CAWQ ACQE

54TH CENTRAL CANADIAN SYMPOSIUM ON WATER QUALITY RESEARCH

Measuring and modelling particle transport in urban wastewater systems

Peter A. Vanrolleghem

YORK UNIVERSITÉ UNIVERSITY LASSONDE SCHOOL OF ENGINEERING Ryerson University UNIVERSITY OF TORONTO

UNIVERSITÉ LAVAL

modelEAU

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54TH CENTRAL CANADIAN SYMPOSIUM ON WATER QUALITY RESEARCH

Measuring and modelling particle transport in urban wastewater systems

Peter A. Vanrolleghem and Paul Lessard
Bertrand Vallet, Émilie Berrouard, Jason Faber Carpenter, Etienne Gaborit, Dirk Muschalla,
Thibaud Maruéjouls, Bastien Wipliez, Sovanna Tik, Julia Ledergerber, Asma Hafhouf, Kamilia Haboub,
Giulia Bacchis, Imen Bel Hadj, Jessy Carpentier, Queralt Plana

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UNIVERSITÉ LAVAL

modelEAU

My initiation to issues of TSS in integrated urban wastewater systems

"Fonctionnement du traitement des eaux usées en cas de fortes variations de débit"
Journée d'étude CB-IAWQ, Liège, 31.05.95

Variabilité des charges solides en suspension à l'exutoire des réseaux de collecte

Michel Verbanck

Université Libre de Bruxelles, Laboratoire de Traitement des Eaux et Pollution

My initiation to issues of TSS in integrated urban wastewater systems

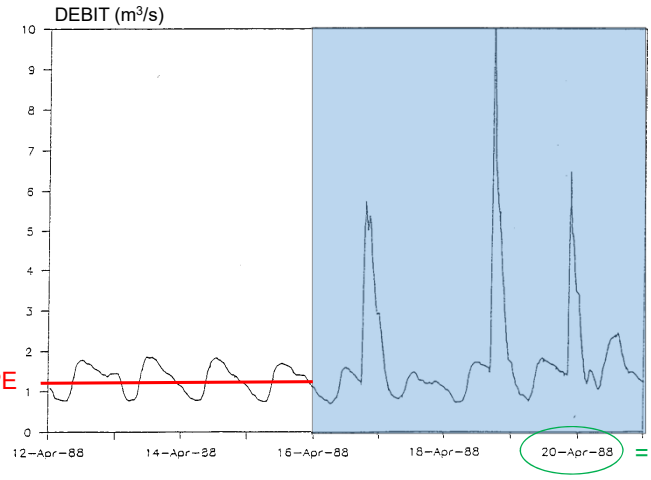
Wastewater treatment operations under high flow variations
Symposium Belgian Branche of IAWQ, May 31 1995

Variability of TSS loads at the outlet of the collection system

Michel Verbanck

Université Libre de Bruxelles, Laboratoire de Traitement des Eaux et Pollution

Brussels – Dry and Wet weather flows

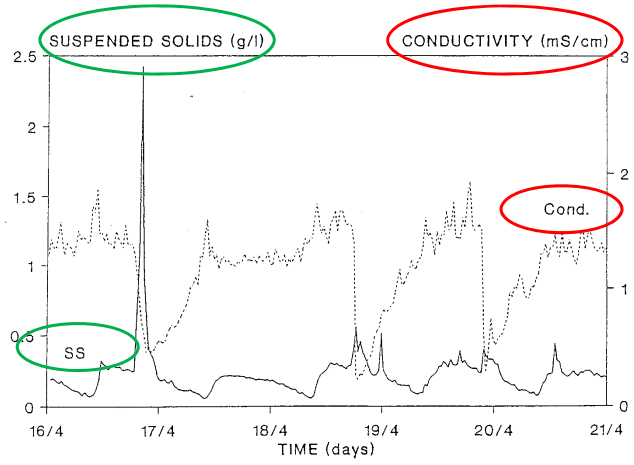


500,000 PE

= 30 years ago!

5

Brussels – Dissolved and particulate pollution



6

TSS in the integrated urban wastewater system

- Vehicle transporting at least 50% of:
  - Organic matter
  - Nitrogen & Phosphorus
  - Pathogens
  - Heavy metals
  - Hydrophobic micropollutants (PAH, pesticides, …)

  - Inorganics (sand) abrasive to downstream equipment

Damage caused by TSS

*Hydro International (2013)

TSS in the integrated urban wastewater system

- Challenging for:
  - Sampling → homogeneity / representativeness difficult to guarantee
  - Modelling → many processes affect TSS in pipes, clarifiers, channels
    - *Horizontal transport: advection & rolling (bed load)*
    - *Vertical transport: settling & resuspension*
    - *Transformation: breakage, aggregation (coag./flocc.), degradation*
  - Characterization: Composition, size, density, settling velocity

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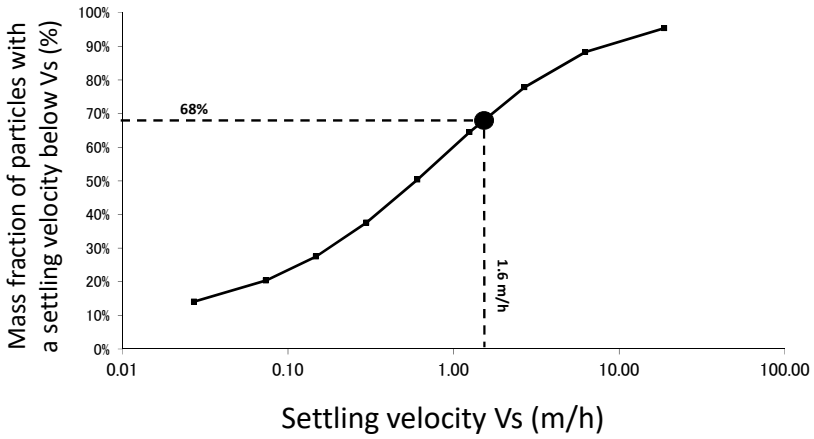
  - Characterization: Composition, size, density, SETTLING VELOCITY

PSVD – Particle Settling Velocity Distribution



PSVD – Particle Settling Velocity Distribution

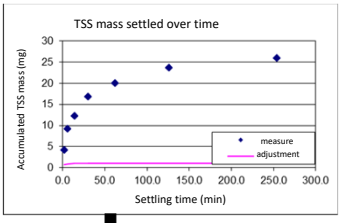
- **ViCAs experimental set-up**
  (Vitesses de Chute en Assainissement)
  Settling velocities in urban drainage

- Simple and fast PSVD measurement

Gromaire and Chebbo, 2009
Journal of Environmental Engineering

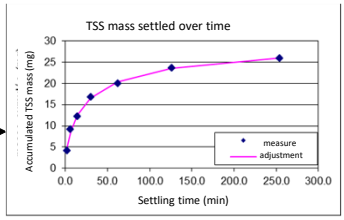
PSVD – Particle Settling Velocity Distribution

Inherent data quality check → Mass balance check ($t_0 - t_{fin}$)

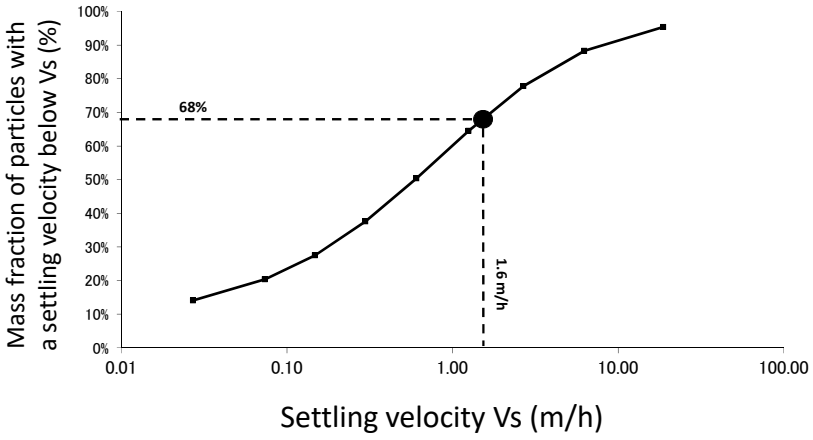


Measurement of TSS collected in cups under the hanging column of wastewater sample

Numerical treatment

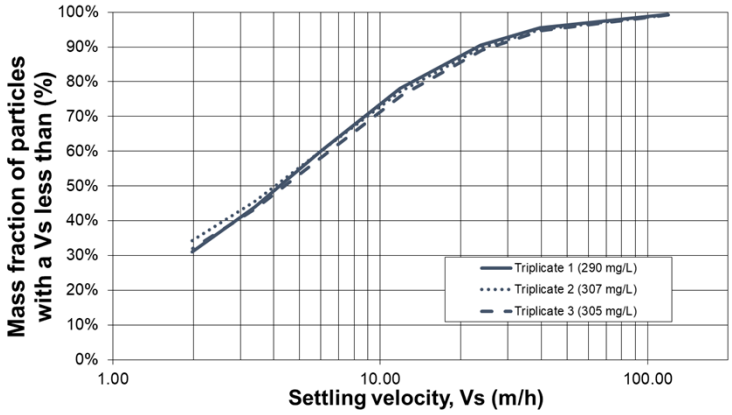


PSVD – Particle Settling Velocity Distribution



ViCAs equipment

- Reproducibility (triplicate test) :

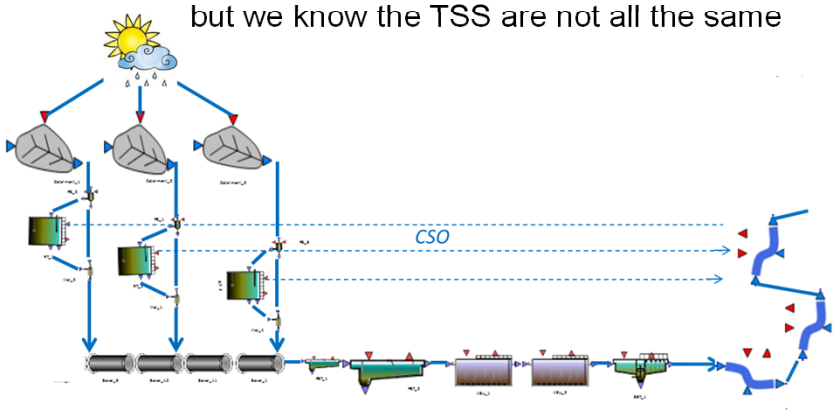


15

Now, what about the modelling?

- The system under study …

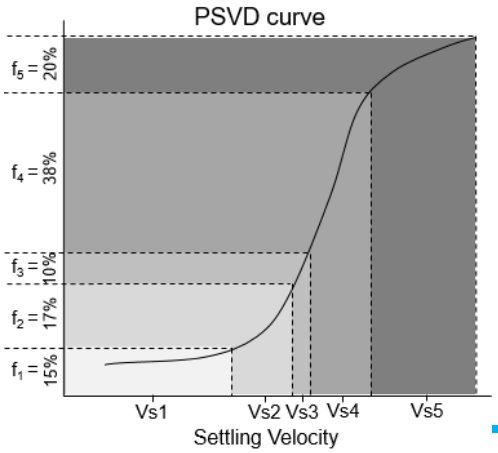
and TSS(t,z) is the main variable of interest
but we know the TSS are not all the same



16

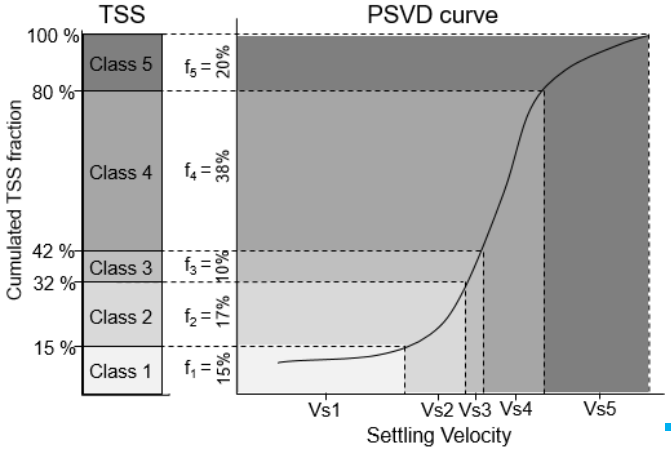
PSVD – Particle Settling Velocity Distribution

- To make a useful model → Split the continuous distribution into classes with characteristic V_s

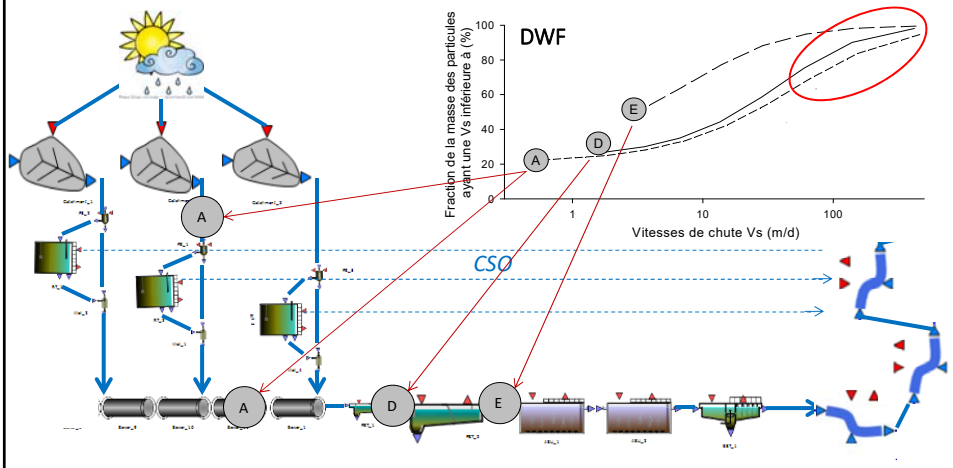


PSVD – Particle Settling Velocity Distribution

- To make a useful model → Split the continuous distribution into classes with characteristic V_s → Mass balances for TSS_i

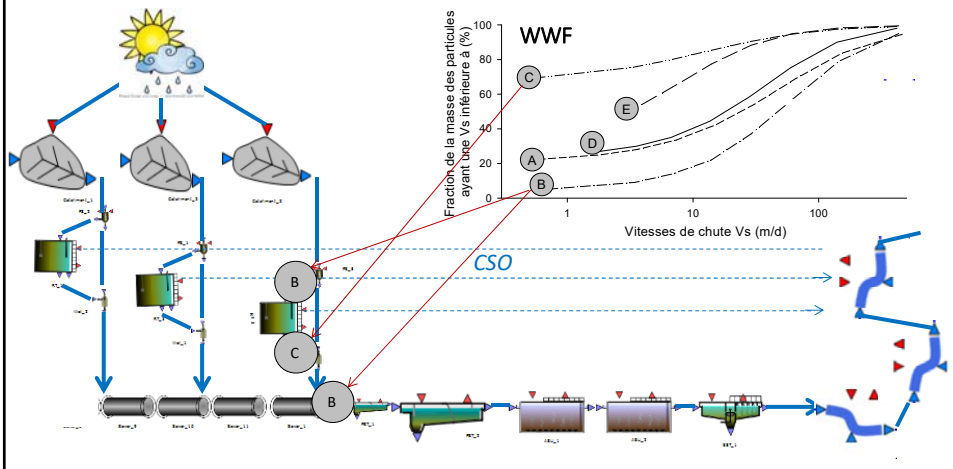


PSVD dynamics in dry weather (DWF)



19

PSVD dynamics in wet weather (WWF)



20

PSVD-model in Combined Sewer Retention Tanks

Urban Water Journal, 2013
http://dx.doi.org/10.1080/1573062X.2013.847462

Taylor & Francis

RESEARCH ARTICLE

Calibration and validation of a dynamic model for water quality in combined sewer retention tanks

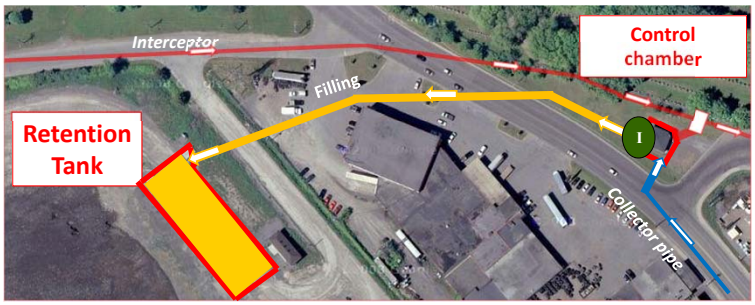
T. Maruéjouls*, P. Lessard and P.A. Vanrolleghem
Département de Génie Civil et de Génie Des Eaux, Université Laval, Québec, Canada

(*Received 26 November 2012; accepted 12 September 2013*)

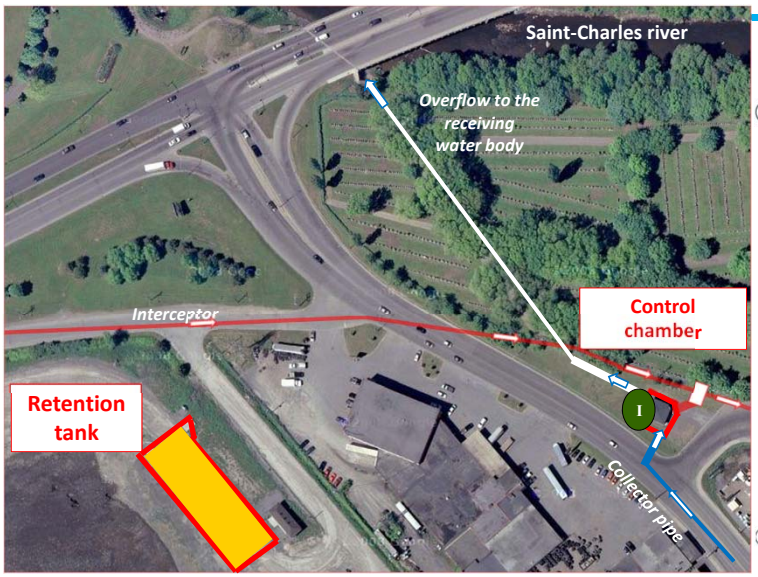
As the integrated management of urban wastewater systems becomes more and more popular, the development of wastewater management subsystem models appears essential to improve the understanding of the pollutant dynamics and their interactions. In such a context, a review of the literature reveals a lack of efficient models describing the dynamics of the water quality stored in off-line retention tanks. A model has thus been proposed based on the fractionation of suspended solids into three classes according to the particle settling velocity distribution measured in the field using the ViCAs settling test. In this paper, a calibration methodology is developed and full-scale field data sets from three different events are used for 1) calibrating this new dynamic retention tank model (two data sets); and 2) validating that model on the last data set. The results show a good agreement between observed and simulated data both for the total suspended solids and the total chemical oxygen demand.

Keywords: combined sewer overflow; settling velocity; stormwater management; urban wastewater modelling; water quality; wet weather

Wet weather (Filling)



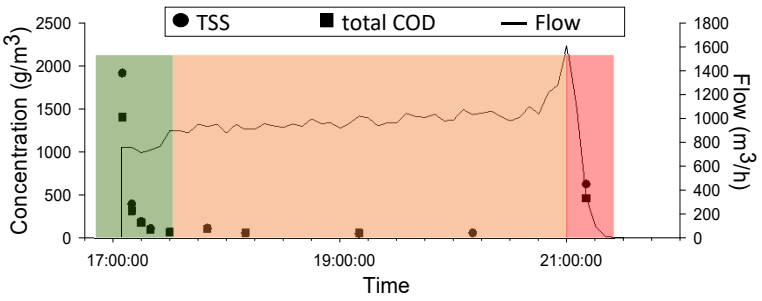
Wet weather (**Overflow**)



Wet weather (**Emptying**)

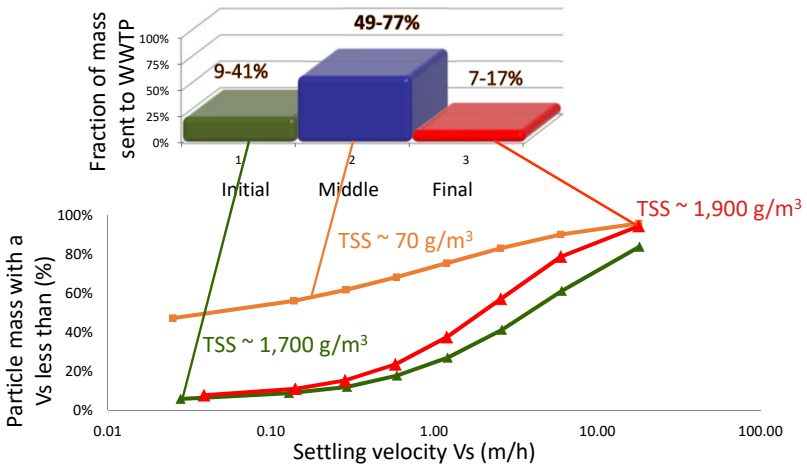
Water Quality Evolution during RT-emptying

- Typical pollutograph during emptying



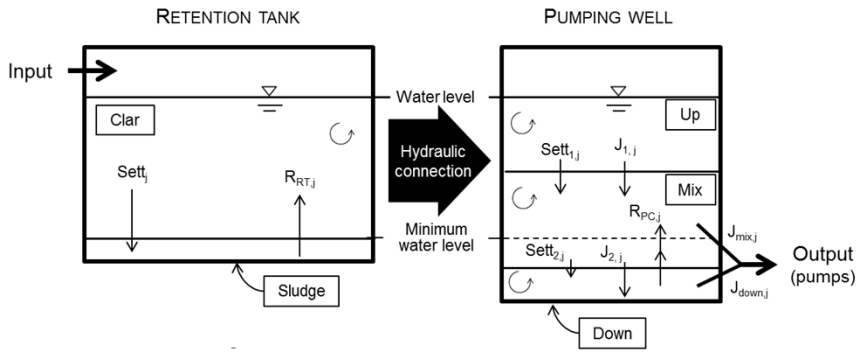
3 phases

TSS Flux and PSVD during RT-emptying



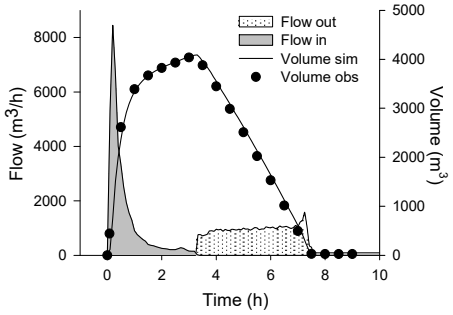
PSVD-model in Combined Sewer Retention Tanks

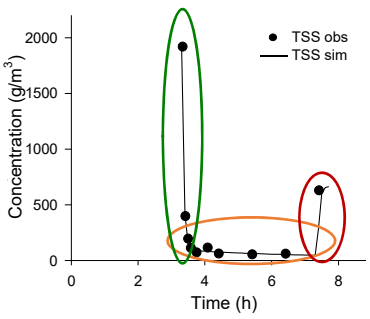
- Two main subsystems to be considered to predict TSS evolution:



PSVD-model in Combined Sewer Retention Tanks

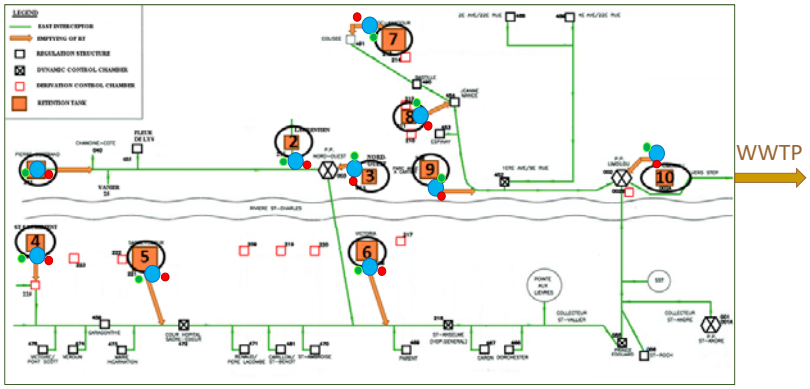
- Model performance





Using PSVD-model for Scheduling of RT Emptying

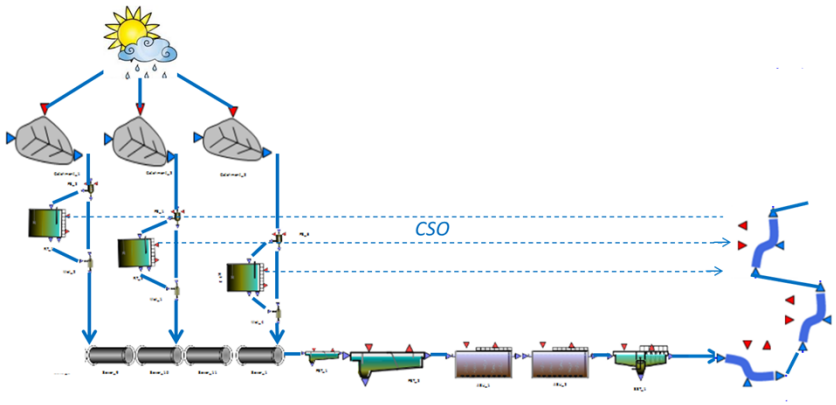
Beginning Middle End



29

Now, what about integrated modelling?

- Bringing all the pieces together,
  including primary clarifier and grit chamber PSVD-models



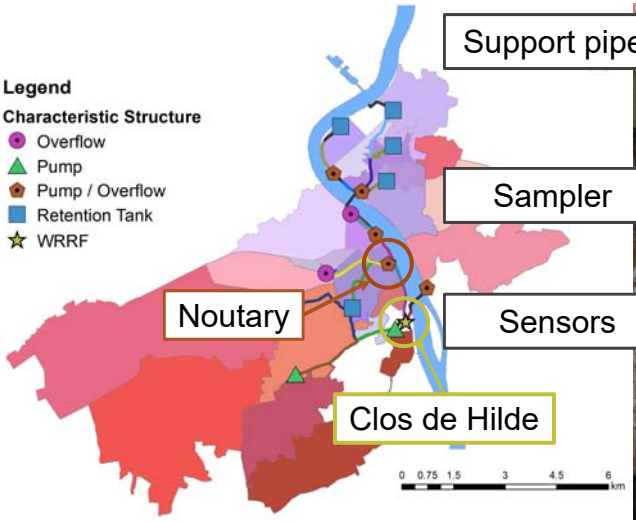
30

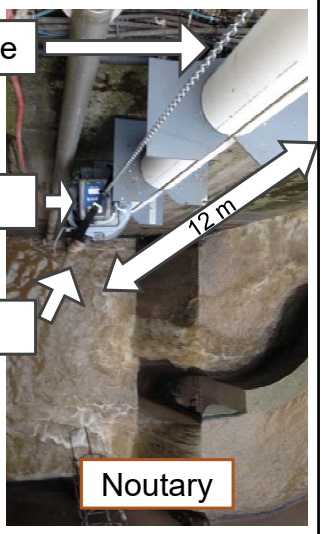
PSVD-model in integrated urban WW application

- Québec City (Canada) → East plant → 300,000 PE
- Bordeaux (France) → Clos-de-Hilde → 400,000 PE

31

PSVD-model application in Bordeaux - Validation

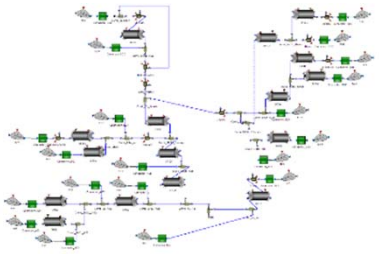




Ledergerber, Maruéjouls & Vanrolleghem (2018)

32

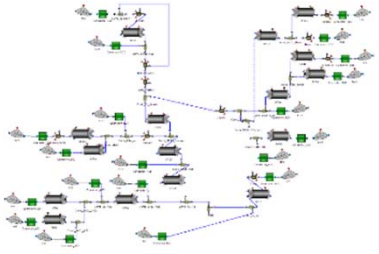
PSVD-model application in Bordeaux - Validation



- Catchment model:
  - KOSIM-WEST model
  - Accumulation/Wash-off
- Sewer model:
  - PSVD-based
  - Linear reservoirs in series
  - Settling and resuspension for ten particle classes

Ledergerber, Maruéjouls & Vanrolleghem (2018) 33

PSVD-model application in Bordeaux - Calibration

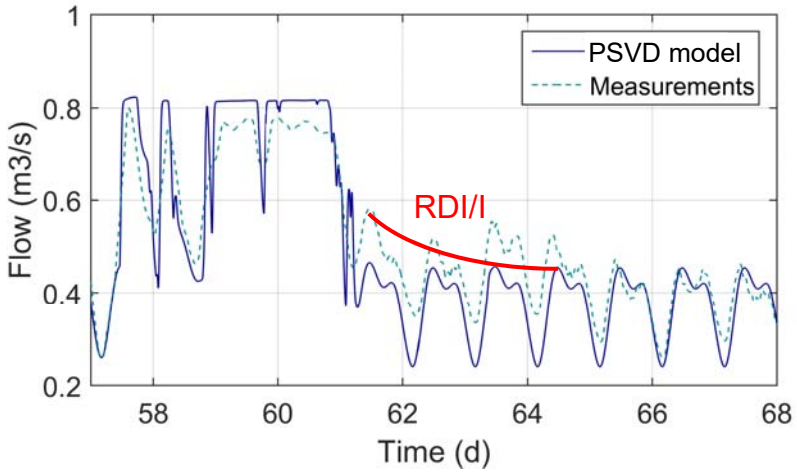


- Quantity
  - Initial calibration on existing Mike Urban by DHI model
  - Validation on flow data
    - Recalibration of DWF
    - Adjustments of characteristics at certain structures
- Quality (TSS at two locations)
  - 10 days of 2017 preliminary measurement campaign
  - ViCAs data
  - Continuous validated TSS data

Ledergerber, Maruéjouls & Vanrolleghem (2018) 34

PSVD-model application in Bordeaux - Validation

- Water quantity (rain → influent flow)

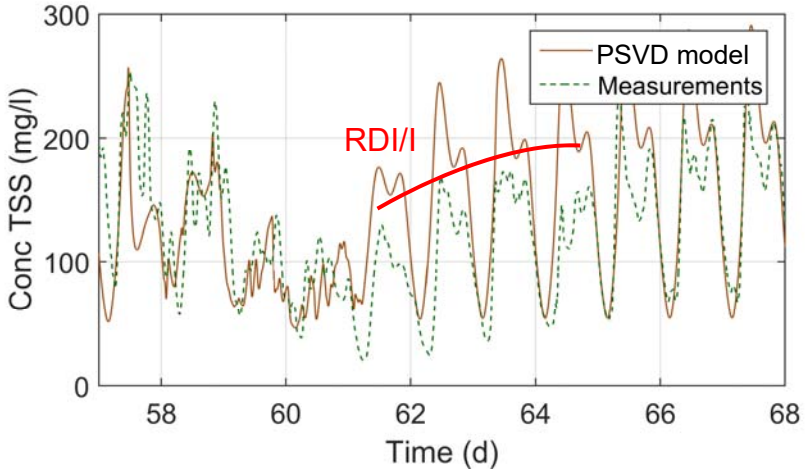


Ledergerber, Maruéjouls & Vanrolleghem (2018)

35

PSVD-model application in Bordeaux - Validation

- Water quality (rain → influent flow)



Ledergerber, Maruéjouls & Vanrolleghem (2018)

36

PSVD in Sewer Catchments

Urban Water Journal, 2013
Vol. 10, No. 4, 230–246, http://dx.doi.org/10.1080/1573062X.2012.726229

Taylor & Francis

RESEARCH ARTICLE

Improving the performance of stormwater detention basins by real-time control using rainfall forecasts

E. Gaborit[a*], D. Muschalla[a,b], B. Vallet[a,c], P. A. Vanrolleghem[a] and F. Anctil[a]

[a]*Département de génie civil et de génie des eaux, Université Laval, 1065 Avenue de la Médecine, Québec, Canada;* [b]*Institute of Urban Water Management and Landscape Water Engineering, Graz University of Technology, Stremayrgasse, Graz, Austria;* [c]*Aquafin NV, Dijkstraat 8, B-2630, Aartselaar, Belgium*

(*Received 22 April 2012; final version received 28 August 2012*)

Dry detention ponds are commonly implemented to mitigate the impacts of urban runoff on receiving water bodies. They currently rely on static control through a fixed limitation of their maximum outflow rate. Real-Time Control (RTC) allows optimizing their performance by manipulation of an outlet valve. This study developed several enhanced RTC scenarios of a dry detention pond located at the outlet of a small urban catchment near Québec City, Canada. The catchment's runoff quantity and TSS concentration were simulated by a SWMM5 model with an improved wash-off formulation. The control procedures rely on rainfall detection, on measures of the pond's water height, and in some of the RTC scenarios on rainfall forecasts. The implemented RTC strategies allow a substantial improvement of the pond's performance - the TSS removal efficiency increases from 46% (current state) to about 90% - while remaining safe and taking a mosquito-breeding risk constraint into account.

Keywords: dry detention pond; hydraulic stress control; rainfall forecasts; RTC; TSS removal; urban runoff mitigation.

PSVD – Specials (1)

- TSS accumulation/wash-off from sewer catchment

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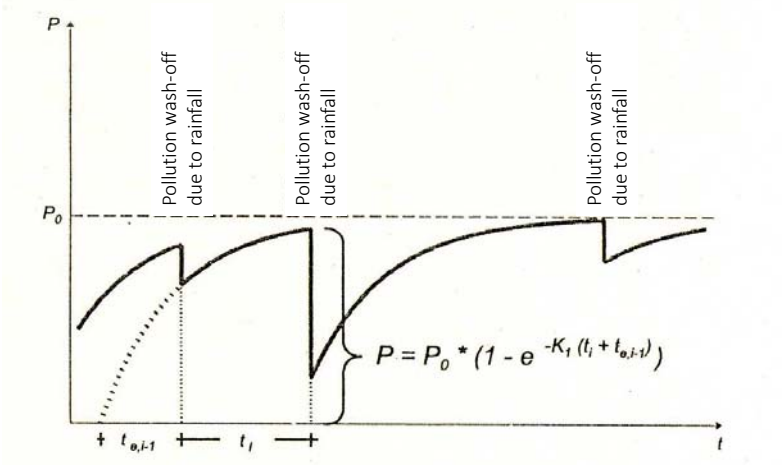
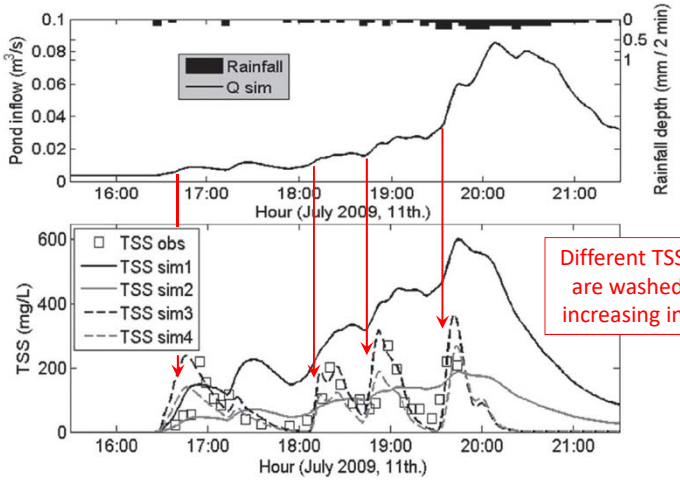


PSVD – Specials (1)

- TSS accumulation/wash-off from sewer catchment



Different TSS-fractions are washed off with increasing inflow rates

PSVD-model in Primary Settling Tanks

1185 © IWA Publishing 2017 Water Science & Technology | 75.5 | 2017

Chemically enhancing primary clarifiers: model-based development of a dosing controller and full-scale implementation

Sovanna Tik and Peter A. Vanrolleghem

ABSTRACT

Chemically enhanced primary treatment (CEPT) can be used to mitigate the adverse effect of wet weather flow on wastewater treatment processes. In particular, it can reduce the particulate pollution load to subsequent secondary unit processes, such as biofiltration, which may suffer from clogging by an overload of particulate matter. In this paper, a simple primary clarifier model able to take into account the effect of the addition of chemicals on particle settling is presented. Control strategies that optimize the treatment process by chemical addition were designed and tested by running simulations with this CEPT model. The most adequate control strategy in terms of treatment

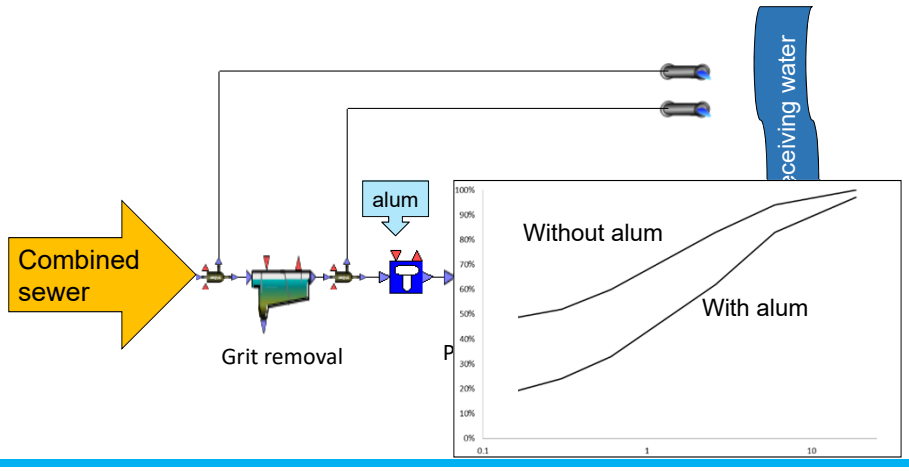
Sovanna Tik (corresponding author)
Peter A. Vanrolleghem
Département de génie civil et de génie des eaux,
modelEAU, Université Laval,
1065 av. de la Médecine,
Québec,
QC,
Canada G1V 0A6
E-mail: sovanna.tik.1@ulaval.ca

PSVD – Specials (2)

- Chemically enhanced primary treatment (CEPT)

PSVD – Specials (2)

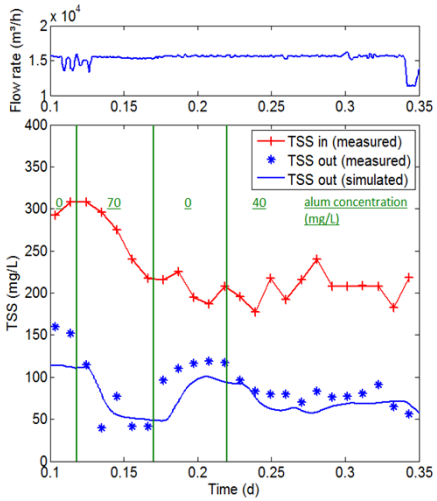
- Chemically enhanced primary treatment (CEPT)



PSVD – Specials (2)

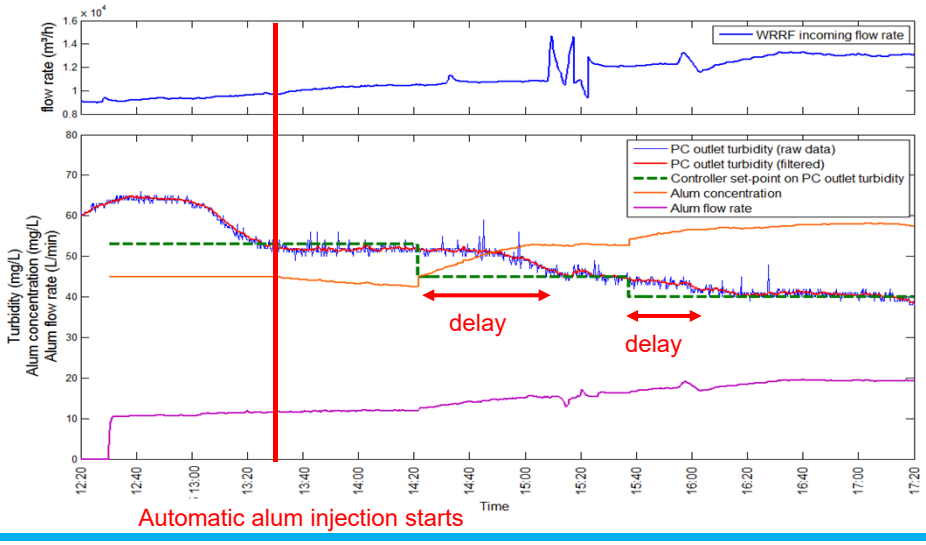
- Chemically enhanced primary treatment (CEPT)

  Model validation on experiment with different levels of chemical addition



PSVD – Specials (2)

- Process control performance:



CONCLUSIONS - Monitoring

- **ViCAs experimental set-up**
  (Vitesses de Chute en Assainissement)
  Settling velocities in urban drainage

- Simple and fast PSVD measurement for all types of particles in sewage
- Cheap to build yourself
- Easy to learn
- Built-in quality control

- Alternatives do exist (e.g. Elutriation)

CONCLUSIONS - Modelling

- PSVD-based models
  - are powerful, yet simple models
  - capture settling phenomena well
  - allow describing different behaviours of different TSS-classes
  - can predict the PSVD at different locations in the system (catchment, storm tanks, pipes, RTs, grit chamb., primary clar.)
  - can be implemented in hydrodynamic models (e.g. in SWMM by Muschalla & Maruéjouls → SWMM6 2021?)
- TSS data and ViCAs characterization are needed to calibrate/validate the models
- PSVD-models can be used for Water Quality-based management, RTC, system optimisation

47

Acknowledgements

BORDEAUX MÉTROPOLE
VILLE DE QUÉBEC
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JOHN MEUNIER
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48