Implementation of a peatland-specific water migration algorithm in the HYDROTEL distributed hydrologic model

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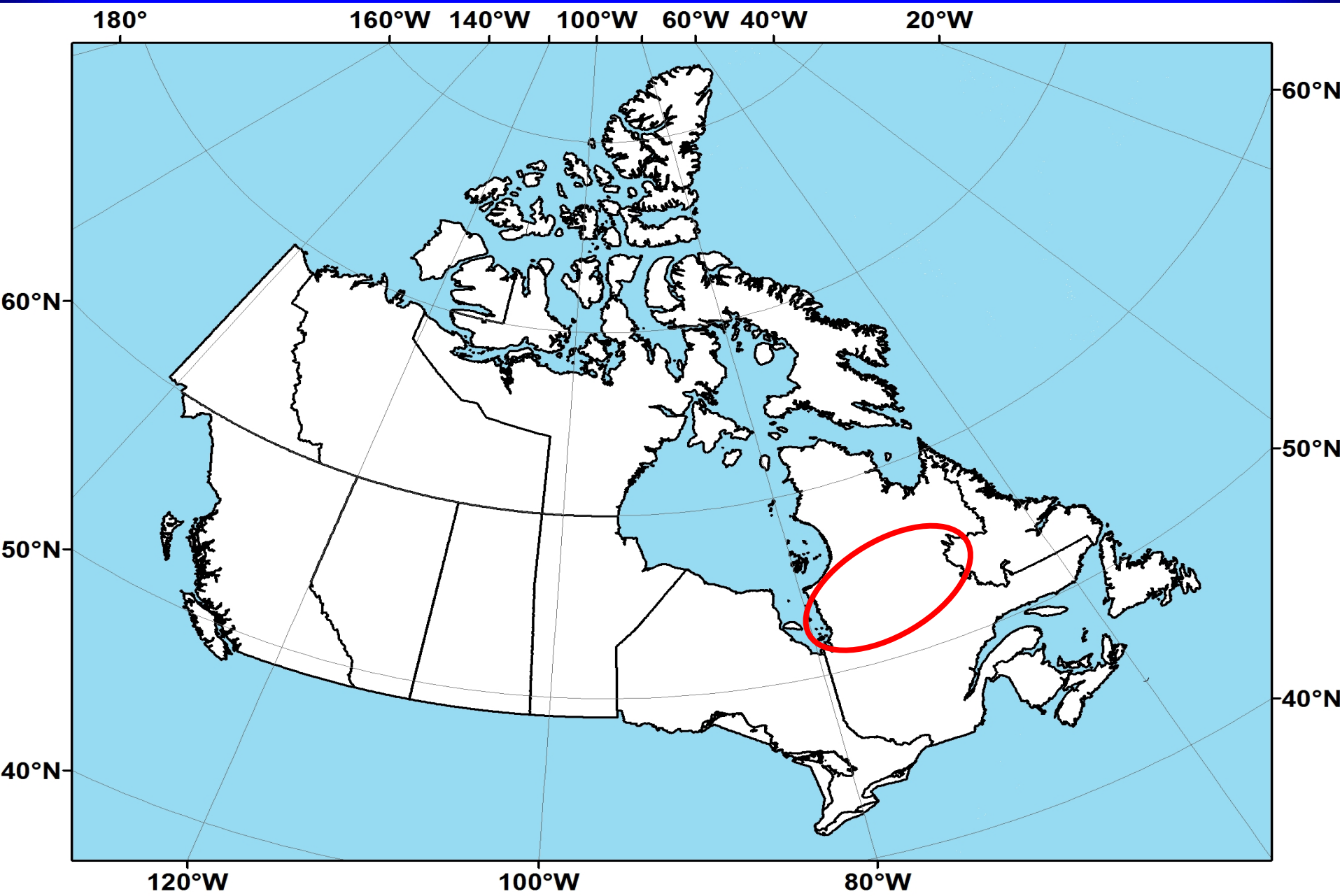
Introduction

- NSERC - CRD Project

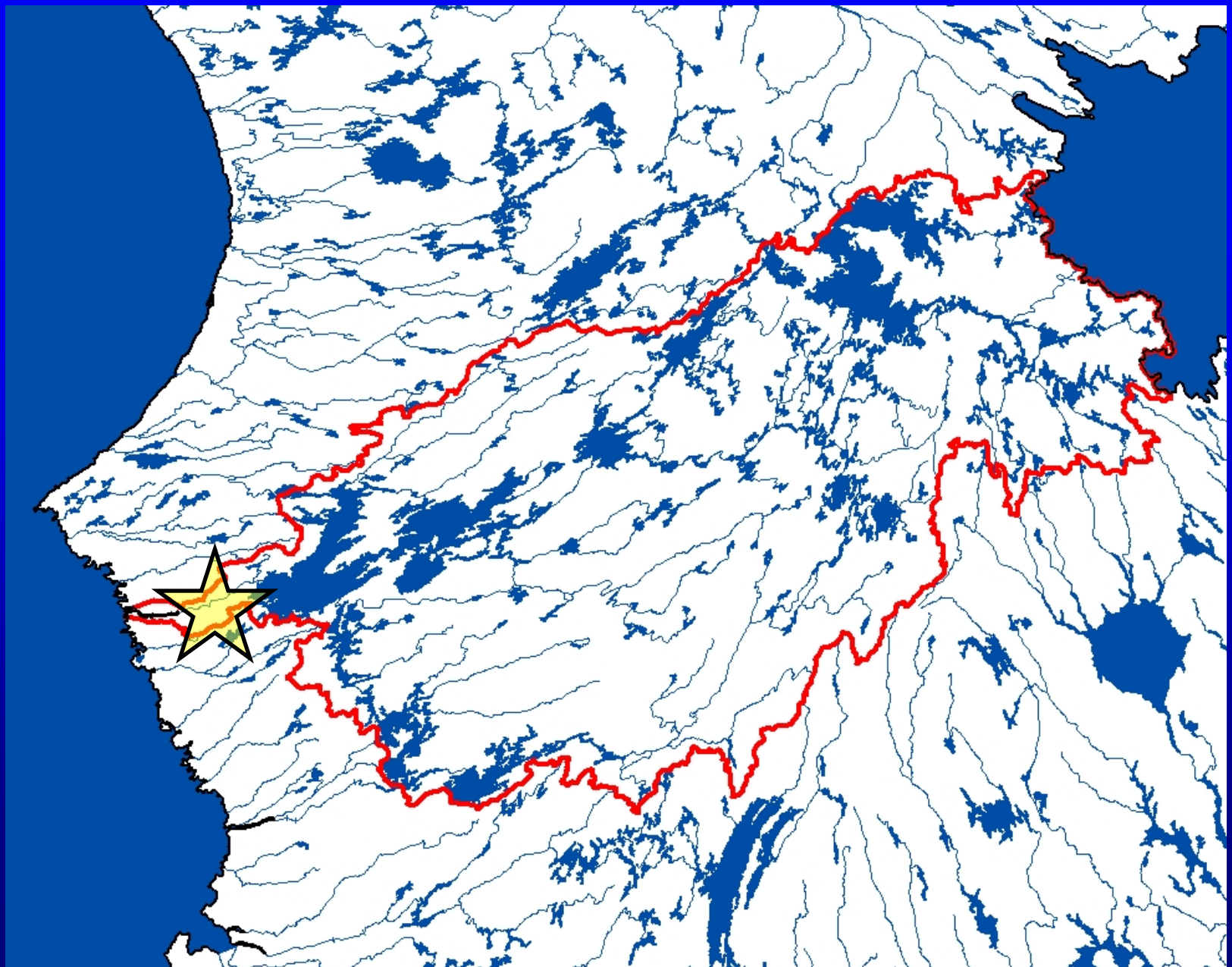
  « Adaptation of the HYDROTEL model to the Quebec North-Boreal environment »

  – Holder : Alain N. Rousseau (INRS-ETE)
    - Developer of HYDROTEL (*Fortin et al. 2001*) :
      – Never been applied in the North-Boreal
  – Industrial partner : Hydro-Québec / Ouranos
    - Hydroelectric reservoir management:
      – Climate change
      – Peatland contribution

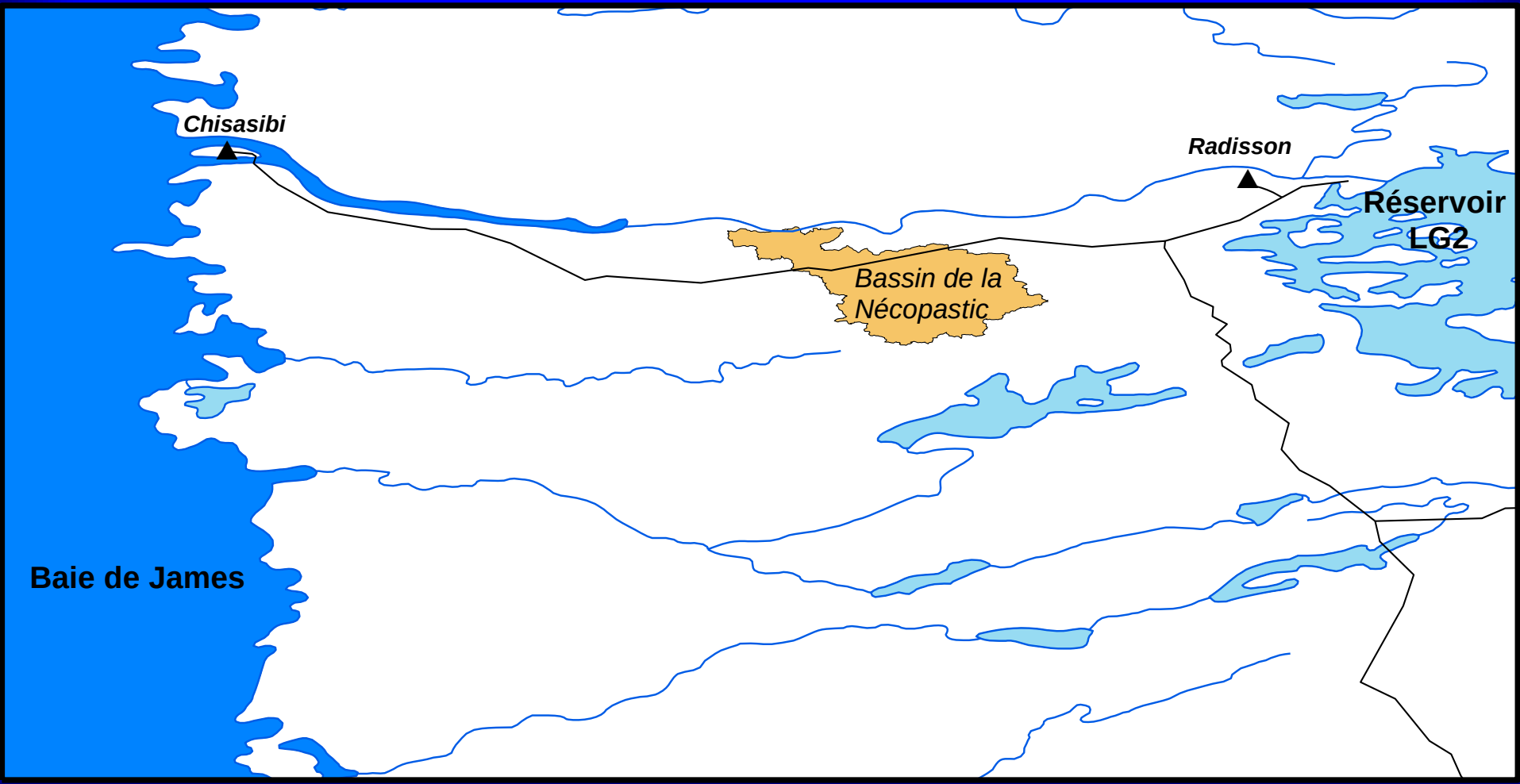
The Great River watershed



The Great River watershed

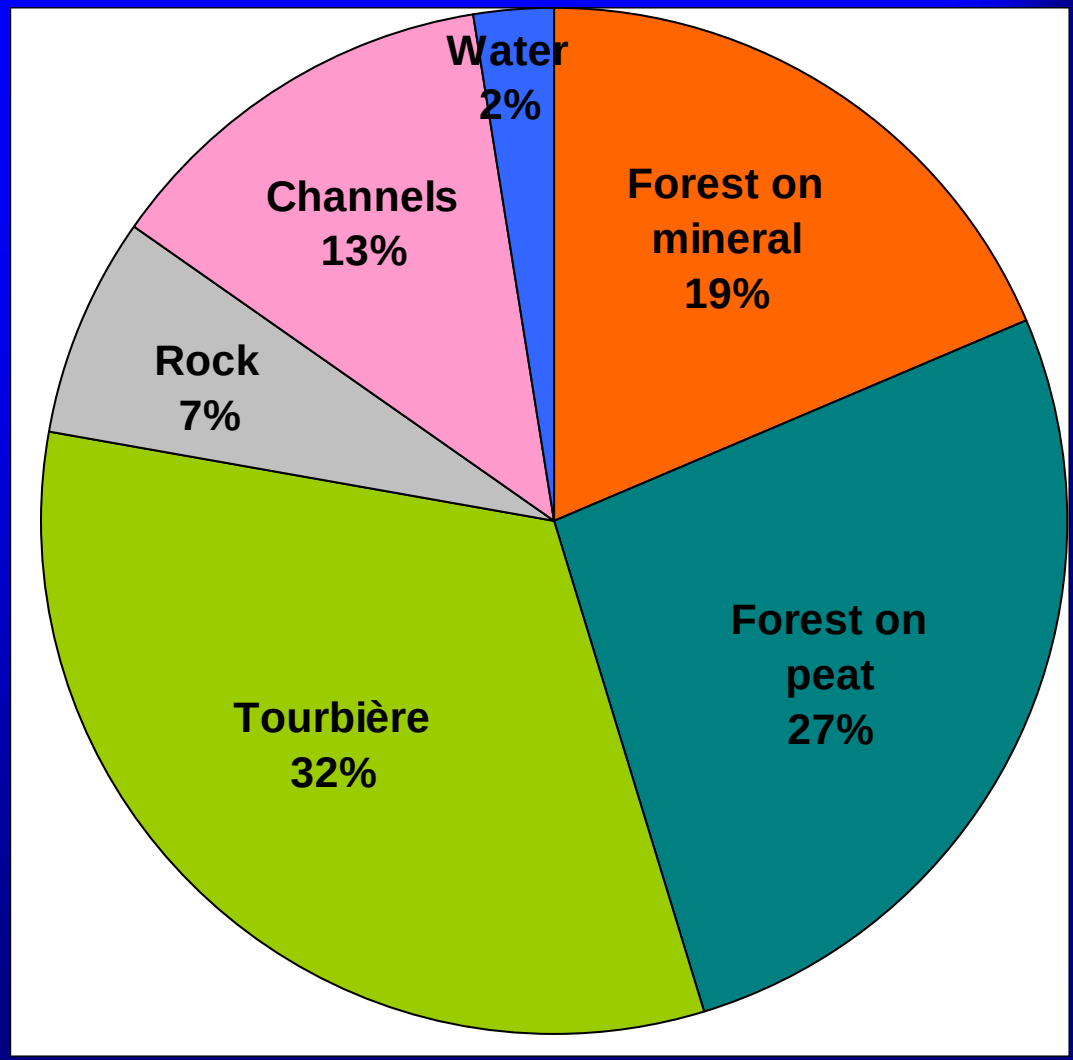


The Necopastic river watershed



The Necopastic river watershed

- 242 km²
- N 53°40'; W 78°10'
- Altitude :
  - 50 m to 175 m
  - 7.5% slope
- Low areas flooded :
  - 8000 BP
  - Post-glacial sea



HYDROTEL

- Distributed hydrologic model:
  - Geographically positioned information
    - Hydrological units
  - Based on physical equations
    - Often simplified
- Strongly oriented on manual calibration
  - Friendly-user interface
  - Numerous parameters

Hydrotel - Neco_17nov2006.prj

Projet Données Sous-modèles Simulation Graphique Affichage Utilitaires Fenêtre Aide

T: 12 - S: SW_CONF T: 12 - S: SW_CONF

Projet - Neco_17nov2006.prj (Première simulation)

Sous-modèles sélectionnés

Interpolation des données météorologiques :	Polygones de Thiessen
Évolution du couvert nival :	Approche mixte (deg.jr. - Bilan éner.)
Évapotranspiration potentielle :	Hydro-Québec
Bilan d'eau vertical :	BV3C
Écoulement sur la partie terrestre du bassin :	Onde cinématique
Écoulement dans le réseau hydrographique :	Onde cinématique

Données météorologiques

Stations: SMER___, LG2___, NECO___, NECO2__, OMBR0

Radar

Données hydrométriques

Stations: SW_CONF, SW__SUD

Paramètres temporels

Début de la simulation :	2005-6-15 0 h
Fin de la simulation :	2005-10-1 0 h
Durée des pas de temps :	24 h

Paramètres spatiaux

Superficie du bassin :	242.4 km^2
Nombre d'UHRH :	242
Nombre de tronçons :	177
Tronçon exutoire :	1

BV3C

Couches | Paramètres | Classes

Groupe d.'UHRH (sol, occupation): SB_Sud

Limite inférieure des couches (m)

Valeur

	utilisateur	optimisée	Optimisation ?	Valeur utilisée
Couche 1	0.2	0.2	NON	0.2
Couche 2	0.5	0.5	NON	0.5
Couche 3	1.5	1.5	NON	1.5

Note: ces valeurs sont les profondeurs à partir de la surface

Humidité relative initiale (fraction de la saturation)

Couche 1	0.9
Couche 2	0.9
Couche 3	0.9

Infiltration

- Infiltration maximale variable (Smith-Parlange)
  - Délai maximal entre deux événements pluvieux: 6 Heures
- Infiltration maximale fixe (Ks)

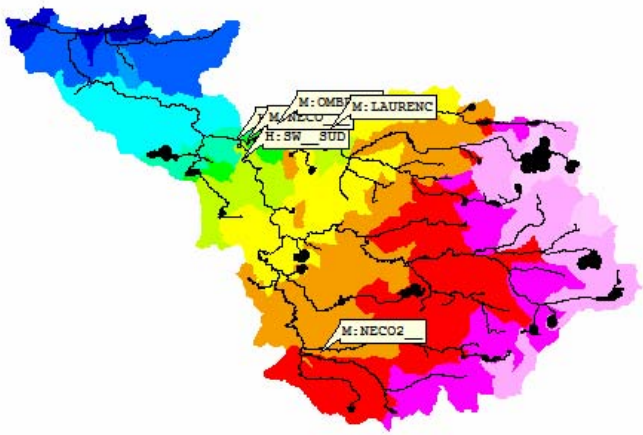
Aide OK Annuler

Altitude moyenne par UHRH - Neco_17nov2006.prj

Légende

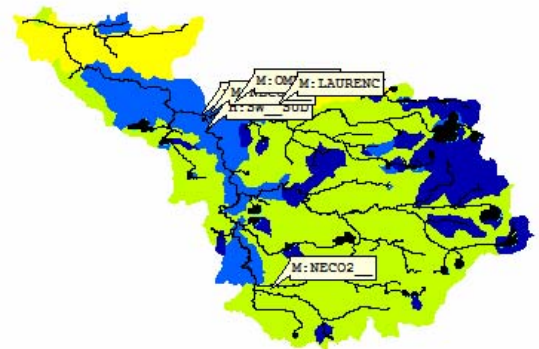
- 172 - 182
- 163 - 171
- 153 - 162
- 143 - 152
- 134 - 142
- 124 - 133
- 114 - 123
- 105 - 113
- 95 - 104
- 85 - 94
- 76 - 84
- 66 - 75
- 56 - 65
- 47 - 55
- 37 - 46

Altitude: - (m)

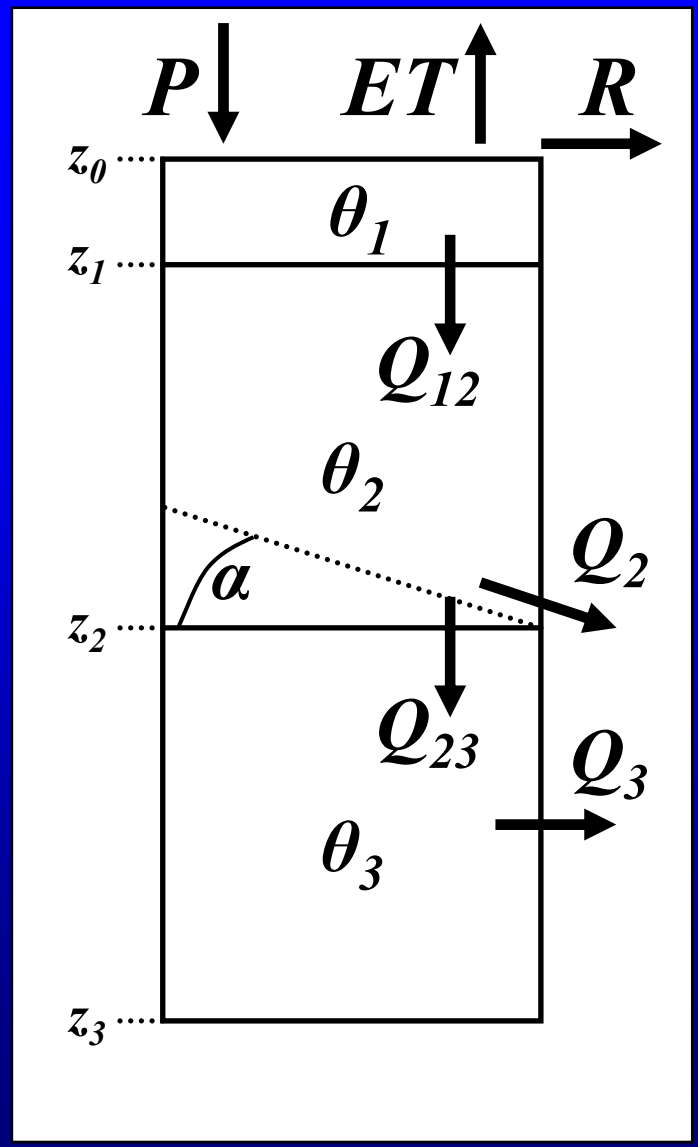


Type de sol par UHRH - Neco_17nov2006.prj

Type de sol
sand
loamy_sand
sandy_loam
loam
silt_loam
sandy_clay_loam
clay_loam
silty_clay_loam
peat_(VP4)
silty_clay
clay

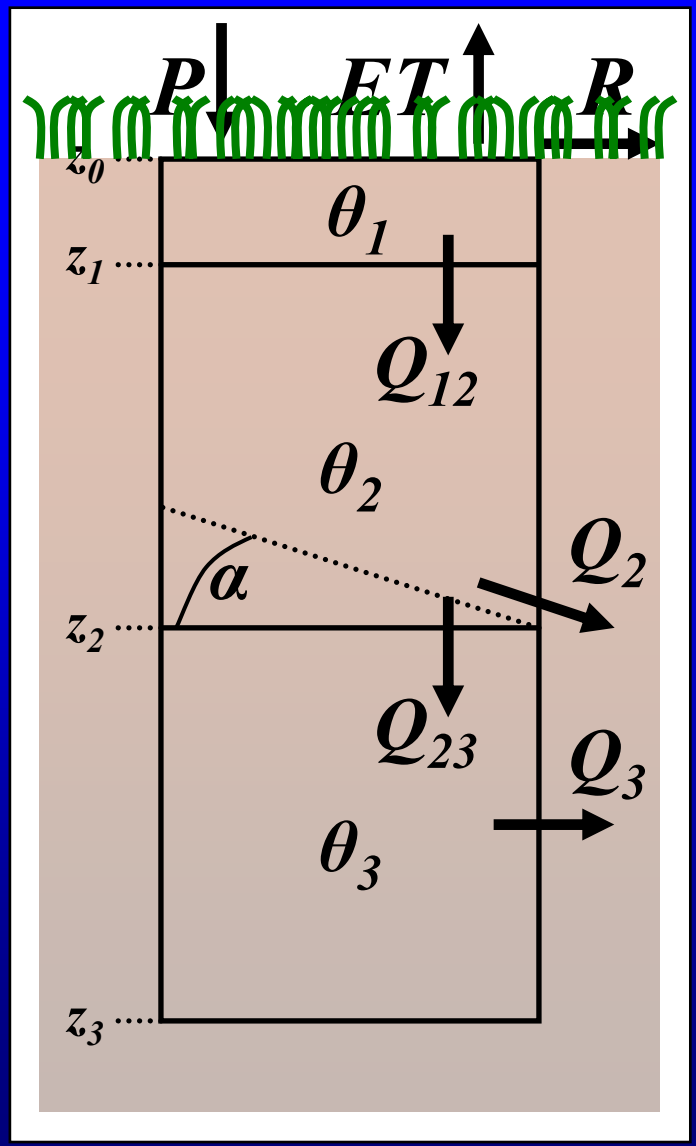


BV3C



BV3C

- 3 soil layers
- Infiltration
  - Surface runoff
- Water migration in the soil matrix
  - Hydraulic properties of each soil type
    - Ks, θs θfc, θwp, ψs, λ
  - Classic equations
    - Based on mineral soils
  - Reasonable estimation of process at a large scale



However…

- Organic soils
  - Hydraulic properties highly variable vertically
  - Difficulty to describe organic soils with mineral soil parameters (Letts et al. 2000)
- After a complete analysis of BV3C
  - Most equations used are inappropriate for organic soils
    - Presence of a water table close to the surface
    - Mineral soil based "K vs θ"

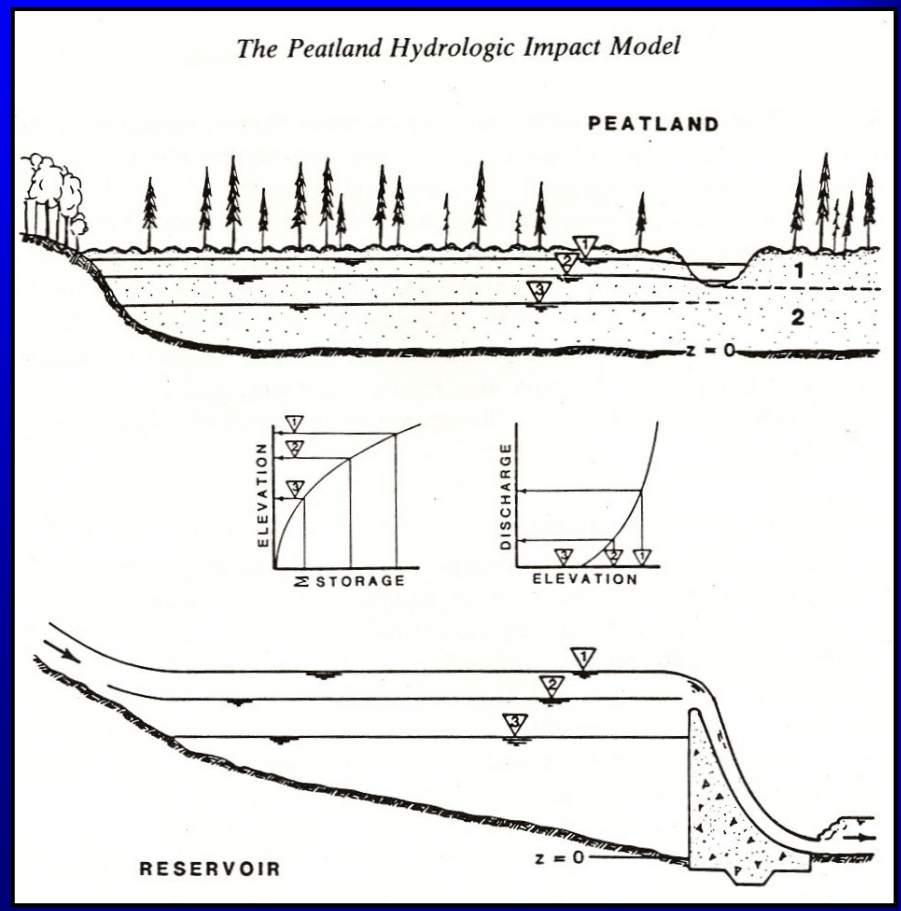
BV3C is not conceptually valid for organic soils

Solutions

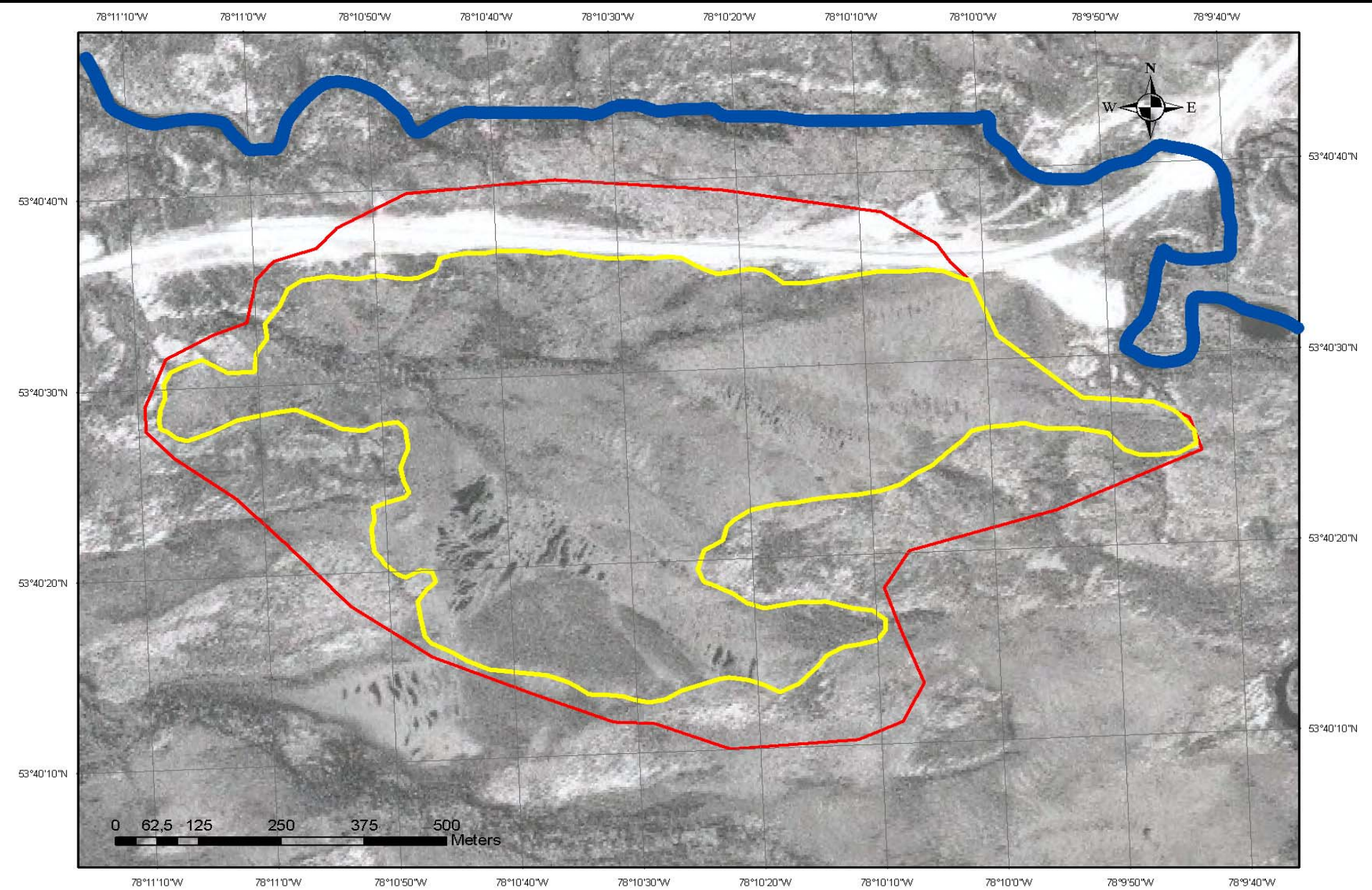
- Modified BV3C
  - Using different parameters for each soil layer
- Organic soil hydraulic properties
  - Validation of the equations for organic soils
  - Gregor Levrel
- Adding other submodels
  - PHIM (Guertin et al. 1987)
  - Weiss et al. (1998; 2006)

Peatland submodel

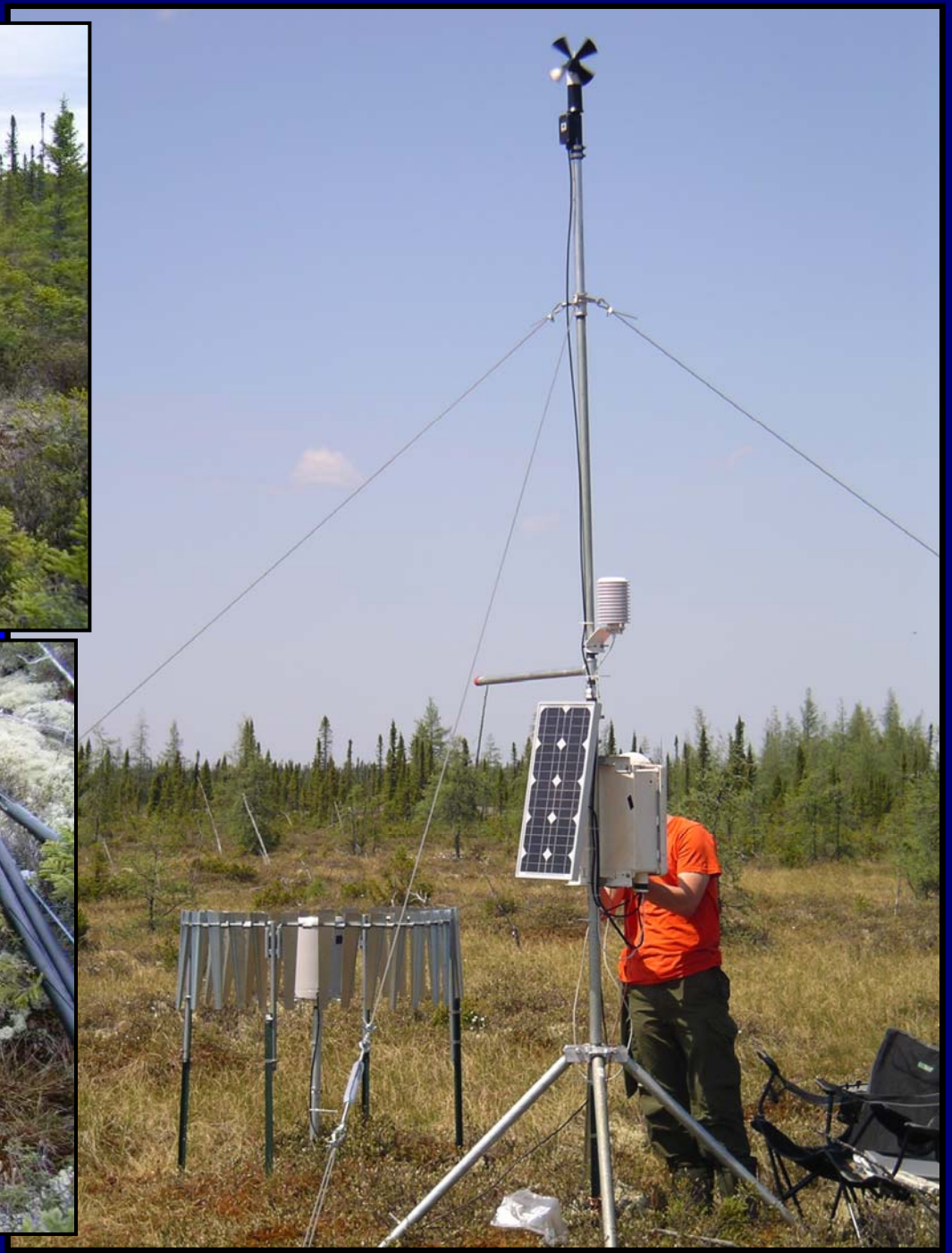
- Inspired of PHIM
  - Peatland Hydrologic Impact Model
  - K. Brooks, UMinnesota
  - Specific to peatlands
  - Two relationship:
    - Storage vs Water table
    - Water table vs Discharge

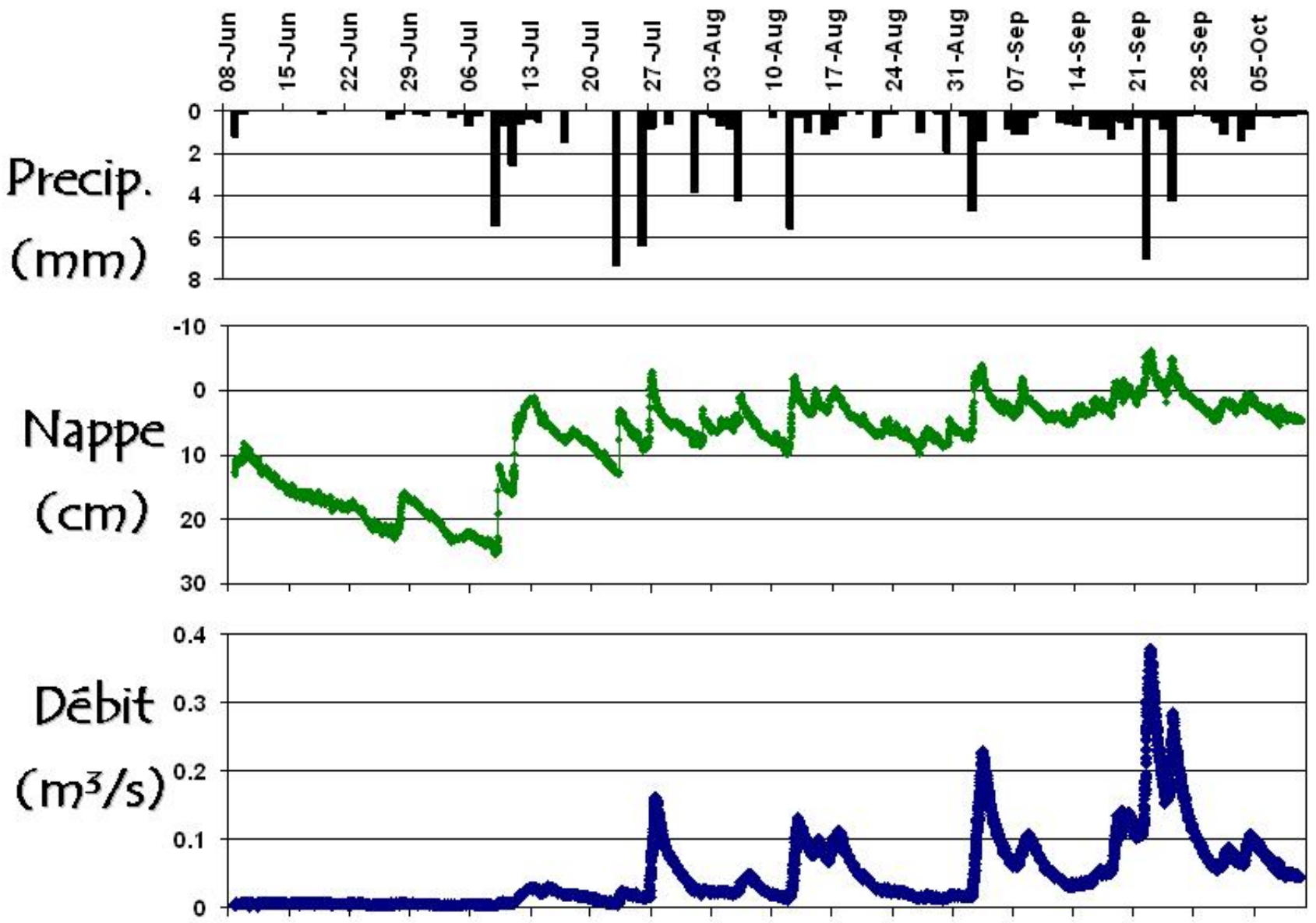


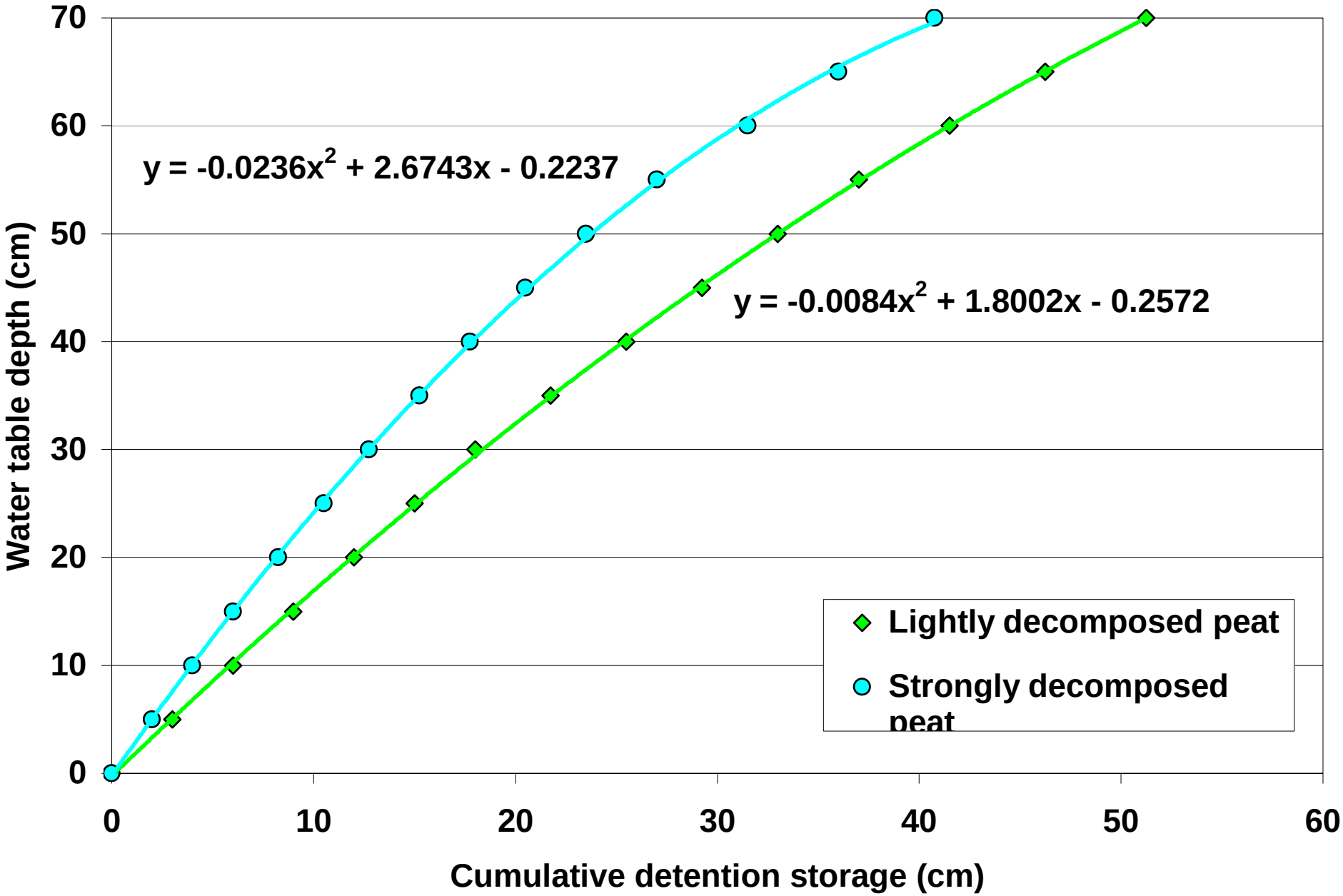
The small peatland watershed (0.9 km²)

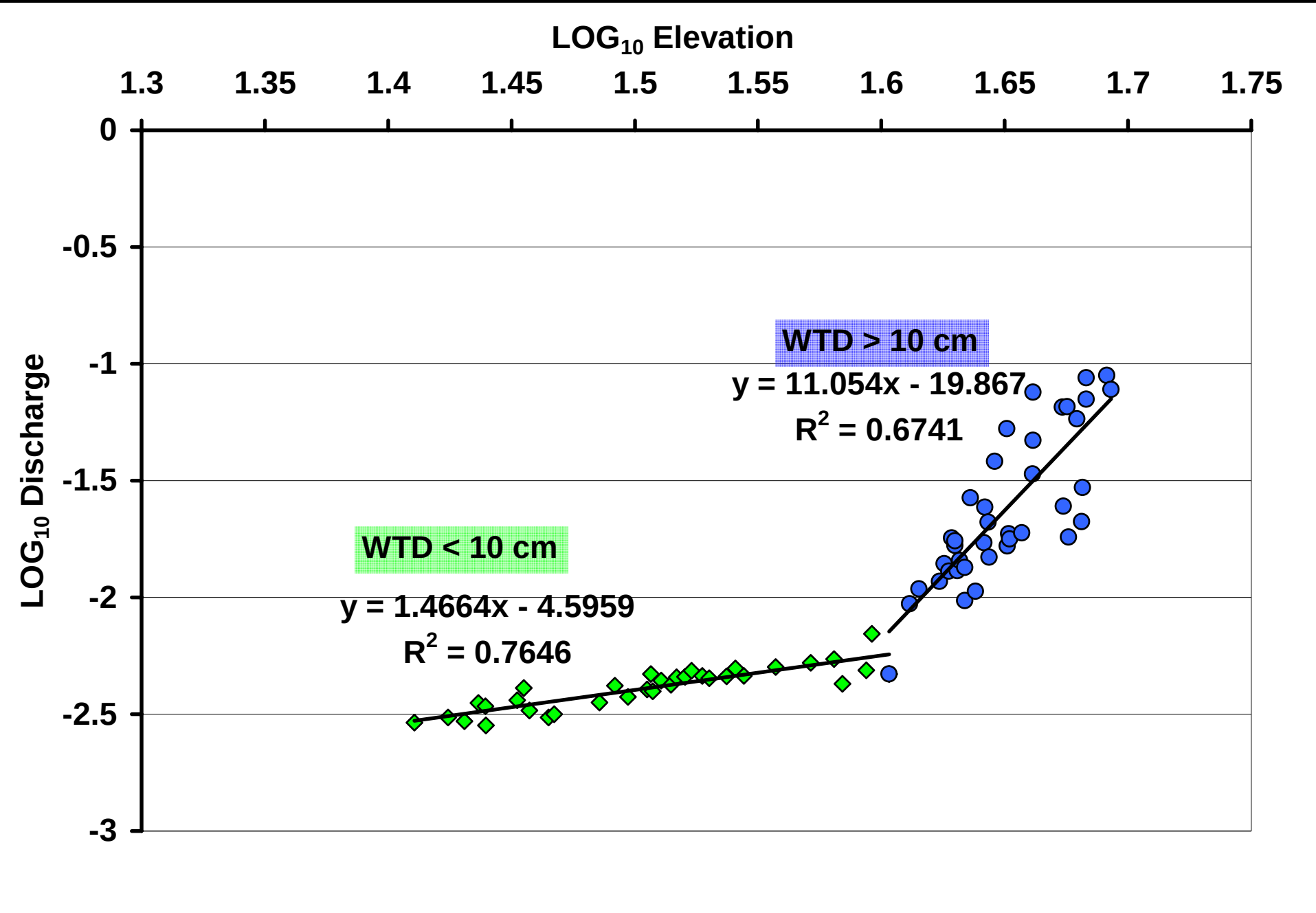



Solinst Levelogger
Model 3001
Made in Canada
LT F15/M5

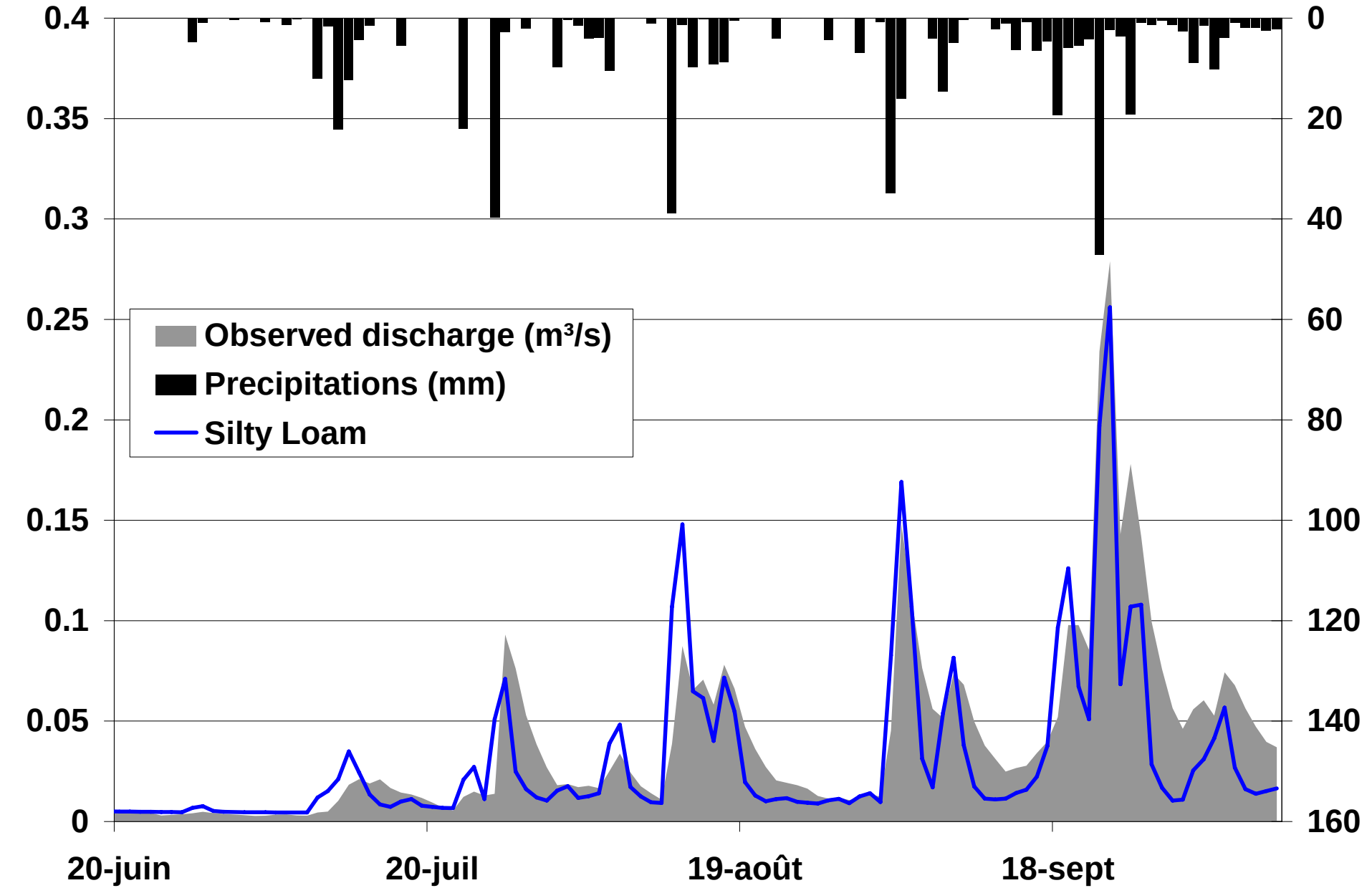



08-Jun
15-Jun
22-Jun
29-Jun
06-Jul
13-Jul
20-Jul
27-Jul
03-Aug
10-Aug
17-Aug
24-Aug
31-Aug
07-Sep
14-Sep
21-Sep
28-Sep
05-Oct
Precip. (mm)
0
2
4
6
8
Nappe (cm)
-10
0
10
20
30
Débit (m³/s)
0.4
0.3
0.2
0.1
0

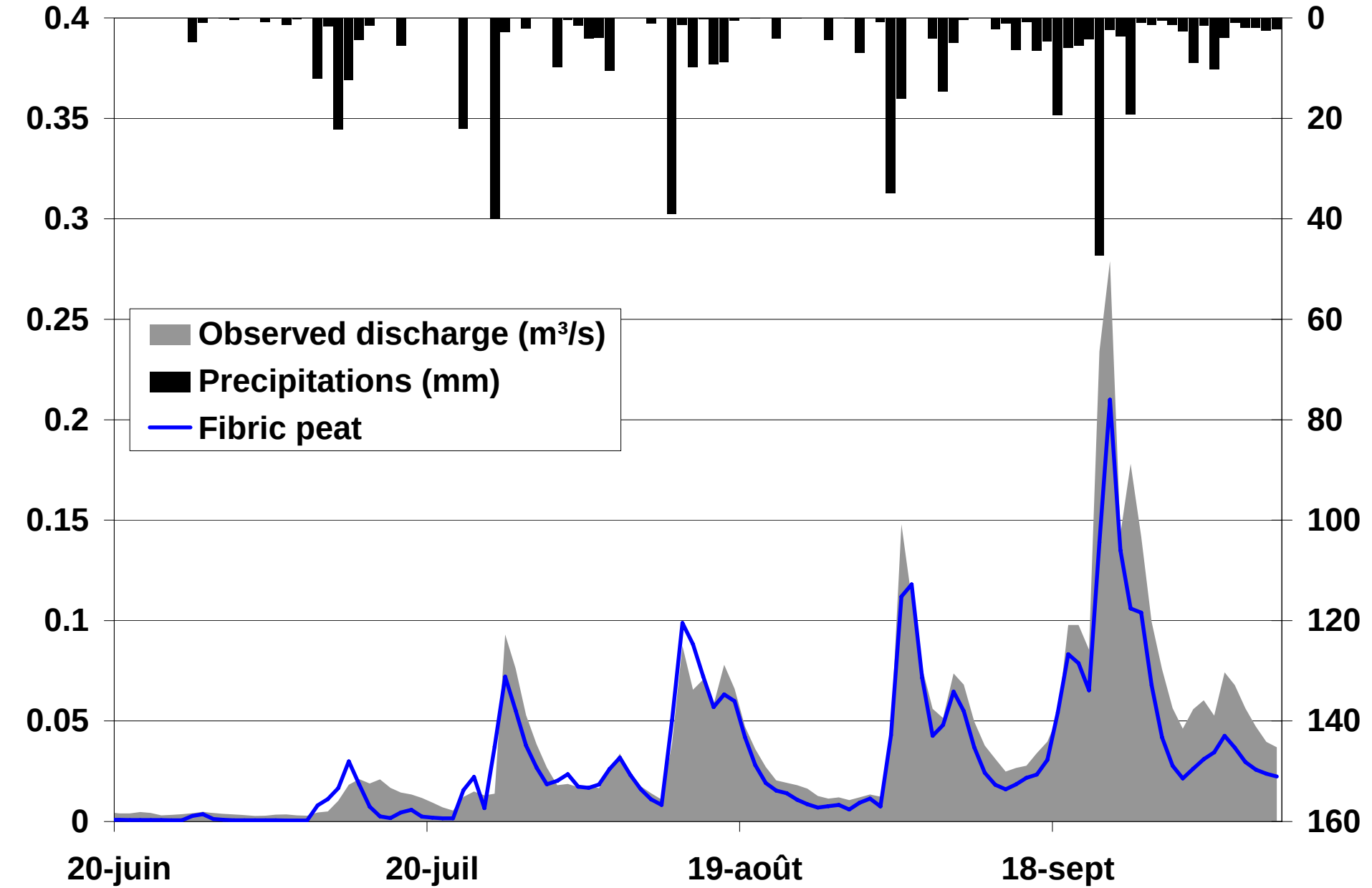

70
60
50
40
30
20
10
0
Water table depth (cm)
y = -0.0236x2 + 2.6743x - 0.2237
y = -0.0084x2 + 1.8002x - 0.2572
Lightly decomposed peat
Strongly decomposed peat
0
10
20
30
40
50
60
Cumulative detention storage (cm)


LOG10 Elevation
1.3
1.35
1.4
1.45
1.5
1.55
1.6
1.65
1.7
1.75
0
-0.5
-1
-1.5
-2
-2.5
-3
LOG10 Discharge
WTD > 10 cm
y = 11.054x - 19.867
R2 = 0.6741
WTD < 10 cm
y = 1.4664x - 4.5959
R2 = 0.7646

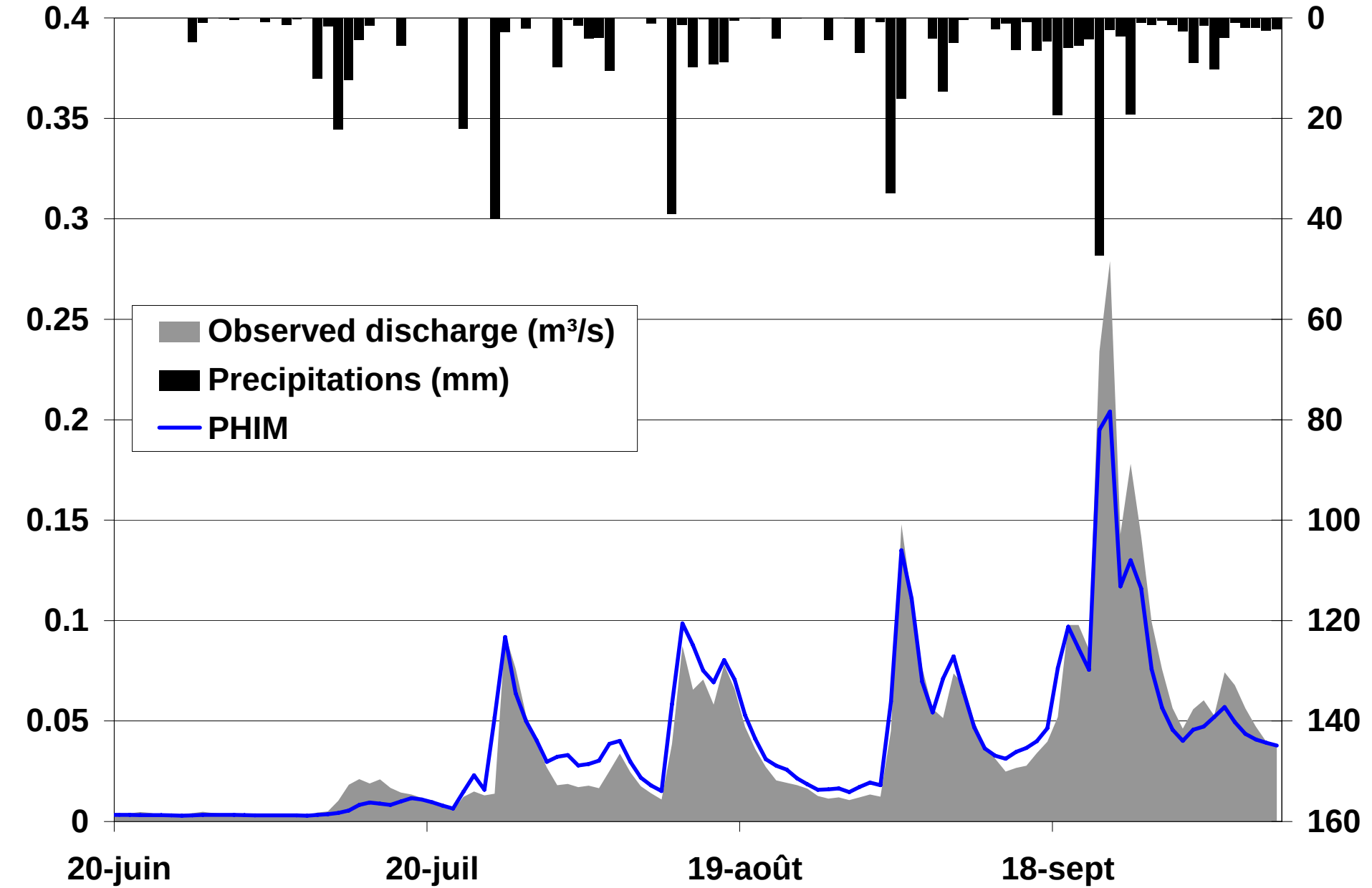
BV3C : Soil = Silty Loam



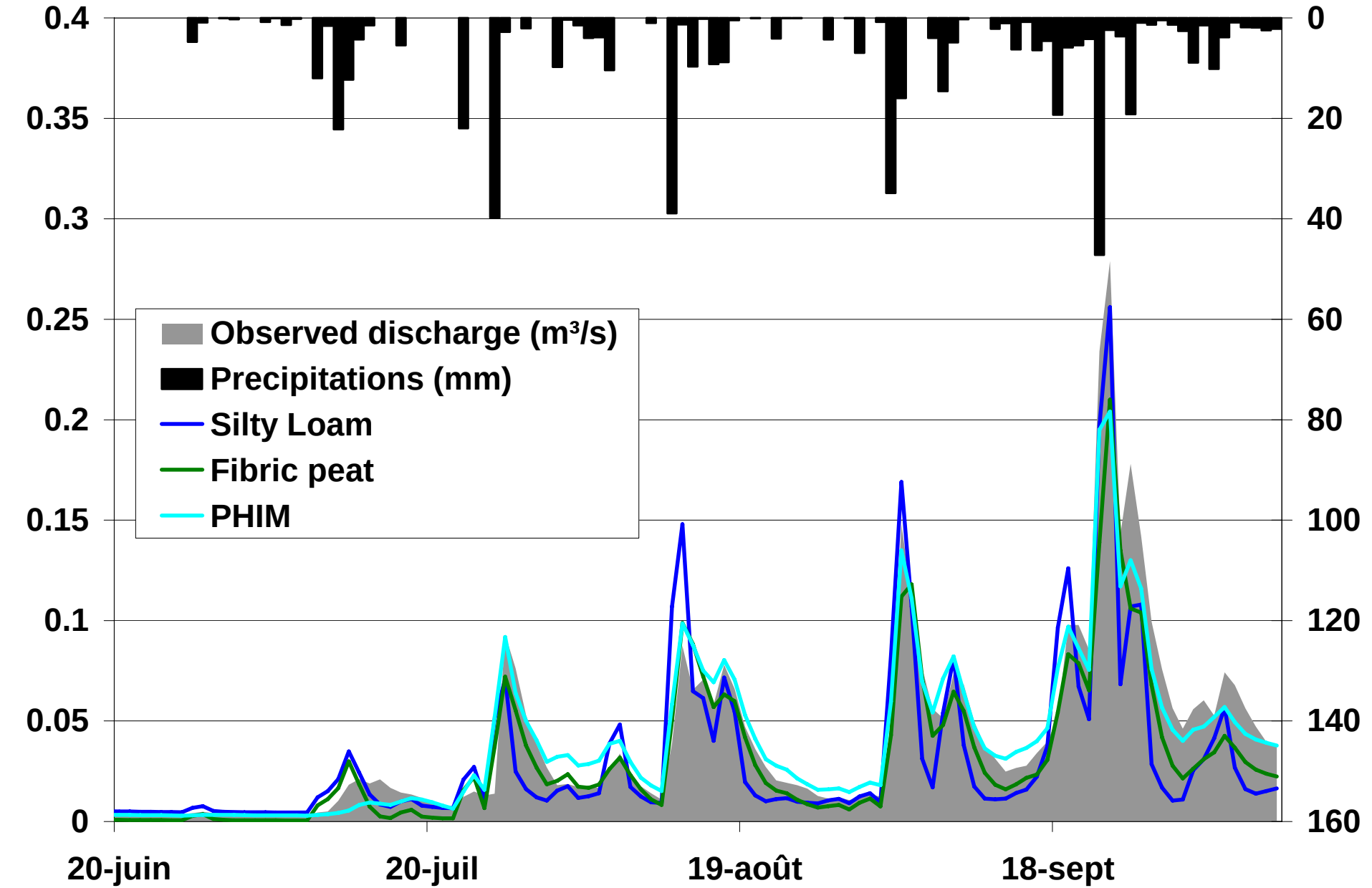
BV3C : Soil = Fibric Peat



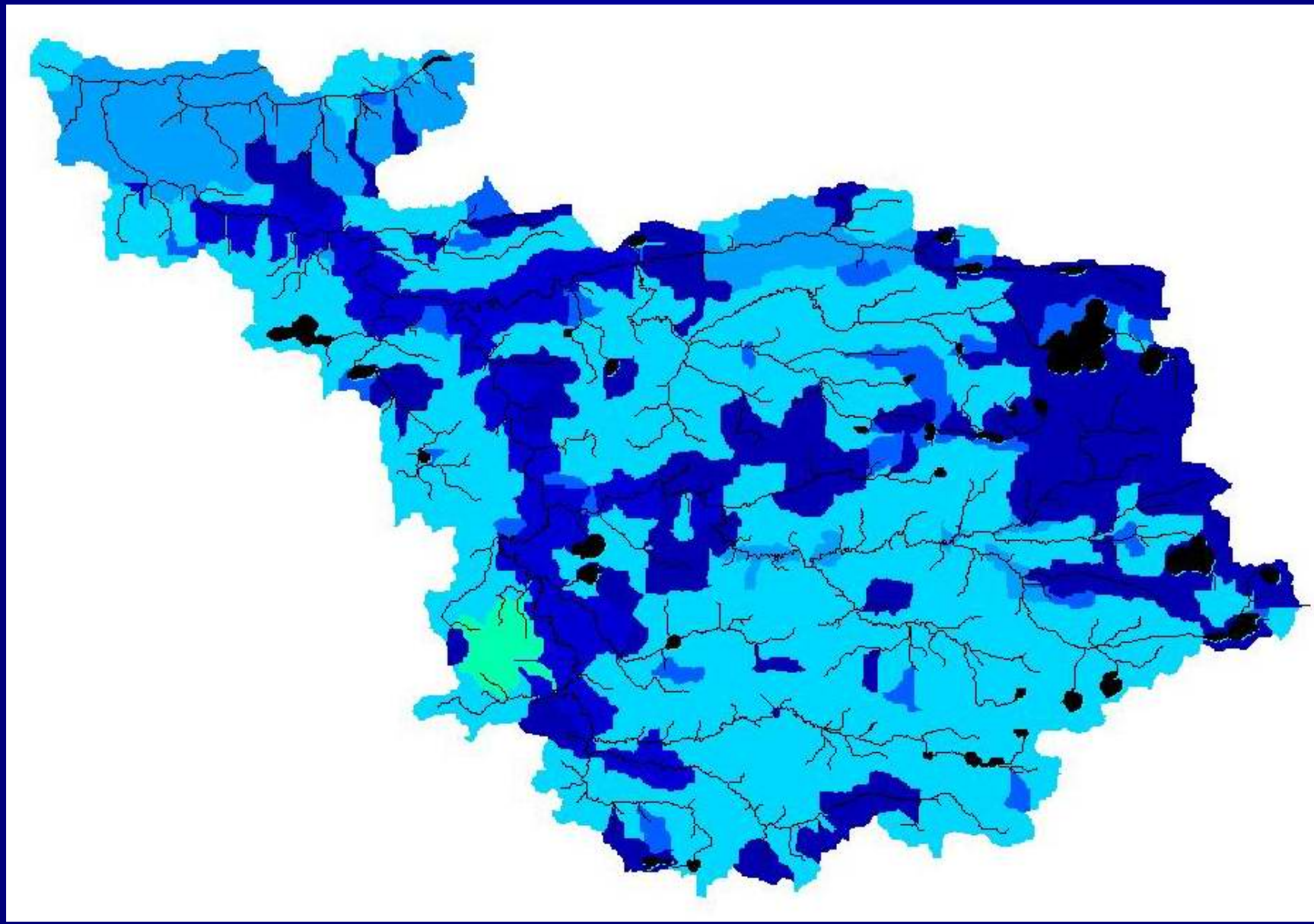
PHIM : Soil = Peat



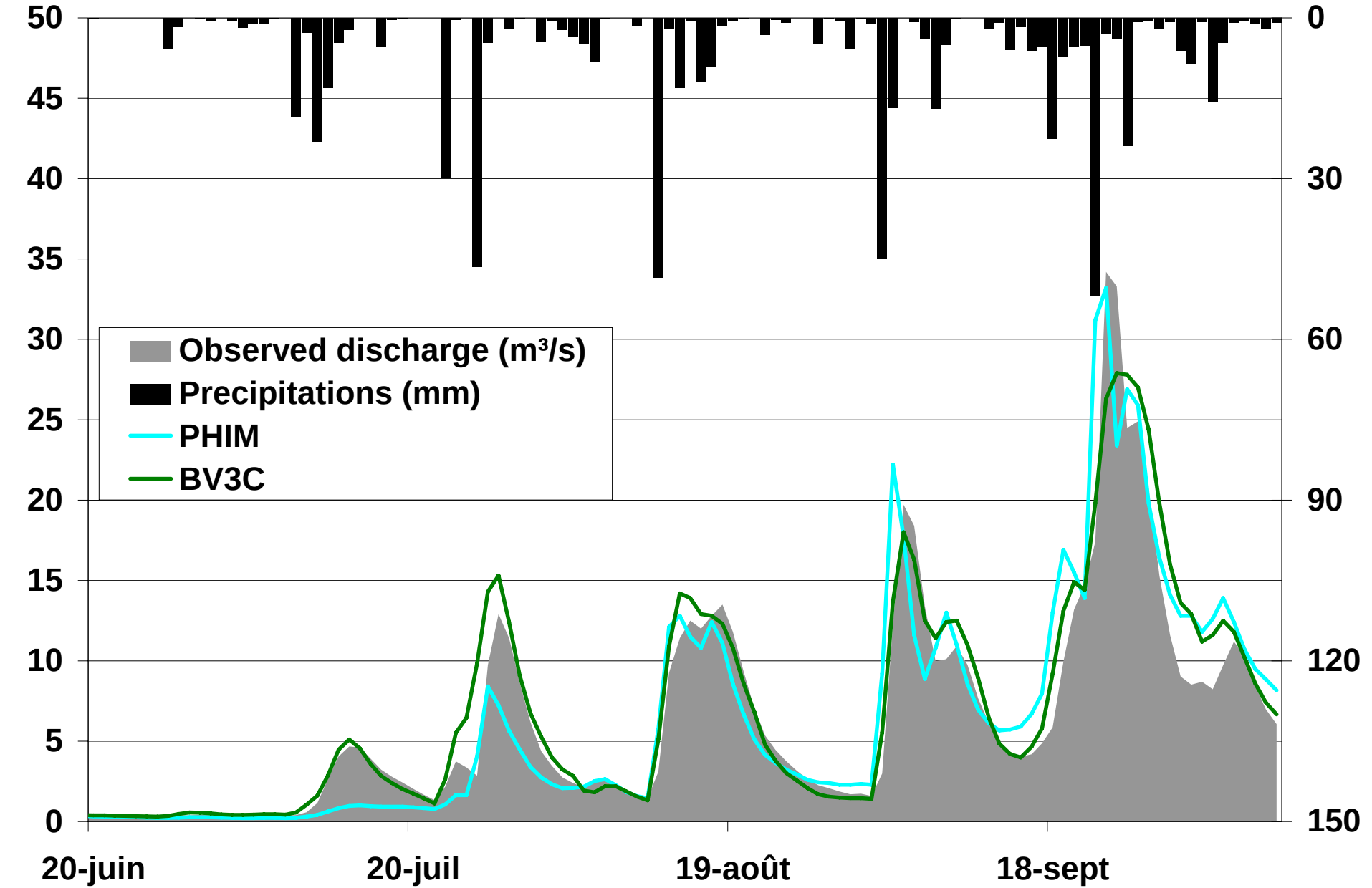
PHIM vs BV3C


0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
20
40
60
80
100
120
140
160
Observed discharge (m³/s)
Precipitations (mm)
Silty Loam
Fibric peat
PHIM
20-juin
20-juil
19-août
18-sept

The whole Necopastic river watershed (240 km²)



PHIM vs BV3C


50
45
40
35
30
25
20
15
10
5
0
0
30
60
90
120
150
Observed discharge (m³/s)
Precipitations (mm)
PHIM
BV3C
20-juin
20-juil
19-août
18-sept

Conclusion

- HYDROTEL
  - BV3C is not representing adequately peat soils
    - However, it gives reasonable discharge values
  - PHIM is representing adequately peat soils
    - Simple and logical calibration
- Still to come
  - Adjustments and timing of the sub-models
  - Comparison of the results
  - Simulation in a climate change scenario