Enhancing water quality in agricultural drains in Middle Delta region

Under supervision

Prof. Dr. Ahmed Wagdy   Dr. Yasmin Nassar

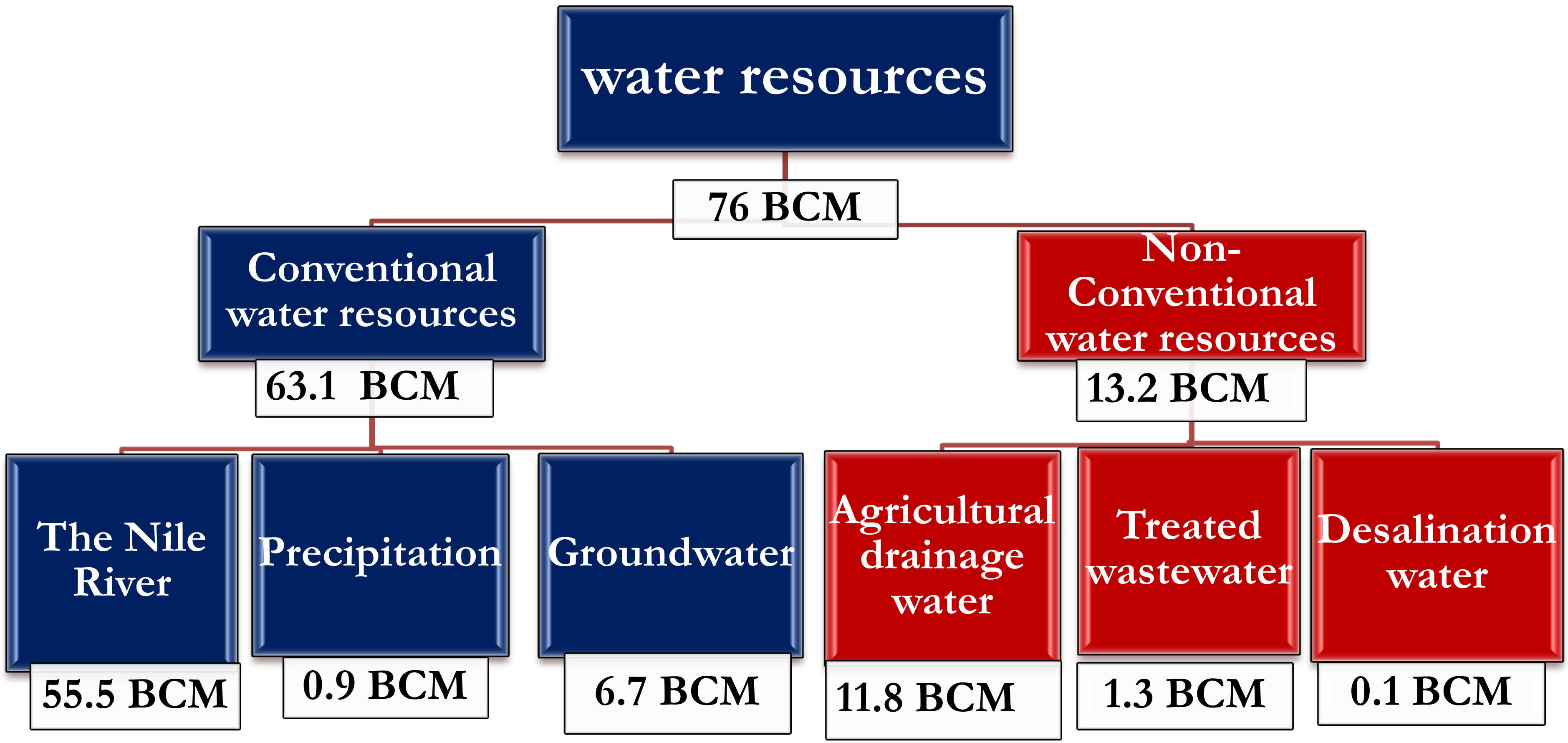
Prepared by

Eng. Emad Mahmoud

Outline

- Problem statement.
- Research objectives.
- Research methodology.
- BOD model.
- Decision Support System (DSS).
- Application.
- Results and Conclusions.
- Recommendations.

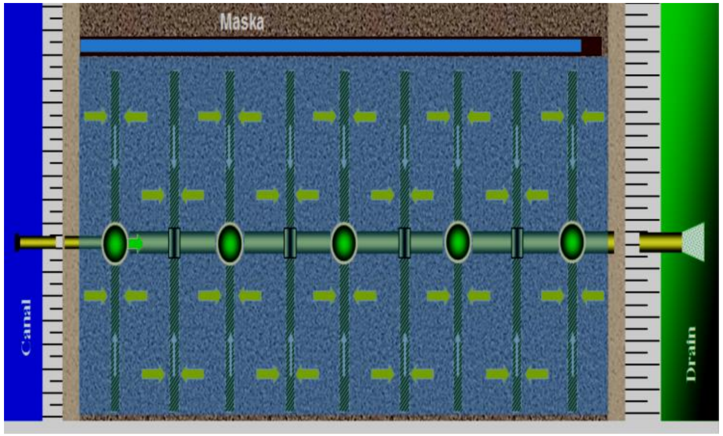
Water Resources in Egypt

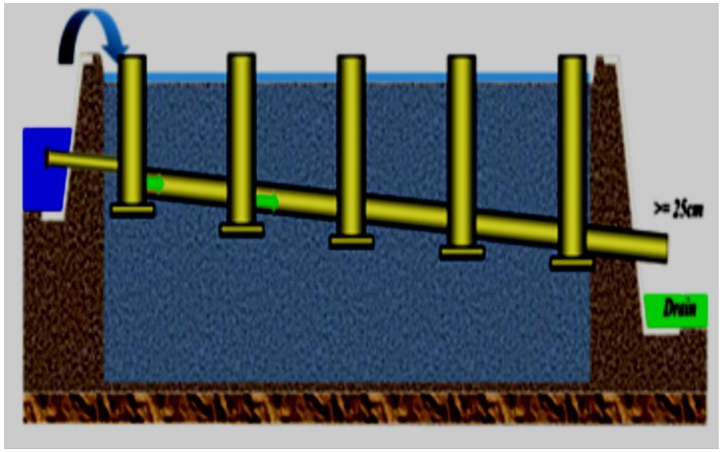


* MWRI-Irrigation Sector 2014

Agriculture drainage water

- It is proposed to substitute shortage in irrigation water by the available agriculture drainage water.
- The Planned drainage water reuse in Delta by 2017 is **8.468** BCM out of **13** BCM/ year. (NWRP 2005).





Problem statement

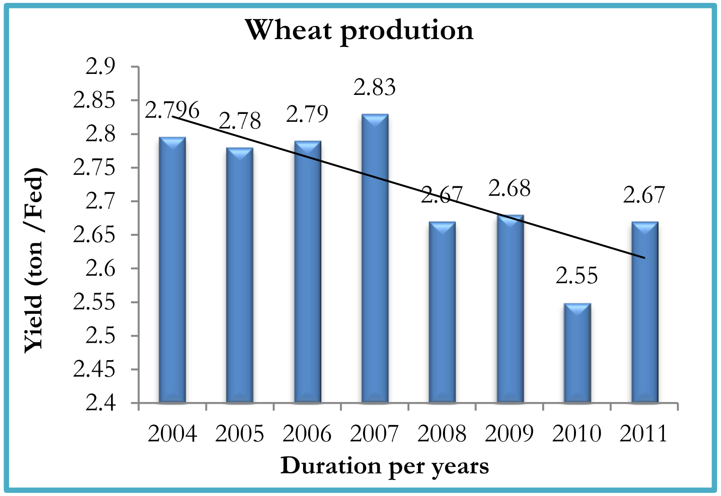
- Poor drainage water quality is increasingly becoming a constraint for the drainage water reuse policy and its future expansion plans
- Agricultural drains contain now domestic, industrial wastewater, fertilizers, pesticides and solid waste.

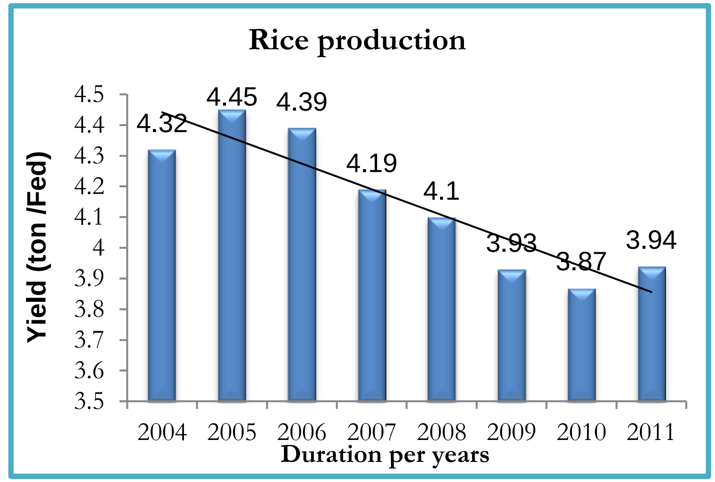
Shortage in Irrigation water

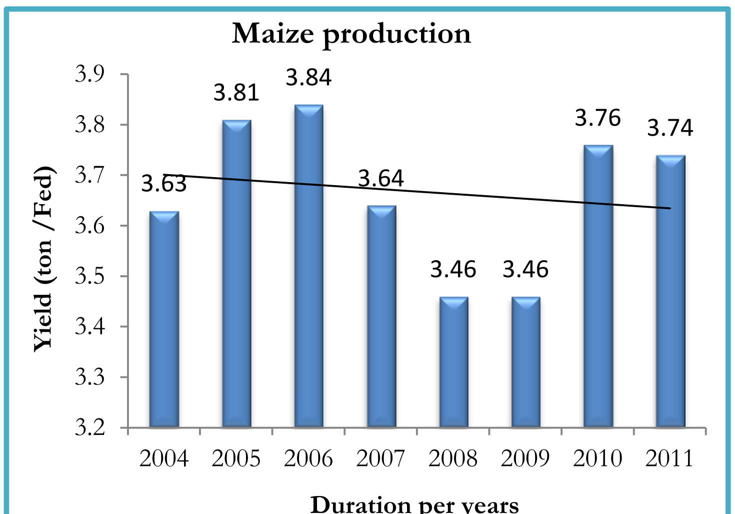
Reuse drainage water in irrigation

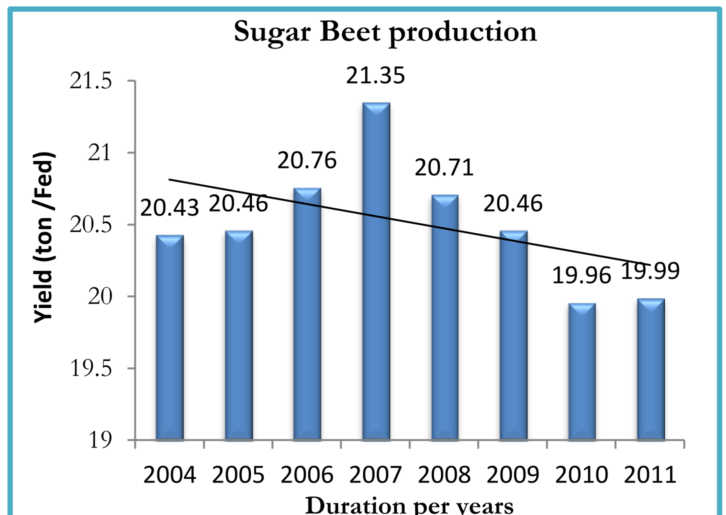
Poor drainage water quality

Effect of water quality on crop yield





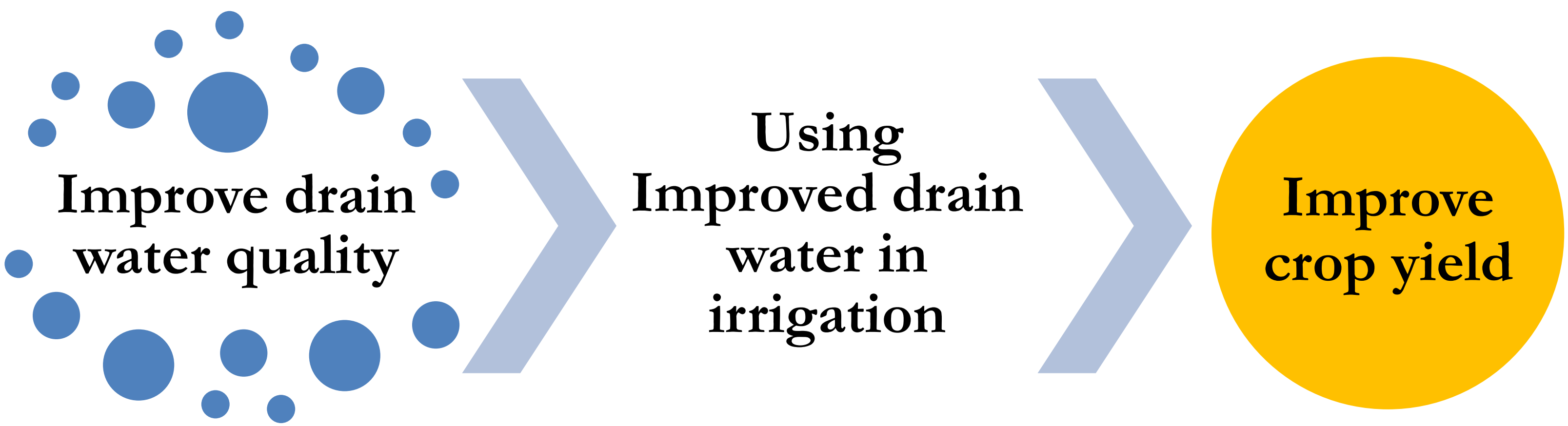




statistics of MALR2012

Research objectives

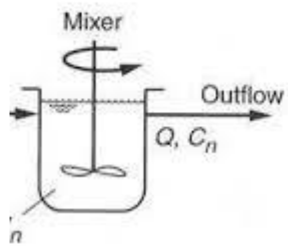
The overall objective of the research is to improve drain water quality for future direct reuse in irrigation.



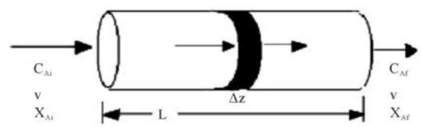
Research methodology

- **Develop BOD model**
  - **Input Data**
    - (BOD) Conc.
    - drain discharge
    - drains cross section
    - water velocity
    - Villages population
  - **Output Data**
    - BOD concentration along the drain
- **Develop DSS**
  - **Input Data**
    - available space
    - Drain discharge
    - Water table
    - capital cost
    - O&M cost
    - the removal efficiency
  - **Output Data**
    - Selection of the suitable method to reduce BOD values
- **Application**
  - **Original DSS**
  - **Modified DSS**
    - Different Temp.
    - Different cross –section
    - Different discharge

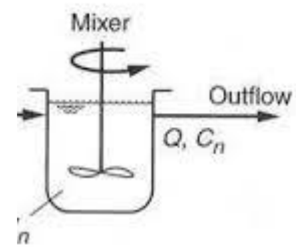
Calculation of BOD concentration along the drain



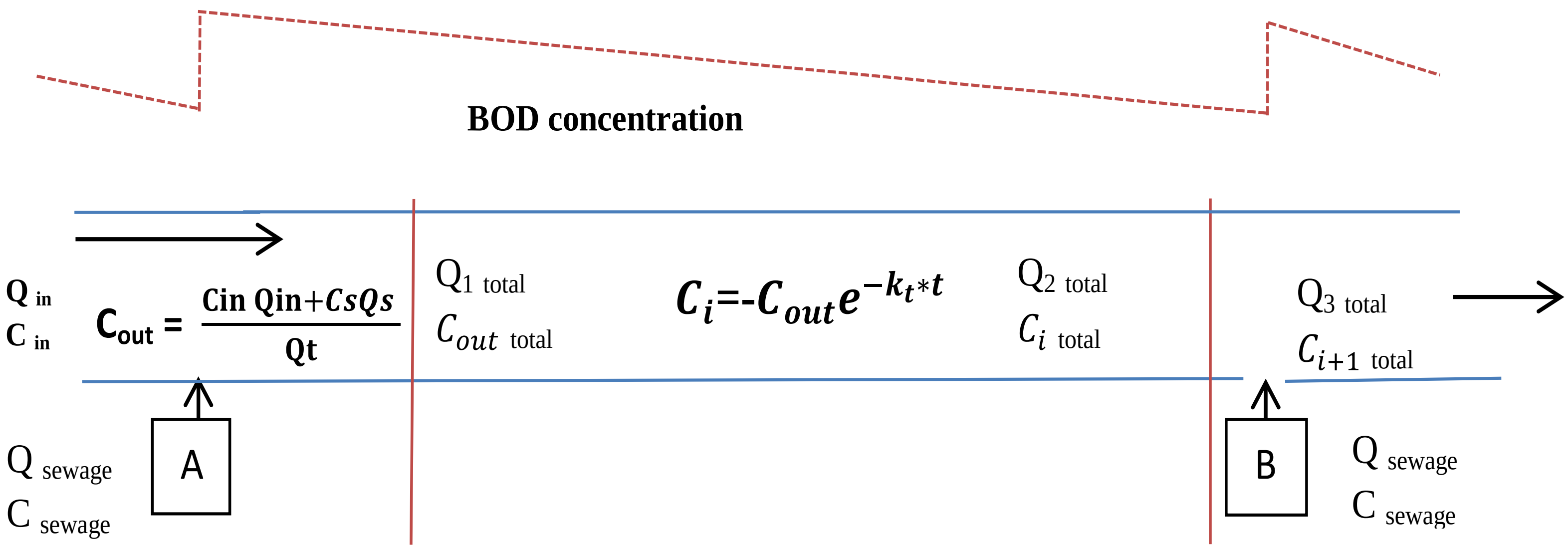
Mixed flow



Plug flow



Mixed flow



BOD Model

BOD Concentration

BOD =		50	gram / day
Water consumption =		125	Lit / capita/day
Q sewage= .8 *125		100	Lit / capita/day
Q drain =		0.7	m3/sec
BOD concentration = Cs		500	mg/l
Cin= From Water quality sheet		18	mg/l
Do mg after mixing with drain water			
k	Biodegrability factor	0.25	day $^{-1}$
kt	$Kt=K_0 * \theta^{t-20}$	0.4311	day $^{-1}$
ϴ	at T is between 20 -30	1.056	
T	Temperature	30	C^0

$C_i=C_0*e^{-k*t}$ **First order decay reaction**

$Ci = (Q_v*C_v+Q_d*C_d)Q_{total}$

Drain design criteria

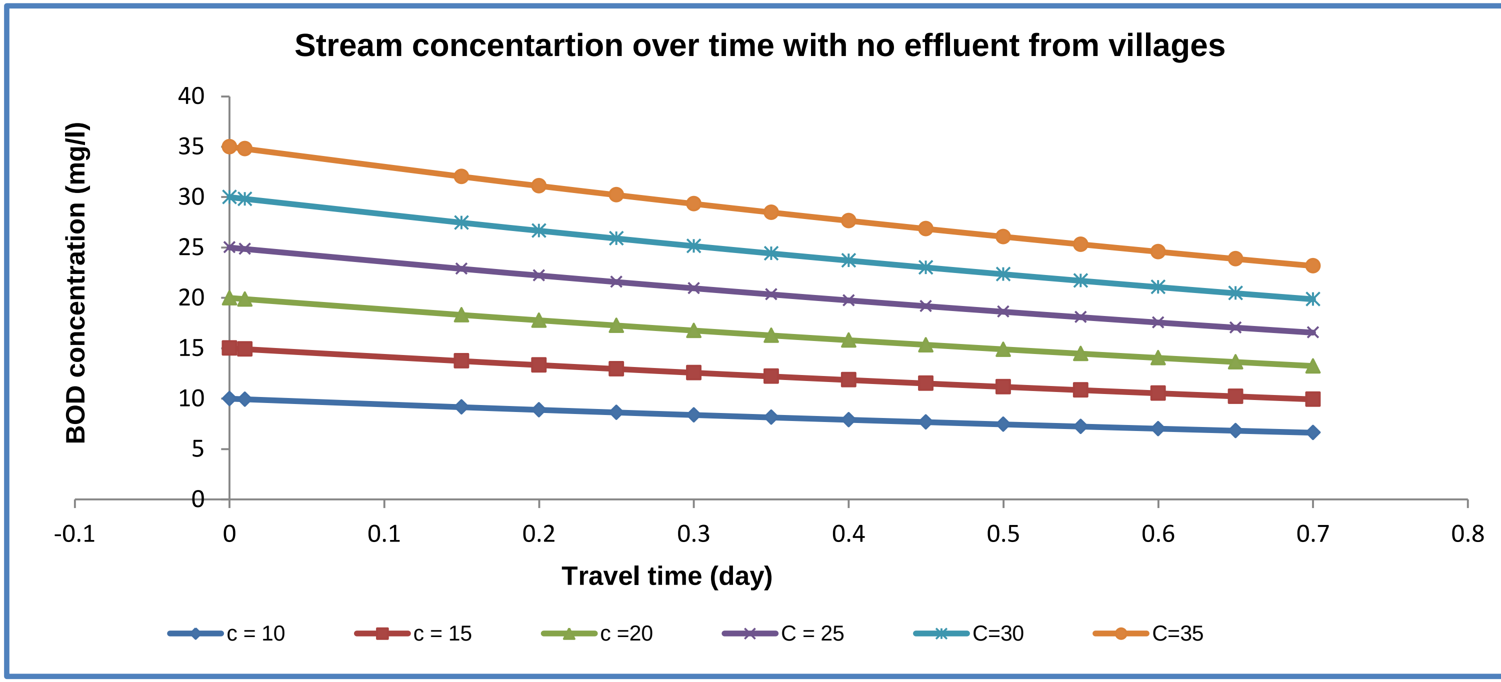
Open channel cross section

R= (b+xy)*y/(b+2y*(1+x^2)^.5		
P= b+2*y*(1+x2)^.		
P=	6.687	Wetted paramet
R=	0.768	hydraulic radius
V=	0.28	Velocity m/S
n=	0.03	manning factor
s=	1E-04	Slope
$V= (R^{2/3} * S^{1/2})/n$		
p	R	V
6.68722	0.768	0.279517357

ross sectio	nsert value	
b=	2	Bottom Width /m
Y=	1.3	Water depth /m
x=	1.5	Side slope
L=	3.52	Drain length /Km
me= distance/Velocit		

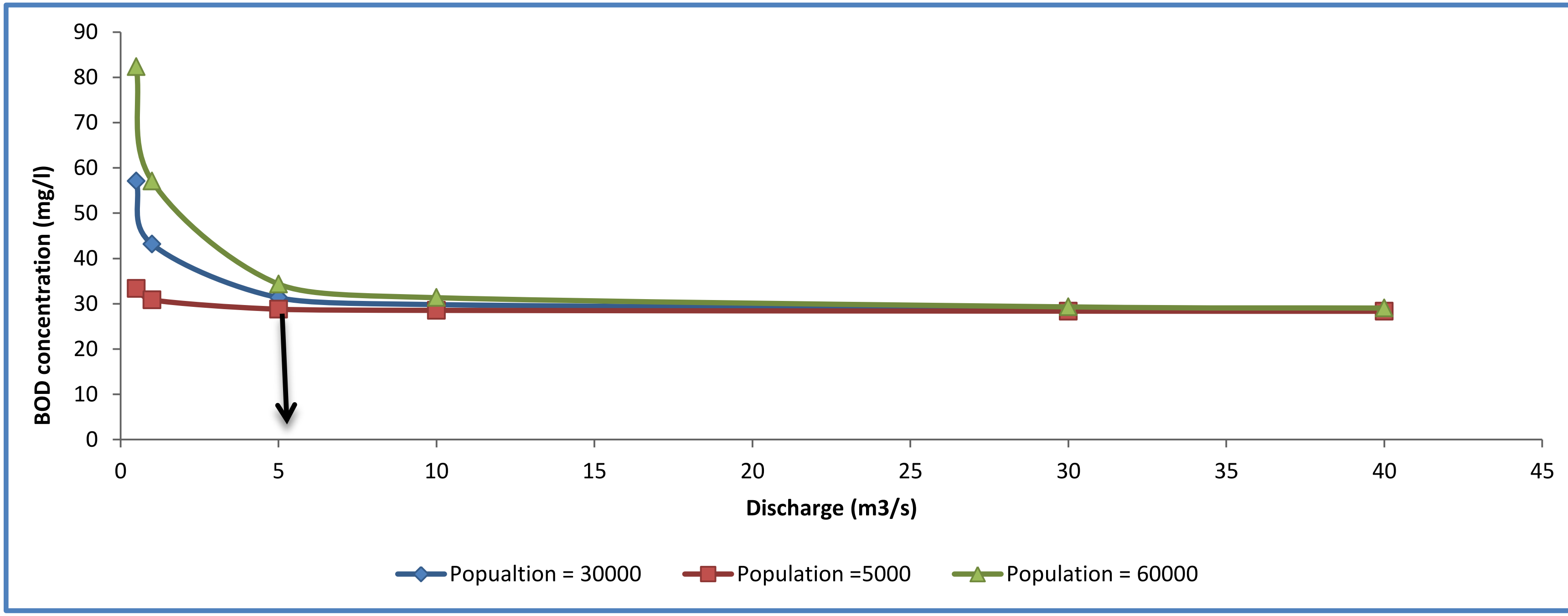
NO.	Village	Populatio	Location	Distance	t	k_t	Q_{drain}	C_{drain}	$Q_{village}$	$C_{village}$	Q_{total}	: before and after Villag $C_i=C_0*e^{-k}$ $C_{drian\ Befor}$	 $C_{i} = (Qv*Cv+Qd*Cd)Q$ $C_{drian\ after}$
	Drain Start	0	0	0	0.000	0.431	0.700	18.000	0.000000	0	0.70	18.00	18.00
1	Izbat Al nahyteen	3860	200	200	0.008	0.431	0.700	18.000	0.004468	100	0.70	17.94	18.46
2	Izbat Ali Abd Almtaal	6577	1100	900	0.037	0.431	0.704	18.456	0.007612	500	0.71	18.16	23.31
3	Izbat AL mosalth	5489	2500	1400	0.058	0.431	0.712	23.313	0.006353	500	0.72	22.74	26.96
4	Izbat Yousf Salama	3658	3100	600	0.025	0.431	0.718	26.958	0.004234	500	0.72	26.67	29.44
5	Izbt Al Hafsa	1480	3500	400	0.017	0.431	0.723	29.444	0.001713	500	0.72	29.23	30.35

Relation between BOD concentration and travel time for different initial BOD concentrations



- The chart shows the degradation of BOD along the stream over the time considering that there is *NO sewage effluent from villages*.

Relation between BOD concentration and drain discharge for different populations



BOD stream concentration = 30 mg/l, at t = 0.1 day

Decision support system

- Based on available space, water supply, drain discharge, ground water table, Accessibility, the available capital cost & operational/maintenance cost and the required removal efficiency.

Low Cost Treatment Technologies

	Criteria	Condition	Anaerobic Baffled Reactor (ABR)			Instream Wetland			UASB			Anaeraobic Filter		
			Value (0-10)	Weight (0-1)	Score (0-10)	Value (0-10)	Weight (0-1)	Score (0-10)	Value (0-10)	Weight (0-1)	Score (0-10)	Value (0-10)	Weight (0-1)	Score (0-10)
Site Specific	Water Supply Availiability	Please Select		0.029			0.029			0.029			0.029	
	Available Space	Please Select		0.142			0.142			0.142			0.142	
	Drain Discharge	Please Select		0.080			0.080			0.080			0.080	
	Groundwater Table	Please Select		0.040			0.040			0.040			0.040	
	Accessibility	Please Select		0.029			0.029			0.029			0.029	
Technology Specific	Available Capital costs	Please Select		0.267			0.267			0.267			0.267	
	Available O & M Costs	Please Select		0.133			0.133			0.133			0.133	
	BOD Removal Efficiency	Please Select		0.200			0.200			0.200			0.200	
	BOD Concentration	Please Select		0.080			0.080			0.080			0.080	

Done Reset

Application

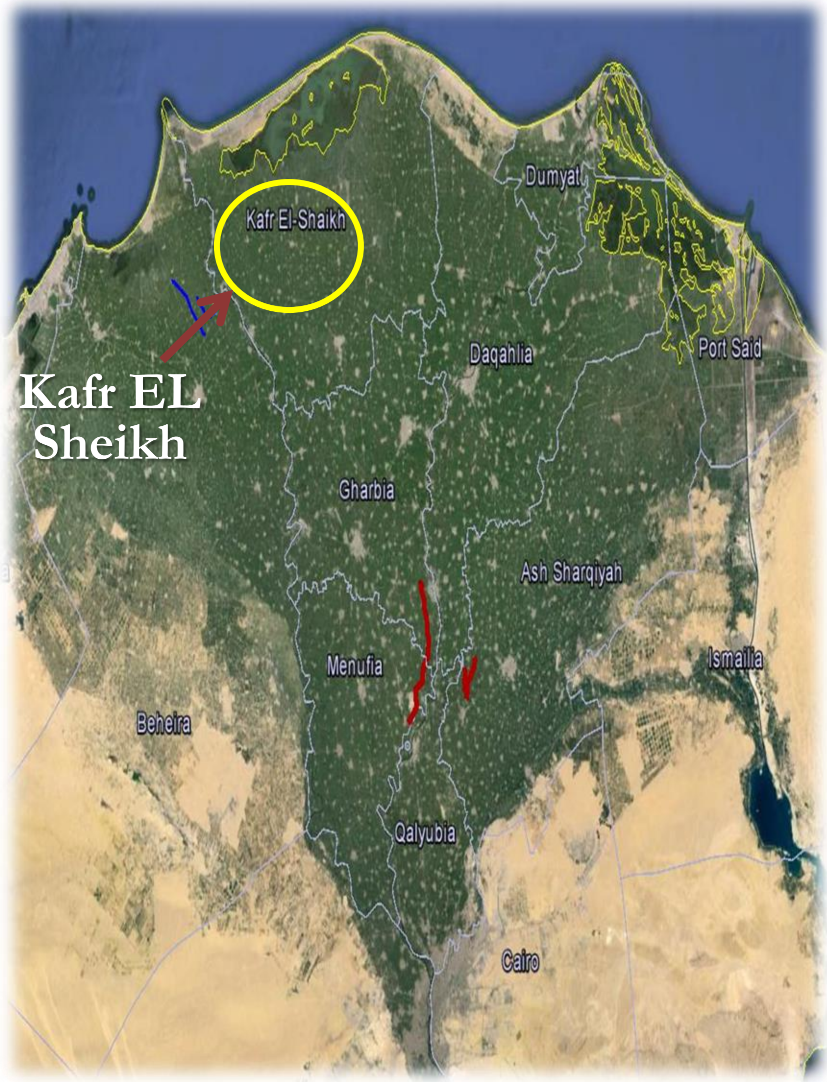
- Collect the required data
- Plot BOD values along the drains
- Validate calculated BOD
- Using DSS to select the suitable technology to reduce BOD
- Evaluate drains salinity

Kafr El Sheikh as a study area

- Water supply (main canals)
  - Bahr Tera
  - Meet Yazeed
  - EL Kasede
  - Bahr Nashrat
  - El Kodaba

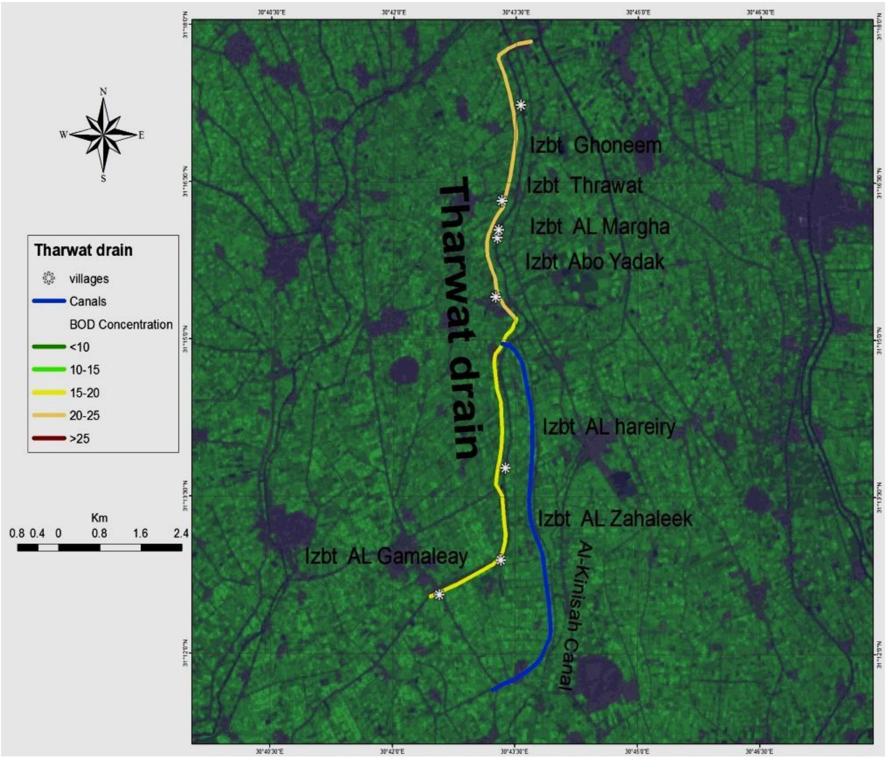
- Excess water from Kafr El Sheik is drained to:
  - The Mediterranean Sea though Burullus lake
  - The Sea direct
  - The sea through Rosetta branch.

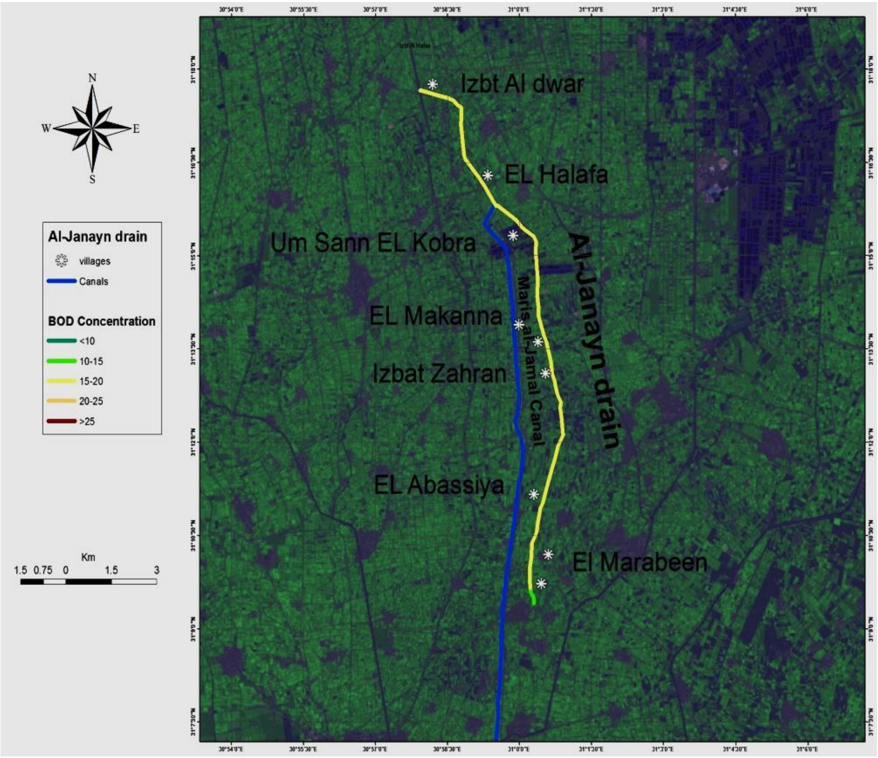
- Total farm land 577,000 Feddan.



Selection of drains

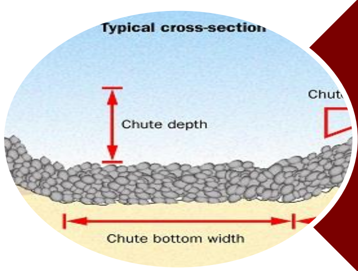
Directorate request → farmers claims → Water quality → 21 drain





Collect the required data

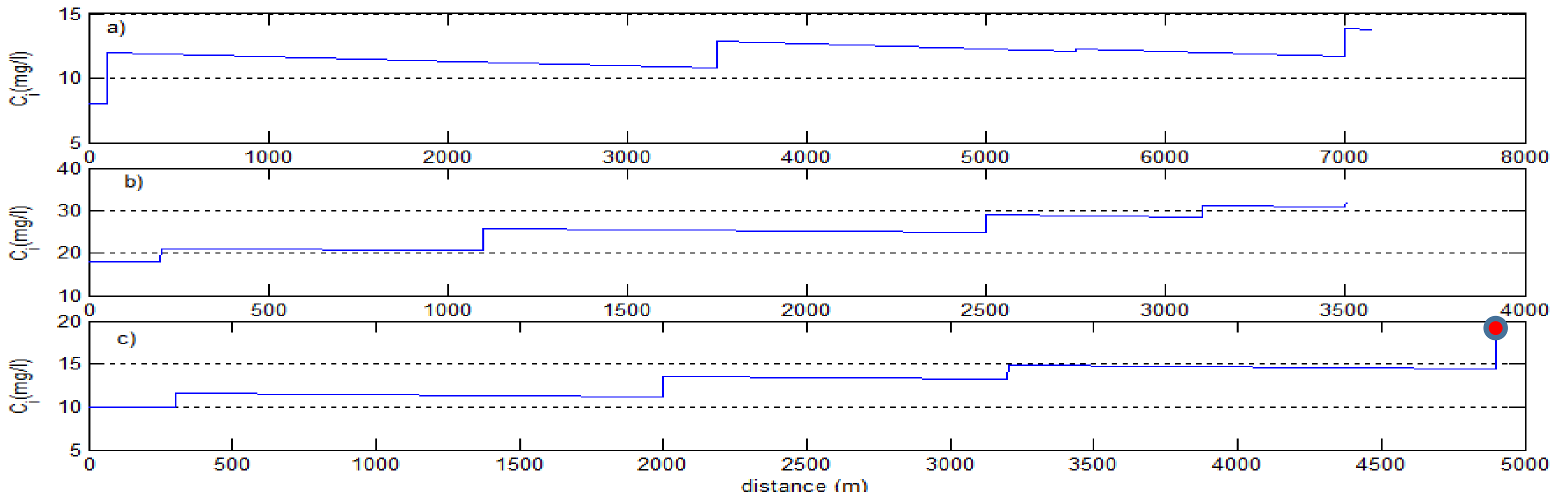
Water quality data



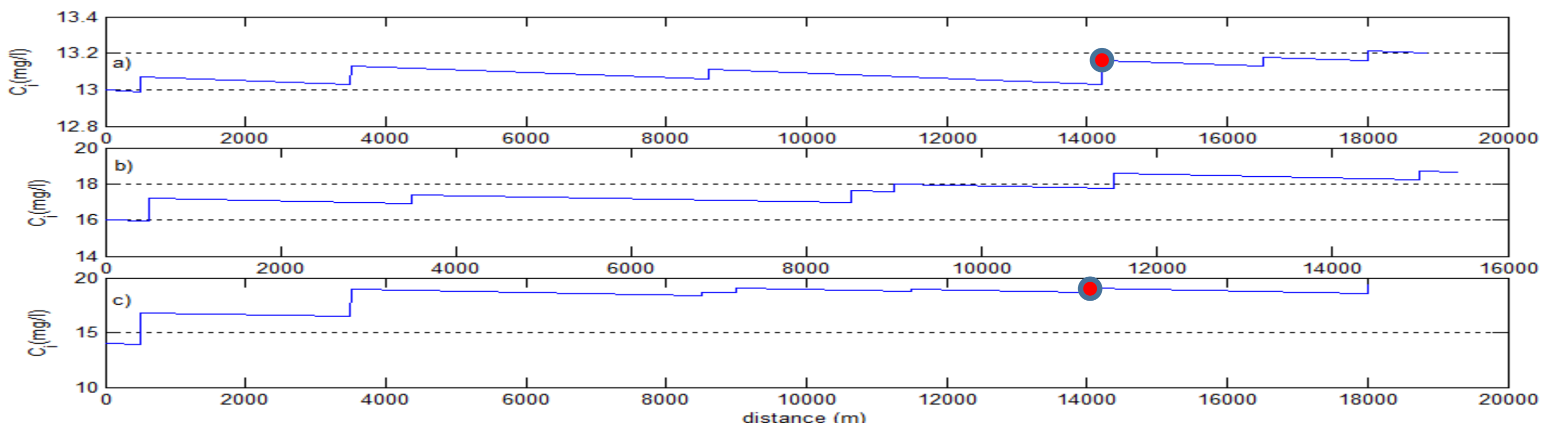
Drain cross section – hydraulic charactrstics

Data related to number of villages, villages distance, and villages population

Plot the BOD values along the drain

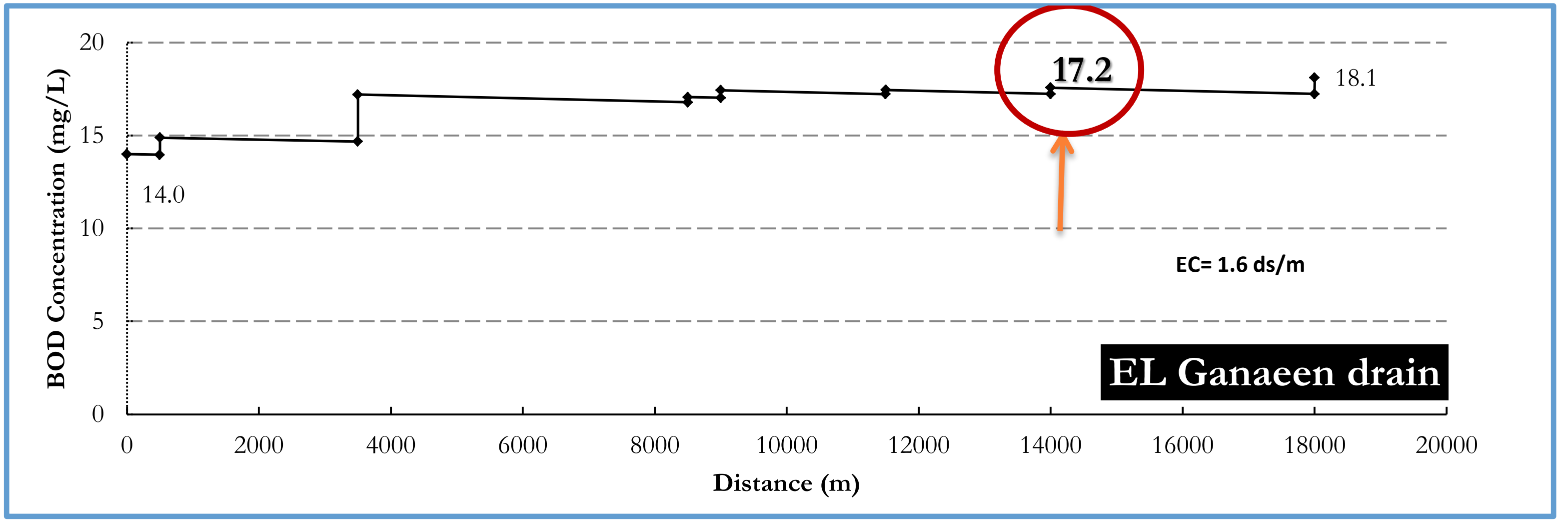


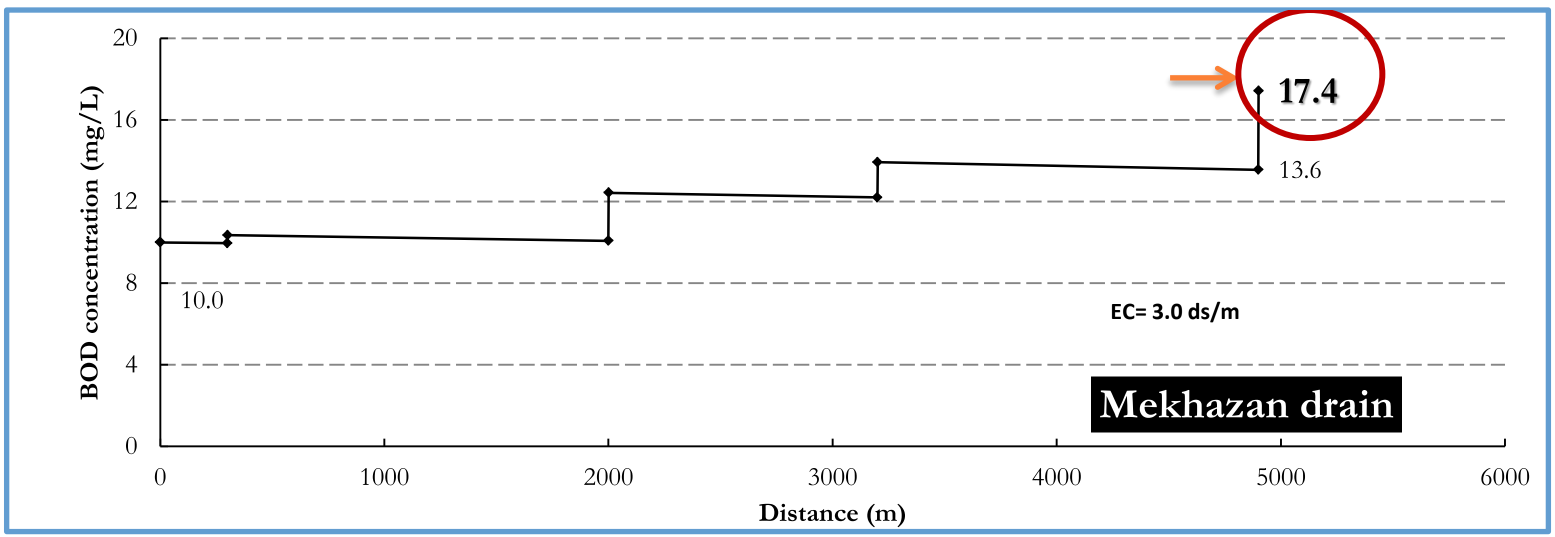
BOD concentration before treatment for drains (a) Arian (b) Abo khashaba (c) Mekhazan



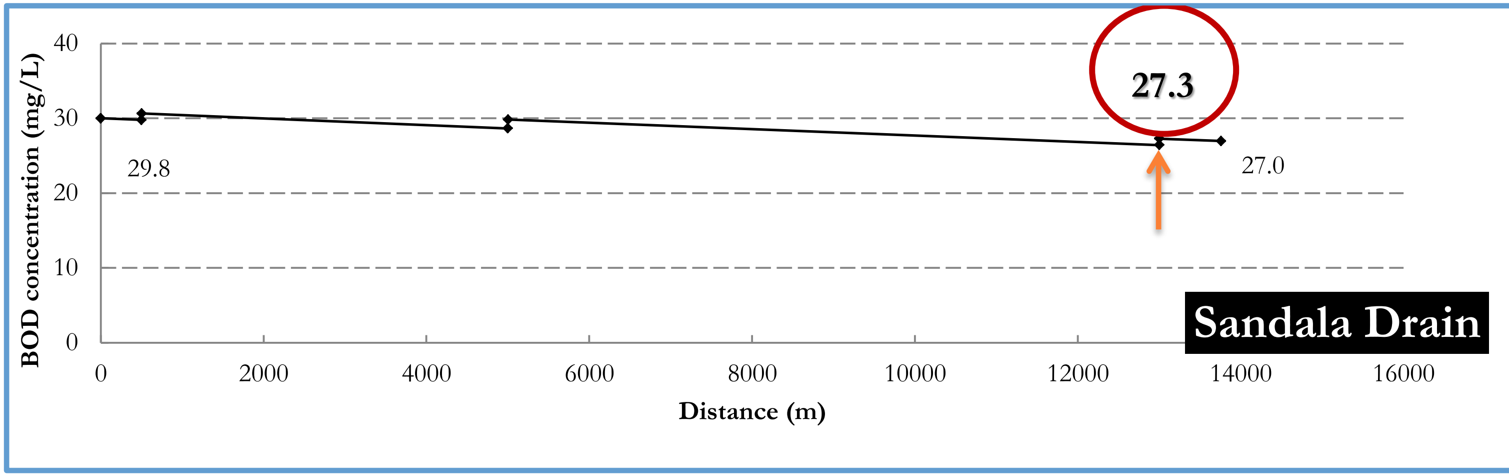
BOD concentration before treatment for drains (a) No. 11 (b) Abo rayaa (c) El Ganeen

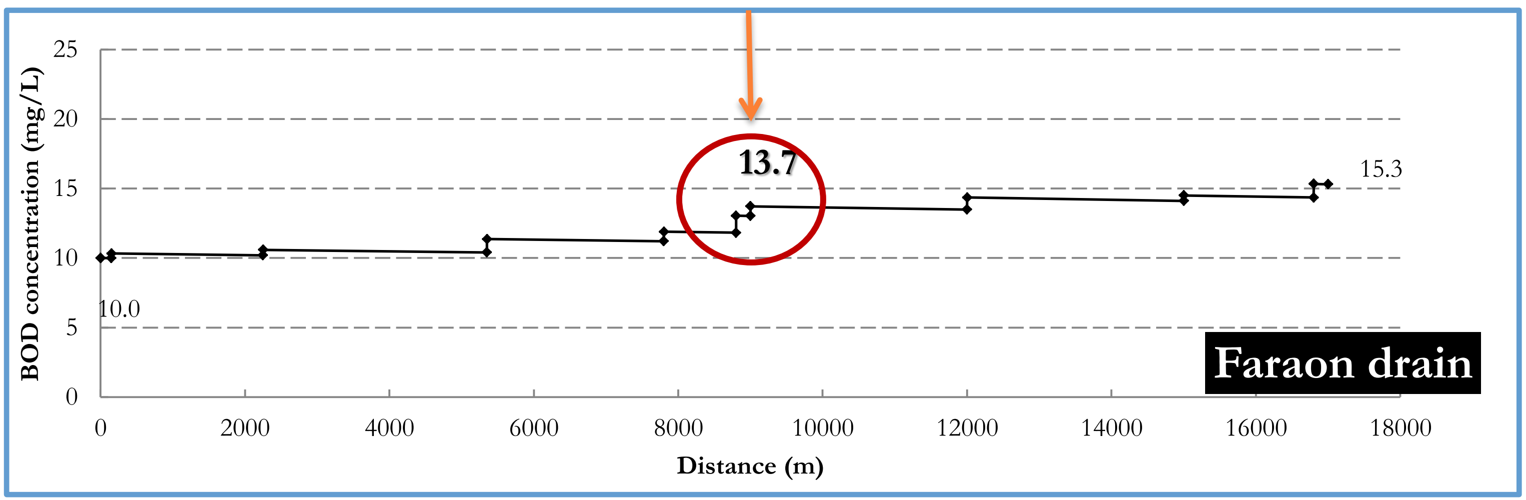
BOD values along the drain





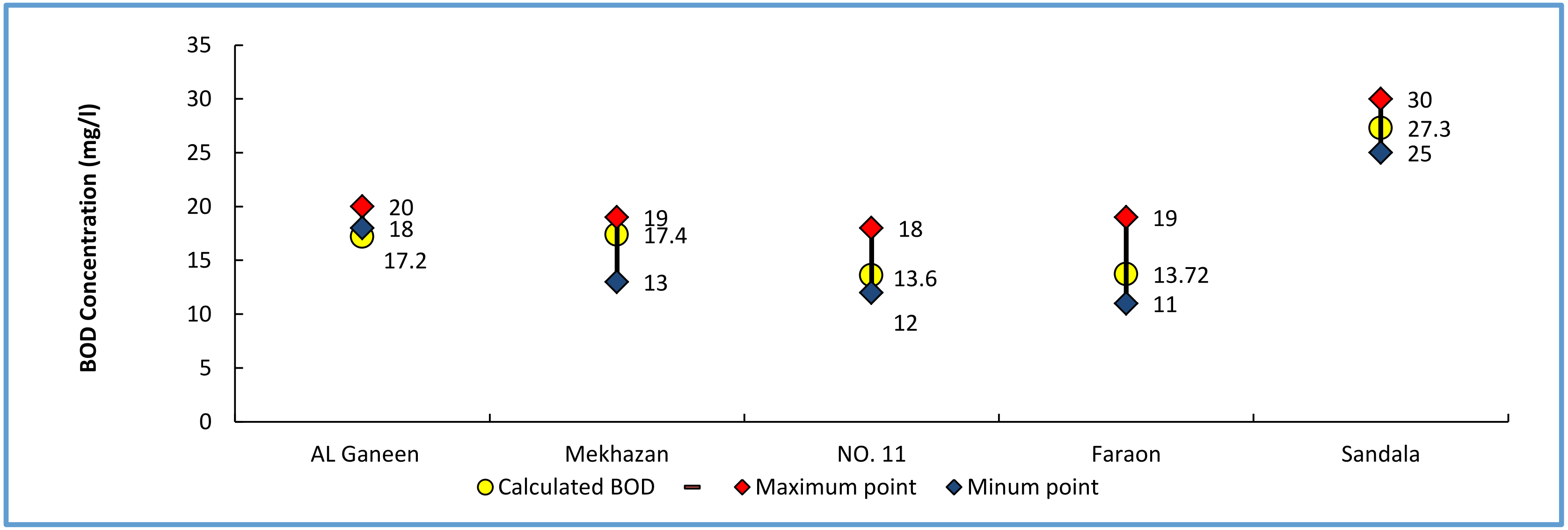
BOD values along the drain



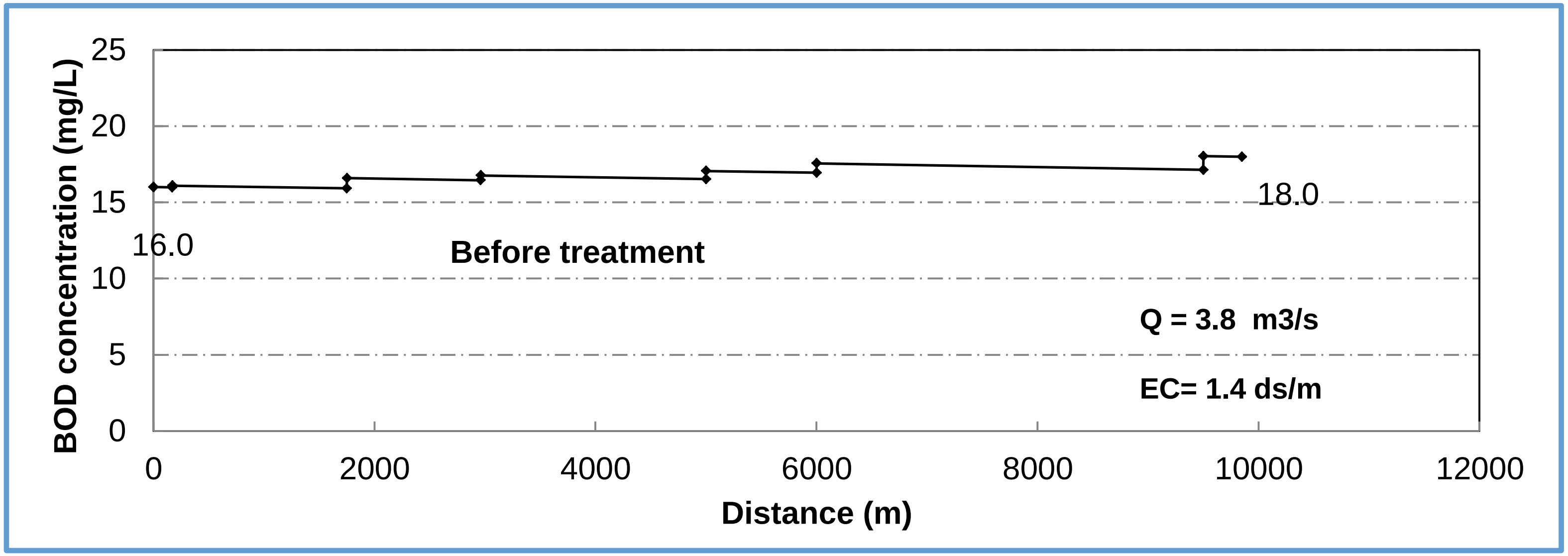


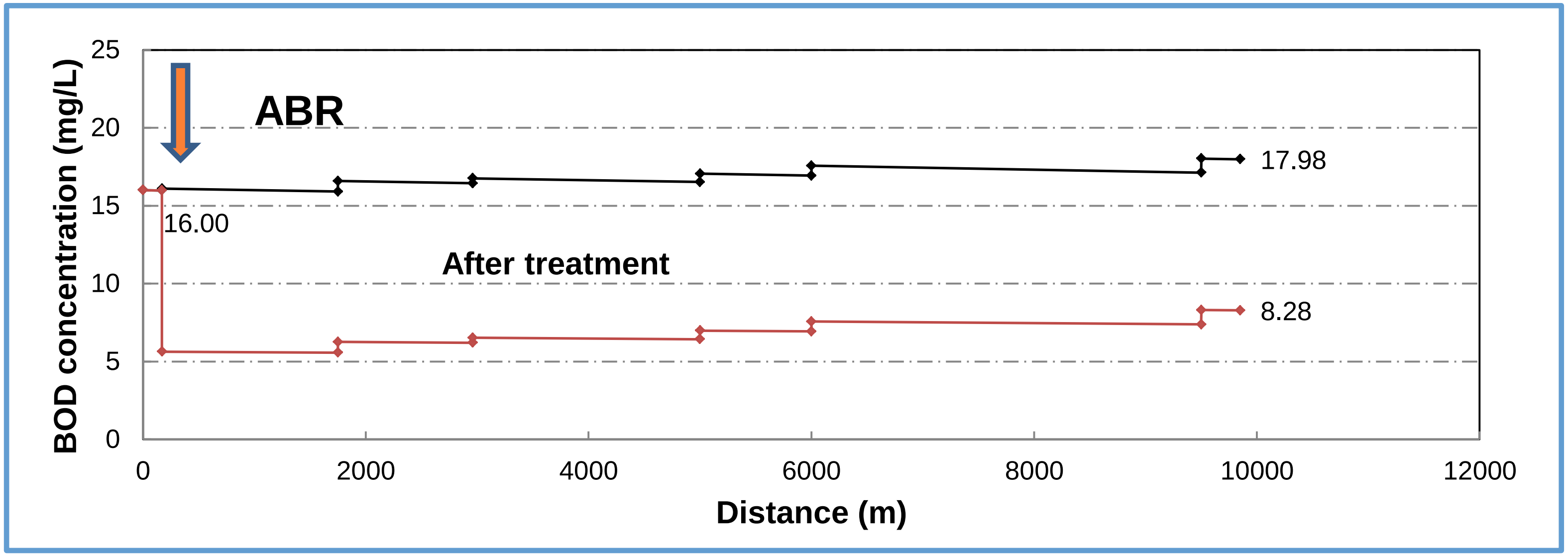
Comparison between BOD calculated and BOD measured

Serial	drain names	BOD Concentration								
		Name of the village	Kilo metrage	BOD calculated	Sep-13	Apr-14	May-14	Jul-14	Aug-14	Sep-14
1	Fasrh AL Ganaeen	Um-Sann AL Kobra	14	17.2	18	18	16	15	21	20
2	Mekhazan	EL Batanoni	4.9	17.4	19	18	14	12	13	12
3	No.11	Tall Motabas	14.2	13.6	13	12	14	18	18	15
4	Faron	AL Mazaniha	9	13.72	19	15	19	19	17	11
5	Sandala	AL Khamseen	13	27.3	25	25	19	30	23	18



Apply DSS on Hood Al Hagar drain





Selected treatment technology through DSS

Decision-Making Support Tool
Low Cost Treatment Technologies

	Criteria	Condition	Anaerobic Baffled Reactor (ABR)			Instream Wetland			UASB			Anaeraobic Filter		
			Value (0-10)	Weight (0-1)	Score (0-10)	Value (0-10)	Weight (0-1)	Score (0-10)	Value (0-10)	Weight (0-1)	Score (0-10)	Value (0-10)	Weight (0-1)	Score (0-10)
Site Specific	Water Supply Availiability	Yes	10	0.029	0.29	10	0.029	0.29	10	0.029	0.29	10	0.029	0.29
	Available Space	Medium	8	0.142	1.136	10	0.142	1.42	10	0.142	1.42	8	0.142	1.136
	Drain Discharge	1.0 - 5.0 CM/S	8	0.080	0.64	0	0.080	0	8	0.080	0.64	8	0.080	0.64
	Groundwater Table	More than 2.0 m	10	0.040	0.4	10	0.040	0.4	10	0.040	0.4	10	0.040	0.4
	Accessibility	Full Access	10	0.029	0.29	10	0.029	0.29	10	0.029	0.29	10	0.029	0.29
Technology Specific	Available Capital costs	00 000 - 1 000 000 LE	8	0.267	2.136	10	0.267	2.67	6	0.267	1.602	6	0.267	1.602
	Available O & M Costs	1 500 - 3 000 LE	10	0.133	1.33	10	0.133	1.33	8	0.133	1.064	10	0.133	1.33
	BOD Removal Efficiency	50%-65%	Yes	0.200	2	No	0.200	0	Yes	0.200	2	Yes	0.200	2
	BOD Concentration	250 - 500kg/d	6	0.080	0.48	6	0.080	0.48	10	0.080	0.8	8	0.080	0.64
	Total			1.000	8.70		1.00	6.88		1.00	8.51		1.00	8.33

Recommendations:

-- It is recommended to use: *Anaerobic Baffled Reactor (ABR)*

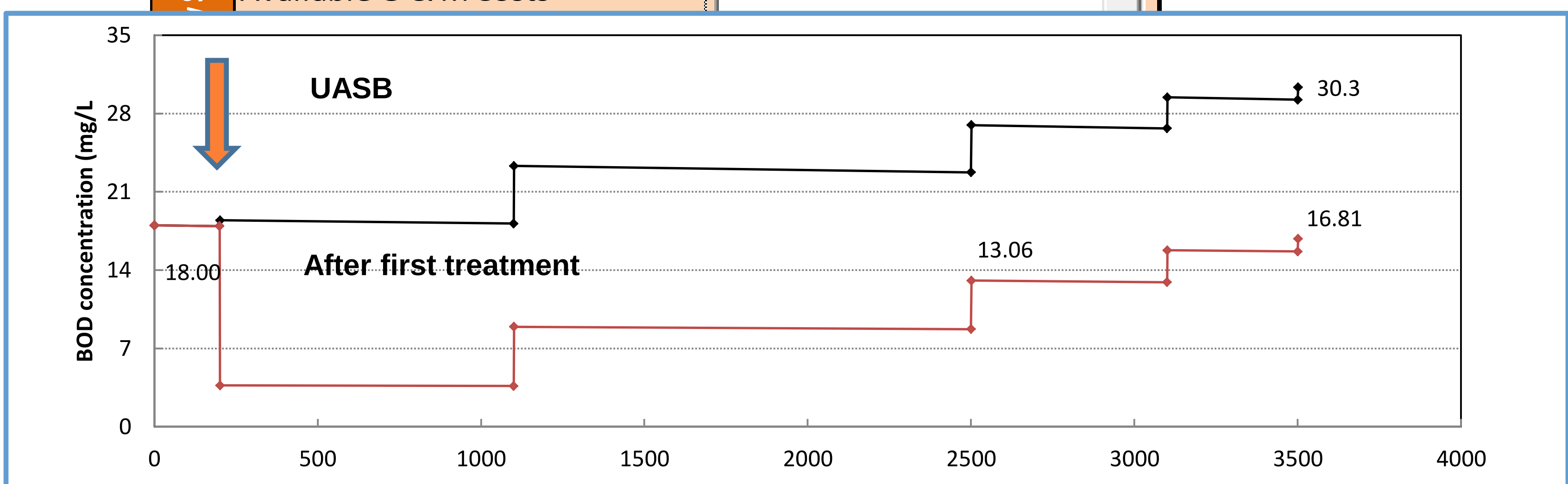
-- The highest Score equal: *8.702*

Done

Reset

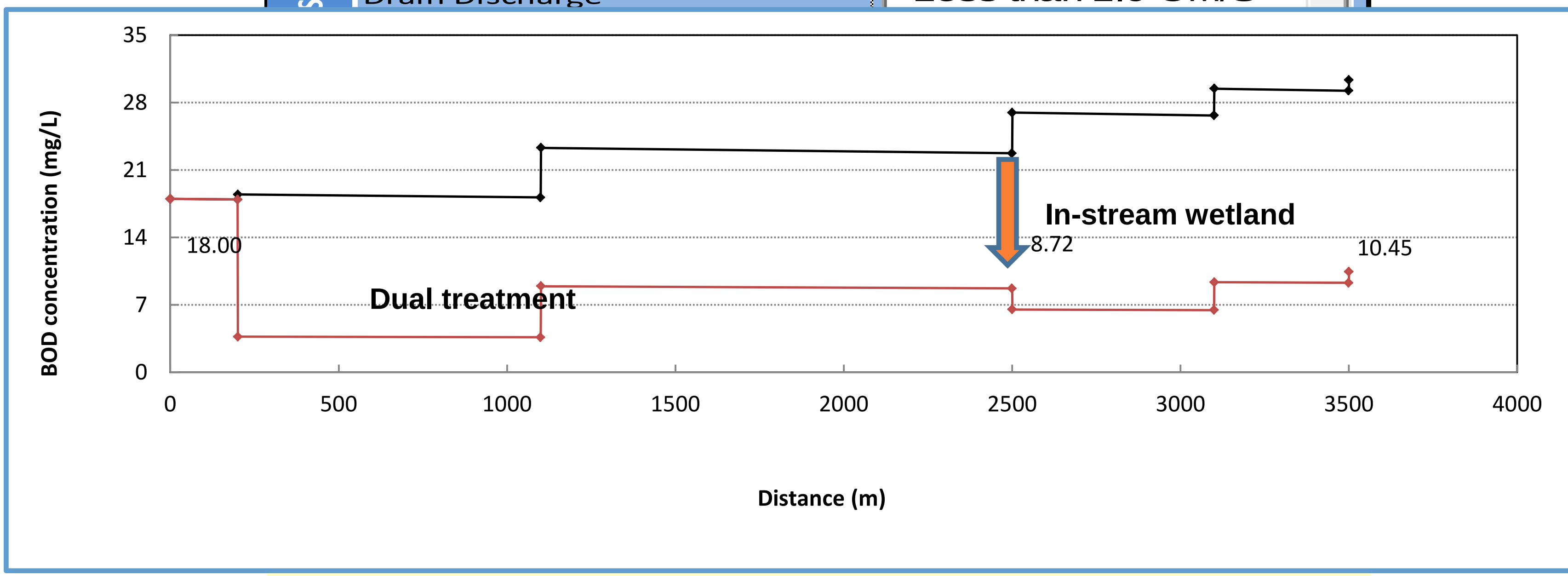
Apply DSS for Abo Khashaba Drain

	Criteria	Condition
Site Specific	Water Supply Availiability	Yes
	Available Space	Small
	Drain Discharge	Less than 1.0 CM/S
	Groundwater Table	Less than 2.0 m
	Accessibility	Full Access
y Specific	Available Capital costs	ore than 1 000 000 LE
	Available O & M Costs	More than 3 000 LE



Apply DSS for Abo Khashaba Drain

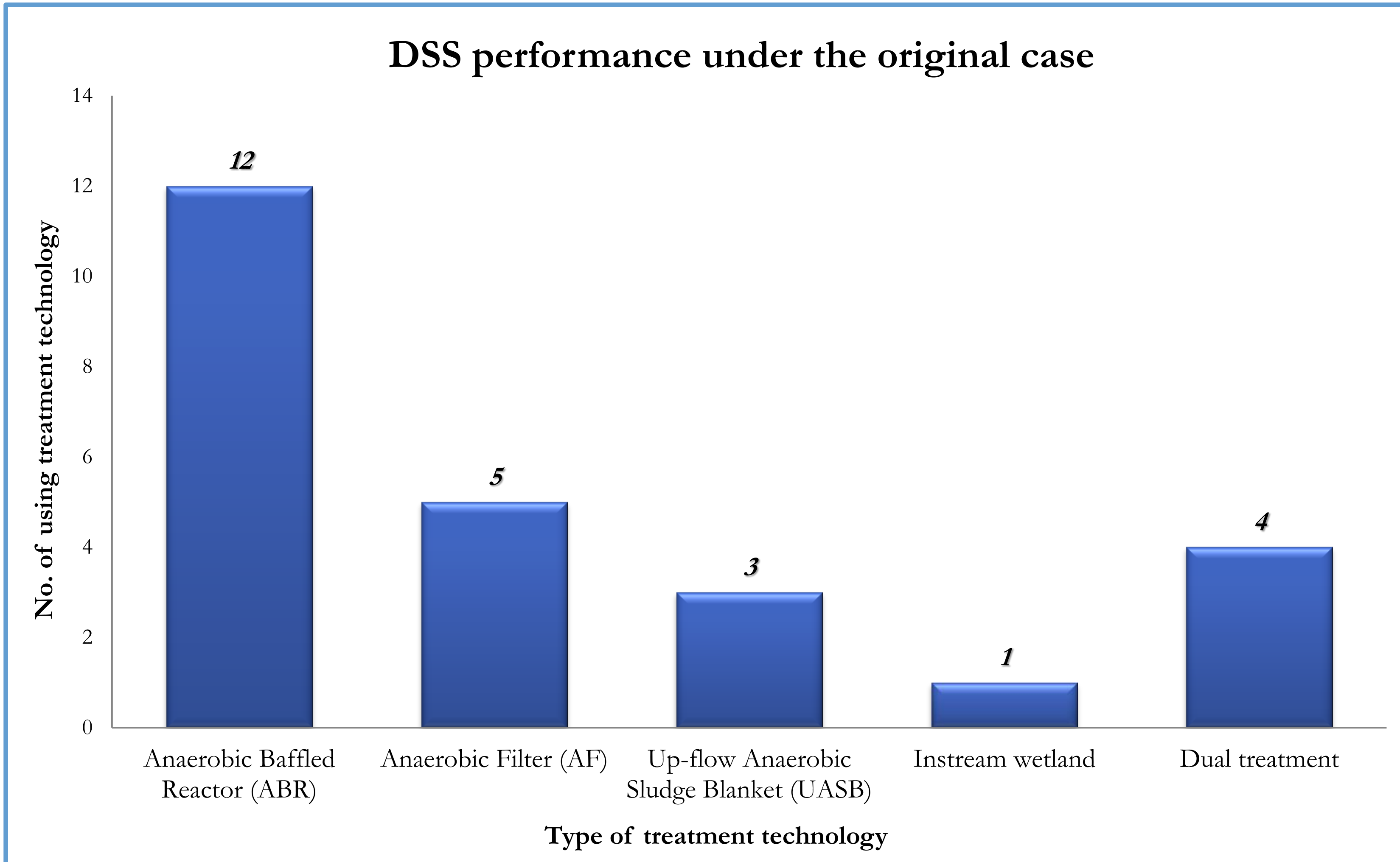
	Criteria	Condition
Specific	Water Supply Availiability	Yes
	Available Space	Small
	Drain Discharge	Less than 1.0 CM/S



-- It is recommended to use: ***Instream Wetland***

-- The highest Score equal: ***10***

DSS performance under the original case



Anaerobic Baffled Reactor (ABR)

Advantages of ABR

- Can be built and repaired with locally available materials
- Long service life
- No real problems with flies or odors if used correctly
- High reduction of organics
- Moderate capital costs, moderate operating c

BOD concentration variability and its effect on decision support system performance

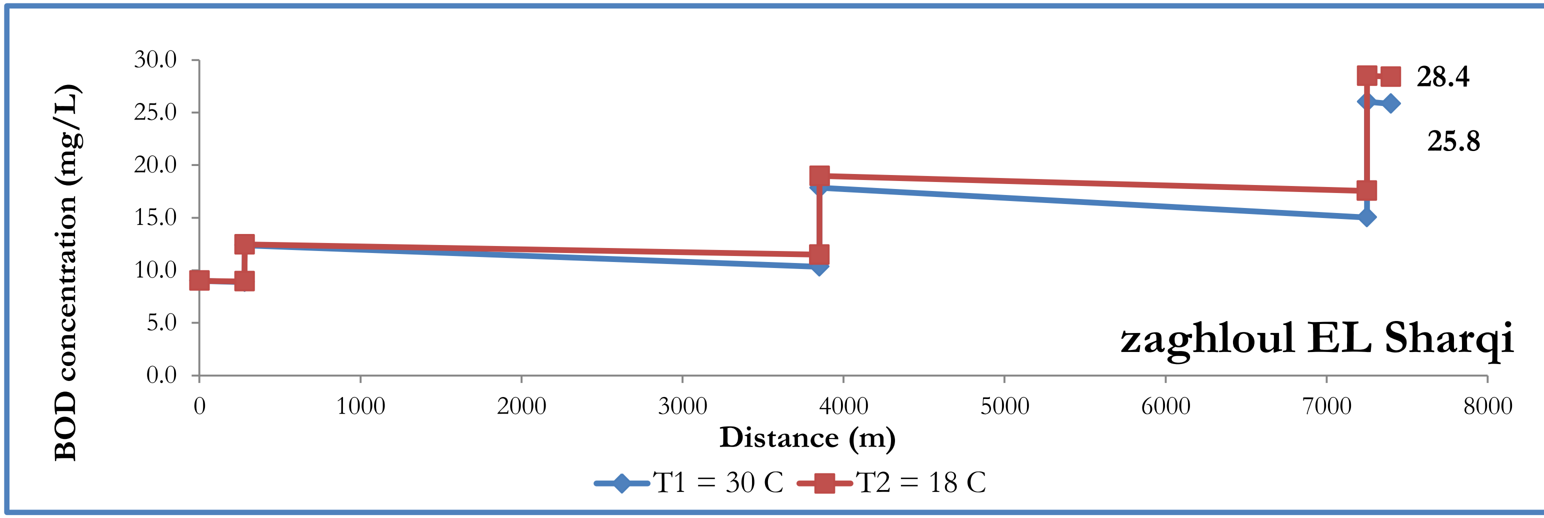
- **BOD concentration variability under different stream discharge, temperature, and cross section, and its effect on sewage waste treatment technology selection through DSS**

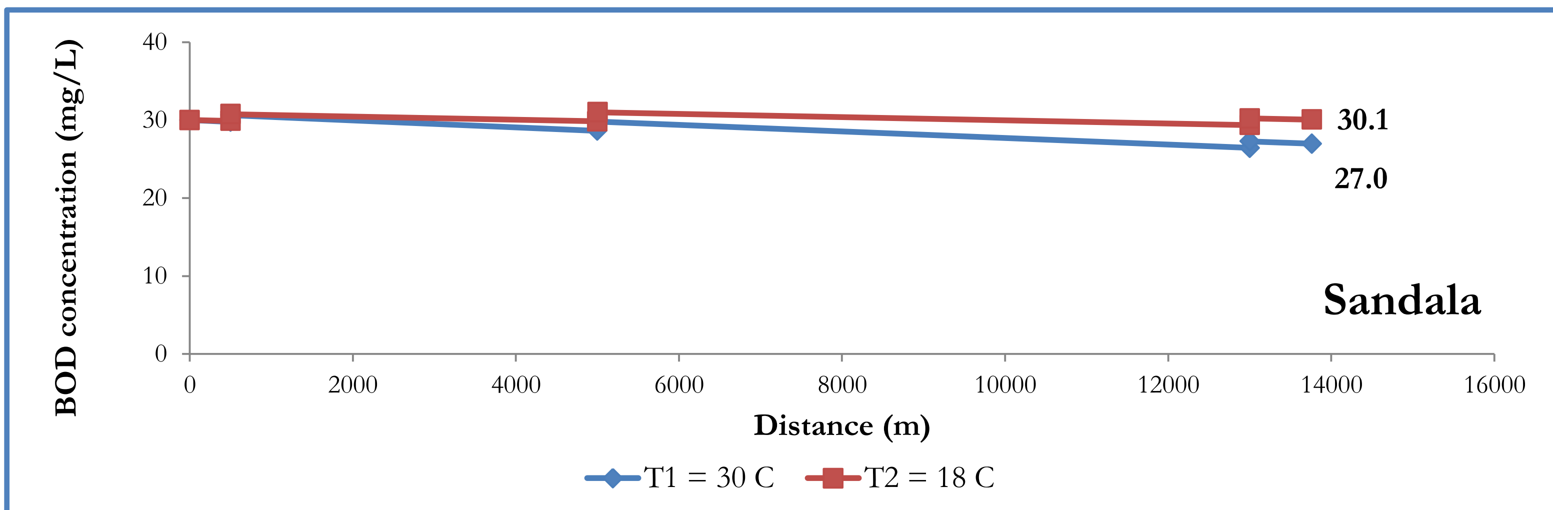
Temperature

Cross section

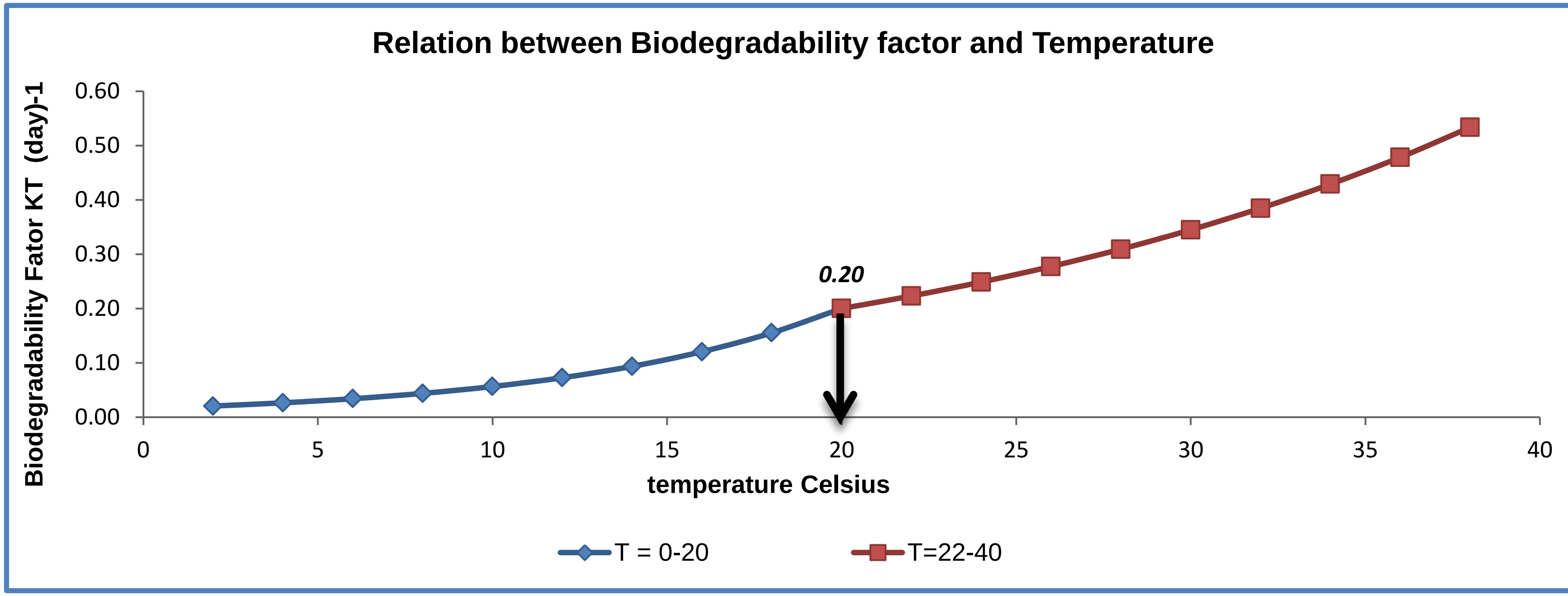
Discharge

BOD concentration variability under different temperature





Biodegradability factor under different temperature



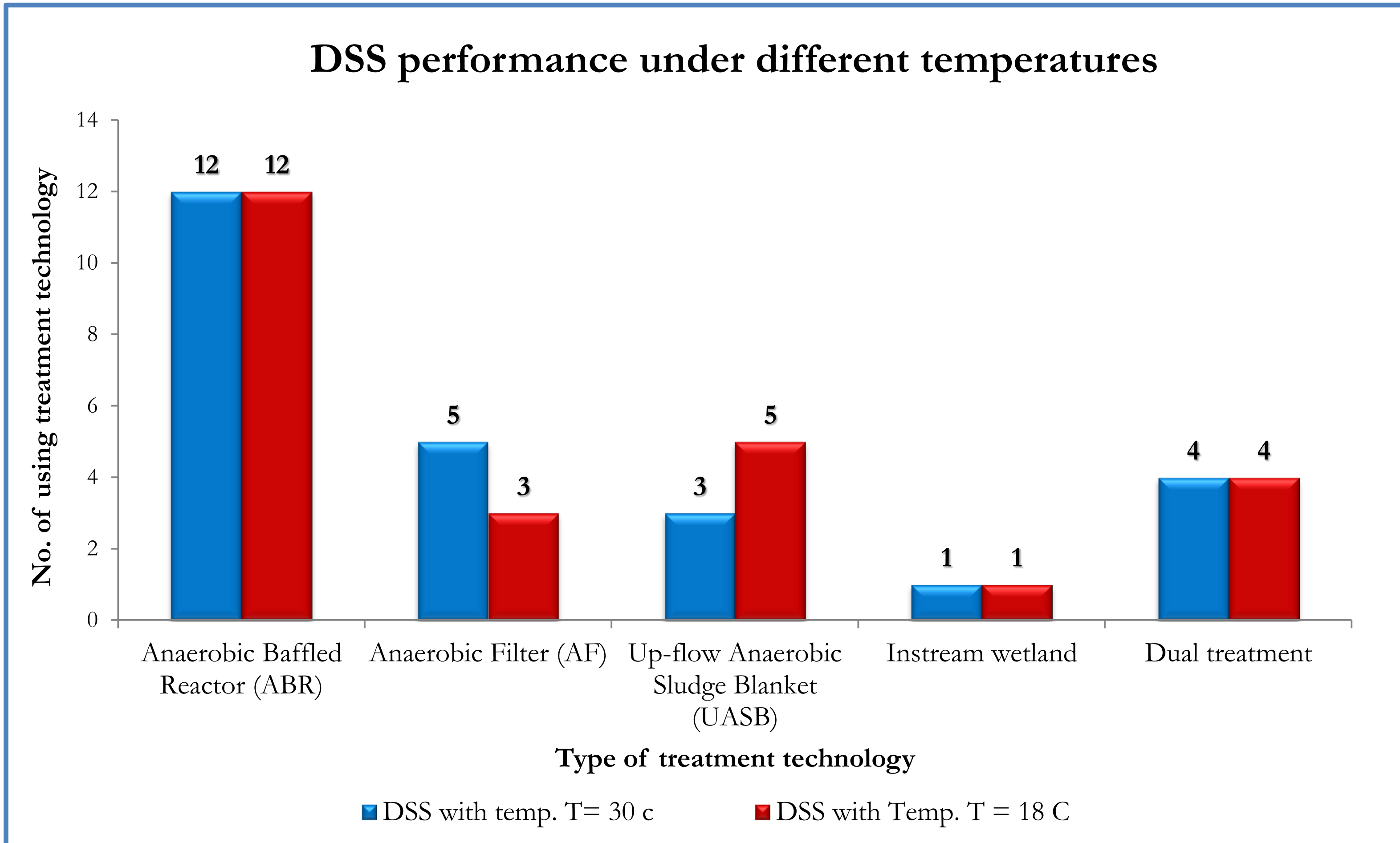
- The relation between the biodegradability factor K day and various temperature.

$k_t = k_0 \theta^{T-20}$

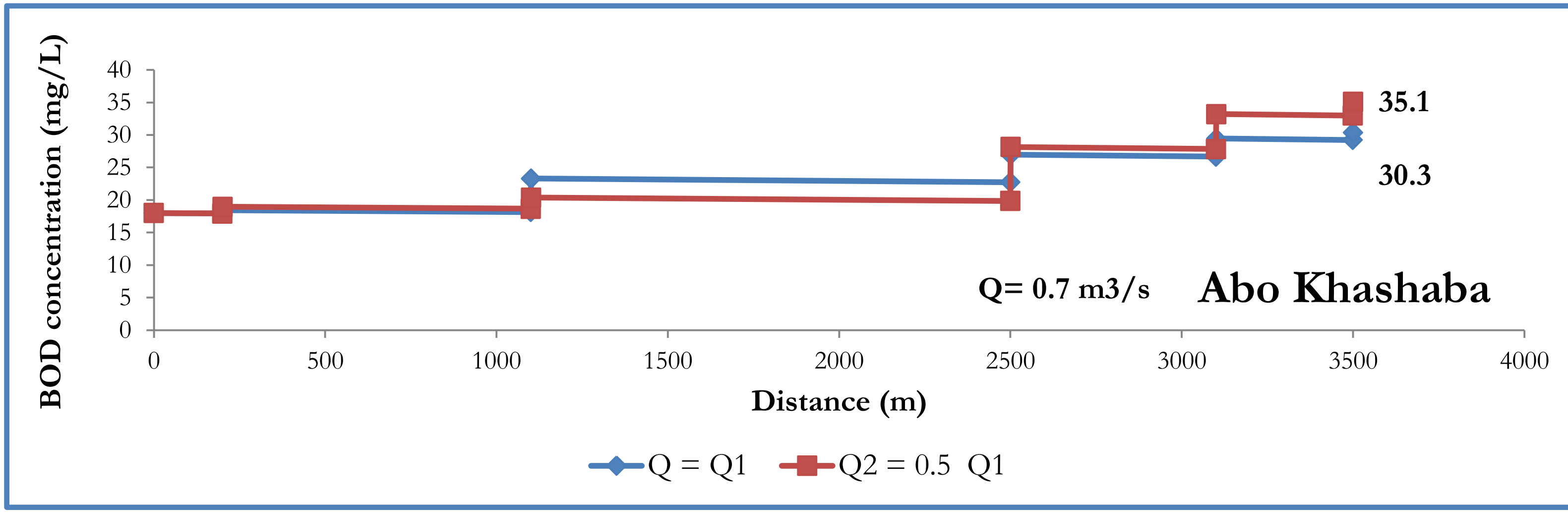
θ = 1.135 for T from (4-20) C^o

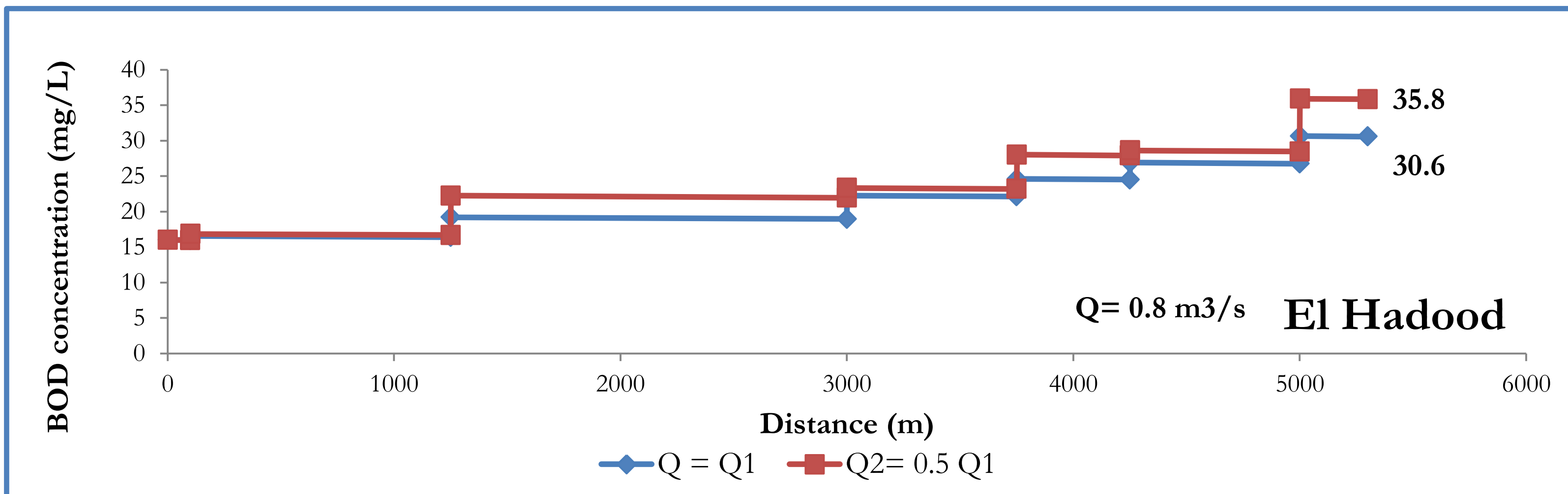
θ = 1.056 for T from (20-30) C^o

DSS performance under different temperature

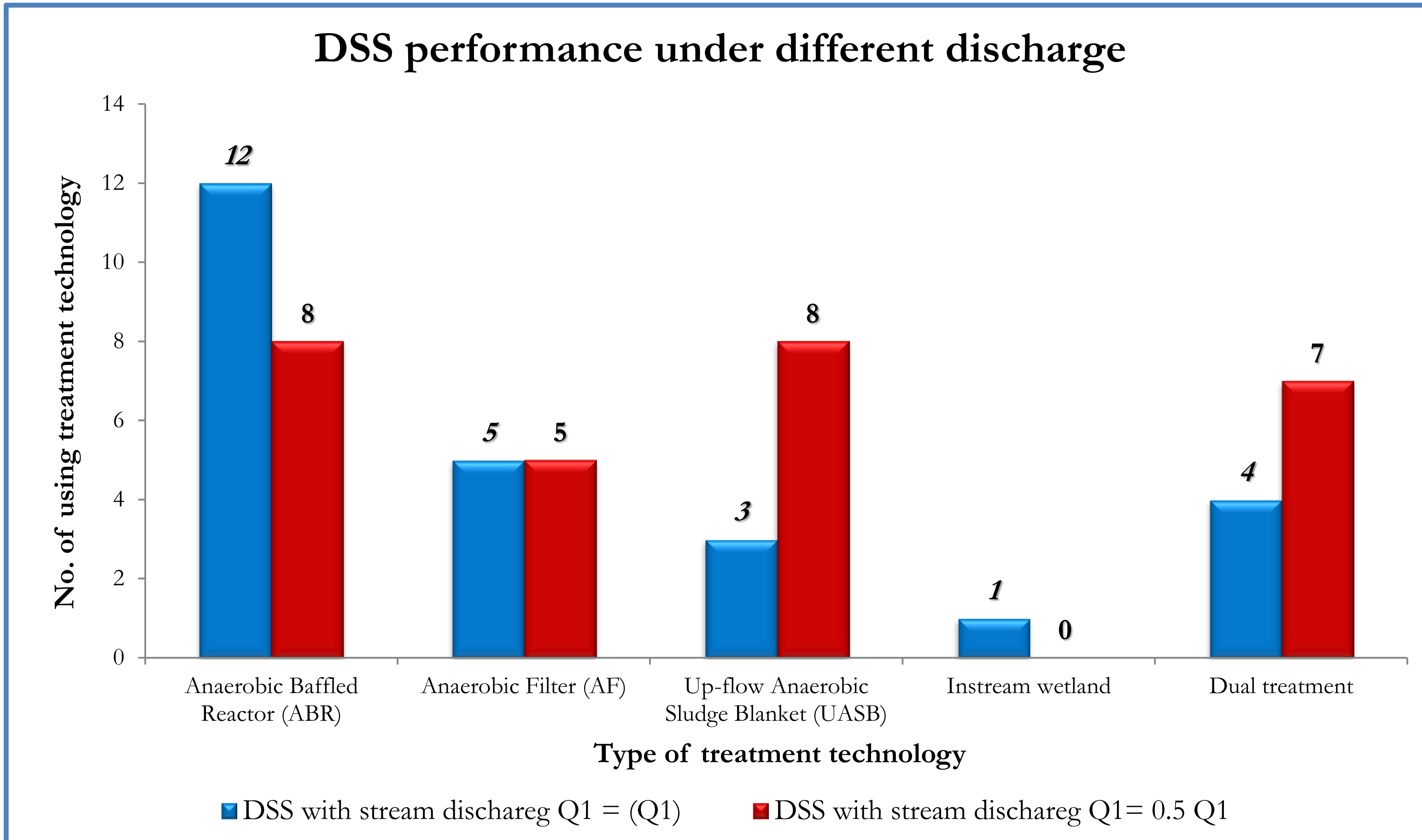


BOD concentration variability under different stream discharge

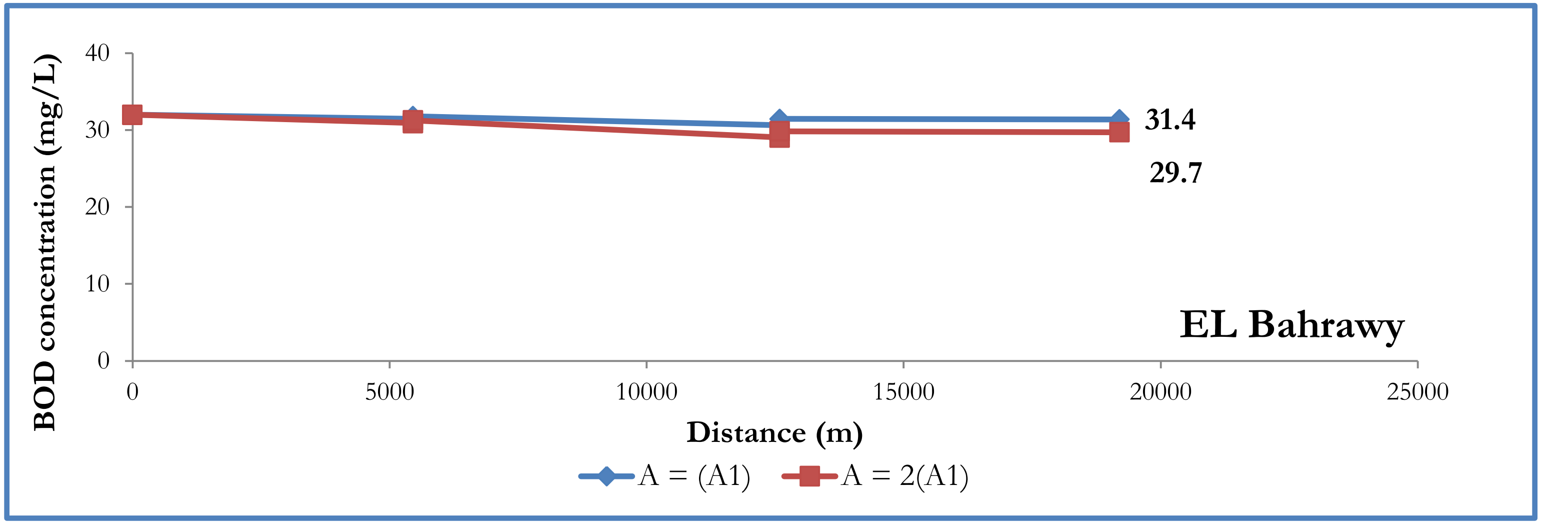


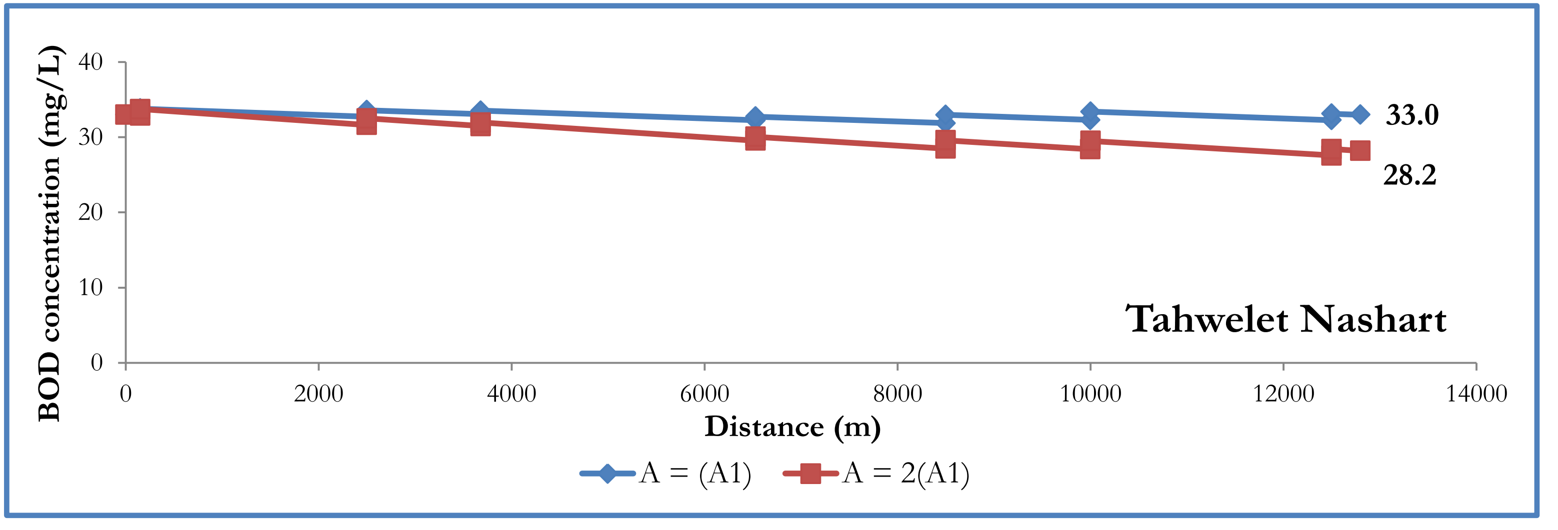


DSS performance under different stream discharge

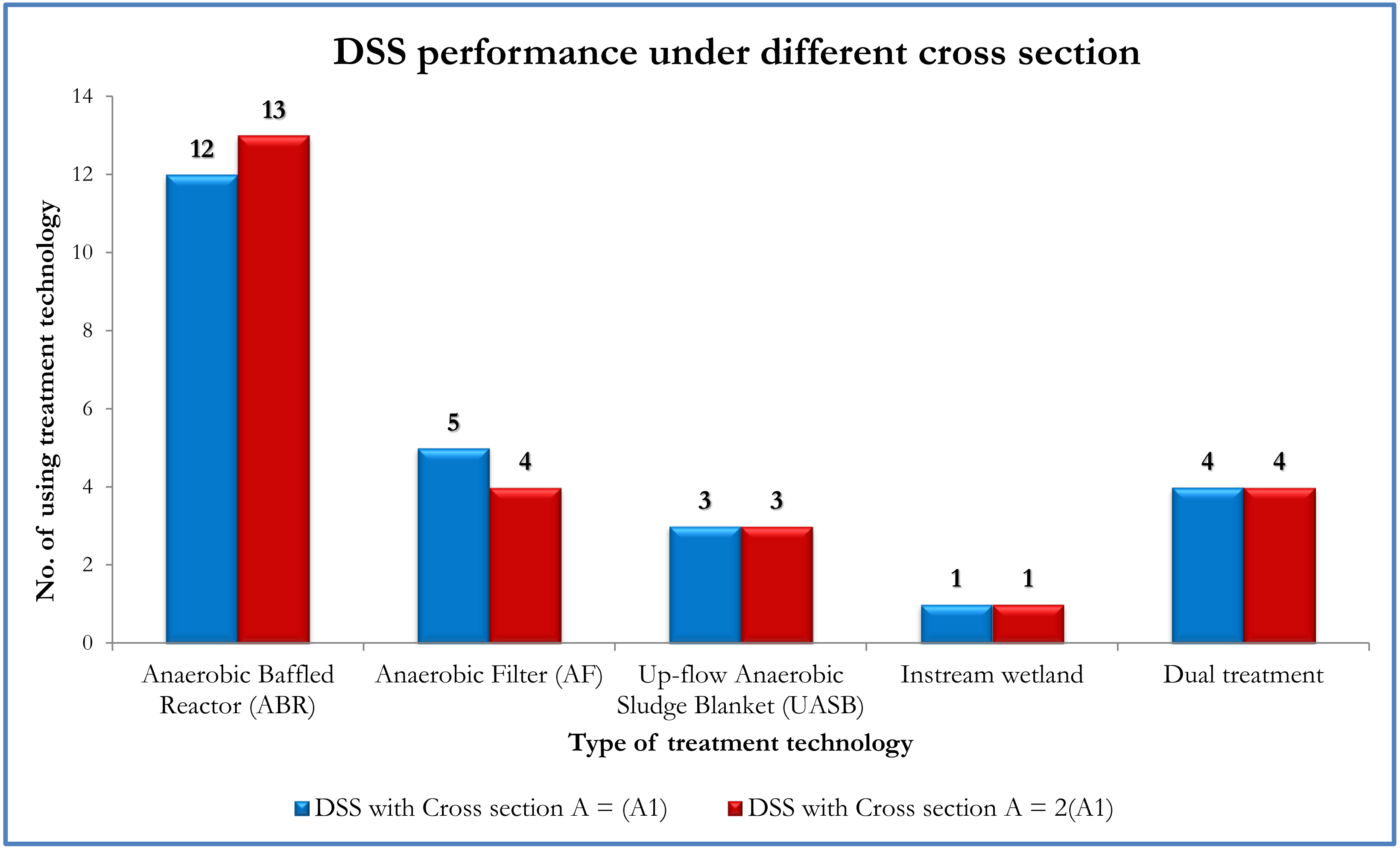


BOD concentration variability under different stream cross-section





DSS performance under different stream cross-section



Scenarios Cost

Treatment technology	Capital Cost / EGP	M&O cost/Month	O& M/ 15 Year (EGP)
ABR	950000	2000	360000
AF	1000000	2500	450000
UASB	1500000	3200	576000
IW	**500000**	1000	180000
Modi Iw	800000	1400	252000

Scenarios for 21 drain	Capital Cost/ Thousand -EGP	M&O Cost/ 15 year
Original DSS	23,400	9,198
Different discharge	32,900	12,351
Different Temp.	26,300	10,260
different cross-section	24,250	9,468

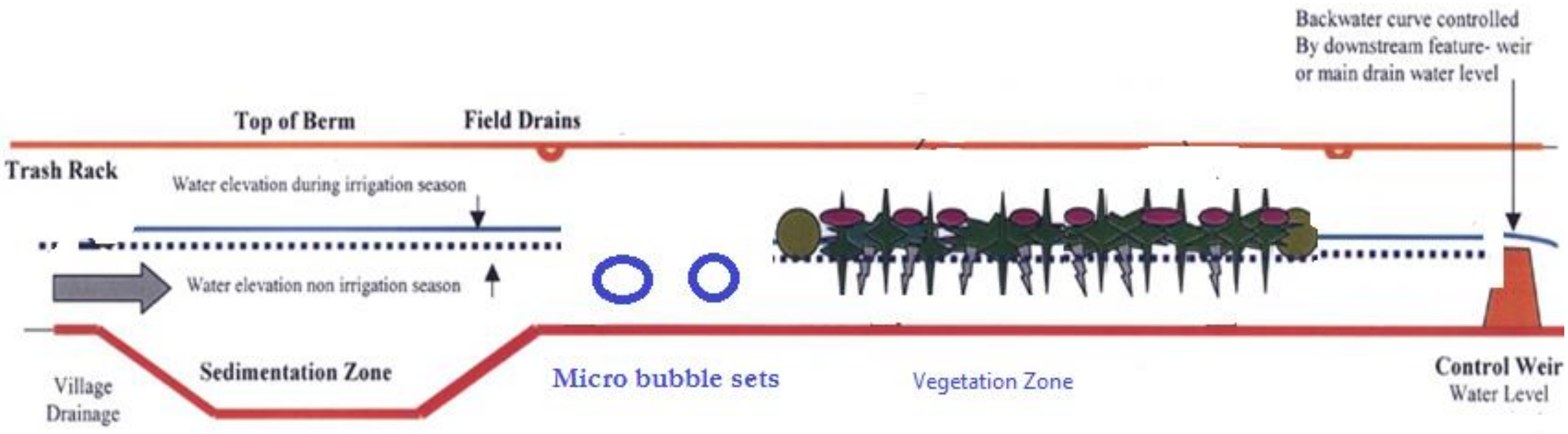
In-stream Wet-land

The analysis of data showed that the In-stream wet-land is proposed to be used in 1 out of 21 drains although this technology is the cheapest option for slightly polluted drains that's because;

The removal efficiency 50 %

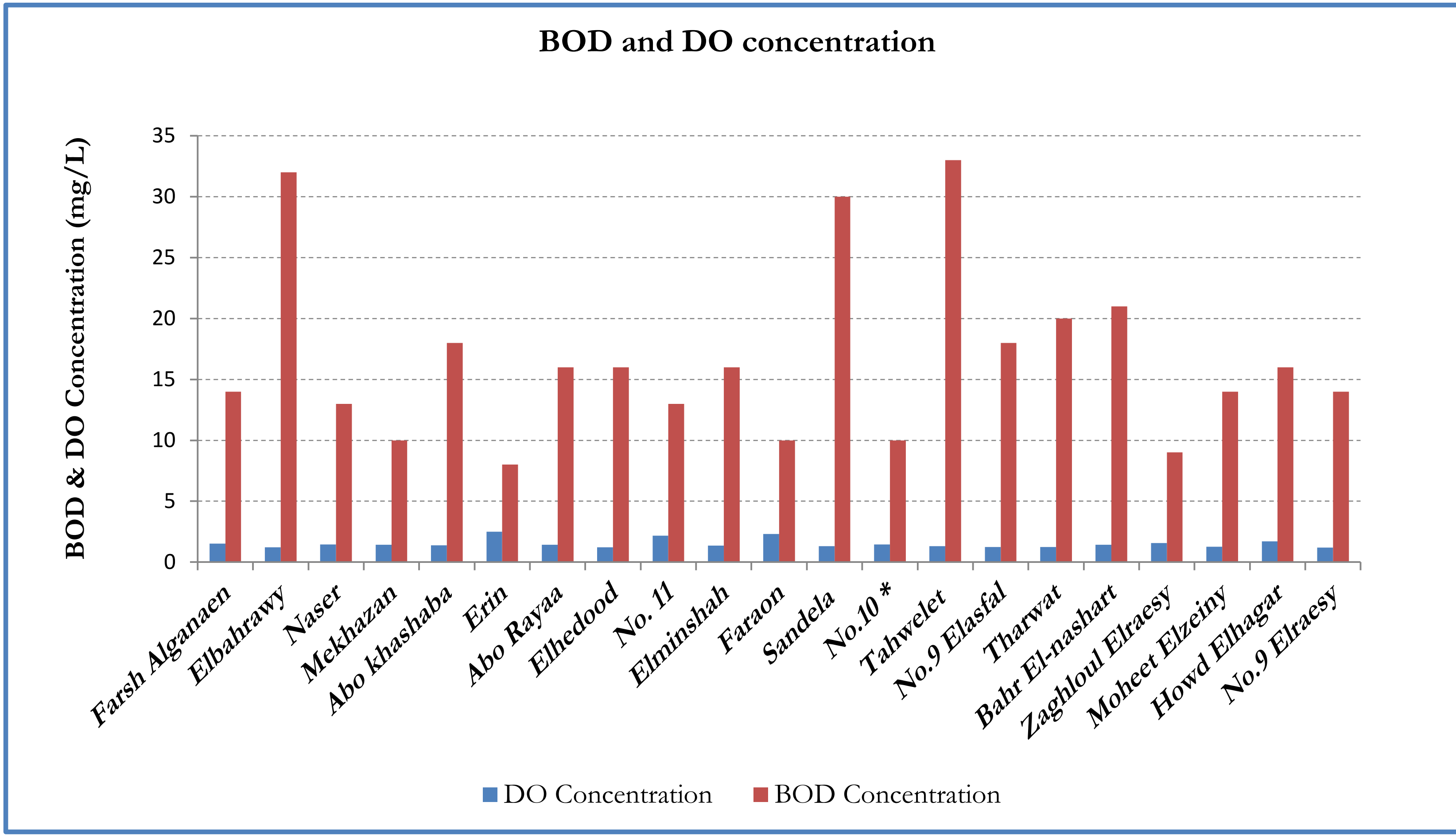
The drain discharge less than 1 m^3/s

Modification of in stream wet-land design



- Increase Air entrainment and DO values through :
  - Micro-bubble an oxygen Producer device (MBD)
  - Drop structure
- That will reflect on BOD removal efficiency.

DO and BOD concentration in Kafr EL Sheikh drains



Modification of in stream wet-land design

- **Micro-bubble device (an oxygen Producer) after sedimentation pond**

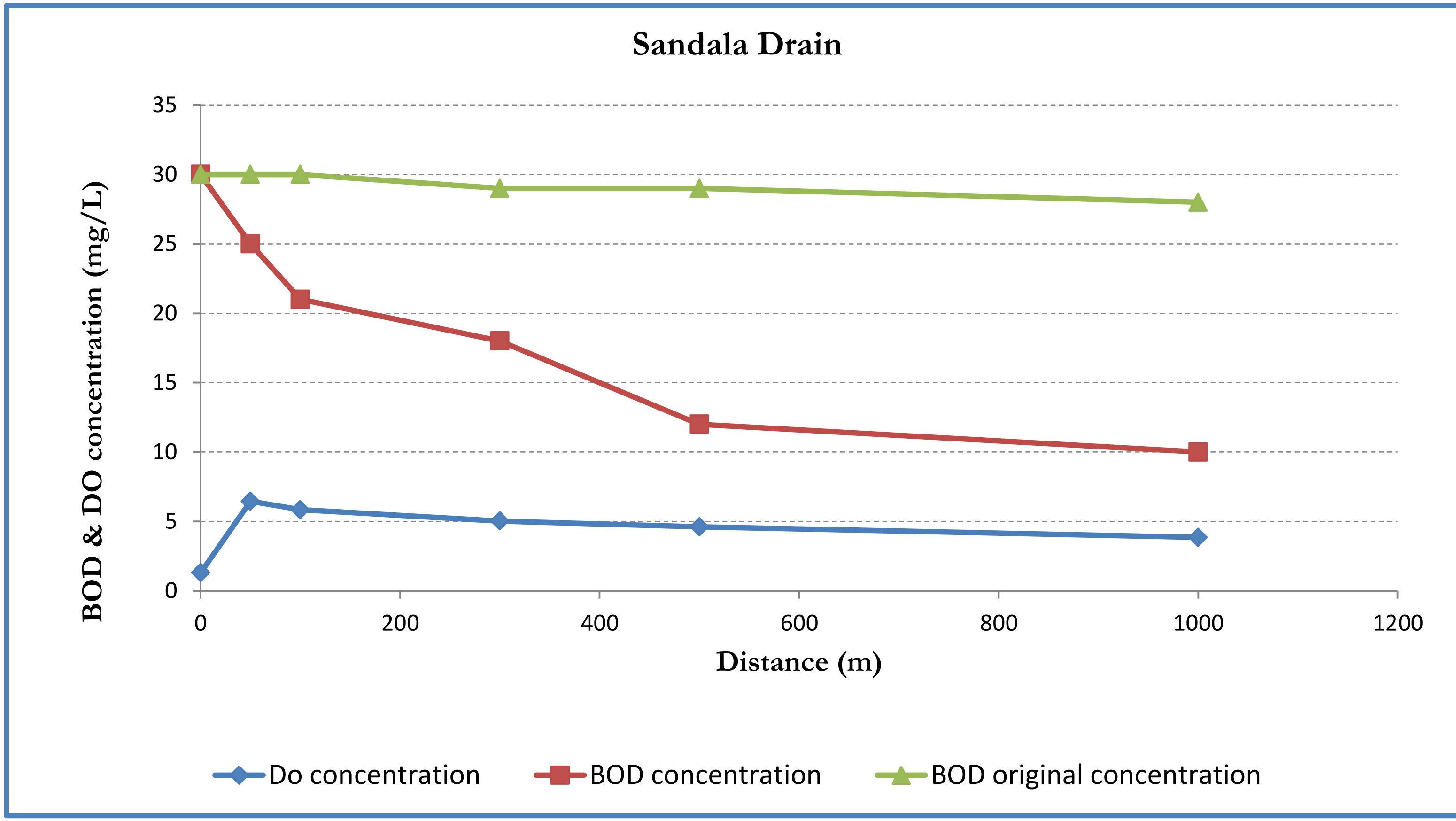
Modification of in stream wet-land design

Micro bubble test results

Time - Distance	DO (mg/l)					NO. of sets
	5m	50m	200m	500m	1000m	
Before operating T=0	DO = 1.3 (mg/l)					
Drain No. 4 T= 3 hours	2.45	1.98	1.5	1.5	1.4	2 sets (21 mm)
T= 1 hour (T. Channel)	6.45	5.45	2.35	2	1.5	1 set (21 mm)
T=1 hour (T. Channel)	6.49	5.84	5.03	4.6	3.85	2 sets (21 mm)
	BOD (mg/l)					
Before operating T=0	BOD = 30 (mg/L)					
T=1 hour (T. Channel)	25	21	18	12	10	2 sets (21 mm)

- Micro-bubble device increase dissolved oxygen (DO) from 1.6 (mg/l) to 4.6 (mg/l) after 1 operating hour (at 500 m)
- COD value improved from50mg/l to 20mg/l and it took approximately 1 hour.

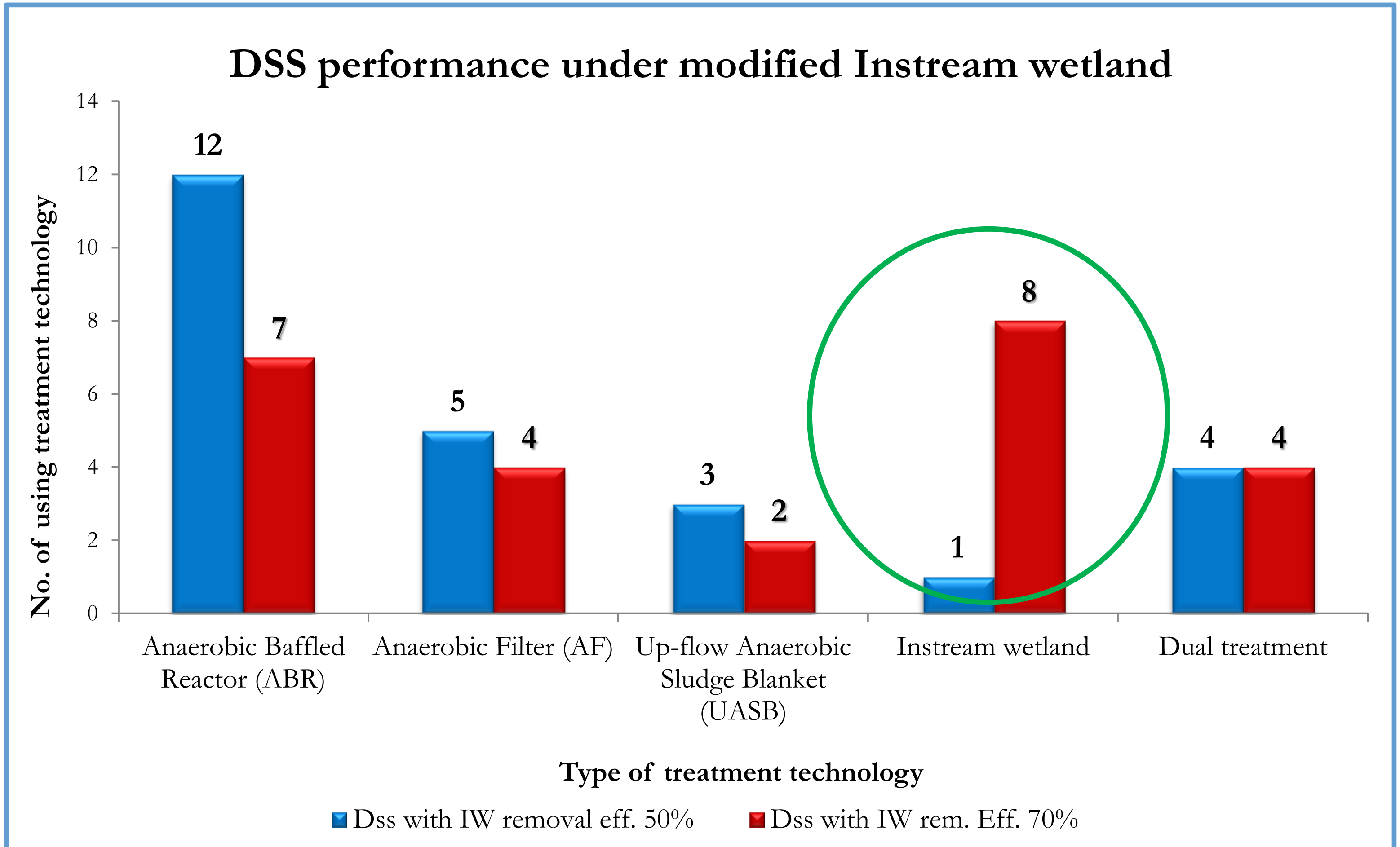
The relation between DO and BOD concentration



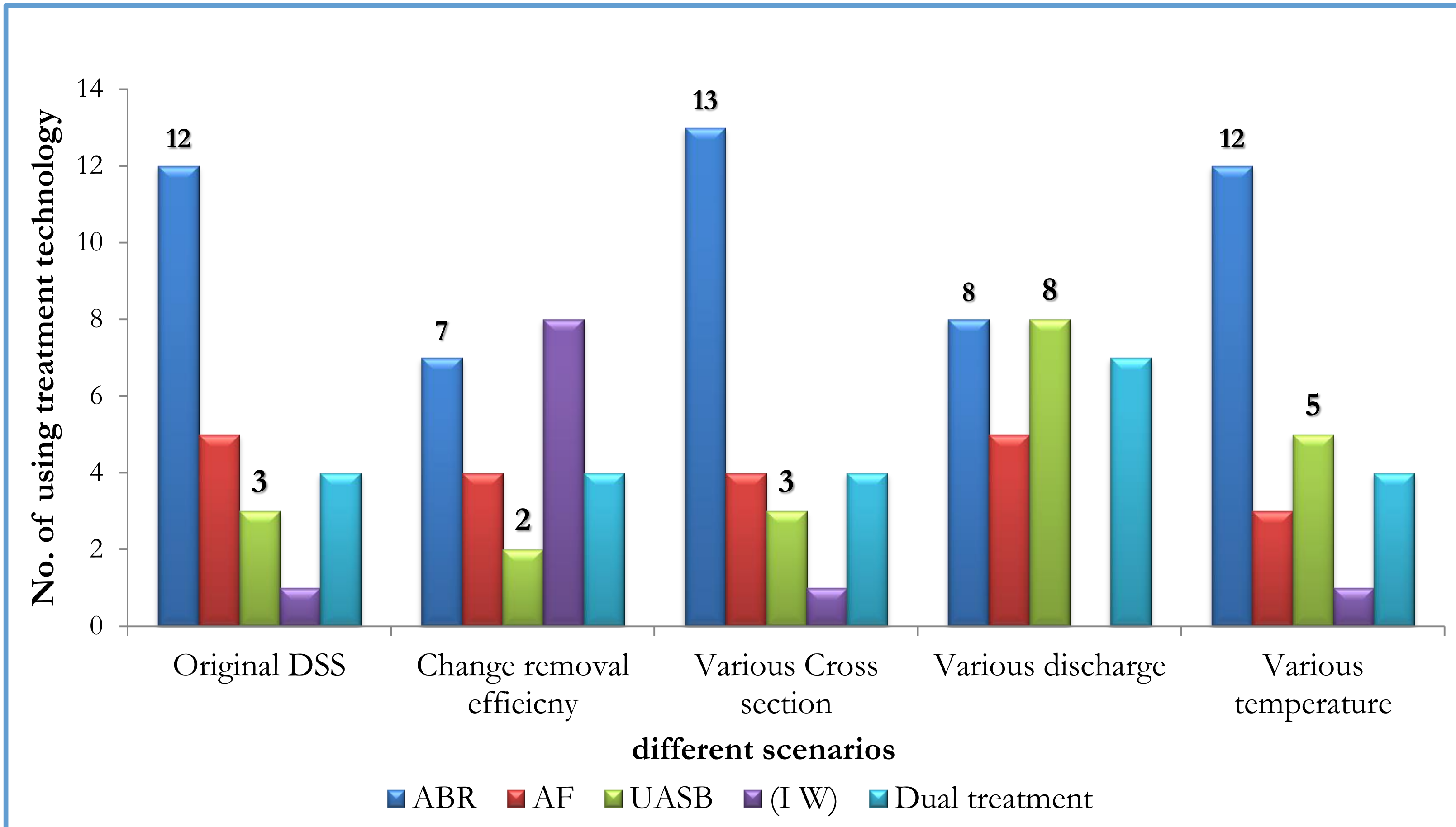
Modified In-stream Wet-land

- Micro Bubble Device increase the in-stream wetland removal efficiency from 50 % to 70 %
- MBD reduce retention time so the in-stream wetland can be used for drains with discharge ranged from **0.1 - 5 m3/s.**
- MBD increase the capital cost from **500,000** EGP to implement in-stream wetland to **800,000** Egyptian pound.

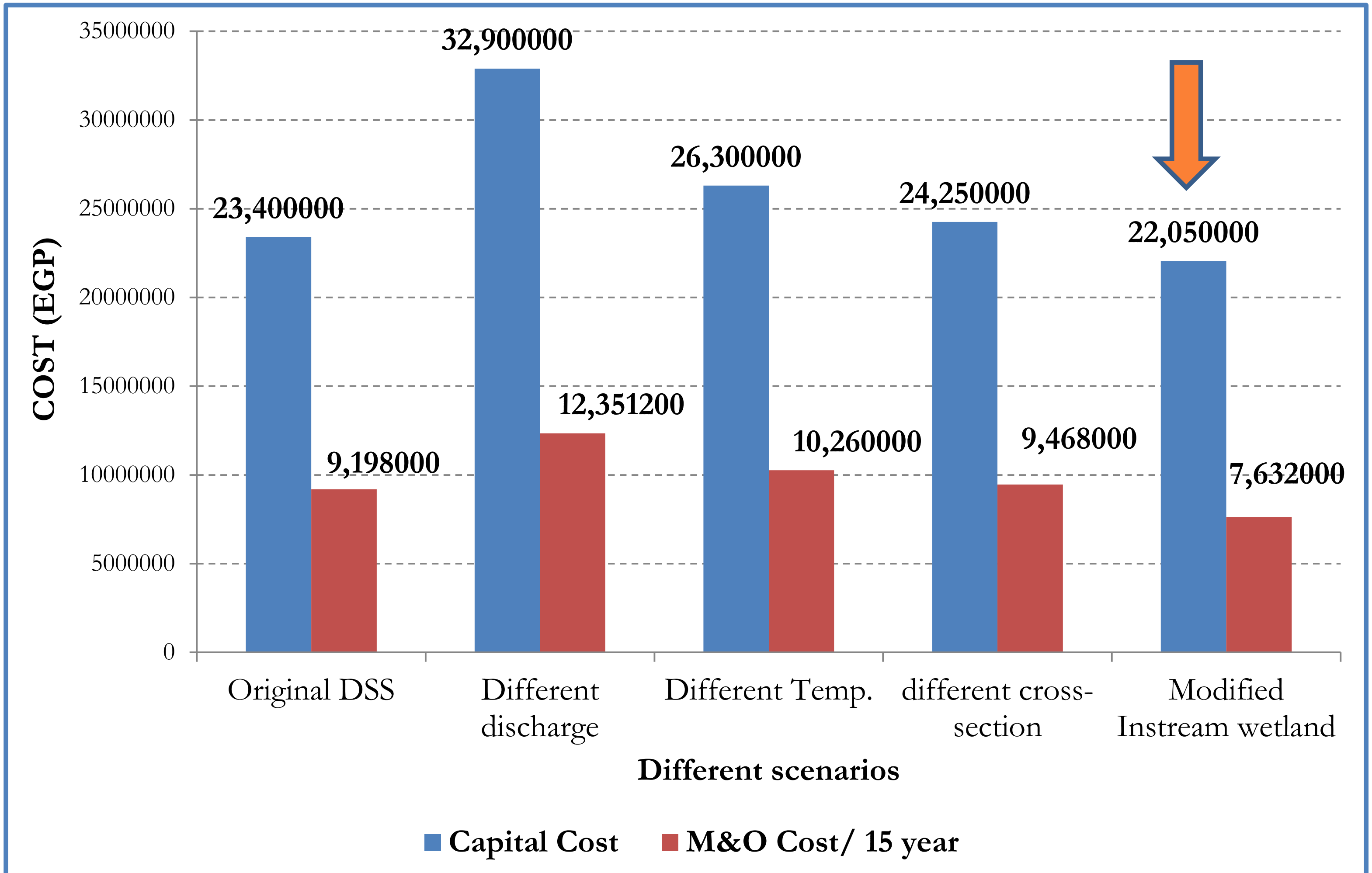
DSS performance under different removal efficiency (Modified instream wetland)



Sensitivity analysis for the selected treatment technologies through DSS

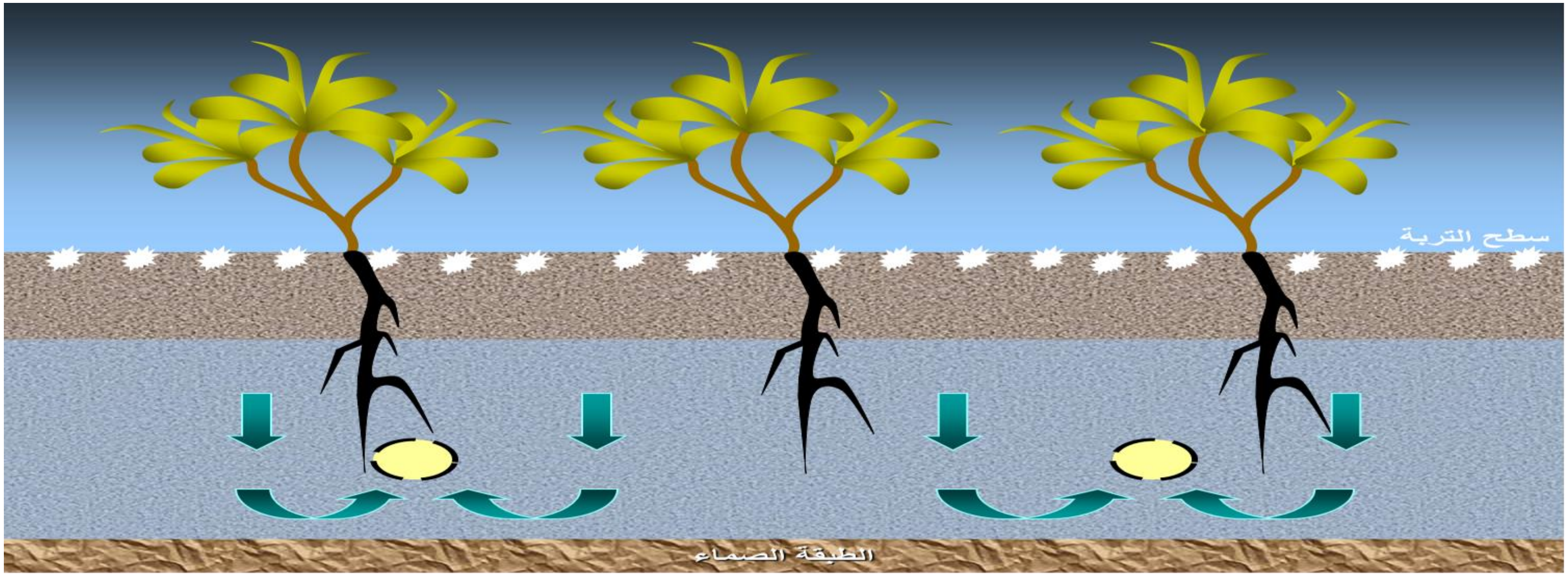


Capital and operational / maintenance cost

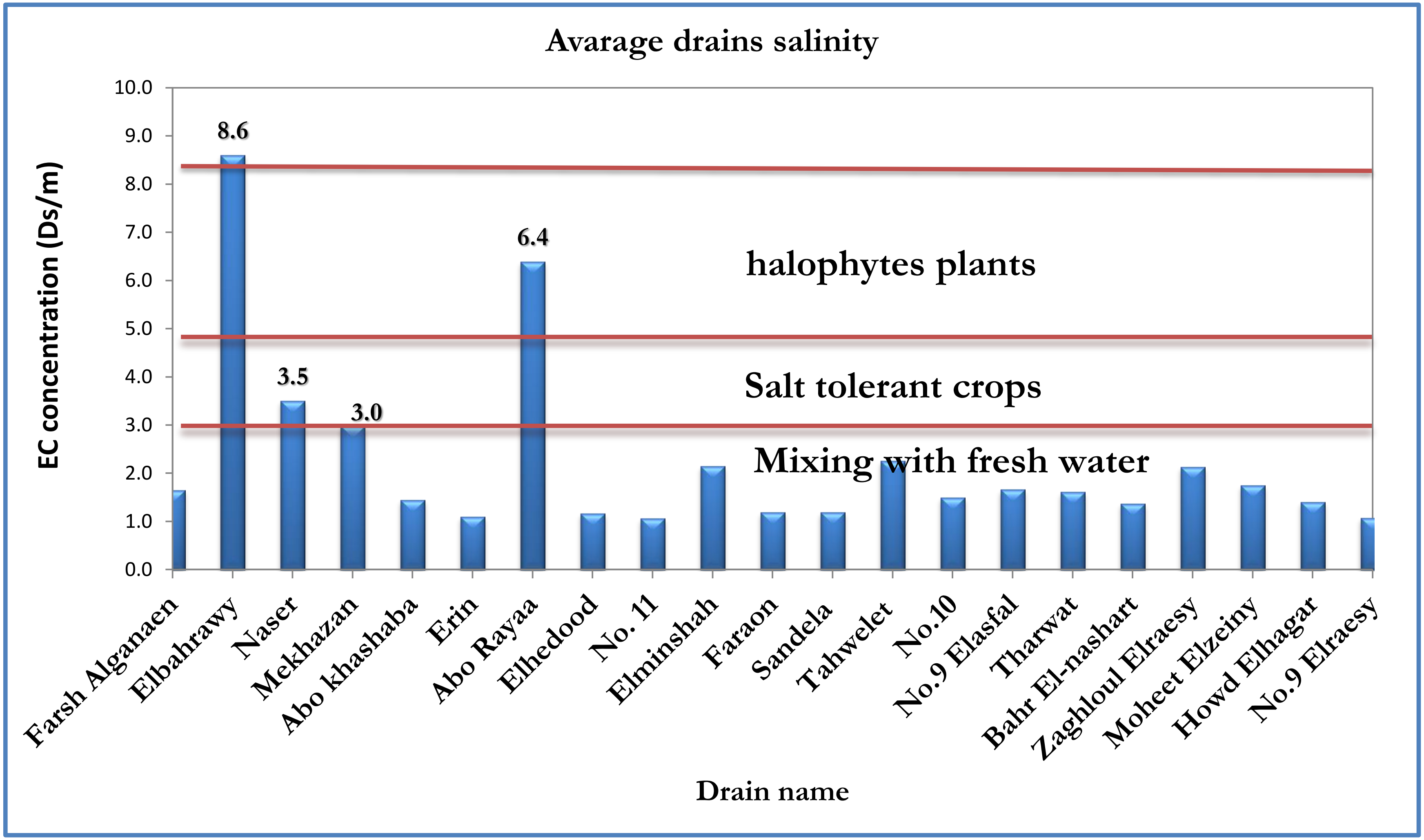


Determination of drains salinity

There are a high salinity values in some agriculture drains in the study area, because of the limited share of good quality irrigation water farmers irrigate their land by drainage water which classified as a low quality water leads to decrease crop yield and productivity.



Measured drains salinity

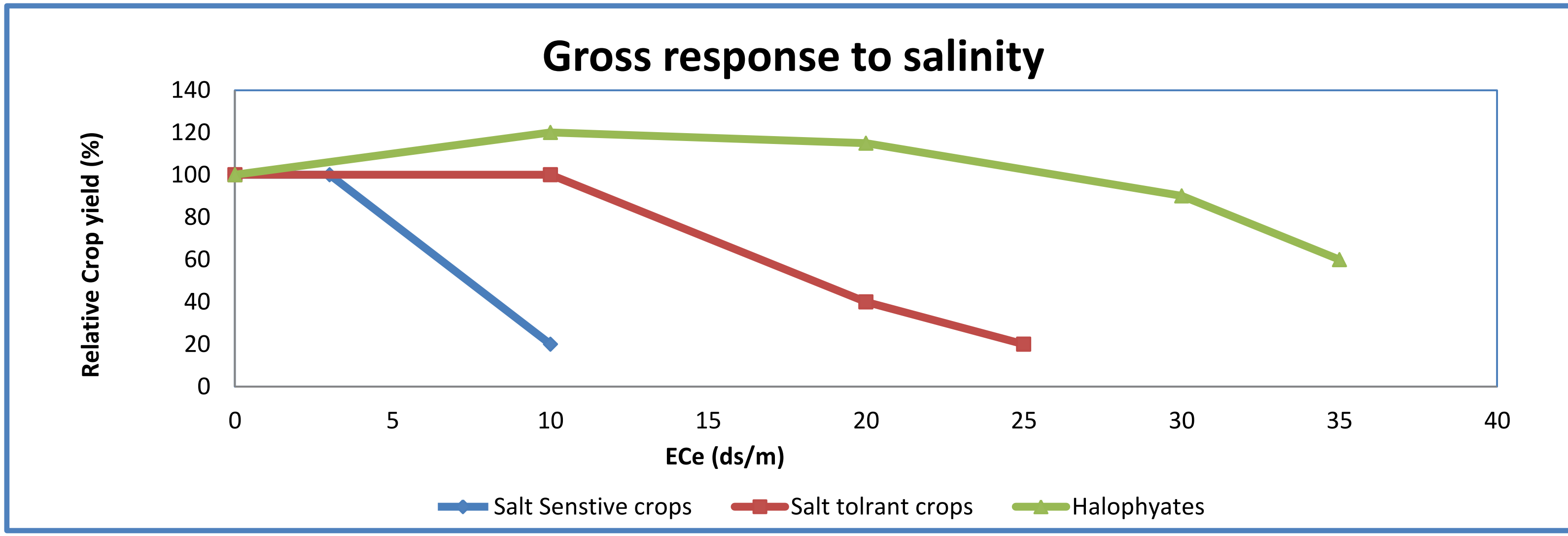


How to overcome salinity problems

- Reduce drains water salinity by mixing with fresh irrigation water with suitable ratio.

Salinity of drainage water (ds/m)	Restriction on use for irrigation
< 1.0	used directly for irrigation
1.0 - 2.3	mixed with canal water at ratio 1:1
2.3 - 4.6	mixed with canal water at ratio 1:2 or 1:3
> 4.6	not used for irrigation

How to overcome salinity problems



- It is recommended to use tolerant crops in the farm-land surrounding drains with EC values more than **3 Ds/m**.
- Use halophytes in the farm-land surrounding drains with EC values more than **5 Ds/m**.

Results and conclusions

- It was observed that drains with discharges more than 5 m3/sec is less affected with BOD effluent from villages with population up to 60,000 inhabitants.
- There is a relation between BOD concentration and crop pattern in the area, where in the summer season BOD values concentration decrease with rice cultivation.
- Irrigation with direct drainage water leads to increase soil salinity Northern East part of Kafr EL sheikh Governorate.

Results and Conclusions

- The change of temperature, stream cross section, and stream discharge have an effect on the BOD concentration and the selected treatment technologies through decision support system.
- Using a decentralized treatment station in the beginning of the drains keep BOD concentration values within the allowable limits which enable to direct reuse of drainage water in irrigation.

Results and conclusions

- Increasing air entrainment in the in-stream wetland technology will increase the BOD removal efficiency from 50% to 70% , and that modified scenario increase using instream wetland to be used in 8 sites out of 21.
- The modified in-stream wetland technology is the most suitable solution in the study area in terms of the required space and construction, operational and maintenance cost (especially drains with discharge less than 5 m3/S.)

Recommendations for further work

- The research focused on the point source of sewage waste pollution comes from villages, it is recommended to consider branch drains and sub-surface drainage effect in the calculation in further works.
- It also recommended to calculate the nitrate decay along the drains.
- Further works should study the behavior of the industrial wastes and heavy metals concentration values in samples of water and sediment along the drains.

Thank you

Typical profile of the instream wetland

Examples of decentralize treatment technology

Sanors village AL Fayoum

Sambo village – AL Garbayia

AL Ibarhimia - Sharkeya

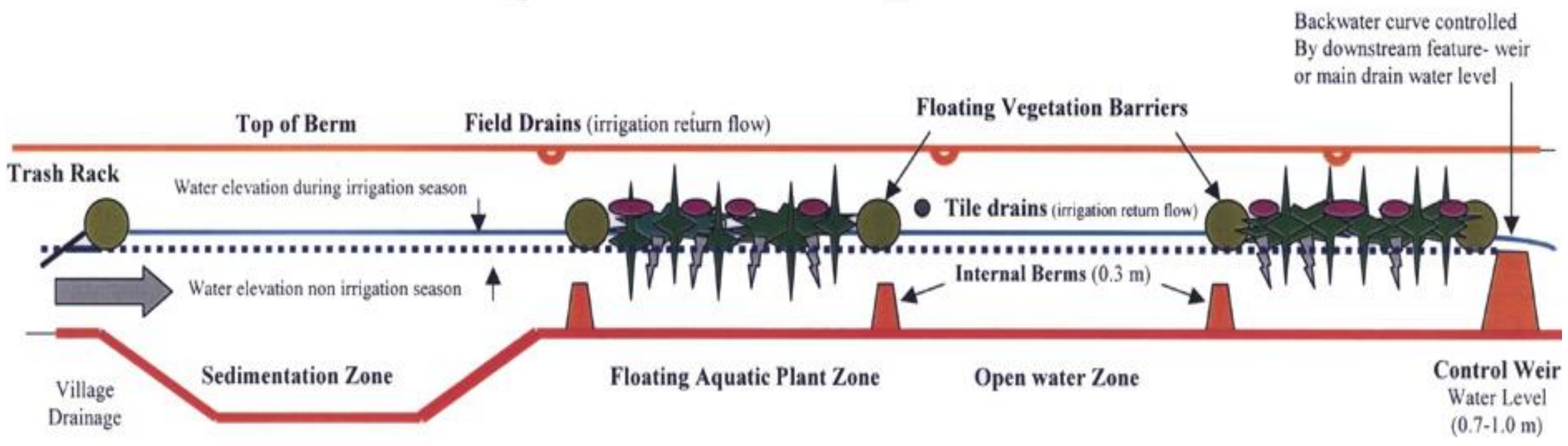
Kafe Al Hamam- AL Shrkiya

Micro bubble capacity

Flow (m3/day)	Flow (m3/S)	MBD		(Pump)Total kW
		Diameter	Units	
5,000	0.058	21 mm	2	3.7
10,000	0.12	21 mm	2	7.4
50,000	0.58	15 mm	6	33.0
100,000	1.16	32 mm	4	45.0
500,000	5.79	32 mm	4	150.0

- From the pervious data installing MBD before the vegetation zone by 500 m will be more efficient and reduce turbidity before the vegetation zone.
- No. of units and pump capacity required depending on stream discharge and the diameter of MBD nozzle.

Typical profile of the instream wetland



- sedimentation pond
- Vegetation pond
- Aeration zone (natural)
- The control weir is located at drain outlet
- EL Bahoo Drain – Idfena drain

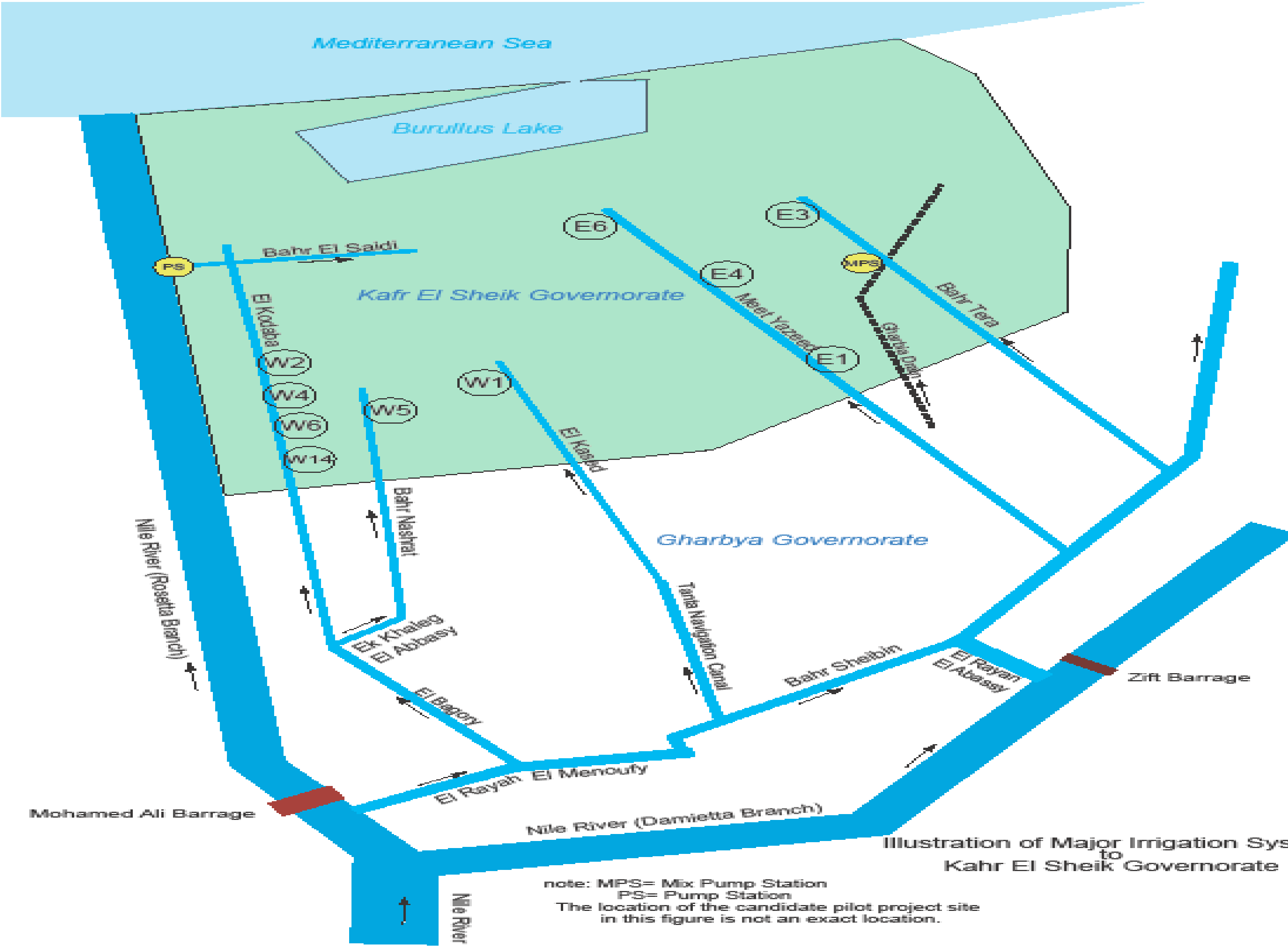


Illustration of Major Irrigation System to Kahr El Sheik Governorate

note: MPS= Mix Pump Station
PS= Pump Station
The location of the candidate pilot project site in this figure is not an exact location.