Empirical Equations for Estimation of Transmission Losses Based on Field Measurements in Ephemeral Streams

H. A. R. Ewea*, A. M. M. Elfeki, J. A. Bahrawi

Department of Hydrology and Water Resources Management, Faculty of Meteorology, Environment & Arid Land Agriculture, King Abdulaziz University, P.O. Box 80208, Jeddah 21589, Saudi Arabia
*Corresponding author

Email: hewea1136@gmail.com

Keywords: Transmission Losses, Ephemeral Streams, Catchment, Kingdom of Saudi Arabia

Transmission losses is caused by infiltration into the streambed in ephemeral streams. The conventional methods for flood routing in wadis is impossible to achieve due to transmission losses. The Muskingum routing procedure in its basic form has two parameters, the channel time lag, Km, and the weighting parameter, x. However, both parameters do not consider transmission losses of floods in channels. O'Donnell 1985 introduced a third parameter, α, in the continuity equation to allow for the lateral movement of floodwater. Elfeki et. Al (2014) carry some modifications of the assumptions such that the negative sign of the parameter α represents transmission losses. In this research, the third-parameter α has been investigated as a tool for estimation of transmission losses using data from Yiba catchment in the Kingdom of Saudi Arabia. A spreadsheet model will be developed to deduce the equations.

EMPIRICAL EQUATIONS FOR ESTIMATION OF TRANSMISSION LOSSES BASED ON FIELD MEASUREMENTS IN EPHEMERAL STREAMS

Authors:
Hatem A. Ewea *, Amro M.M. Elfeki**, and Jarbou A. Bahrawi

Dept. of Hydrology and Water Resources Management ,Faculty of Meteorology, Environment & Arid Land Agriculture, King Abdulaziz University , P.O. Box 80208 Jeddah 21589 Saudi Arabia

*Faculty of Engineering Azhar University
** Faculty of Engineering Mansoura University

10/17/2016 *Hatem A. Ewea *, Amro M.M. Elfeki**, and Jarbou A. Bahrawi*

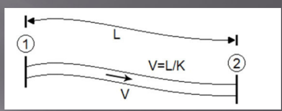
Outline

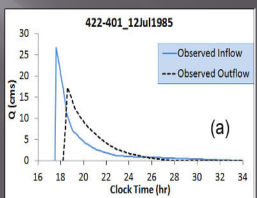
1. Problem Statement.
2. Research Objective.
3. Study Area.
4. Field Observations and Measurements.
5. Muskingum Method incorporating Transmission losses
6. Model results and Parameter Estimation
7. Results
8. Conclusions

10/17/2016 Hatem A. Ewea *, Amro M.M. Elfeki**, and Jarbou A. Bahrawi

Problem Statement

- In the literature, researchers usually use three parameter Muskingum method for river flood routing with lateral inflow (O'Donnell, T. (1985).
- Recently the method has been applied on ephemeral channels to incorporate transmission losses (α) with success by Elfeki, et al. (2014).





10/17/2016 Hatem A. Ewea *, Amro M.M. Elfeki**, and Jarbou A. Bahrawi

Research Objective

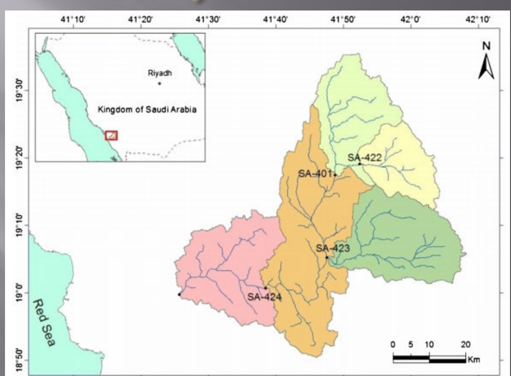
1. To Investigate The parameter (α)as a tool for estimation of transmission losses using data from Yiba catchment in the Kingdom of Saudi Arabia.
2. To develop A spreadsheet model to deduce the empirical equations for estimation (α) in ephemeral channels

10/17/2016 Hatem A. Ewea *, Amro M.M. Elfeki**, and Jarbou A. Bahrawi

Study Area

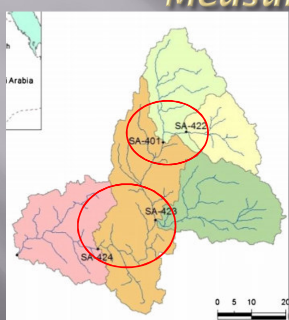
Yiba basin is located in Makkah Al-Mukaramah region, in the southwestern part of Saudi Arabia.

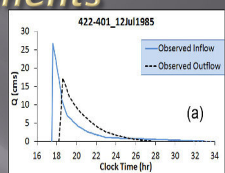
It has an area of 2346 km^2 and drains its water towards the Red Sea.

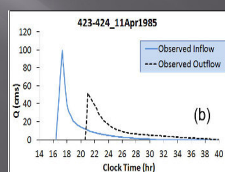


10/17/2016 Hatem A. Ewea *, Amro M.M. Elfeki**, and Jarbou A. Bahrawi

Field Observations and Measurements



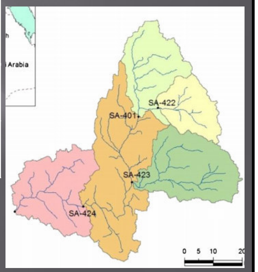




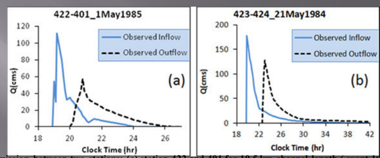
10/17/2016 Hatem A. Ewea *, Amro M.M. Elfeki**, and Jarbou A. Bahrawi

Catchments and Channel Characteristics

Station	Area (km^2)	Length of the main stream (km)	Basin Slope (m/m)	Channel reach length (km)
422	306.01	23.3	0.3322	10.5
401	764.96	35.07	0.2833	
423	612.83	36.2	0.2657	32.2
424	2346.27	51.8	0.1969	



Muskingum Method incorporating Transmission losses



Observed hydrograph transmission between two stations: (a) station 422 and 401 for 10.5 km channel length (event 1st of May 1985), (b) station 423 and 424 for 16.1 km channel length (event 21st of May1984).

O'Donnell, (1985) expressed the three parameter model as follows:

$$I(1+\alpha)=O+\frac{dS}{dt} \quad \text{.......................................(1)}$$

where:

S is the channel storage,

I is the inflow hydrograph into the channel segment,

O is the outflow hydrograph from the channel segment, and

α is the coefficient of lateral flow.

The empirical formula for the channel storage is given by

$$S=K_m\left[(1+\alpha)xI+(1-x)O\right] \quad \text{.......................................(2)}$$

where,

K_m is the channel time lag (the hydrograph movement time), and

x is a weighting parameter

$$O_{t+\Delta t}=d_1 I_t+d_2 I_{t+\Delta t}+d_3 O_t \quad \text{.......................................(3)}$$

where, d_1, d_2, and d_3 are the coefficients that can be obtained by the matrix inversion least square solution

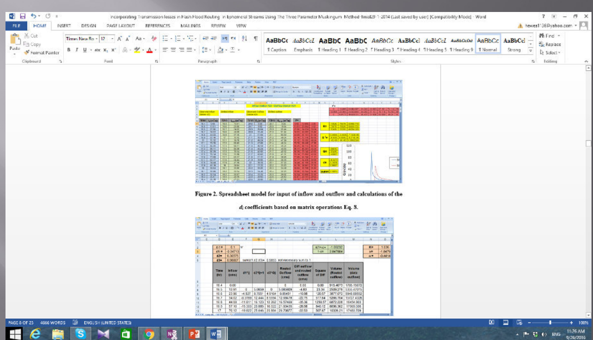
The three parameters, K_m, x and α, are related to d_1, d_2, and d_3 by the following formulas (O'Donnell, 1985),

$$K_m=\Delta t\,\frac{d_1+d_2 d_3}{(1-d_3)(d_1+d_2)} \quad \text{.......................................(4)}$$

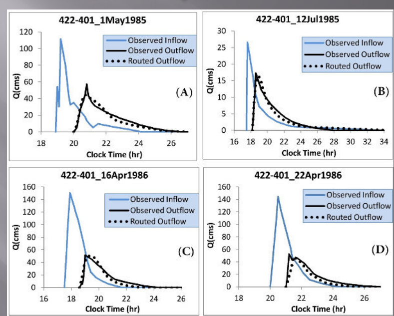
$$x=0.5\left(1-\frac{d_2+d_1 d_3}{d_1+d_2 d_3}\right) \quad \text{.......................................(5)}$$

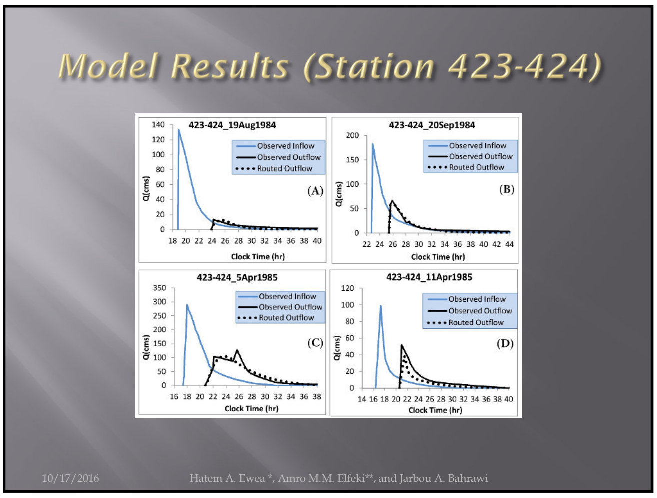
$$\alpha=\frac{d_1+d_2+d_3-1}{1-d_3} \quad \text{.......................................(6)}$$

Parameter Estimation



Model Results (Station 422-401)

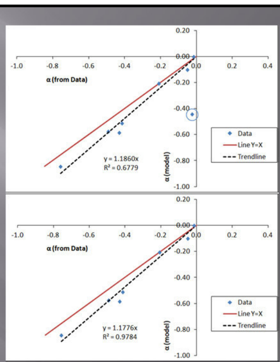




Summary of Parameter Estimation

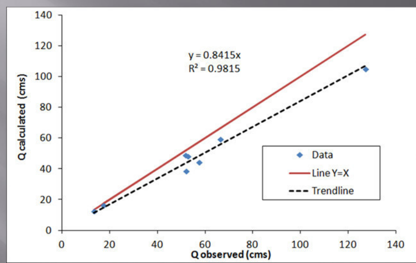
Reach	Date	d_1	d_2	d_3	K_r (hr)	x	α (model)	$α_D$ (from Data)	T_{lag} (hr)	Q_p (Obs.)	Q_p (Routed)	RMSE	K_t (hr)	K_t+K_r (hr)
Inflow 422 Outflow 401	1May1985	0.05	0.08	0.86	0.65	-0.02	-0.10	-0.05	1.6	57.35	44.38	1.45	1.1	1.75
	12Jul1985	0.05	0.15	0.80	0.42	-0.06	0.00	-0.02	1	17.35	16.38	0.56	0.7	1.12
	16Apr1986	0.22	-0.11	0.75	0.50	0.31	-0.58	-0.49	1.3	51.75	48.91	2.10	1.1	1.60
	22Apr1986	-0.23	0.30	0.82	0.15	-2.33	-0.58	-0.43	0.7	52.76	48.30	2.95	1	1.15
Avearge		0.02	0.11	0.81	0.43	-0.53	-0.31	-0.25	1.15	44.80	39.50	1.76	0.98	1.41
SD		0.18	0.17	0.05										
Upper Limit		0.21	0.28	0.85										
Lower Limit		-0.16	-0.07	0.76										
Inflow 423 Outflow 424	19Aug1984	-0.01	0.02	0.90	0.88	-0.12	-0.84	-0.76	5.3	13.35	12.63	1.60	5.1	5.98
	20Sep1984	-0.25	0.30	0.89	0.33	-1.50	-0.51	-0.41	3.0	66.29	59.19	2.21	2.7	3.03
	5Apr1985	-0.01	0.04	0.96	2.49	-0.04	-0.21	-0.21	7.7	127.20	104.86	8.49	3.4	5.89
	11Apr1985	-0.35	0.37	0.97	1.04	-1.85	**-0.44**	**-0.03**	4.2	51.94	38.70	5.02	4.2	5.24
Avearge		-0.09	0.12	0.92	1.23	-0.55	-0.52	-0.46	5.33	68.94	58.89	4.10	3.73	4.97
SD		0.14	0.16	0.04										
Upper Limit		0.05	0.28	0.96										
Lower Limit		-0.23	-0.03	0.88										

10/17/2016 Hatem A. Ewea *, Amro M.M. Elfeki**, and Jarbou A. Bahrawi

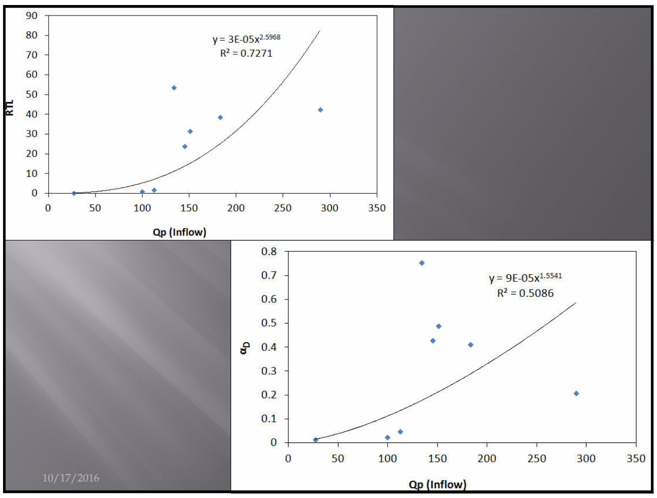


Comparison bewteen observed and calculated α-parameter (top) with all data points, (bottom) after ommitting the extreme value as shown in Table 2 (bold face number in α-parameter columns).

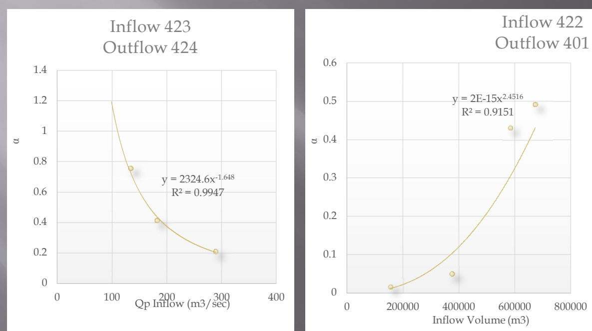
10/17/2016 Hatem A. Ewea *, Amro M.M. Elfeki**, and Jarbou A. Bahrawi



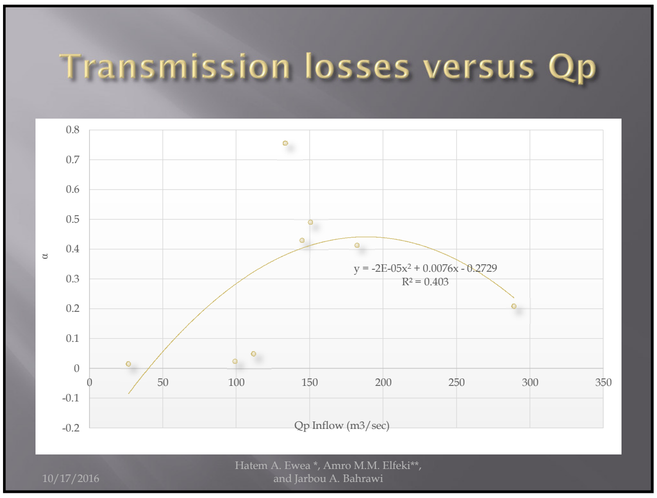
10/17/2016 Hatem A. Ewea *, Amro M.M. Elfeki**, and Jarbou A. Bahrawi

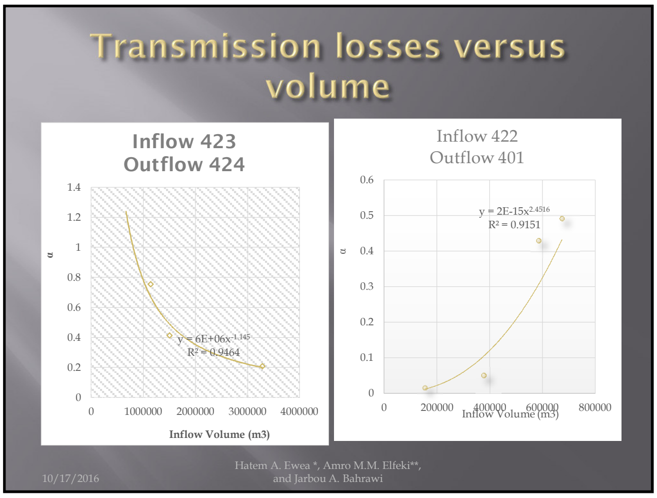


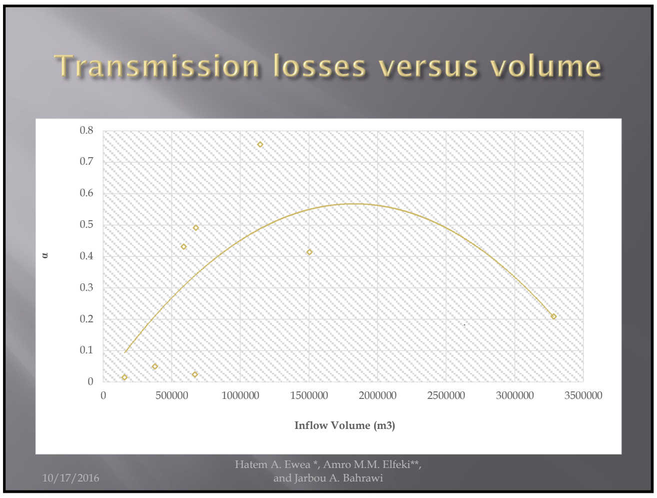
Transmission losses versus Qp

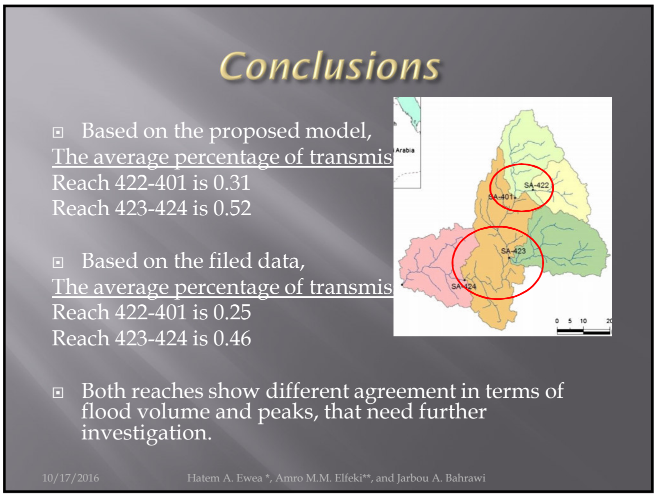


10/17/2016 Hatem A. Ewea *, Amro M.M. Elfeki**, and Jarbou A. Bahrawi


Transmission losses versus Qp
y = -2E-05x² + 0.0076x - 0.2729
R² = 0.403
α
Qp Inflow (m3/sec)
10/17/2016
Hatem A. Ewea *, Amro M.M. Elfeki**,
and Jarbou A. Bahrawi


Transmission losses versus volume
Inflow 423
Outflow 424
y = 6E+06x-1.145
R² = 0.9464
Inflow Volume (m3)
Inflow 422
Outflow 401
y = 2E-15x2.4516
R² = 0.9151
Inflow Volume (m3)
α
10/17/2016
Hatem A. Ewea *, Amro M.M. Elfeki**,
and Jarbou A. Bahrawi


Transmission losses versus volume
α
Inflow Volume (m3)
10/17/2016
Hatem A. Ewea *, Amro M.M. Elfeki**,
and Jarbou A. Bahrawi


Conclusions
Based on the proposed model,
The average percentage of transmis
Reach 422-401 is 0.31
Reach 423-424 is 0.52
Based on the filed data,
The average percentage of transmis
Reach 422-401 is 0.25
Reach 423-424 is 0.46
Both reaches show different agreement in terms of flood volume and peaks, that need further investigation.
SA-422
SA-401
SA-423
SA-424
10/17/2016
Hatem A. Ewea *, Amro M.M. Elfeki**, and Jarbou A. Bahrawi