Länsstyrelsen Skåne

One of BwN project aims: to "*generate the evidence-base that is currently lacking to incorporate building with nature solutions in national policy and investment programs*"

Interreg North Sea Region Building with Nature
European Regional Development Fund

EUROPEAN UNION

Lussebäcken "control" channel, Site 4
Photo: EA International (March 2019)

In-situ assessment of hydraulic roughness in a vegetated channel – *an example of well established 2-stage restored channels from Southern-Sweden*

Lussebäcken two-stage channel, Site 1
Photo: EA International (March 2019)

presented by

Ret.-Prof. Jean O. Lacoursière, PhD
(Lena B.-M. Vought, PhD, ret.)
Environmental Awareness International, Sweden

in collaboration with

Christofer Karlsson, DHI Sverige AB, Sweden

Pär Persson, **County Administrative Board of Skåne**, Sweden

Prof. Ian Guymer, Ph.D., The University of Sheffield, United Kingdom

Swedish Partner
(our client)

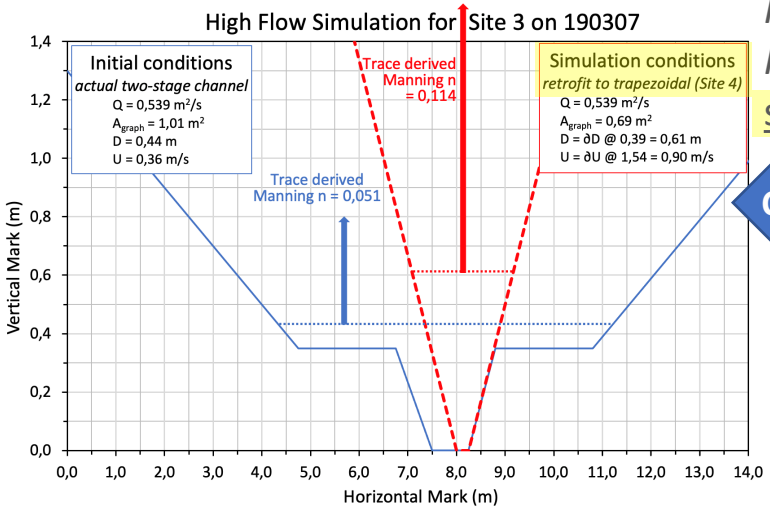
A presentation to the Workshop and Dissemination event
Mixing Processes in Pipes, Sewers & the natural Environment – from Theory to Practice
18th & 19th April 2023, University of Sheffield, UK

Länsstyrelsen Skåne

Background of this presentation…

Focus of this presentation

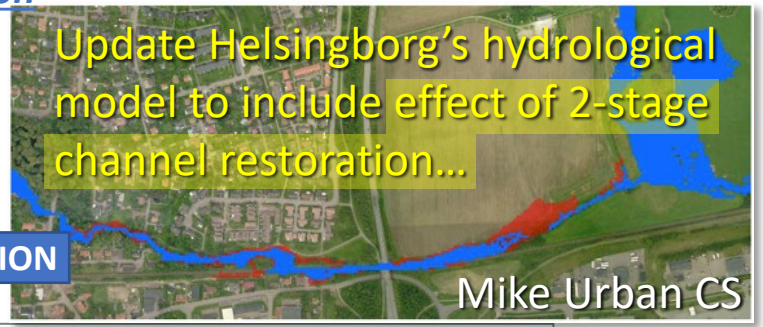
Interreg North Sea Region Building with Nature — European Regional Development Fund — EUROPEAN UNION



Hydraulogical Performance

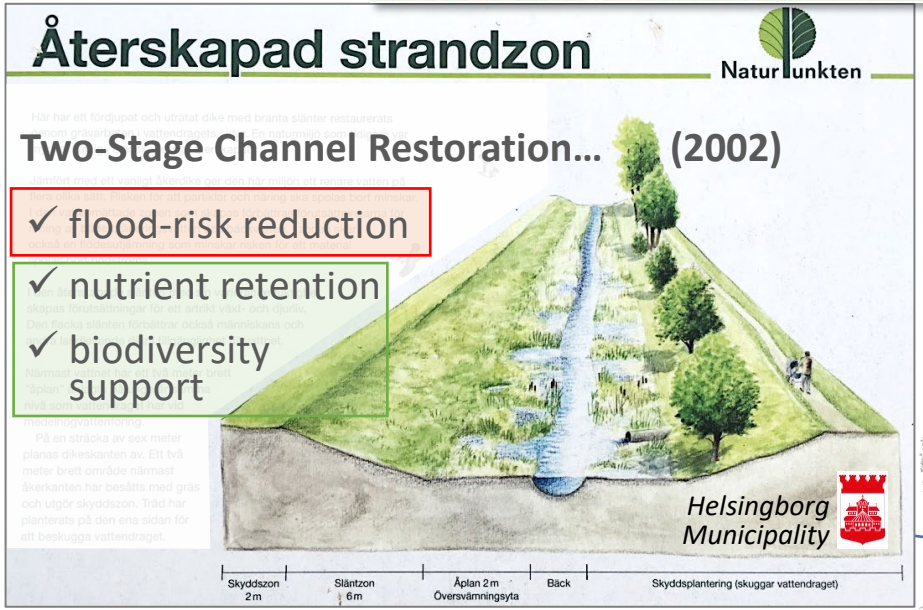
simulation DHI

CALIBRATION / VALIDATION

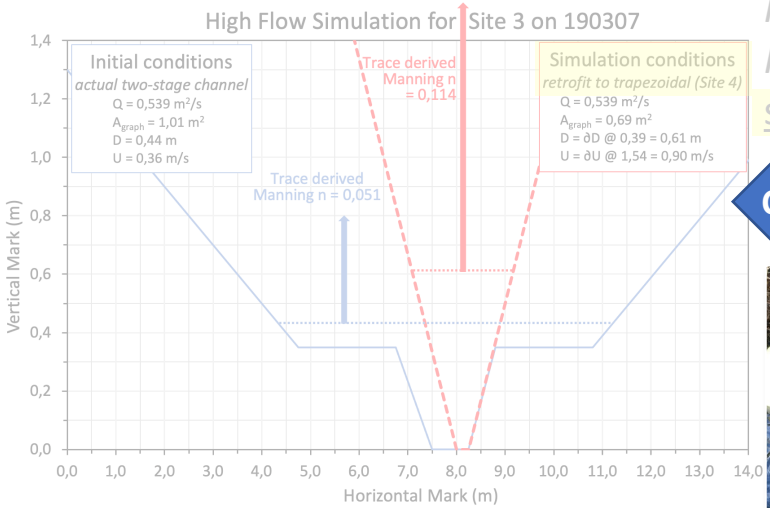


Hydrological Performance

- Peak-flow & Velocity reduction…
- overbank flow frequency



Background of this presentation…



Hydrological Performance simulation

CALIBRATION / VALIDATION

Update Helsingborg's hydrological model to include effect of 2-stage channel restoration…

Mike Urban CS

Hydrological Performance

- Peak-flow & Velocity reduction…
- overbank flow frequency

Conservative Tracing

✓ *hydrological data that integrate an entire reach*

Namely:

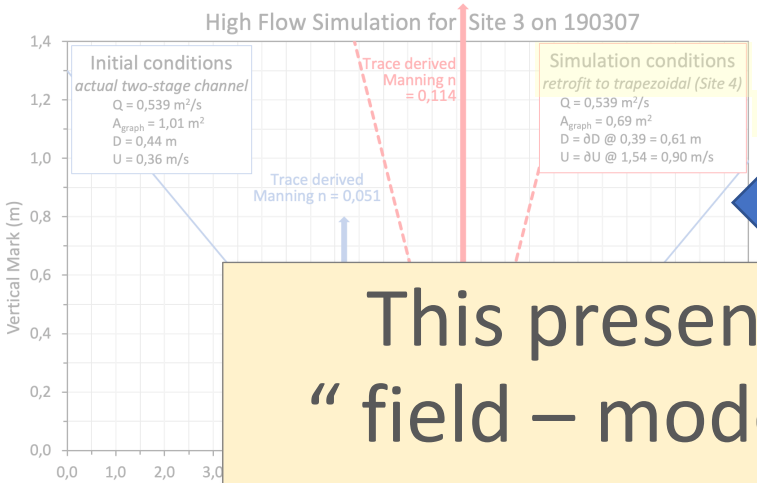
- trace-derived *average cross-sectional velocity* (U_{trace}), *assessed from Average Travel Time* ($\bar{\tau}$) of the tracer
- trace-derived discharge (Q_{trace})

… U_{trace} used to estimate a trace-derived reach-average energy loss coefficient (Manning's n_{trace})

Länsstyrelsen Skåne

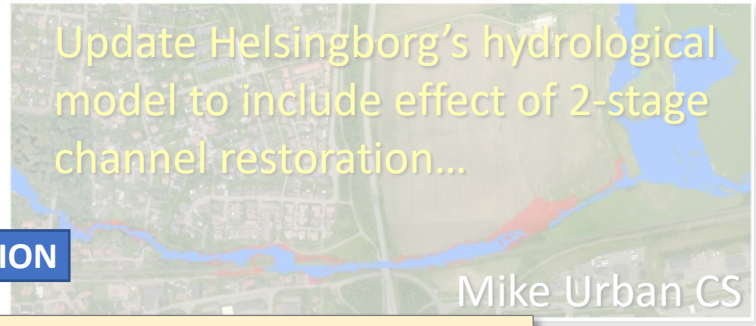
Background of this presentation…

Interreg North Sea Region Building with Nature
European Regional Development Fund
EUROPEAN UNION



Hydrological Performance simulation DHI

CALIBRATION / VALIDATION



This presentation focusses on the
" field – modelling " approach used…

the results of the flood-protection assessment of 2-stage channel restoration is left for an other time

Hydrologic… Performance

overbank flow frequency

…rate

…s-sectional …om Average

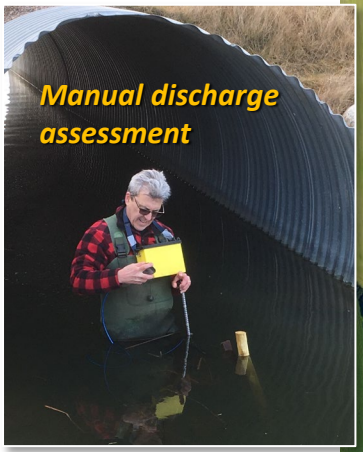
…race)

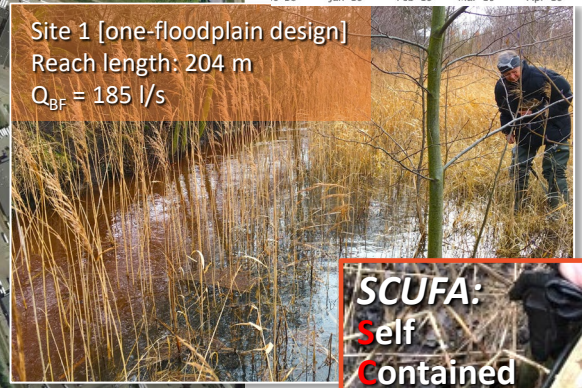
… U_{trace} used to estimate a trace-derived reach-average energy loss coefficient (Manning's n_{trace})

Länsstyrelsen Skåne

Study sites overview…

Interreg North Sea Region Building with Nature
European Regional Development Fund
EUROPEAN UNION





Länsstyrelsen Skåne

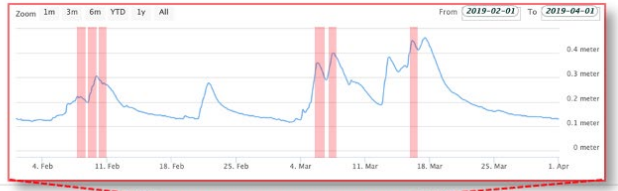
Conservative tracing… overview

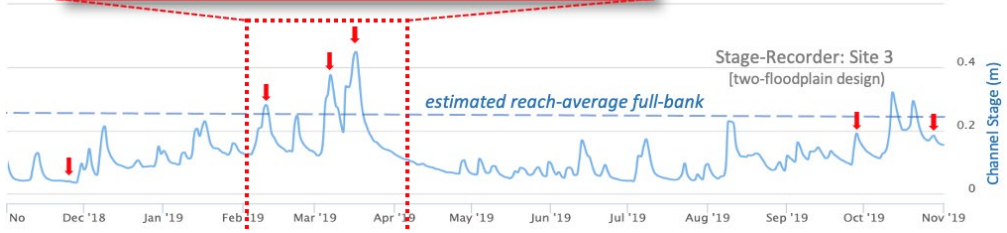
Interreg North Sea Region Building with Nature — European Regional Development Fund — EUROPEAN UNION

… all 4 sites traced within ca. 30 min

Pegs set for rapid deployment

Known distance (d) between injection and recording…

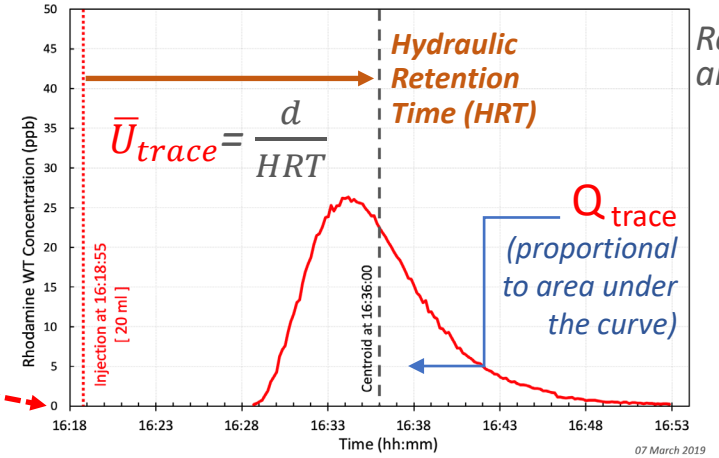




Timing of traces to cover base-flow or peak of hydrograph…

below, at and above $Q_{Bank\ Full}$

… travel time home-to-site = 45 min



Residence Time Distribution analysis

$\bar{U}_{trace}$: Average *Cross-sectional* Velocity (m/s)

Q_{trace} : Flow [discharge] (l/s)

Total: 10 traces/site

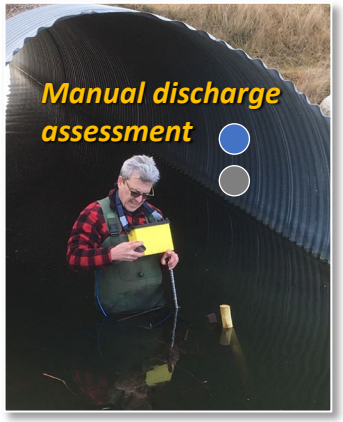
only sites 1 & 3 used in this presentation

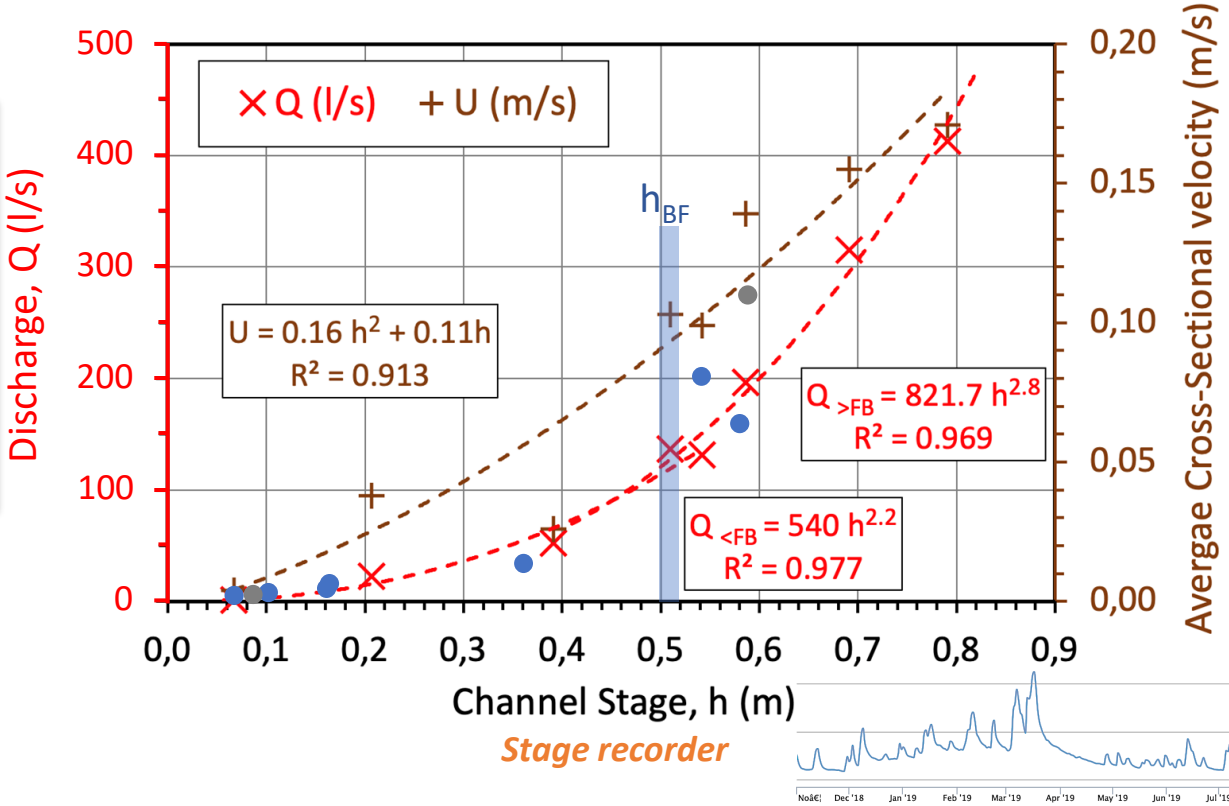
Länsstyrelsen Skåne

Conservative tracing… results

Interreg North Sea Region Building with Nature
European Regional Development Fund
EUROPEAN UNION

- ✓ Flow (discharge) rating curves
- ✓ Average Cross-Sectional Velocity





Länsstyrelsen Skåne

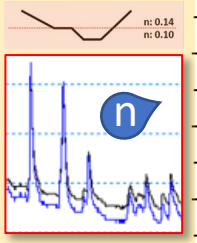
Conservative tracing…
Input to the calibration – validation process

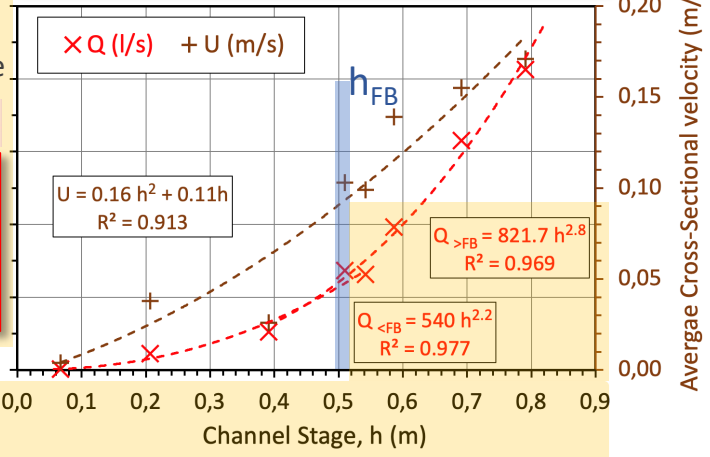
Interreg North Sea Region Building with Nature — European Regional Development Fund — EUROPEAN UNION

Significant in-channel vegetation

No in-channel vegetation

2) adjust model's *Manning roughness coefficient (n)* until resulting depth (h) provided a good fit to the automatically recorded channel stage

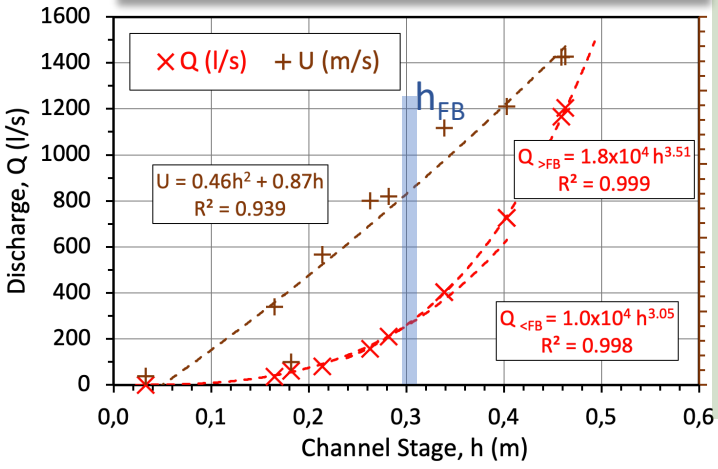




1) INPUTs

by comparing "model average velocity" (*i.e.*, trace simulation)

to the observed $\bar{U}_{trace}$



Länsstyrelsen Skåne

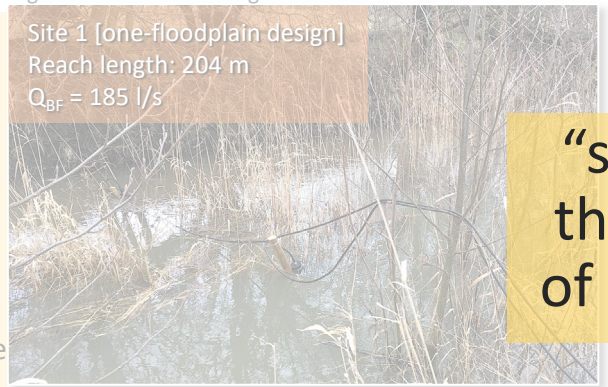
Conservative tracing…
Input to the calibration – validation process

Interreg North Sea Region Building with Nature
European Regional Development Fund
EUROPEAN UNION

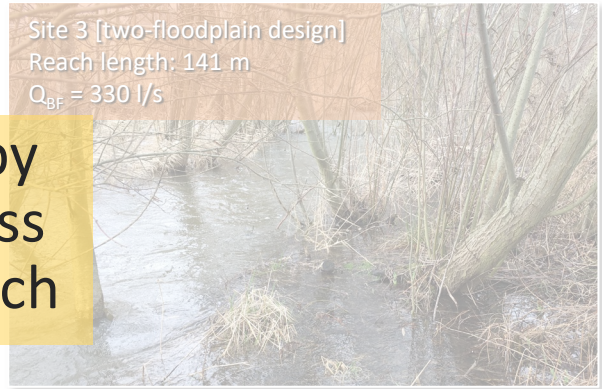
DHI

“surprised” by the robustness of the approach

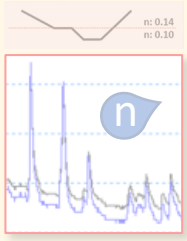
Significant in-channel vegetation



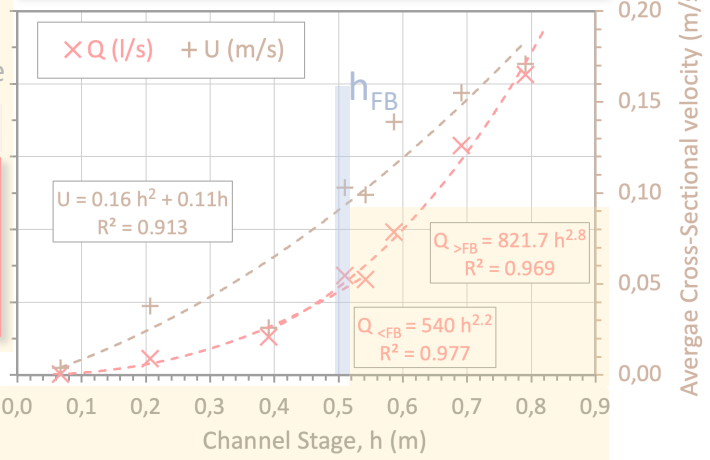
No in-channel vegetation

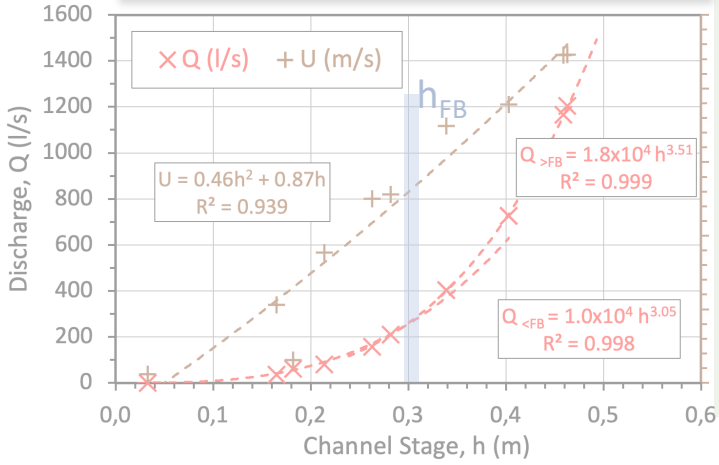


2) adjust model’s *Manning roughness coefficient (n)* until resulting depth (h) provided a good fit to the automatically recorded channel stage

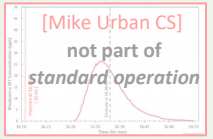


1) INPUTs





by comparing “model average velocity” (*i.e.*, trace simulation)



to the observed $\bar{U}_{trace}$

Länsstyrelsen Skåne

Calibrated Model…

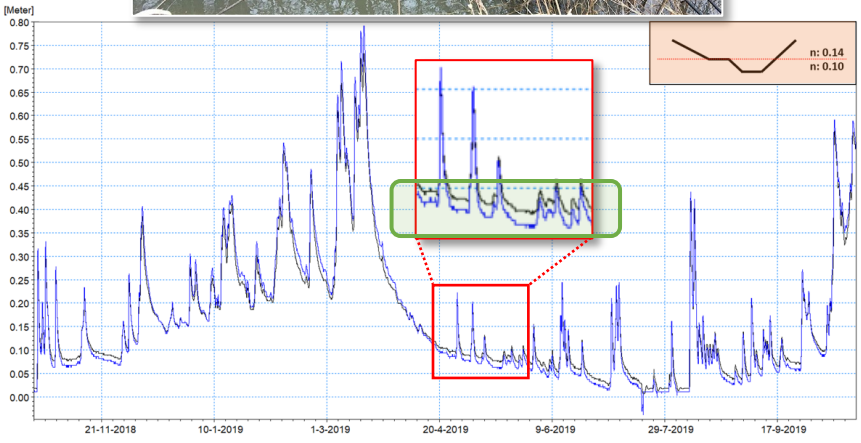
Trends and feedback well captured by the approach

Interreg North Sea Region Building with Nature
European Regional Development Fund
EUROPEAN UNION

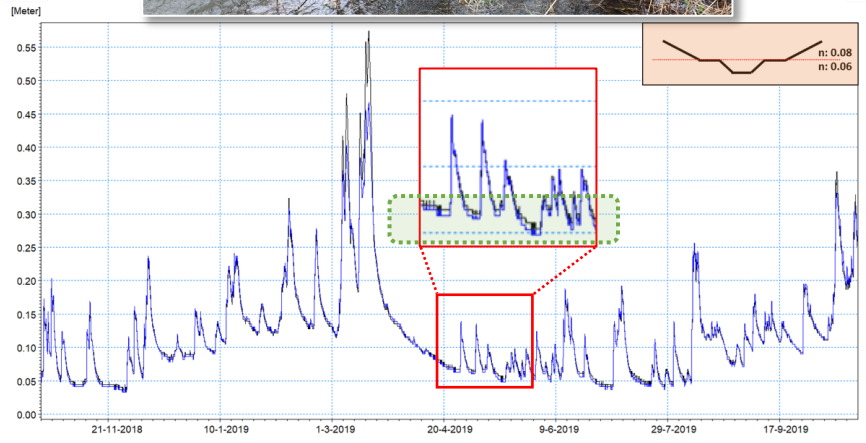
Significant in-channel vegetation

DHI
Mike Urban CS

No in-channel vegetation



Observed Simulated



Observed Simulated

Länsstyrelsen Skåne

Calibrated Model Validation outcome…
Trends and feedback well captured by the approach

Interreg North Sea Region Building with Nature
European Regional Development Fund
EUROPEAN UNION

Significant in-channel vegetation

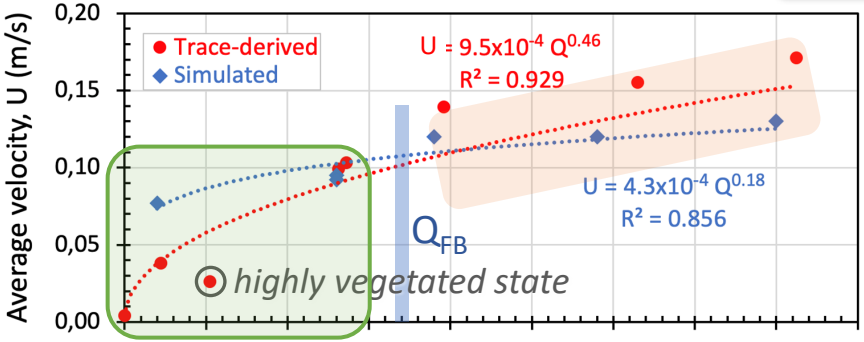
DHI
Mike Urban CS
trace simulation vs.

No in-channel vegetation

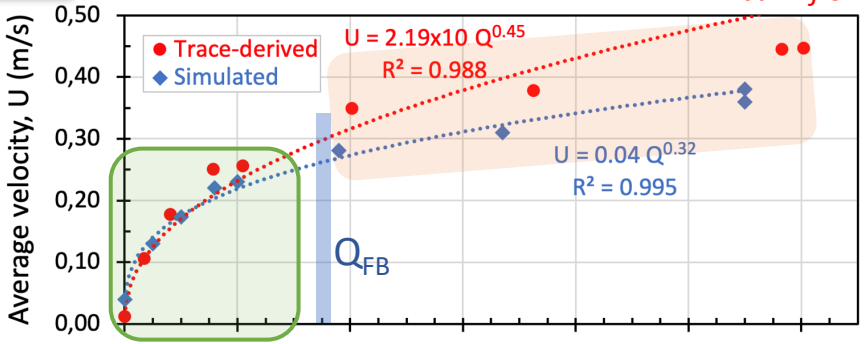
Better vertical mixing at injection would slightly improve results…

Trace "effect"

Generates slightly "inflated" velocities at over-bank flow…



… but not fully capture VEGETATION influence at lower flows (over estimate)



Model captures very well below full-bank flows in vegetation-free channel…

Vegetation effect

Länsstyrelsen Skåne

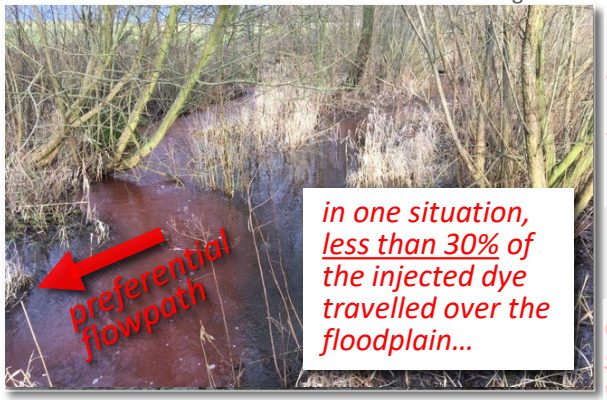
Conservative tracing…
Further key information provided by the approach

Interreg North Sea Region Building with Nature
European Regional Development Fund
EUROPEAN UNION

Significant in-channel vegetation

DHI
Mike Urban CS
trace simulation
vs.

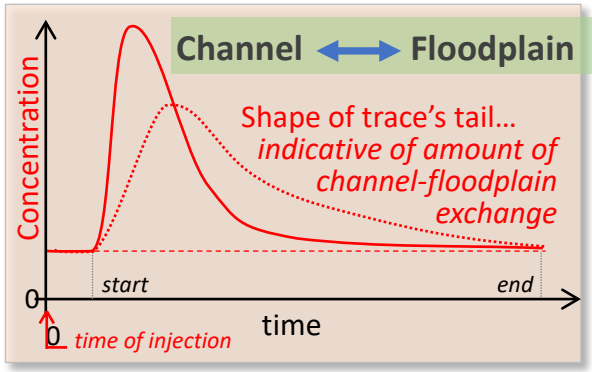
No in-channel vegetation



Better vertical mixing at injection would slightly improve results…

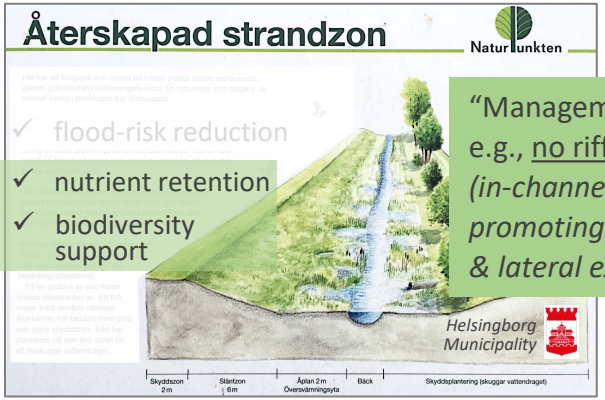
Trace "effect"

Generates slightly "inflated" velocities at over-bank flow…



preferential flowpaths

…affected nutrient and particle trapping efficiency by floodplains…



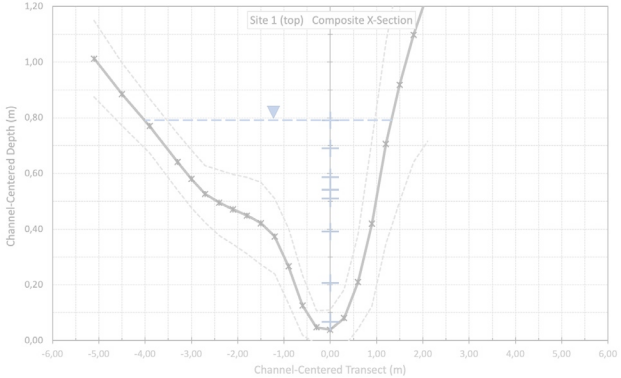
"Management issues"… e.g., no riffle-pool *(in-channel structure promoting overbank flow & lateral exchange)…*

Länsstyrelsen Skåne

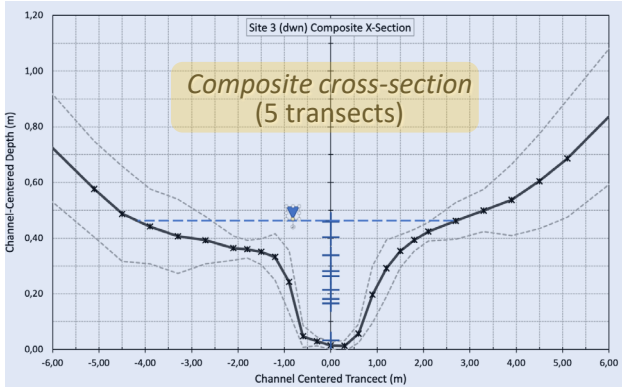
Conservative Tracing approach…

A quick word about "Trace-Derived flow resistance" (Manning *n*)

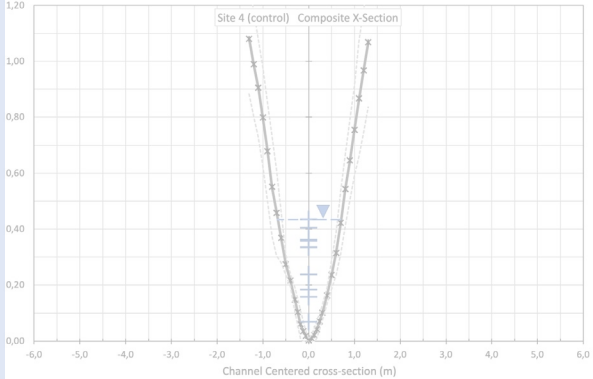
Interreg North Sea Region Building with Nature — European Regional Development Fund — EUROPEAN UNION



Significant in-channel vegetation



No in-channel vegetation



Significant "canopy" vegetation

$$Q = \frac{A\ R^{2/3}\ \sqrt{S}}{n}$$

Manning equation…

"reached-averaged"

$$R = \frac{A}{P}$$

A — area

P — wetted perimeter

hydraulic radius
(for each water depth)

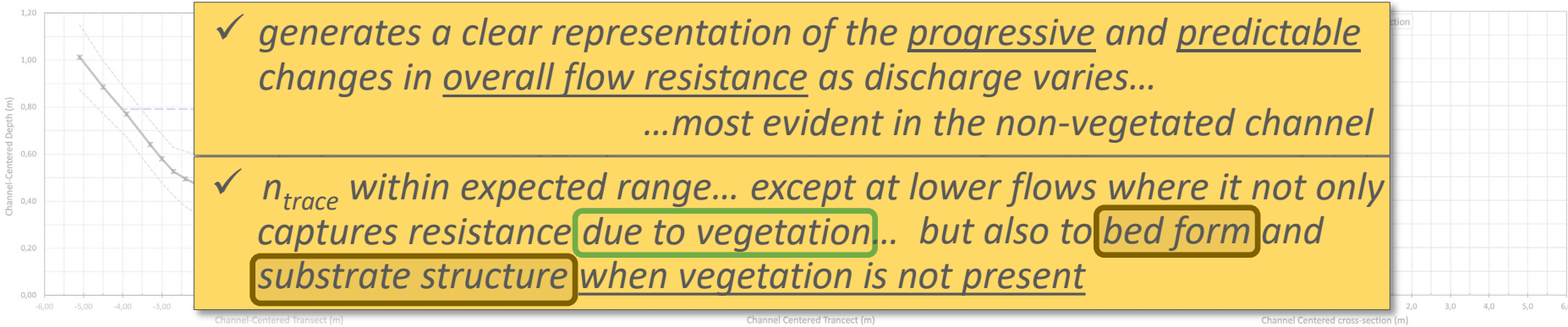
" bed friction " energy losses

ONE number…

$$n_{trace} = \frac{R^{2/3}\ \sqrt{S}}{U_{trace}}$$

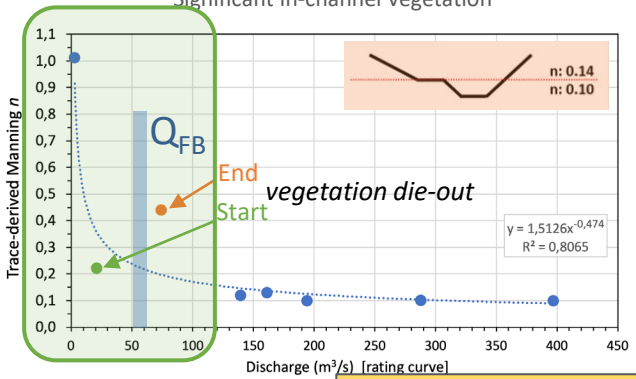
… representing both main-channel and floodplains… both frictional energy losses and 3D retardation phenomena

Conservative Tracing approach…
A quick word about *"Trace-Derived flow resistance"* (Manning *n*)

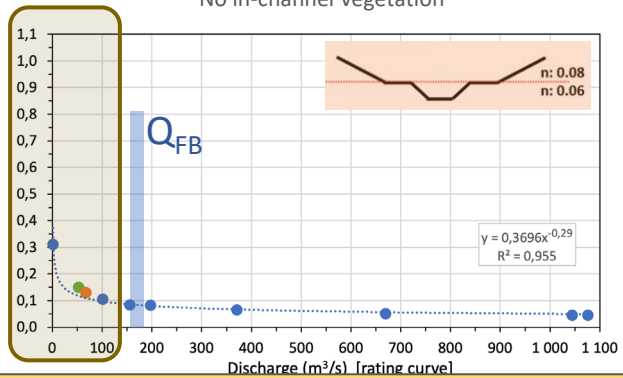


- ✓ *generates a clear representation of the progressive and predictable changes in overall flow resistance as discharge varies…*
  …most evident in the non-vegetated channel
- ✓ n_{trace} *within expected range… except at lower flows where it not only captures resistance due to vegetation… but also to bed form and substrate structure when vegetation is not present*

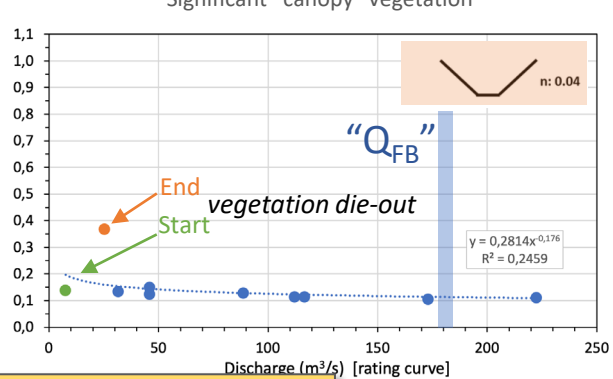
Significant in-channel vegetation



No in-channel vegetation



Significant "canopy" vegetation

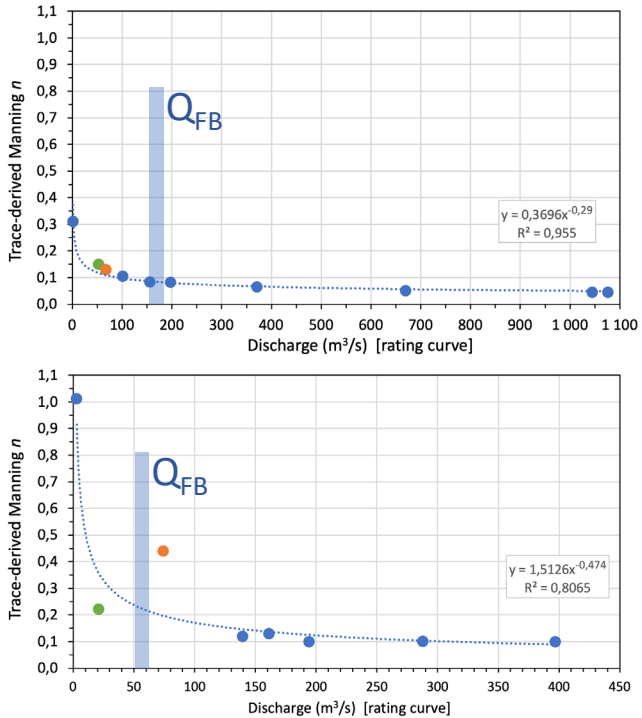


Would have been great to have more data points (traces)… but the spread over the entire hydrograph nevertheless demonstrates the viability of the approach

Länsstyrelsen Skåne

Conservative Tracing approach…
A quick word about "Trace-Derived flow resistance" (Manning *n*)

Interreg North Sea Region Building with Nature
European Regional Development Fund
EUROPEAN UNION



n_{trace} *not used in the calibration- validation process of the hydrological model due to contractual time constraint…*

Adjustments to modelling software are needed to easily incorporate a coefficient representing an "integrated value" of all flow resistance (hydrological and hydrodynamical) encountered over an entire reach…

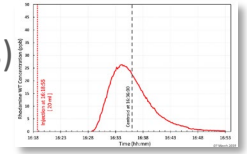
…could be a way to inject 3D information into 1D and 2D hydrological modelling !

Länsstyrelsen Skåne

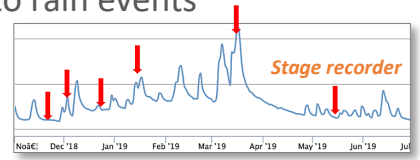
Key takeaway…

Interreg North Sea Region Building with Nature
European Regional Development Fund
EUROPEAN UNION

A bit of "dye dipping" (Residence Time Distribution analysis) easily provides *reach-integrated* flow parameters…

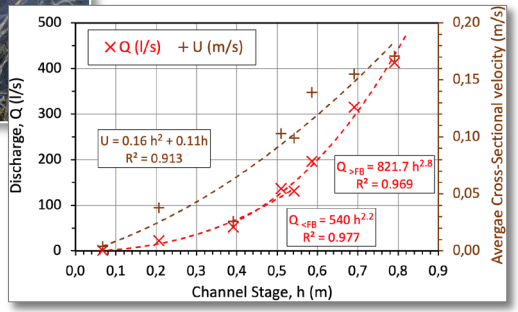


✓ ***Discharge Rating Curves***, as traces can be quickly performed timed to rain events along the full range of flows (baseflow to extreme flooding)…



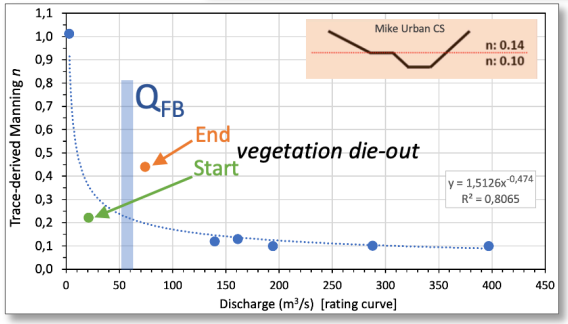
…efficiently characterising the *single location depth recording* key to end-user hydrological modelling;

We demonstrated it can be successfully used in the CALIBRATION process.



✓ of special interest is ***Travel Times***, from which ***Average Cross-Sectional Velocity*** is determined… specially within seasons, reflecting vegetation effects on flows;

We demonstrated it can be successfully used in the VALIDATION process… using, at least in Mike Urban CS, the little know function "virtual trace".



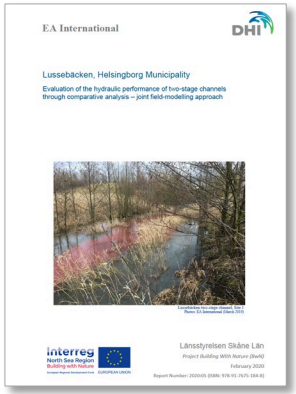
✓ *Average Cross-Sectional Velocity*, derived from Travel Time, is useful in **roughness & energy loss estimations**… specially within seasons, reflecting vegetation effects on flows;

We demonstrated that **Trace-Derived Manning *n*** have a significant potential in hydrological modelling… and that *interest in furthering the idea exists*.

Länsstyrelsen Skåne

If you are interested in the performance assessment of 2-stage channel restoration of agricultural streams… it is unfortunately at the moment part of the "grey-literature"

Interreg North Sea Region Building with Nature
European Regional Development Fund
EUROPEAN UNION

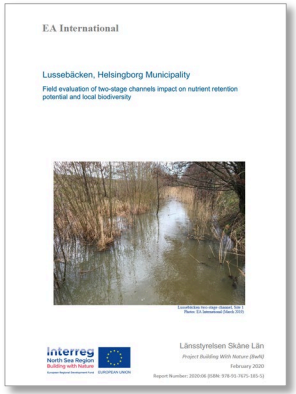


Details of the studies vailable at the *County Administrative Board of Skåne* (Länsstyrelsen Skåne)
Contact person: Pär Persson (par.persson@lansstyrelsen.se)

Lussebäcken - hydraulic performance of two-stage channels

https://www.lansstyrelsen.se/publikation?entry=M_2020_05&context=18

Contractual assessment performed by EA-International and DHI **for the *County Board of Skåne***, the Swedish partner of the INTEREG Project "***Building with Nature***". [https://northsearegion.eu/building-with-nature]



Råån - two-stage channels impact on biodiversity and nutrient retention

https://www.lansstyrelsen.se/publikation?entry=M_2020_06&context=18

Interreg North Sea Region Building with Nature
European Regional Development Fund
EUROPEAN UNION

This work was supported as part of Building with Nature, an Interreg project supported by the North Sea Programme of the European Regional Development Fund of the European Union