Equilibrium Water Balance Model - EWBM (NWRI)

EWBM was elaborated as a hydrological tool for groundwater and climate interaction estimation in frame of KW405-000223 project “Estimation of groundwater and climate interaction over the area of Southern Ontario using simplified water balance equation”. As the matter of fact, this is monthly water balance model, in which the lowest value of groundwater head above the riverbed has the highest correlation with air temperature. Monthly water balance equation of EWBM can be written as following:

$$E = P - S - R + dG + dM$$

Where

P - month amount of precipitation on examined drainage area (watershed), mm
S - amount of water in snow pack, mm (estimated by Adjusted, Simplified or Retention Models for snow accumulation and melting estimation)
R - river runoff, mm
dG - changing in ground water storage, mm
dM - changing in soil moisture storage, mm
E - evapotranspiration, mm

River runoff includes STP outflows and diminished by any withdrawals of water from the stream or reservoirs, so

$$R = Rm - STP + WS$$

Where

Rm - measured runoff, mm
STP - total outflows from STP within an examined watershed, mm
WS - total water withdrawals from surface water within examined watershed, mm

Changing in groundwater storage dG was estimated using the following:

$$dG = dH*Y*1000$$

where

dH - changing of groundwater level within examined period, m (dH was accepted as a difference between average levels for previous and current months: H previous - H current).
Y - average water yield of watershed deposits (effective saturation), dimensionless.
1000 - transformation coefficient from meters to mm.
For different deposits on Etobicoke watershed Y was taken as following:

Till	Clay	Silt	Fine sand	Medium sand	Gravel
0.02	0.005	0.035	0.12	0.2	0.3

Prepared by Rimma Vedom

Equilibrium Water Balance Model

Distribution of deposits were estimated from the map n4 in State of the Watershed Report: Etobicoke and Mimico Creek watersheds, TRCA, 1998 (further: State Report).

Average water table level for each month was estimated as the following:

$$H = 1000*I \text{ if } H = Hmin,$$

Where

Hmin - head of water table above the creek bed within the lowest "uniform area-sink", where relation between H and I remain to be linear.

I - average gradient of water table, dimensionless

$$I = B/(F*K*0.0864)$$

B - baseflow, m3/s (B = Bm – STP + WS + WG)

Bm - baseflow obtained by SimpleBase model from Rm, m3/s

WG - total withdrawals from groundwater (depth of wells not deeper than river bed)

F - watershed area, km2

0.0864 - summarised adjusting coefficient between day and second, km and m

K - hydraulic transmissivity of deposits above river bed, m/day

$$K = Y*\exp(0.8/(1 - 2.5*Y))$$

If actual H is higher than H min,

$$H = Hmin + LN(1 + I*r/K)$$

where

r - radius of cones, which slope surface area is equal to the area of watershed (Daniel, 1976)

$$r = SQRT(2*F/3.14)$$

To estimate Hmin the F for river valley was accepted as mach as 3 km2 (1-5 km2 according to Vermulst and Lange, 1999 is an average "uniform area-sink") that was estimated for European experimental watersheds that tend to be small (less than 10 km2) and heavily instrumented". And there is the room for further improvements: the "uniform area-sink" is nothing else as river valley and can be estimated proportionally to watershed area.

Changing in soil moisture storage dM was estimated as the following

$$dM = dH*Y/(1+Y*20)$$

This equation was based on the following statement (simplification):

Due to topography information was not available for that project, and there was no possibility to estimate the depth of unsaturated layer, it was accepted that soil moisture fluctuations can be taken as mach as difference between total and residual saturation within water table fluctuation.

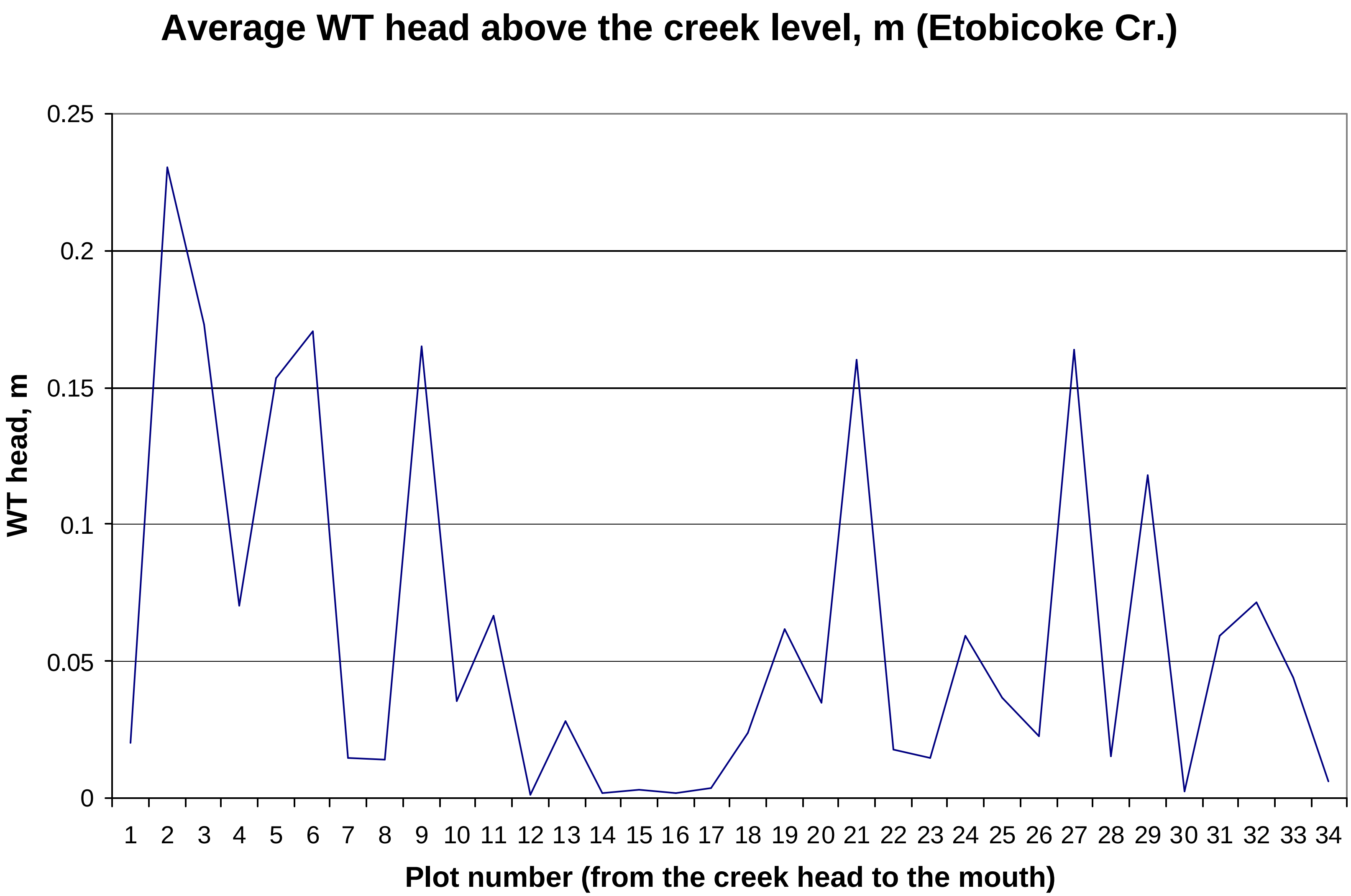
An application of EWBM to Etobicoke Cr. for monthly water table and evapotranspiration changing along the creek length was done using preliminary division into 34 examined plots (see Water Resources Inventory Model project).

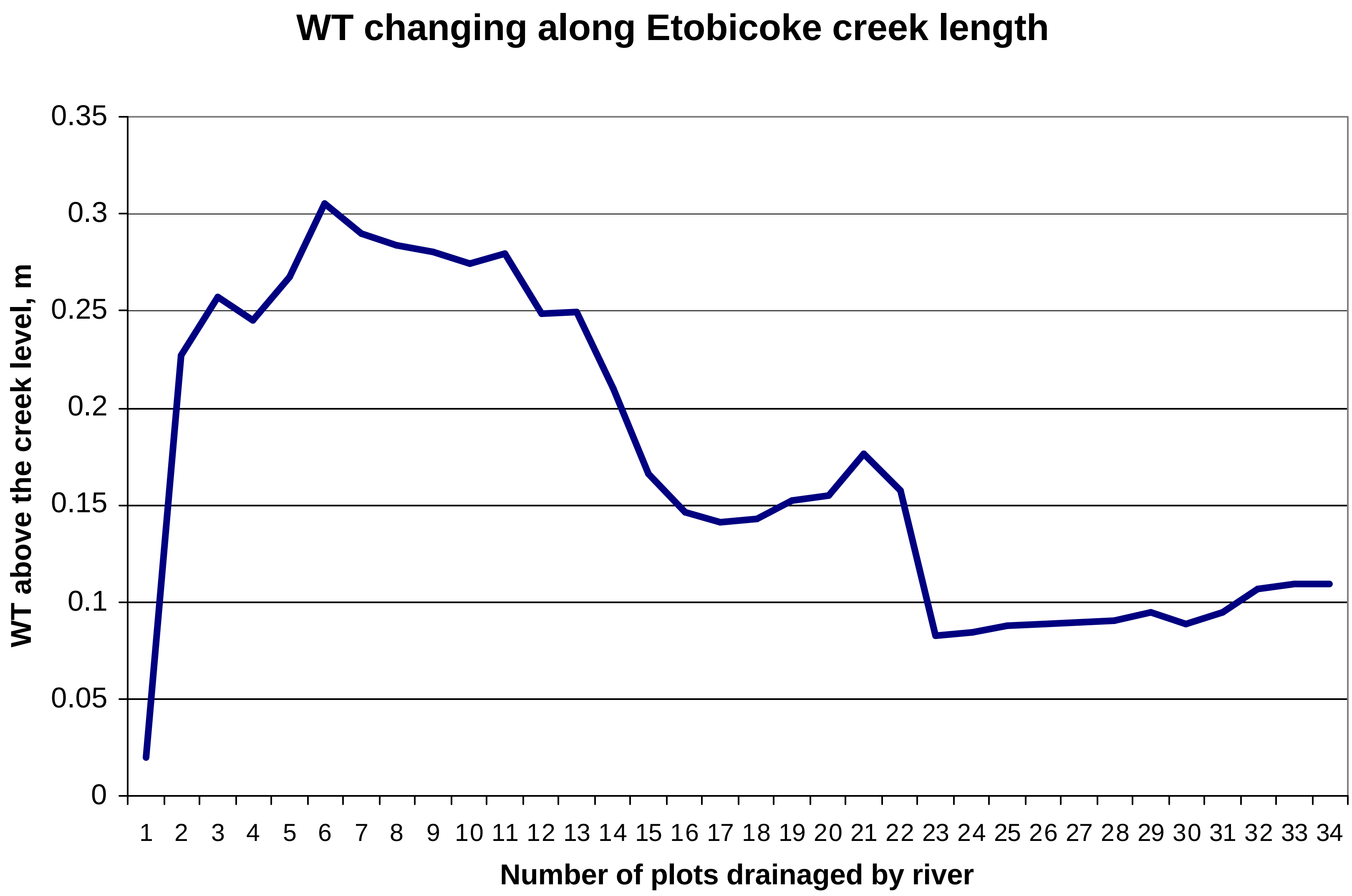
Results are presented below:

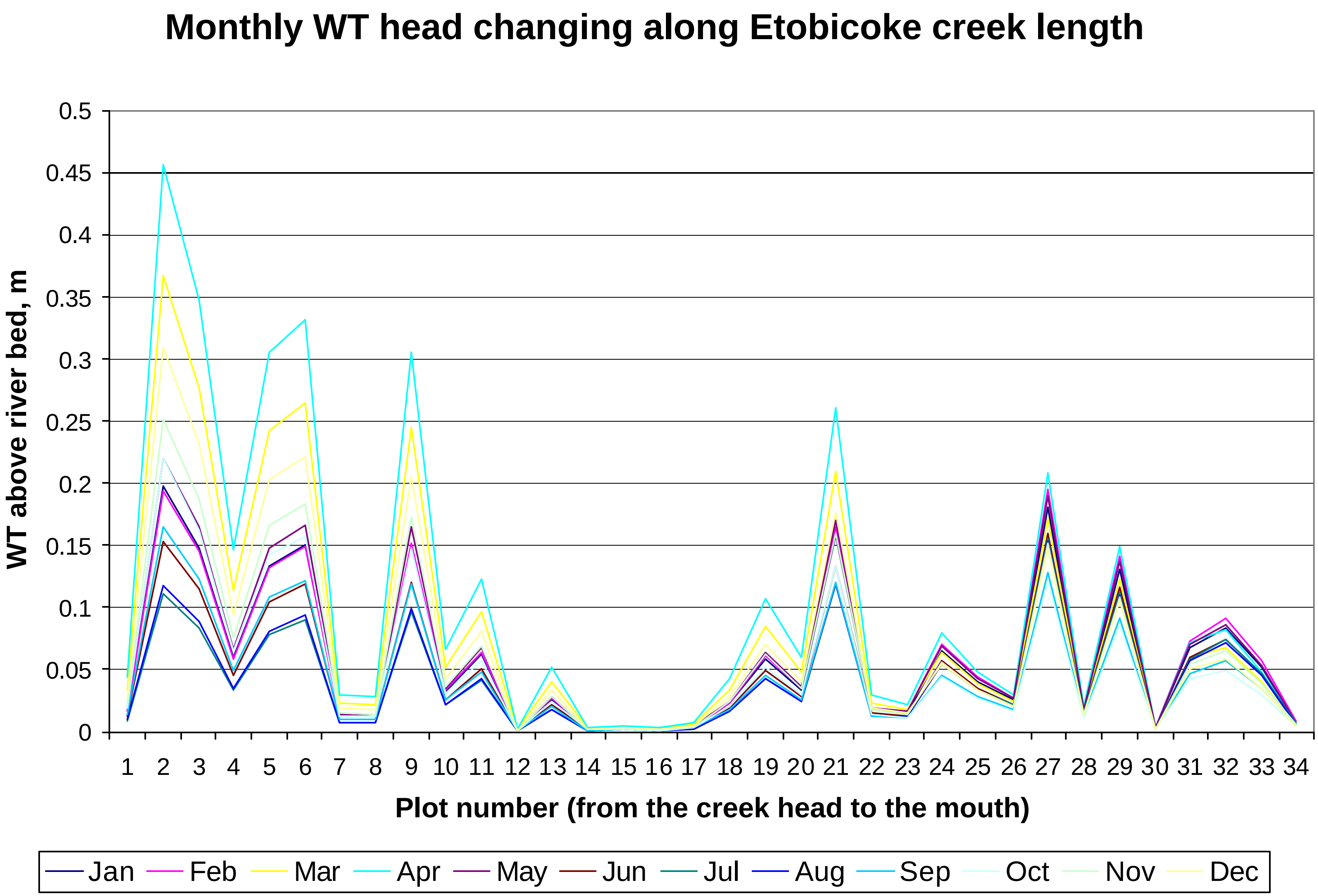
Water table

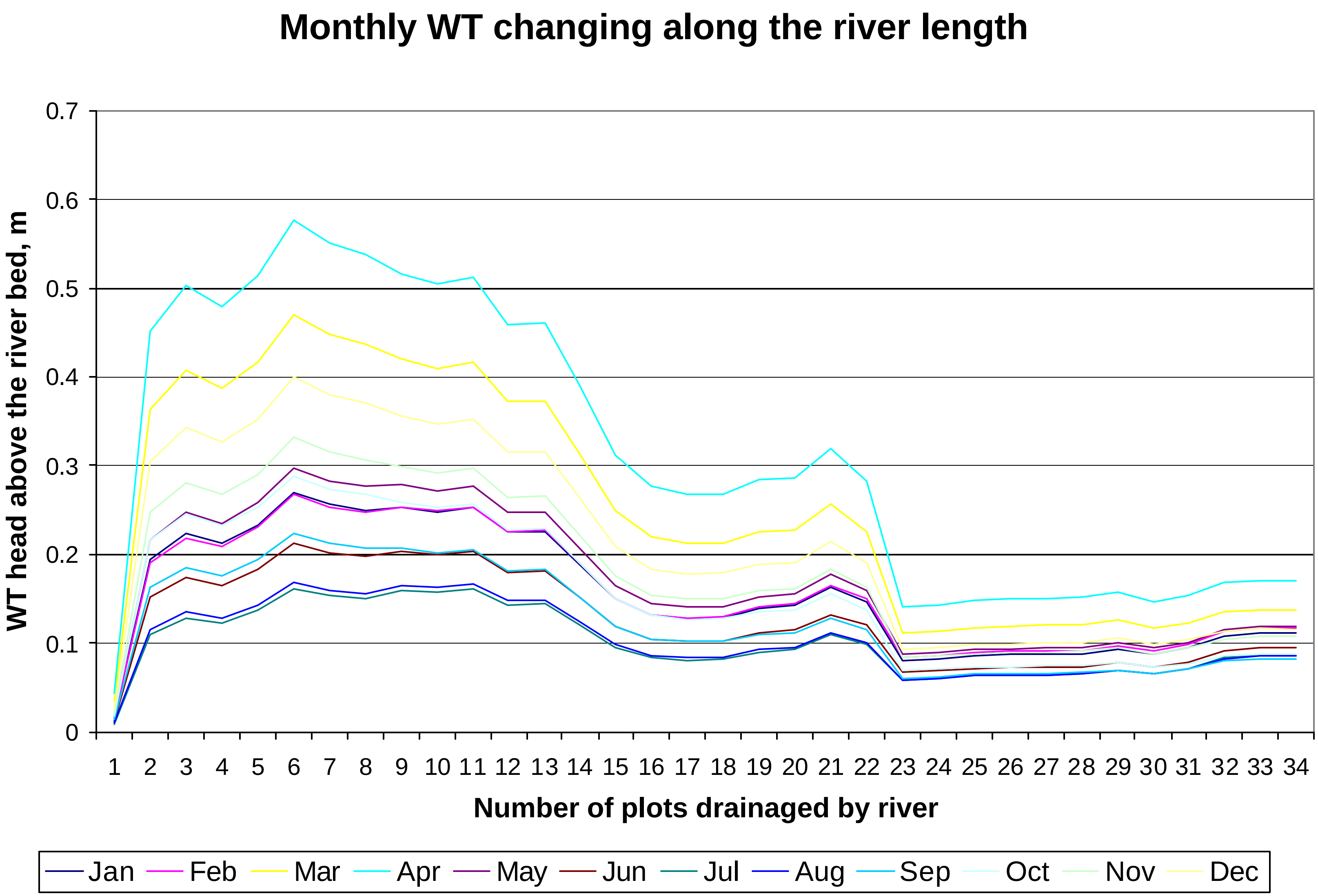
Evapotranspiration

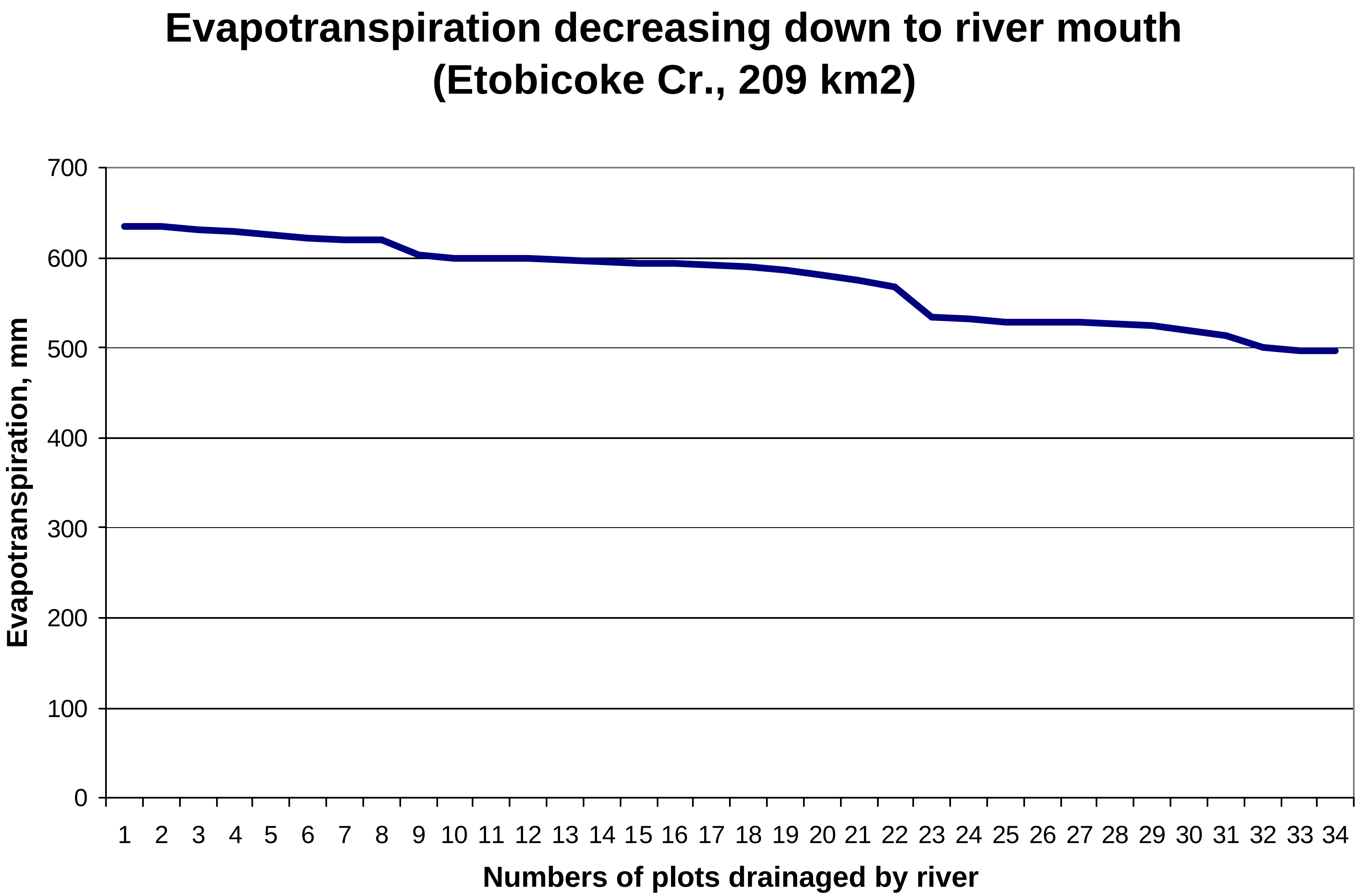
There is the comparison of results for different rivers

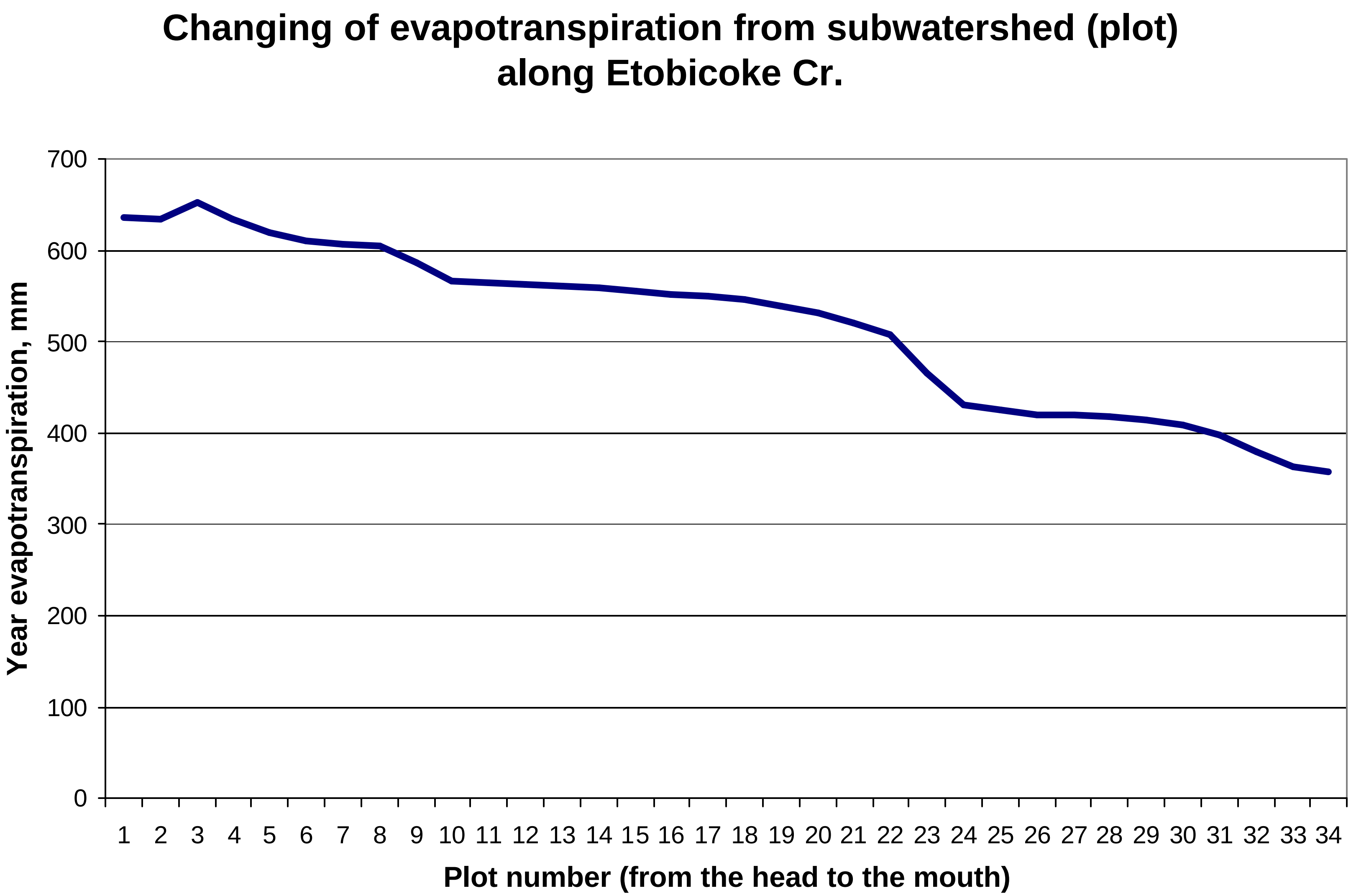

Average WT head above the creek level, m (Etobicoke Cr.)
WT head, m
0.25
0.2
0.15
0.1
0.05
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34
Plot number (from the creek head to the mouth)

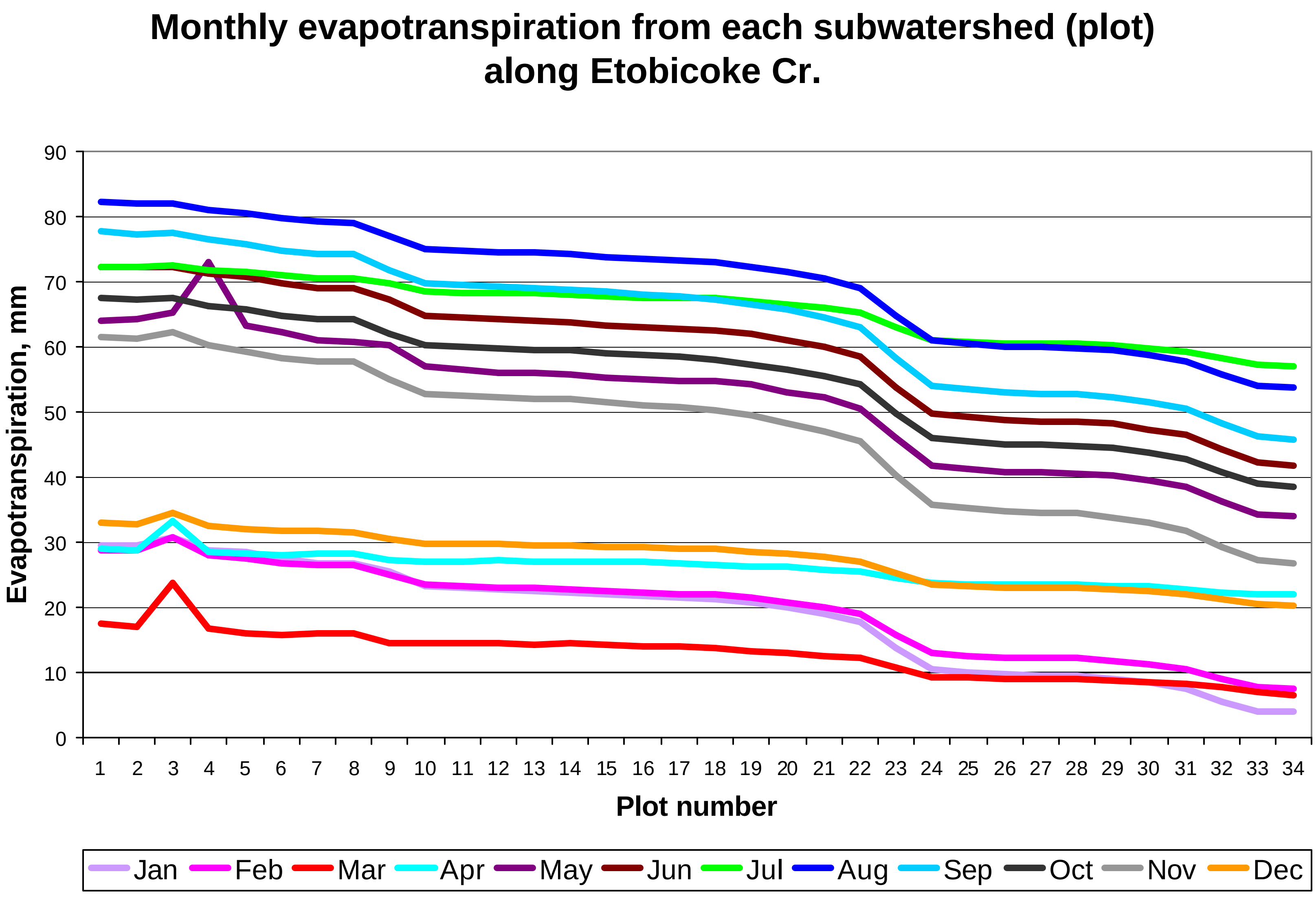

WT changing along Etobicoke creek length
WT above the creek level, m
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34
Number of plots drainaged by river

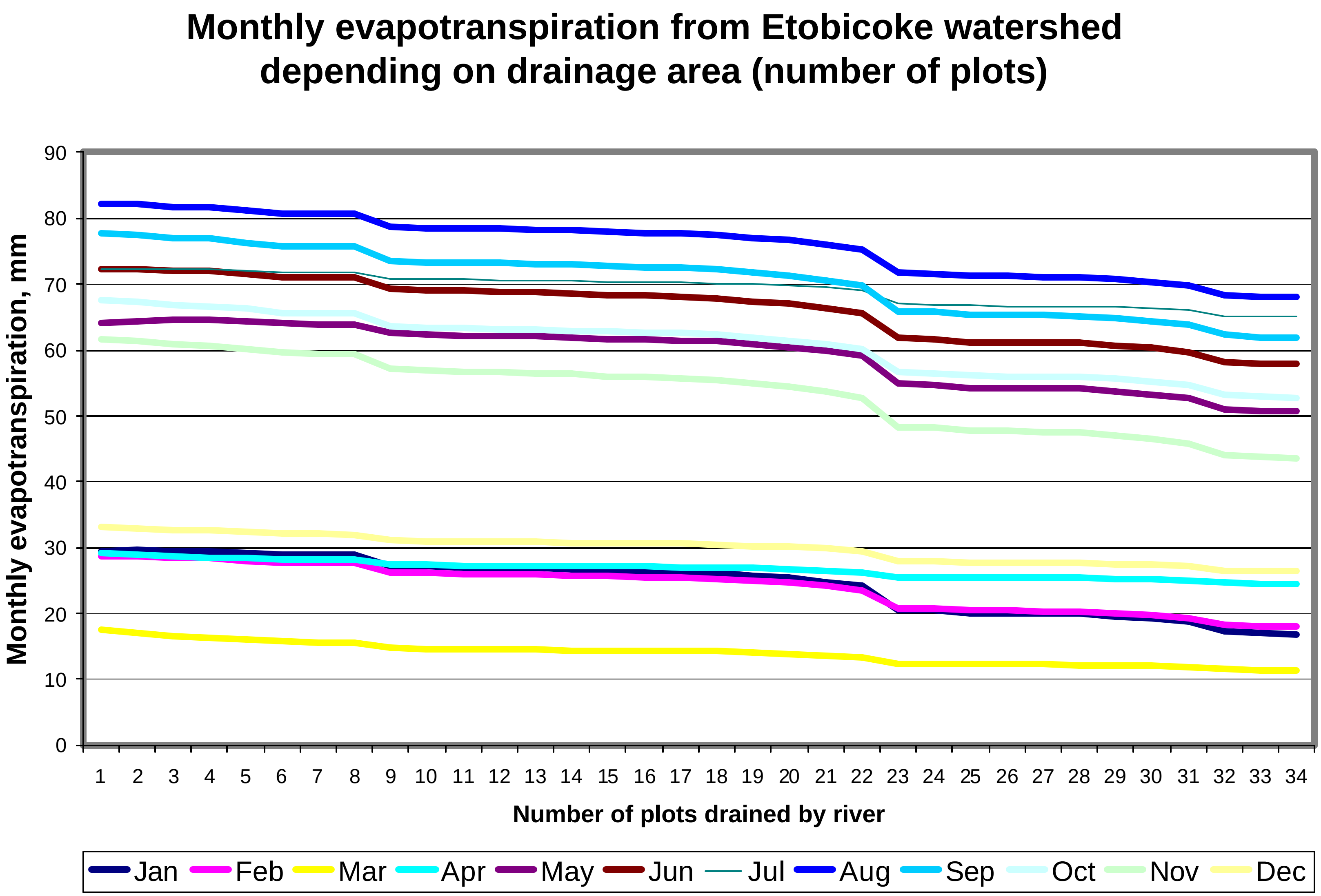

Monthly WT head changing along Etobicoke creek length
WT above river bed, m
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34
Plot number (from the creek head to the mouth)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Monthly WT changing along the river length
WT head above the river bed, m
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34
Number of plots drainaged by river
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Evapotranspiration decreasing down to river mouth
(Etobicoke Cr., 209 km2)
Evapotranspiration, mm
0
100
200
300
400
500
600
700
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34
Numbers of plots drainaged by river


Changing of evapotranspiration from subwatershed (plot)
along Etobicoke Cr.
Year evapotranspiration, mm
700
600
500
400
300
200
100
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34
Plot number (from the head to the mouth)


Monthly evapotranspiration from each subwatershed (plot)
along Etobicoke Cr.
Evapotranspiration, mm
0
10
20
30
40
50
60
70
80
90
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34
Plot number
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Monthly evapotranspiration from Etobicoke watershed depending on drainage area (number of plots)
Monthly evapotranspiration, mm
Number of plots drained by river
0
10
20
30
40
50
60
70
80
90
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

