.98	4.35	4.17	0.46	2.15	2.26	2.21
El-Mahgara	1.70	1.53	2.33	0.23	0.28	0.39	0.43	0.41	0.32	5.13	5.43	5.28
Kohafa	1.64	1.48	2.27	0.23	0.28	0.38	0.41	0.40	0.30	4.19	4.94	4.57
El-Aalam	6.55	5.90	7.08	0.61	0.74	4.00	4.37	4.19	0.46	2.15	2.26	2.21
Tanhala	9.68	8.71	10.13	0.81	0.98	7.84	8.54	8.19	0.52	1.77	1.80	1.79
Dar ElRamad	1.73	1.56	2.36	0.24	0.29	0.42	0.45	0.44	0.31	4.26	4.94	4.60
Hawwara	2.52	2.27	3.13	0.31	0.38	0.78	0.86	0.82	0.35	3.69	4.00	3.85
Baga	1.56	1.40	2.19	0.22	0.27	0.34	0.38	0.36	0.30	4.63	5.22	4.93
Al-Agoose	2.34	2.11	2.96	0.29	0.35	0.68	0.74	0.71	0.35	4.21	4.46	4.34

Table (10): Simons-Albertson Equations

Zaghlola

Sec. No.	P m	B m	B_e m	R m	Y m	P.R m^2	B.Y m^2	A_{av} m^2	V m/sec.	S_1 $x10^4$	S_2 $x10^4$	S_{av} $x10^4$
1	11.68	10.51	12.09	0.884	1.07	10.33	11.25	10.79	0.80	5.39	1.93	3.66
2	11.15	10.04	11.58	0.855	1.04	9.53	10.44	9.99	0.79	5.55	1.97	3.76
3	10.12	9.11	10.57	0.800	0.97	8.10	8.84	8.47	0.76	5.65	2.07	3.86
4	9.50	8.55	9.96	0.761	0.92	7.23	7.87	7.55	0.75	6.00	2.17	4.09
5	8.26	7.43	8.74	0.689	0.83	5.69	6.17	5.93	0.73	6.74	2.42	4.58
6	5.84	5.26	6.38	0.536	0.65	3.13	3.42	3.28	0.66	8.26	2.99	5.63
7	2.97	2.67	3.57	0.330	0.40	0.98	1.07	1.03	0.54	11.93	4.50	8.22

El-Zahiara

Sec. No.	P m	B m	B_e m	R m	Y m	P.R m^2	B.Y m^2	A_{av} m^2	V m/sec.	S_1 $x10^4$	S_2 $x10^4$	S_{av} $x10^4$
1	10.98	9.88	11.40	0.845	1.02	9.28	10.08	9.68	0.79	5.68	2.01	3.85
2	9.50	8.55	9.96	0.761	0.92	7.23	7.87	7.55	0.75	6.00	2.17	4.09
3	5.65	5.09	6.20	0.524	0.63	2.96	3.21	3.09	0.65	8.23	3.04	5.64
4	4.33	3.90	4.90	0.432	0.52	1.87	2.03	1.95	0.61	10.00	3.69	6.85
5	2.78	2.50	3.38	0.314	0.38	0.87	0.95	0.91	0.53	12.39	4.71	8.55

Shoha

Sec. No.	P m	B m	B_e m	R m	Y m	P.R m^2	B.Y m^2	A_{av} m^2	V m/sec.	S_1 $x10^4$	S_2 $x10^4$	S_{av} $x10^4$
1	6.29	5.66	6.82	0.566	0.69	3.56	3.91	3.74	0.67	7.74	2.80	5.27

Table (11): Lacey's Equations

Zaghlola

Sec. No.	Q m^3/sec.	P m	A m^2	R m	V m/sec.	S x10^6
1	8.611	14.180	33.15	2.340	0.260	2.640
2	7.850	13.540	30.69	2.270	0.256	2.690
3	6.460	12.280	26.09	2.130	0.248	2.760
4	5.695	11.533	23.49	2.038	0.243	2.830
5	4.310	10.033	18.62	1.860	0.232	2.960
6	2.150	7.080	10.43	1.473	0.206	3.330
7	0.556	3.600	3.38	0.940	0.165	4.180

El-Zahiara

1	7.617	13.340	24.78	1.860	0.307	6.840
2	5.695	11.533	19.45	1.690	0.293	7.180
3	2.014	6.860	8.18	1.193	0.246	8.530
4	1.181	5.252	5.24	1.000	0.225	9.330
5	0.486	3.370	2.502	0.743	0.194	10.81

Shoha

1	2.50	7.641	6.90	0.903	0.363	4.820
2	1.11	5.092	3.50	0.690	0.317	5.710
3	0.63	3.840	2.19	0.570	0.288	6.040

Table(12): Blench's Equations.

Zaghlola

Sec. No.	B m	D m	A=D.B m^2	V m/sec.	S x 10^5
1	0.85	15.64	13.29	0.65	2.68
2	0.81	15.16	12.28	0.64	2.72
3	0.74	14.21	10.52	0.61	2.81
4	0.69	13.63	9.41	0.61	2.87
5	0.60	12.40	7.44	0.58	3.01
6	0.43	9.85	4.24	0.51	3.38
7	0.22	6.27	1.38	0.40	4.24

El-Zahiro

Sec. No.	B m	D m	A=D.B m^2	V m/sec.	S x 10^5
1	1.08	10.41	11.24	0.68	4.32
2	0.93	9.45	8.79	0.65	4.54
3	0.55	6.68	3.67	0.55	5.39
4	0.42	5.59	2.35	0.50	5.89
5	0.27	4.16	1.12	0.43	6.83

Shoha c = 0.00

Sec. No.	B m	D m	A=B.D m^2	V m/sec.	S x 10^4
1	1.04	3.54	3.68	0.60	1.26
2	0.70	2.70	1.89	0.59	1.45
3	0.52	2.24	1.17	0.54	1.59

Shoha **C = 500 P.P.m.**

1	8.13	0.290	2.36	1.06	1.23
2	5.42	0.174	0.94	1.16	1.41
3	4.08	0.144	0.59	1.07	1.55

Table (13): Comparison between Actual and Calculated Properties

Damietta Branch (1976), K.M. 221.5

$Q_{max.}$ = 105.2 m^3/sec.

	P m	B m	B_s m	R m	Y m	D m	A m^2	S x10^5	V m/sec.
Actual	286.7	194.1	294.0	6.170	9.33	5.88	172.70	-	-
Lacey	49.57	-	-	3.072	-	-	152.19	2.92	0.69
Blench	-	16.2	-	-	-	5.52	89.42	10.63	1.18
Simons, et al.	65.03	58.53	64.28	3.060	3.46	3.12	200.75	2.99	0.52

Damietta Branch (1938), K.M. = 171.0

$Q_{max.}$ = 132.52 m^3/sec.

	P m	B m	B_s m	R m	Y m	D m	A m^2	S x10^5	V m/sec.
Actual	268.1	204.1	255.0	7.00	9.275	9.535	1876.0	-	-
Lacey	55.63	-	-	3.32	-	-	184.40	2.81	0.72
Blench	-	142.17	-	-	-	0.490	69.66	84.00	1.90
Simons, et al.	72.98	65.68	72.05	3.32	3.700	3.370	242.66	2.95	0.55

Bahr Yusuf (1980), Downstream El-Lahoun Regr.

Max; Q = 66.9 m^3/sec.

	P m	B m	B_s m	R m	Y m	D m	A m^2	S x10^5	V m/sec.
Actual	42.57	29.07	39.47	2.910	4.25	3.130	123.50	36.33	-
Lacey	39.53	-	-	2.709	-	-	107.09	2.79	0.625
Blench	-	6.63	-	-	-	9.260	61.39	7.05	1.090
Simons et al.	38.52	34.67	38.35	2.200	2.66	2.307	88.48	7.50	0.760

Table (18): One Way ANOVA

$F_{0.05,1,28} = 4.2$

Dakahlia (Zghlola, El-Zahiara and Shoha)

Source of variation	d.f.	Mean sum squares	P	B	B_s	R	Y	D	A	S	V
Between Groups	1	s_L^2	0.042	-	-	4.214	-	-	575.30	10.170	-
		s_B^2	-	344.60	-	-	-	902.10	37.260	17.450	-
		s_S^2	36.974	13.09	0.508	1.405	7.754	3.135	158.43	150.93	-
Within Groups	28	s_1^2	10.800	-	-	0.218	-	-	70.400	163.15	-
		s_2^2	-	1.782	-	-	-	10.305	22.470	24.580	-
		s_3^2	8.990	5.700	7.606	0.056	0.114	0.070	19.390	38.057	-
F-Calculated		F_L	0.004	-	-	19.33	-	-	8.100	0.062	-
		F_B	-	193.40	-	-	-	87.540	3.260	0.710	-
		F_S	4.110	2.30	0.070	25.31	68.01	45.110	8.180	0.004	-
Between Groups	1	s_{LB}^2	-	-	-	-	-	-	1059.2	11.380	1.526
		s_{LS}^2	34.52	-	-	10.48	-	-	1337.6	144.86	2.700
		s_{BS}^2	-	492.0	-	-	-	1011.6	16.22	152.14	0.1654
Within Groups	28	s_1^2	-	-	-	-	-	-	66.24	314.37	4.7×10^{-3}
		s_2^2	11.55	-	-	0.203	-	-	63.10	432.04	5.6×10^{-3}
		s_3^2	-	3.982	-	-	-	10.28	15.19	361.47	7.75×10^{-3}
F-Calculated		F_{LB}	-	-	-	-	-	-	16.00	0.040	324.7
		F_{LS}	2.99	-	-	51.63	-	-	21.20	0.003	482.1
		F_{BS}	-	123.60	-	-	-	98.40	1.08	0.004	22.05

Table (19): One-Way ANOVA

$F_{0.05,1,28} = 4.2$

Bahr Yusuf Distributaries 1980.

Source of variation	d d.f.	Mean sum squares	P	B	B_s	R	Y	D	A	S	V
Between Groups	1	s_L^2	167.94	-	-	0.005	-	-	66.402	149.03	-
		s_B^2	-	420.08	-	-	-	48.55	284.75	66.15	-
		s_S^2	151.69	14.17	60.24	0.444	6.475	0.960	156.49	9.769	-
Within Groups	28	s_1^2	23.73	-	-	0.121	-	-	56.260	1.600	-
		s_2^2	-	5.910	-	-	-	0.990	36.640	1.660	-
		s_3^2	22.67	13.700	20.840	0.095	0.192	0.113	45.130	2.524	-
F-Calculated		F_L	7.077	-	-	0.041	-	-	1.180	93.140	-
		F_B	-	71.080	-	-	-	49.04	7.772	39.880	-
		F_S	6.691	1.034	2.890	4.674	33.72	8.50	3.470	3.870	-
Between Groups	1	s_{LB}^2	-	-	-	-	-	-	76.140	16.601	0.762
		s_{LS}^2	0.413	-	-	0.5415	-	-	19.020	82.490	0.170
		s_{BS}^2	-	279.94	-	-	-	63.610	19.050	25.080	0.216
Within Groups	28	s_1^2	-	-	-	-	-	-	39.240	0.0840	0.013
		s_2^2	21.04	-	-	0.1143	-	-	47.730	0.950	0.0076
		s_3^2	-	8.38	-	-	-	0.98	28.110	1.012	0.014
F-Calculated		F_{LB}	-	-	-	-	-	-	1.940	197.63	58.62
		F_{LS}	0.020	-	-	4.740	-	-	0.400	86.83	22.25
		F_{BS}	-	33.41	-	-	-	64.45	0.680	24.78	15.43

STATISTICAL ANALYSES:

(i) Analysis of Variance:

A one-way ANOVA table was used for the analysis of variance between every method used for the estimation of section properties and the actual measurements, and also between the different methods. The large the number of observations on each treatment the smaller will be the standard error of the difference between two treatments means and hence the large the power of the resulting significant test Ref.(1). However 5% level of significance was considered in all analyses.

$$F_{calculated} = \frac{\text{Treatment mean square}}{\text{Residual mean square}} \quad .....(22)$$

(ii) Least Significant Difference:

The next step after a construction of one way ANOVA table, is to decide if this table indicates that there is a significant difference between any two treatments. The least significant difference has to be calculated by the two tailed t-test; using the equation

$$s \,.\, \sqrt{\frac{2}{n}} \,.\, t_{\frac{1}{2}\alpha\,,\; m(n-1)} \quad .....(23)$$

in which;

s = square root of the residual mean square;
α = level of significance;
$m(n-1)$ = degree of freedom;
n = number of observation; and
m = number of treatments = 2.

If the gap between any two means is less than the least significant difference then the treatments are not significantly different.

A one way ANOVA showed that the wetted perimeter given by Lacey's equations, could be accepted at 5% level of significance for all canals under investigation except for Bahr Yusuf distributaries in which this parameter could be accepted at 5% level by the least significant difference. For median particle size d_{50} varies between 0.006 mm and 0.05 mm, the hydraulic radius according to Lacey gave acceptable results at the same level Tables (16 & 17).

The water area was not given directly by Blench, it was calculated by the mean depth D multiplied by the mean width B. A one way ANOVA table provided water area, A, which could be accepted at 5% level of significance, Table (14): One-Way ANOVA

$F_{0.05,1,12} = 4.75$

Zaghlola 1977/1978.

Source of variation	d.f.	Mean sum squares	P	B	B_s	R	Y	D	A	S	V
Between		s_L^2	19.71	-	-	5.300	-	-	1052.15	120.80	-
Groups	1	s_B^2	-	160.34	-	-	-	902.23	0.321	12.95	-
		s_S^2	0.137	35.340	15.541	0.630	3.230	1.19	24.220	1.35×10^4	-
Within		s_1^2	7.951	-	-	0.127	-	-	56.690	0.0730	-
Groups	12	s_2^2	-	1.073	-	-	-	4.807	14.590	0.2030	-
		s_3^2	5.960	4.437	5.608	0.037	0.134	0.043	12.001	115.74	-
F-Calculated		F_L	2.480	-	-	41.732	-	-	18.560	1654.8	-
		F_B	-	149.43	-	-	-	187.691	0.0220	63.790	-
		F_S	0.023	7.965	2.771	17.027	24.104	27.674	2.0180	116.64	-
Between		s_{LB}^2	-	-	-	-	-	-	1089.2	54.650	0.810
Groups	1	s_{LS}^2	23.14	-	-	9.582	-	-	1395.6	1.6×10^4	1.681
		s_{BS}^2	-	346.24	-	-	-	968.91	18.970	1.43×10^4	0.158
Within		s_1^2	-	-	-	-	-	-	58.100	0.1330	0.0038
Groups	12	s_2^2	10.340	-	-	0.124	-	-	55.510	115.67	0.004
		s_3^2	-	3.410	-	-	-	4.803	13.410	115.80	0.0069
F-Caclulated		F_{LB}	-	-	-	-	-	-	18.750	410.90	21.090
		F_{LS}	2.240	-	-	77.270	-	-	25.140	138.41	419.20
		F_{BS}	-	101.5	-	-	-	201.73	1.420	123.49	22.930

Table (15): One Way ANOVA

$F_{0.05,1,8} = 5.32$

El-Zahiara 1976/1977.

Source of variation	d.f.	Mean sum squares	P	B	B_s	R	Y	D	A	S	V
Between		s_L^2	15.00	-	-	0.545	-	-	22.58	22.180	-
Groups	1	s_B^2	-	151.97	-	-	-	188.81	100.00	29.620	-
		s_S^2	49.71	0.168	4.530	0.780	3.600	1.551	138.87	1.52×10^4	-
Within		s_1^2	13.65	-	-	0.137	-	-	60.21	0.06	-
Groups	8	s_2^2	-	2.90	-	-	-	2.804	30.90	0.47	-
		s_3^2	11.344	6.743	9.236	0.0674	0.130	0.136	29.023	154.93	-
F-Calculated		F_L	1.100	-	-	3.980	-	-	0.375	370.45	-
		F_B	-	52.403	-	-	-	67.340	3.240	63.02	-
		F_S	4.382	0.025	0.491	11.57	27.69	11.404	4.785	98.11	-
Between		s_{LB}^2	-	-	-	-	-	-	217.60	103.07	0.477
Groups	1	s_{LS}^2	10.10	-	-	2.63	-	-	273.43	3.27×10^3	0.853
		s_{BS}^2	-	124.05	-	-	-	224.58	3.184	1.38×10^4	0.054
Within		s_1^2	-	-	-	-	-	-	44.55	0.430	0.0052
Groups	8	s_2^2	11.95	-	-	0.1082	-	-	42.68	154.90	0.0053
		s_3^2	-	3.94	-	-	-	2.822	13.37	155.30	0.0087
F-Calculated		F_{LB}	-	-	-	-	-	-	4.88	239.70	91.73
		F_{LS}	0.845	-	-	24.31	-	-	6.41	21.10	160.94
		F_{BS}	-	31.49	-	-	-	79.582	0.24	88.86	6.19

Table (16): One-Way ANOVA

$F_{0.05,1,4} = 7.71$

Shoha, 1978/1979.

Source of variation	d.f.	Mean sum squares	P	B	B_s	R	Y	D	A	S	V
Between Groups	1	s_L^2	8.320	-	-	0.00003	-	-	5.230	0.608	-
		s_B^2	-	38.820	-	-	-	12.270	32.334	0.550	-
		s_S^2	15.323	0.203	2.881	0.2240	1.080	0.466	32.413	96.02	-
Within Groups	4	s_1^2	23.712	-	-	0.168	-	-	68.840	1.587	-
		s_2^2	-	5.775	-	-	-	1.820	38.123	1.613	-
		s_3^2	22.671	13.70	20.84	0.095	0.192	0.113	54.130	2.524	-
F-Calculated		F_L	0.351	-	-	0.00002	-	-	0.076	0.383	-
		F_B	-	6.722	-	-	-	6.742	0.848	0.341	-
		F_S	0.676	0.015	0.138	2.360	5.625	4.124	0.600	38.04	-
Between Groups	1	s_{LB}^2	-	-	-	-	-	-	4.440	2.311	0.253
		s_{LS}^2	2.823	-	-	0.229	-	-	11.490	111.92	0.242
		s_{BS}^2	-	33.410	-	-	-	17.51	0.00005	82.06	5×10^{-5}
Within Groups	4	s_1^2	-	-	-	-	-	-	2.530	0.0104	0.0022
		s_2^2	2.100	-	-	0.014	-	-	2.572	0.590	0.0017
		s_3^2	-	0.710	-	-	-	0.150	1.160	0.600	0.0029
F-Calculated		F_{LB}	-	-	-	-	-	-	4.520	222.21	115.00
		F_{LS}	1.344	-	-	16.36	-	-	4.470	189.70	142.40
		F_{BS}	-	47.06	-	-	-	116.73	4.3×10^{-5}	136.77	0.02

Table (17): One-Way ANOVA

$F_{0.05,1,4} = 7.71$

Shoha 1957/1958.

Source of variation	d.f.	Mean sum squares	P	B	B_s	R	Y	D	A	S	V
Between Groups	1	s_L^2	2.823	-	-	0.0024	-	-	2.730	0.656	-
		s_B^2	-	8.772	-	-	-	1.191	44.560	580.92	-
		s_S^2	11.291	0.0192	1.600	0.277	0.875	0.527	25.420	129.71	-
Within Groups	4	s_1^2	2.300	-	-	0.028	-	-	6.053	0.0507	-
		s_2^2	-	2.098	-	-	-	0.028	3.375	85.850	-
		s_3^2	1.892	1.370	1.571	0.023	0.0441	0.0309	3.684	0.636	-
F-Calculated		F_L	1.227	-	-	0.086	-	-	0.540	12.940	-
		F_B	-	4.181	-	-	-	42.540	13.203	6.77	-
		F_S	5.968	0.014	1.019	12.04	19.84	17.060	5.900	203.95	-
Between Groups	1	s_{LB}^2	-	-	-	-	-	-	25.23	542.55	1.825
		s_{LS}^2	2.823	-	-	0.214	-	-	11.49	111.92	0.242
		s_{BS}^2	-	9.612	-	-	-	0.134	2.67	161.63	0.738
Within Groups	4	s_1^2	-	-	-	-	-	-	2.263	85.810	0.002
		s_2^2	2.10	-	-	0.137	-	-	2.573	0.590	0.0017
		s_3^2	-	2.100	-	-	-	0.071	0.984	86.392	0.0027
F-Calculated		F_{LB}	-	-	-	-	-	-	11.15	6.323	912.50
		F_{LS}	1.344	-	-	1.562	-	-	4.47	189.69	142.35
		F_{BS}	-	4.577	-	-	-	18.873	2.99	1.871	273.33

Table (20): Least Significant Differences.

$t = 2.179$
$0.025;\ 12$

Zaghlole

	P	B	B_s	R	Y	D	A	S	V
$\bar{x}_a - \bar{x}_L$	1.678	-	-	0.87	-	-	12.26	4.154	-
$\bar{x}_a - \bar{x}_B$	-	4.786	-	-	-	11.353	0.214	1.360	-
$\bar{x}_a - \bar{x}_S$	0.14	2.247	1.49	0.30	0.679	0.412	1.860	43.84	-
s_1	2.82	-	-	0.36	-	-	7.53	0.270	-
s_2	-	1.036	-	-	-	2.190	3.82	0.451	-
s_3	2.44	2.110	2.37	0.192	0.366	0.207	3.464	10.76	-
	3.29	-	-	0.420	-	-	8.77	0.315	-
L.S.D.	-	1.21	-	-	-	2.550	4.45	0.525	-
	2.84	2.46	2.76	0.224	0.43	0.241	2.17	12.54	-
$\bar{x}_L - \bar{x}_B$	-	-	-	-	-	-	12.47	2.790	[illegible]
$\bar{x}_L - \bar{x}_S$	1.817	-	-	1.17	-	-	14.12	48.0	0.053
$\bar{x}_S - \bar{x}_B$	-	7.033	-	-	-	11.77	1.650	45.2	0.002
s'_1	-	-	-	-	-	-	7.622	0.365	0.062
s'_2	3.22	-	-	0.352	-	-	7.450	10.76	0.0632
s'_3	-	1.850	-	-	-	2.192	3.662	10.76	0.083
	-	-	-	-	-	-	8.88	0.430	0.072
L.S.D.	3.75	-	-	0.41	-	-	8.68	12.54	0.074
	-	2.16	-	-	-	2.550	4.27	12.54	0.007

L.S.D. = Least Significant Difference.

Mean Value, Standard Deviation and Coefficient of Variation.

	P	B	B_s	R	Y	D	A	S $\times 10^5$	V
$\bar{x}_a$	8.643	5.406	7.490	0.994	1.519	1.097	8.580	4.460	-
$\bar{x}_L$	10.321	-	-	1.864	-	-	20.84	0.306	0.230
$\bar{x}_B$	-	0.620	-	-	-	12.45	9.366	3.100	0.570
$\bar{x}_S$	8.503	7.653	8.980	0.694	0.840	0.685	6.720	48.30	0.720
σ_a	1.889	1.450	2.830	0.183	0.222	0.216	3.630	0.3785	-
σ_L	3.512	-	-	0.463	-	-	10.01	0.0506	0.031
σ_B	-	0.209	-	-	-	3.093	4.000	0.5130	0.082
σ_S	2.890	2.602	2.830	0.183	0.461	0.200	3.290	15.21	0.084
S_L	3.892	-	-	1.030	-	-	15.851	4.157	-
S_B	-	4.791	-	-	-	11.766	4.006	1.461	-
S_S	2.8934	3.438	3.1983	0.3514	0.7144	0.458	3.780	46.40	-
Cv_L	0.4503	-	-	1.091	-	-	1.8474	0.932	-
Cv_B	-	0.8862	-	-	-	10.726	0.4669	0.3274	-
Cv_S	0.3348	0.636	0.427	0.3535	0.4493	0.4180	0.4405	10.404	-

Table (21): Least Significant Difference

El-Zehaira

$t = 2.306$
$0.025,8$

	P	B	B_s	R	Y	D	A	S	V
$\bar{x}_a - \bar{x}_L$	1.732	-	-	0.330	-	-	2.125	2.106	-
$\bar{x}_a - \bar{x}_B$	-	5.513	-	-	-	6.145	4.472	2.434	-
$\bar{x}_a - \bar{x}_S$	3.153	0.183	0.951	0.395	0.848	0.557	5.270	55.04	-
s_1	3.700	-	-	0.370	-	-	7.760	0.245	-
s_2	-	1.703	-	-	-	1.680	5.560	0.690	-
s_3	3.370	2.600	3.040	0.260	0.361	0.370	5.390	12.45	-
	5.510	-	-	0.550	-	-	11.56	0.360	-
L.S.D.	-	2.540	-	-	-	2.500	8.280	1.030	-
	5.020	3.870	4.530	0.390	0.540	0.551	8.030	18.55	-
$\bar{x}_L - \bar{x}_B$	-	-	-	-	-	-	6.600	4.540	0.312
$\bar{x}_L - \bar{x}_S$	1.421	-	-	0.725	-	-	7.395	57.15	0.416
$\bar{x}_S - \bar{x}_B$	-	5.330	-	-	-	6.702	0.800	52.61	0.104
s'_1	-	-	-	-	-	-	6.680	0.660	0.072
s'_2	3.460	-	-	0.330	-	-	6.530	12.45	0.073
s'_3	-	1.990	-	-	-	1.680	3.660	12.46	0.094
	-	-	-	-	-	-	9.950	0.983	0.107
L.S.D.	5.160	-	-	0.492	-	-	9.730	18.55	0.109
	-	2.970	-	-	-	2.503	5.450	18.56	0.140

L.S.D. = Least Significant Difference.

Mean Value, Standard Deviation and Coefficient of Variation.

	P	B	B_s	R	Y	D	A	S $\times 10^5$	V
$\bar{x}_a$	9.803	6.163	8.1214	0.970	1.542	1.113	9.906	2.960	-
$\bar{x}_L$	8.071	-	-	1.300	-	-	12.031	0.8538	0.253
$\bar{x}_B$	-	0.650	-	-	-	7.258	5.434	5.394	0.562
$\bar{x}_S$	6.650	5.980	7.170	0.575	0.694	0.556	4.636	58.00	0.666
σ_a	3.612	2.388	3.038	0.308	0.450	0.345	6.823	0.314	-
σ_L	3.775	-	-	0.420	-	-	8.594	0.145	0.042
σ_B	-	0.307	-	-	-	2.343	3.904	0.916	0.093
σ_S	3.105	2.790	3.040	0.200	0.241	0.392	3.390	17.60	0.094
S_L	4.1534	-	-	0.5341	-	-	8.853	2.100	-
S_B	-	5.520	-	-	-	6.5772	5.9363	2.601	-
S_S	4.4252	2.796	3.1854	0.4428	0.8816	0.681	6.2662	57.79	-
Cv_L	0.4237	-	-	0.5507	-	-	0.8937	0.7095	-
Cv_B	-	0.896	-	-	-	5.910	0.600	0.8790	-
Cv_S	0.4514	0.4537	0.3922	0.4564	0.5717	0.612	0.6326	19.522	-

Table (22): Least Significant Difference.

t = 2.776
0.025,4

Shoha 1978/1979.

	P	B	B_s	R	Y	D	A	S	V
$\bar{x}_a - \bar{x}_L$	1.290	-	-	0.003	-	-	1.330	0.450	-
$\bar{x}_a - \bar{x}_B$	-	3.597	-	-	-	2.022	3.283	0.430	-
$\bar{x}_a - \bar{x}_S$	2.260	0.260	0.980	0.273	0.600	0.394	3.287	5.660	-
a_1	4.870	-	-	0.410	-	-	8.300	1.260	-
a_2	-	2.400	-	-	-	1.350	6.174	1.270	-
a_3	4.760	3.700	4.570	0.310	0.440	0.336	7.360	1.590	-
	11.04	-	-	0.930	-	-	18.82	2.860	-
L.S.D.	-	5.440	-	-	-	3.060	14.00	2.880	-
	10.79	8.390	10.36	0.703	1.00	0.762	24.20	3.610	-
$\bar{x}_L - \bar{x}_B$	-	-	-	-	-	-	1.953	0.880	0.280
$\bar{x}_L - \bar{x}_S$	0.970	-	-	0.276	-	-	1.957	6.110	0.284
$\bar{x}_S - \bar{x}_B$	-	3.337	-	-	-	2.416	0.004	5.230	0.004
$'a_1$	-	-	-	-	-	-	1.590	0.102	0.047
$'a_2$	1.450	-	-	0.118	-	-	1.604	0.768	0.041
$'a_3$	-	0.843	-	-	-	0.387	1.080	0.775	0.054
	-	-	-	-	-	-	4.420	0.231	0.107
L.S.D.	3.290	-	-	0.268	-	-	3.640	1.741	0.093
	-	1.910	-	-	-	0.880	2.450	1.760	0.122

L.S.D. = Least Significant Difference.

Mean Value, Standard Deviation and Coefficient of Variation.

	P	B	B_s	R	Y	D	A	S x10^4	V
$\bar{x}_a$	6.810	4.350	6.090	0.718	1.140	0.808	5.530	1.0025	-
$\bar{x}_L$	5.520	-	-	0.721	-	-	4.200	0.5523	0.323
$\bar{x}_B$	-	0.753	-	-	-	2.830	2.247	1.430	0.603
$\bar{x}_S$	4.550	4.090	5.110	0.445	0.540	0.414	2.243	6.660	0.607
σ_a	2.349	1.005	1.990	0.239	0.507	0.285	3.763	0.626	-
σ_L	1.582	-	-	0.138	-	-	1.985	0.0515	0.031
σ_B	-	0.216	-	-	-	0.538	1.056	0.135	0.058
σ_S	1.302	1.170	1.280	0.0915	0.112	0.101	1.097	1.083	0.049
S_L	2.0413	-	-	0.138	-	-	2.389	0.4531	-
S_B	-	3.6035	-	-	-	2.09235	3.448	0.4483	-
S_S	2.6082	1.1885	1.6121	0.2879	0.6104	0.407	3.4652	5.9170	-
Cv_L	0.2998	-	-	0.192	-	-	0.4321	0.452	-
Cv_B	-	0.8284	-	-	-	2.590	0.624	0.4472	-
Cv_S	0.383	0.2755	0.2647	0.4010	0.5354	0.503	0.6266	7.024	-

Table (23): Least Significant Difference.

t = 2.776
0.025,4

Shoha 1957/1958.

	P	B	B_s	R	Y	D	A	S	V
$\bar{x}_a - \bar{x}_L$	0.970	-	-	0.028	-	-	0.954	0.468	-
$\bar{x}_a - \bar{x}_B$	-	1.710	-	-	-	0.630	3.854	13.92	-
$\bar{x}_a - \bar{x}_S$	1.940	0.080	0.730	0.304	0.540	0.419	2.911	6.580	-
a_1	1.520	-	-	0.167	-	-	2.250	0.225	-
a_2	-	1.450	-	-	-	0.167	1.840	9.270	-
a_3	1.376	1.171	1.253	0.152	0.210	0.176	1.920	0.800	-
	3.450	-	-	0.379	-	-	5.100	0.510	-
L.S.D.	-	3.290	-	-	-	0.389	4.170	21.00	-
	3.120	2.660	2.840	0.345	0.476	0.400	4.350	1.810	-
$x_L - x_B$	-	-	-	-	-	-	2.900	13.45	0.780
$x_L - x_S$	0.970	-	-	0.276	-	-	1.957	6.110	0.284
$x_S - x_B$	-	1.810	-	-	-	0.211	0.943	7.340	0.496
$'a_1$	-	-	-	-	-	-	1.504	9.260	0.045
$'a_2$	1.450	-	-	0.370	-	-	1.604	0.768	0.041
$'a_3$	-	1.450	-	-	-	0.084	0.950	9.300	0.052
	-	-	-	-	-	-	3.410	21.00	0.102
L.S.D.	3.290	-	-	0.840	-	-	3.640	1.740	0.093
	-	3.290	-	-	-	0.190	2.150	21.10	0.118

L.S.D. = Least Significant Difference.

Mean Value, Standard Deviation and Coefficient of Variation.

	P	B	B_s	R	Y	D	A	S x10^4	V
$\bar{x}_a$	6.490	4.170	5.840	0.749	1.188	0.833	5.154	0.0845	-
$\bar{x}_L$	5.520	-	-	0.721	-	-	4.200	0.552	0.323
$\bar{x}_B$	-	5.880	-	-	-	0.203	1.300	14.00	1.103
$\bar{x}_S$	4.550	4.090	5.110	0.445	0.648	0.414	2.243	6.660	0.607
σ_a	1.445	1.170	1.226	0.192	0.275	0.227	2.483	0.314	-
σ_L	1.582	-	-	0.138	-	-	1.985	0.0515	0.031
σ_B	-	1.681	-	-	-	0.063	0.765	13.10	0.0544
σ_S	1.302	1.170	1.280	0.0915	0.112	0.101	1.097	1.083	0.049
S_L	1.856	-	-	0.1408	-	-	2.221	0.2782	-
S_B	-	2.400	-	-	-	0.633	3.930	21.730	-
S_S	2.3364	1.1727	1.4735	0.3175	0.650	0.431	3.111	5.760	-
Cv_L	0.286	-	-	0.188	-	-	0.4308	0.330	-
Cv_B	-	0.5750	-	-	-	0.7601	0.7624	25.73	-
Cv_S	0.360	0.2812	0.2523	0.4239	0.6576	0.517	0.6036	5.750	-

Table (24): Least Significant Difference Dakahlia Inspectorate.

	P	B	B_e	R	Y	D	A	S $\times 10^4$	V
$\bar{x}_e - \bar{x}_L$	0.053	-	-	0.530	-	-	6.193	0.330	-
$\bar{x}_e - \bar{x}_B$	-	4.793	-	-	-	10.305	22.470	0.123	-
$\bar{x}_e - \bar{x}_S$	1.570	0.934	0.184	0.306	0.719	0.457	3.250	5.037	-
s_1	3.290	-	-	0.470	-	-	8.390	0.319	-
s_2	-	1.340	-	-	-	3.210	4.740	0.418	-
s_3	3.000	2.390	2.760	0.240	0.340	0.270	4.400	1.227	-
	2.460	-	-	0.530	-	-	6.270	0.240	-
L.S.D.	-	1.000	-	-	-	2.400	3.540	0.310	-
	2.242	1.785	2.062	0.176	0.253	0.200	3.290	0.920	-
$\bar{x}_L - \bar{x}_B$	-	-	-	-	-	-	8.403	0.460	0.319
$\bar{x}_L - \bar{x}_S$	1.517	-	-	0.836	-	-	9.443	5.370	0.424
$\bar{x}_S - \bar{x}_B$	-	5.727	-	-	-	8.212	1.041	4.910	0.105
$'s_1$	-	-	-	-	-	-	8.140	0.340	0.070
$'s_2$	3.900	-	-	0.451	0.451	-	7.940	1.200	0.075
$'s_3$	-	2.000	-	-	-	3.210	3.900	1.230	0.088
	-	-	-	-	-	-	6.090	0.250	0.051
L.S.D.	2.542	-	-	0.337	-	-	5.940	0.900	0.056
	-	1.492	-	-	-	2.400	2.920	0.920	0.065

L.S.D.=Least Significant Difference.

Mean Value Standard Deviation & Coefficient of Variation.

	P	B	B_e	R	Y	D	A	S $\times 10^4$	V
$\bar{x}_e$	8.663	5.450	7.420	0.910	1.450	1.045	8.380	0.0483	-
$\bar{x}_L$	8.610	-	-	1.440	-	-	14.573	0.1532	0.256
$\bar{x}_B$	-	0.657	-	-	-	8.800	6.170	0.611	0.575
$\bar{x}_S$	7.093	6.384	7.604	0.604	0.731	0.588	5.130	5.520	0.680
σ_e	2.870	1.870	2.430	0.266	0.411	0.303	5.160	0.403	0.680
σ_L	3.790	-	-	0.604	-	-	10.684	0.203	0.050
σ_B	-	0.252	-	-	-	4.530	4.280	0.432	0.083
σ_S	3.120	2.810	3.055	0.200	0.241	0.218	3.4700	1.690	0.093
S_L	3.790	-	-	0.804	-	-	12.350	0.387	-
S_B	-	4.800	-	-	-	8.980	4.817	0.451	-
S_S	3.490	2.962	3.060	0.370	0.758	0.506	4.7550	5.310	-
Cv_L	0.438	-	-	0.880	-	-	1.474	0.801	-
Cv_B	-	0.880	-	-	-	8.590	0.574	0.934	-
Cv_S	0.403	0.543	0.412	0.401	0.523	0.484	0.570	11.00	-

Table (25): Least Significant Difference

$t_{0.025,28} = 2.048$

Bahr Yusuf Distributeries Q_{max}.

	P	B	B_e	R	Y	D	A	S	V
$\bar{x}_e - x_L$	3.346	-	-	0.018	-	-	2.104	3.152	-
$\bar{x}_e - x_B$	-	5.292	-	-	-	1.799	4.357	2.100	-
$\bar{x}_e - x_S$	3.180	0.972	2.004	0.172	0.527	0.253	3.230	0.807	-
s_1	4.870	-	-	0.348	-	-	7.500	1.270	-
s_2	-	2.431	-	-	-	1.000	6.053	1.290	-
s_3	4.760	3.700	4.570	0.308	0.436	0.336	6.720	1.590	-
	3.653	-	-	0.261	-	-	5.630	0.953	-
L.S.D.	-	1.820	-	-	-	0.750	4.540	0.970	-
	3.570	2.775	3.430	0.231	0.329	0.252	5.040	1.193	-
$\bar{x}_L - \bar{x}_B$	-	-	-	-	-	-	2.253	1.052	0.2254
$\bar{x}_L - \bar{x}_S$	0.166	-	-	0.190	-	-	1.126	2.345	0.1054
$\bar{x}_B - \bar{x}_S$	-	4.320	-	-	-	1.037	1.127	1.293	0.120
$'s_1$	-	-	-	-	-	-	6.264	0.290	0.114
$'s_2$	4.590	-	-	0.338	-	-	6.910	0.980	0.0874
$'s_3$	-	2.900	-	-	-	0.990	5.300	1.060	0.1183
	-	-	-	-	-	-	4.700	0.220	0.086
L.S.D.	3.440	-	-	0.254	-	-	5.180	0.735	0.066
	-	2.180	-	-	-	0.743	3.980	0.800	0.089

L.S.D. = Least Significant Difference.

Mean Value, Standard Deviation and Coefficient of Variation.

	P	B	B_e	R	Y	D	A	S $\times 10^4$	V
$\bar{x}_e$	9.110	6.310	8.474	0.713	1.044	0.770	7.990	3.840	-
$\bar{x}_L$	5.764	-	-	0.731	-	-	5.886	0.688	0.3146
$\bar{x}_B$	-	1.018	-	-	-	2.569	3.633	1.740	0.540
$\bar{x}_S$	5.930	5.338	6.470	0.541	0.517	0.517	4.760	3.033	0.420
σ_e	5.036	3.350	4.752	0.318	0.505	0.346	7.325	1.7805	-
σ_L	4.700	-	-	0.374	-	-	7.672	0.1416	0.0814
σ_B	-	0.768	-	-	-	1.362	4.429	0.384	0.138
σ_S	4.470	4.022	4.370	0.298	0.368	0.325	6.050	1.370	0.093
S_L	5.770	-	-	0.3744	-	-	7.960	3.156	-
S_B	-	5.347	-	-	-	2.045	6.213	0.2136	-
S_S	5.486	4.138	4.809	0.3340	0.5283	0.412	6.8582	1.368	-
Cv_L	0.6333	-	-	0.5252	-	-	0.996	0.822	-
Cv_B	-	0.8475	-	-	-	1.959	0.778	0.556	-
Cv_S	0.60221	0.6558	0.5675	0.4825	0.5065	0.535	0.8584	0.3563	-

although B and D could be rejected at the same level. This is for Zahlola, El-Zahiara and Shoha. But for Shoha 1957/1958 the water area could be accepted at the same level using the least significant difference. A comparison between Shoha 1978/1979 and Shoha 1957/1958 may indicate that clear water could provide more acceptable section properties than silty water.

The bed slope introduces many uncertainties even if equations like (7), (12), (20) and (21) give a correct value of minimum bed slope to which the channel will automatically adjust itself it may be possible to use greater slopes with wider channel Ref.(4). A further point is that if as it seems likely equation (2) of wetted perimeter by Lacey is strongly dependent on equation (7) of bed slope, the designer should be were of using equation (2) in natural river, where the bed slope may not have reached its stable value. This is particularly true in coarse alluvium Ref.(4).

Also the ANOVA and Least significant Difference tables demonstrate the degree of accuracy between every pair of approaches in calculating the section properties for canals understudy; i.e. between Lacey's method and Blench's method; Lacey's method and Simons-Albertson's method and between Blench's method and Simons-Albertson's method.

(iii) Coefficient of Variation:

The coefficient of variation is defined as $S/\bar{x}_a$, where S is the standard deviation from the actual mean and $\bar{x}_a$ is the arithmetic mean of the measured section property.

The coefficient of variation could be used for the comparison between the accuracy of the different methods. The section properties which could be accepted by Simons-Albertson's equations are more accurate than those given by Lacey's formulae, for Bahr Yusuf's distributaries, Zaghlola, El-Zahiara, but for Shoha which has a bigger median particle size $d_{50} = 0.05$ mm; Lacey's approach provided more accurate results than the corresponding values given by Simons-Albertson's method. The section propertes which could be accepted at 5% level of significance may exhibit relative larger values of some coefficients of variation, Table (25). This is mainly due to certain error in the actual measurements Ref.(9).

Table (26) demonstrates the section properties of canals under investigation which could be accepted at 5% level of significance. Also the common properties between every two approaches which could be accepted at the same

Table (26): Section Properties Which Could be Accepted at 5% Level of Significance.

Equation	Zaghlola 1977/1978	El-Zahiara 1976/1977	Shoha 1978/1979	Shoha 1957/1958	Dakahlia	Bahr Yusuf Distributaries
Lacey	P	P,R,A	P,R,A,S	P,R,A,S	P,S	P^{*},R,A
Blench	A	A	B,D,A,S	B,A^{*},S	A,S	A
Simons,et al.	P,B_s,B^{*},A	P,B_s,B,A	P,B_s,B,R,Y, D,A	P,B_s,B,R^{*},A,	P,B_s,B, A^{*},S	P^{*},B_s,B,A, R^{*},S
Lacey-Blench	V^{*}	A	A	S	S	A
Lacey - Simons,et al.	P,V^{*}	P,A^{*}	P,A	P,R,A	P,S	P,A
Blench - Simons,et al.	A,V^{*}	A,V^{*}	A,V	B,A,S	A,S	A

* Accepted only by least significant difference.

level when calculated by any one of the two approaches, for example there is no significant difference between the calculated wetted perimeter by using either Lacey's equation or Simons-Albertson equations at 5% level of significance.

It should be emphasized that the analyses in this study were based on the maximum discharges which could have a little frequency during the year Tables (3 & 4). All canals under this investigation like all natural rivers are subjected to flow which is not steady not only does the flow vary with season of the year but it could also vary from year to year. It would be necessary to relate these calculation to some sort of dominant discharge. This could be true for calculations related to depth and breadth, but bed slope does not respond to a pronounced extent to the discharge variation.

CONCLUSIONS:

1) This study has confirmed that neither coefficients nor exponents of the equations are true constants, but they depend on the locality of the channel and the value of sediment discharge. This is must be expected as the regime equations are not based on rational deduction but they are equation of an empirical nature.

2) Discrepancies were observed between calculated properties and field data as well as between the results from various formulae under different conditions.

3) Simons-Albertson's method gives values of some section properties closest to the natural conditions Lacey's equations too, give reasonable results, but Blench's equations overestimate the depth and underestimate the mean width, but they could provide water area accepted at 5% level of significance.

4) Lacey's equations could possibly represent an alternative solution for some section properties especially for the wetted perimeter and hydraulic radius, as indicated in Table (26), but the designer would probably be safer with Simons-Albertson's equations, which have shown to fit a comprehensive range of data.

5) The study revealed that the more deviation of discharge from steady condition, the more discrepancies between the observed and calculated section properties (Damietta branch). This could be true as most of the regime equations were usually derived for steady state conditions. Clear water could provide more accurate results than silty water.

6) It was found in all canals under investigation that most of their natural cross sections exhibit wider surface breadths, and shallower depths than the designed typical sections (Ornakes) given by Ministry of Irrigation. However it would be recommended to collect more extensive data in order to establish more accurate regime equations being more relevant to the egyptian canals especially after the erection of Aswan High Dam.

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APPENDIX (II) NOTATION:

The following symbols are used in this paper.

A = water area;
ANOVA = analysis of variance;
B = water mean width;
C = chezy's roughness coefficient;
C_v = coefficient of variation;
c = sediment concentration in p.p.m.;
D = mean water depth A/B_s;
d.f. = degree of freedom;
d_{50} = median particle size in mm;
F = F-test;
f = silt factor;
f_b = bed factor;
f_s = side factor;
g = acceleration due to gravity;
K_1, K_2, K_3, K_4 = coefficient used for Simons-Albertson's eqns.;
L.S.D. = least significant difference;
m = number of treatments;
n = coefficient;
= number of observations or calculated properties;
Q = water discharge;
R = hydraulic radius;
S = critical bed slope;
= standard deviation from the actual mean;
S_{av} = average bed slope;
s = square root of the treatments mean square;
s_1 = square root of the residual mean square using Lacey's equations;
s_2 = square root of the residual mean square using Blench's equations;
s_3 = square root of the residual mean square using Simons-Albertson's equations.
${}'s_1$ = square root of the residual mean square within Lacey and Blench's equations;
${}'s_2$ = square root of the residual mean square within Lacey and Simons-Albertson equations;
${}'s_3$ = square root of the residual mean square within Blench and Simons-Albertson equations;
$\bar{x}_a$ = mean of the actual measurements;
$\bar{X}$ = mean of the calculated values;
α = level of significance;
ν = kinematic viscosity of water; and
σ = standard deviation.

Subscripts

a = actual measurements;
B = Blench's equations;
L = Lacey's equations;
S = Simons-Albertson's equations;
LB = Lacey-Blench;
LS = Lacey-Simons-Albertson; and
BS = Blench-Simons-Albertson.