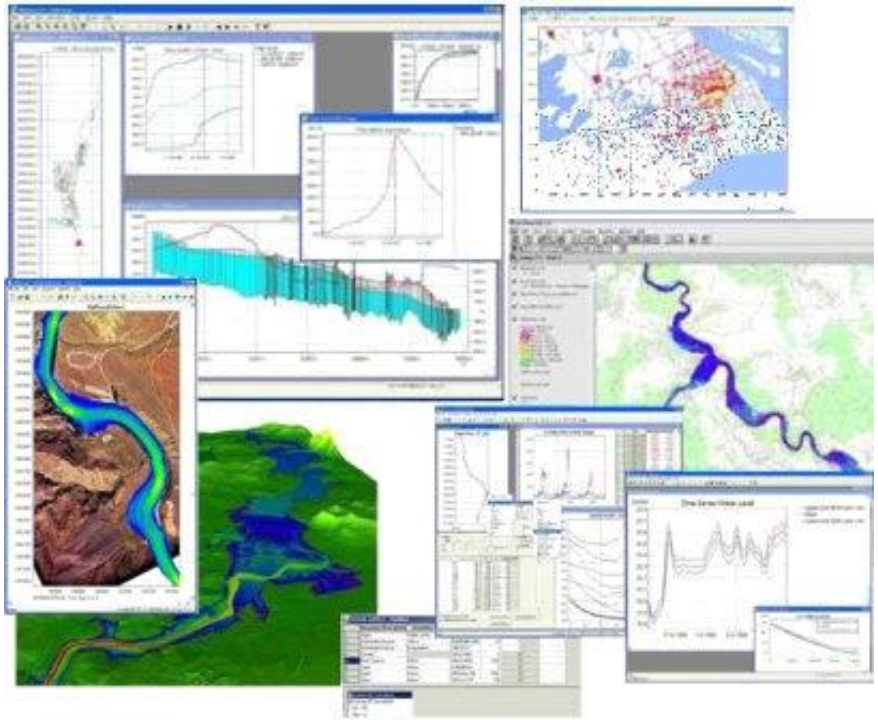
River Modelling



Assignment1: Data Pre-Analysis

Assignment 1

Web Page

- https://euroaquae.tu-cottbus.de
- Semester 3 –> Lecture Notes
- Module 3.1 -> River Rhine

  general modelling steps Assignment 1-3

  literature related to the case study

  Assignment 1 Web Page

    data and tools (Python/R, GIS including tutorial)

    Mike11/HEC-RAS material

    tasks (to be defined today)

Modelling Process

Typical Modelling Steps

- **data collection and pre-analysis and -processing**
- model set-up
- model calibration
- model validation
- model application
- data post-processing
- ….

Modelling Process

Data Collection and Pre-Analysis (1D model)

- river bathymetry -> cross sections point data (ASCII file)
  pre-analysis using **GIS** for spatial analysis
  MIKE11 for cross section analysis

- flow characteristics -> Q and h time series (ASCII files)
  pre-analysis using **R/Python** for time series analysis

-> Rhine Exercise Web page

Data Pre-Analysis

Geometrical Data / Bathymetry

- slope
- cross section values, e.g. river width, A(H), P(H), R(H)
- A/h relationship -> Q -> c -> Courant Number -> time step
- …

Data Pre-Analysis

Slope

- assuming constant slope
- $slope = \frac{\Delta h}{length} = \frac{(11{,}72-6{,}95)m}{33{,}4\ km} = 0{,}014\ \%$

Interpretation ?

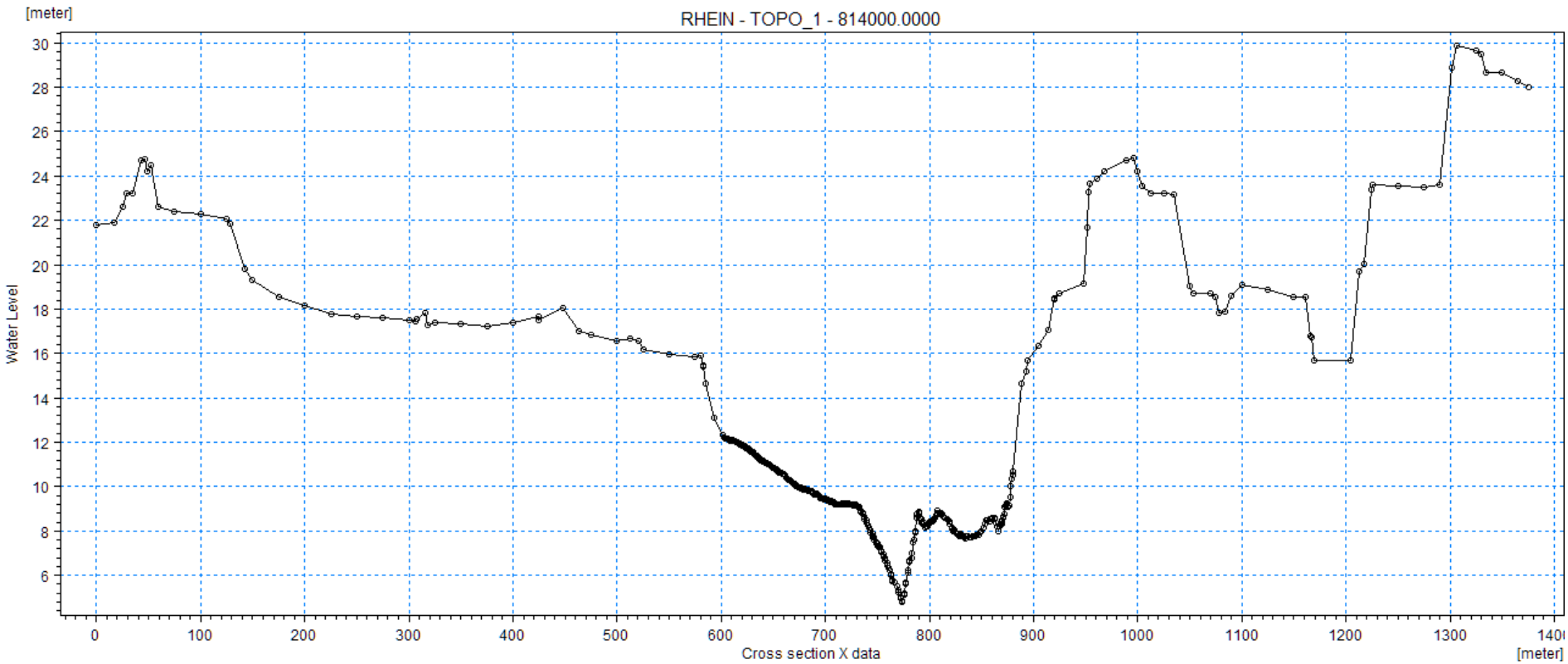
- Basel (250 m asl) to North Sea: 1000km -> 0.0250 %
- Wesel (25 m asl) to North Sea: 200km -> 0.0125 %

- Manning-Strickler equation $v_m = k_{st} R^{\frac{2}{3}} \sqrt{S}$

Data Pre-Analysis

Cross Section Data

- river width, A(H), P(H), R_h(H)



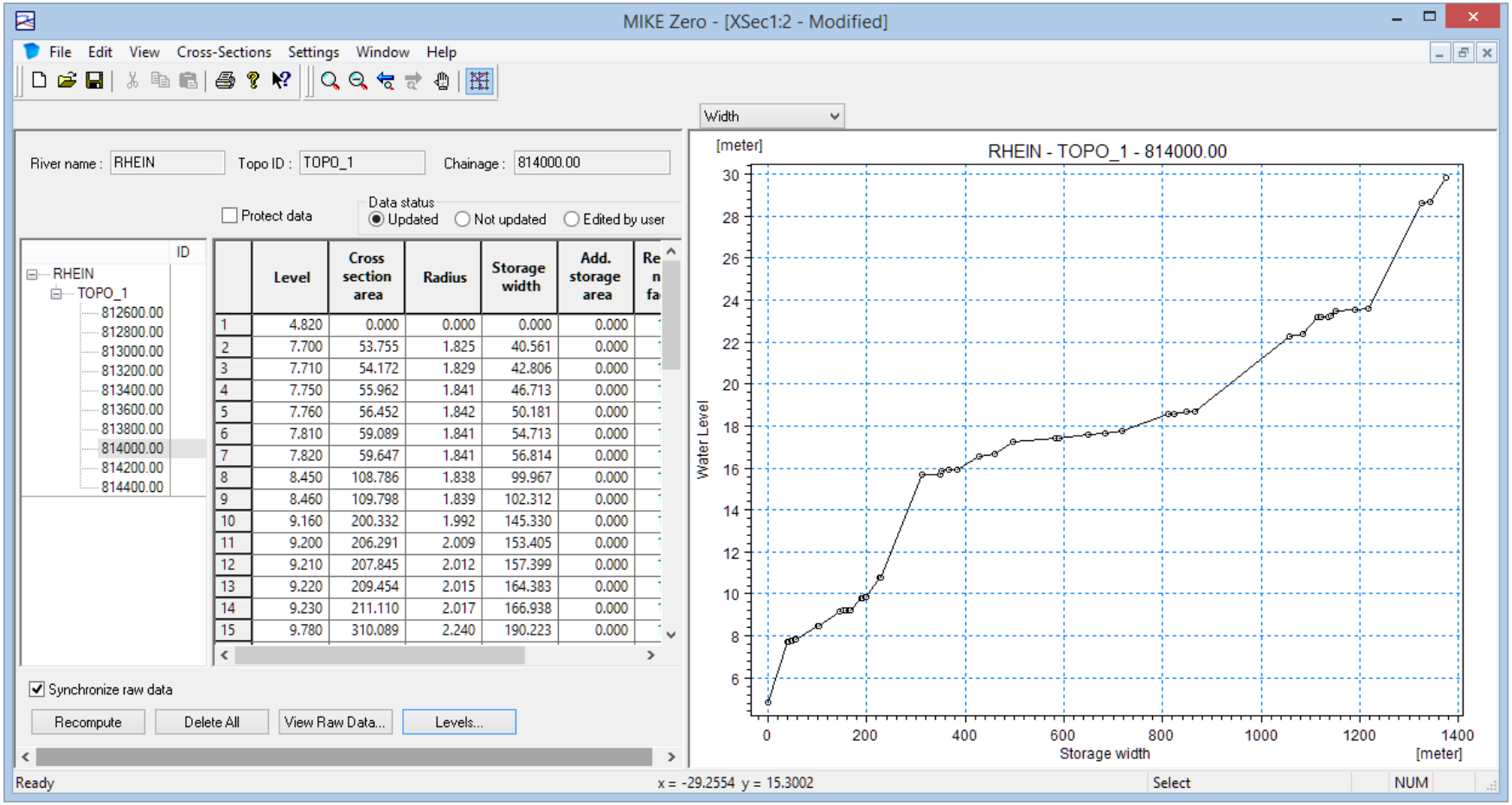
Data Pre-Analysis

Cross Section Data

- river width: 300 m – 1 km
- wetted area A(h) -> diagram
- wetted perimeter P(h) -> diagram
- hydraulic radius R_h (h) = A/P -> diagram

Data Pre-Analysis

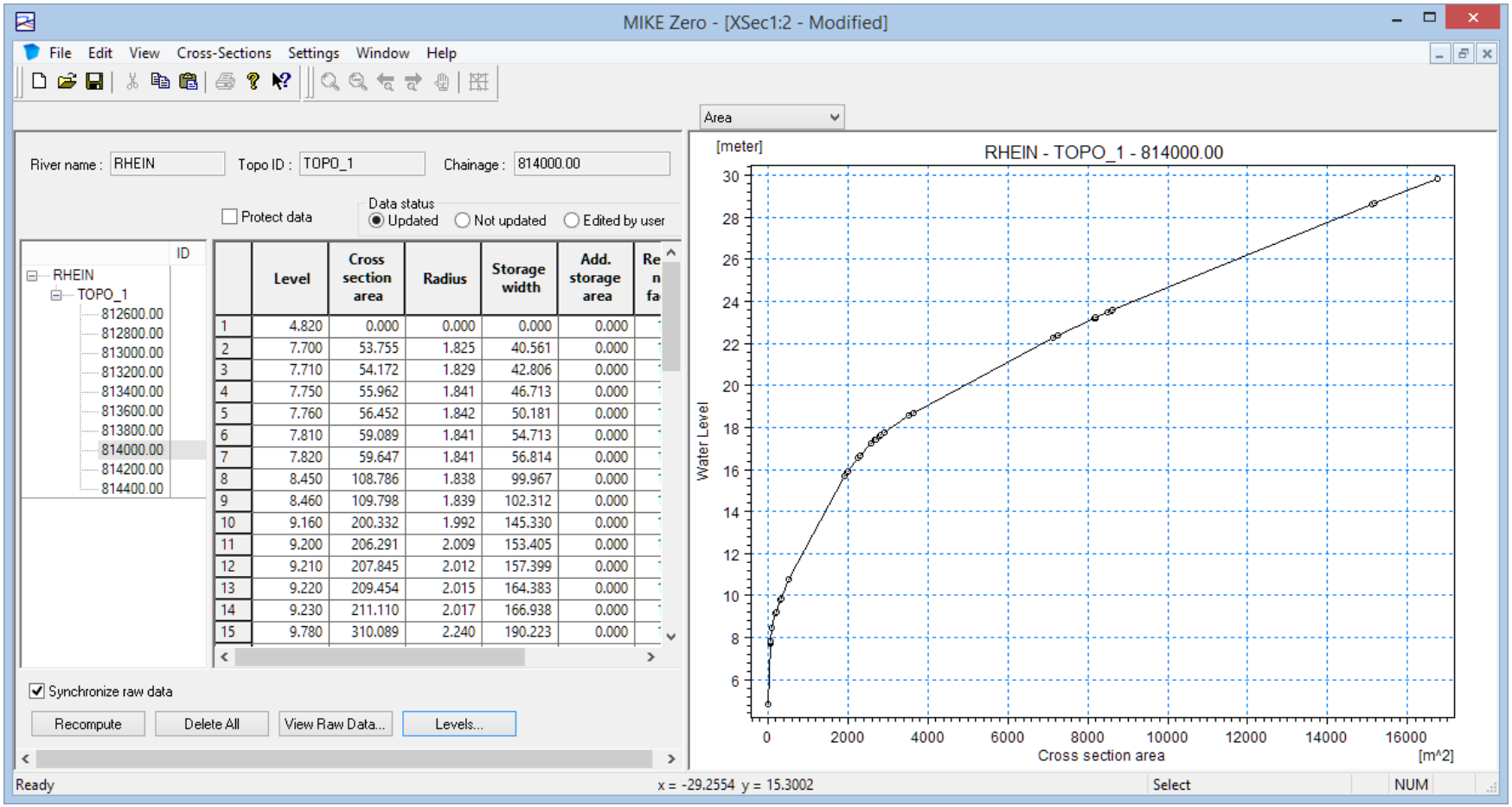
Example: surface width w(h)



	Level	Cross section area	Radius	Storage width	Add. storage area
1	4.820	0.000	0.000	0.000	0.000
2	7.700	53.755	1.825	40.561	0.000
3	7.710	54.172	1.829	42.806	0.000
4	7.750	55.962	1.841	46.713	0.000
5	7.760	56.452	1.842	50.181	0.000
6	7.810	59.089	1.841	54.713	0.000
7	7.820	59.647	1.841	56.814	0.000
8	8.450	108.786	1.838	99.967	0.000
9	8.460	109.798	1.839	102.312	0.000
10	9.160	200.332	1.992	145.330	0.000
11	9.200	206.291	2.009	153.405	0.000
12	9.210	207.845	2.012	157.399	0.000
13	9.220	209.454	2.015	164.383	0.000
14	9.230	211.110	2.017	166.938	0.000
15	9.780	310.089	2.240	190.223	0.000

Data Pre-Analysis

Example: wetted area A(h)



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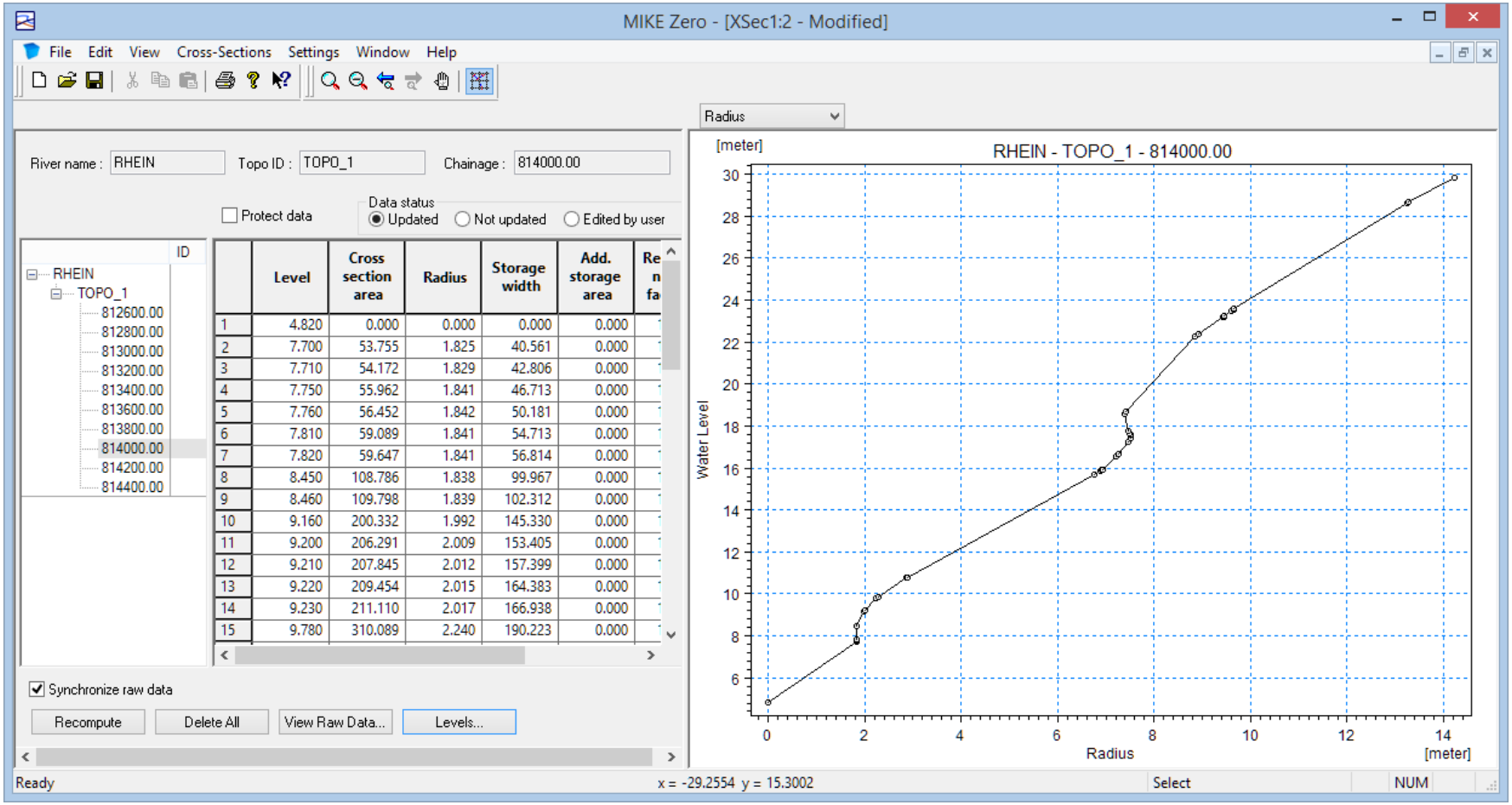
Data Pre-Analysis

Example: hydraulic radius $R_h(h)$



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Data Pre-Analysis

Vertical Coordinate

- local measurement using local datum
  -> local water depth
- water level = water depth + sensor level
- sensor level -> absolute vertical datum (masl Amsterdam)
  e.g. Wesel: 11.218 m

Data Pre-Analysis

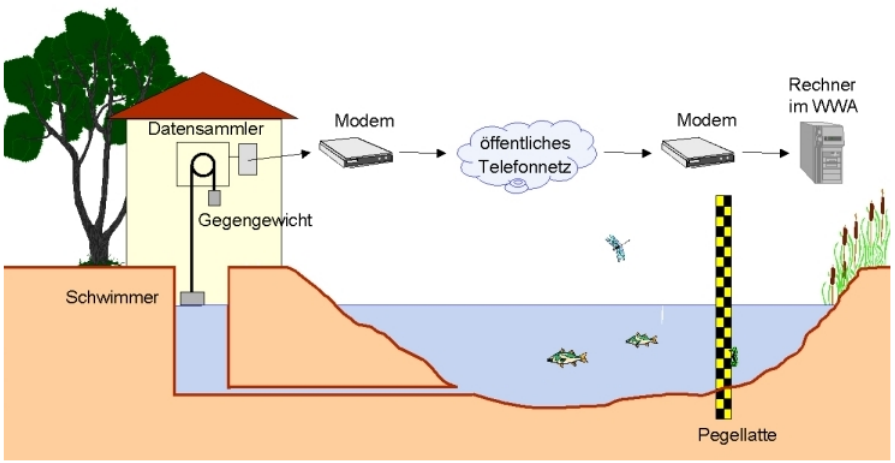
Meta Data “Pegel Wesel”

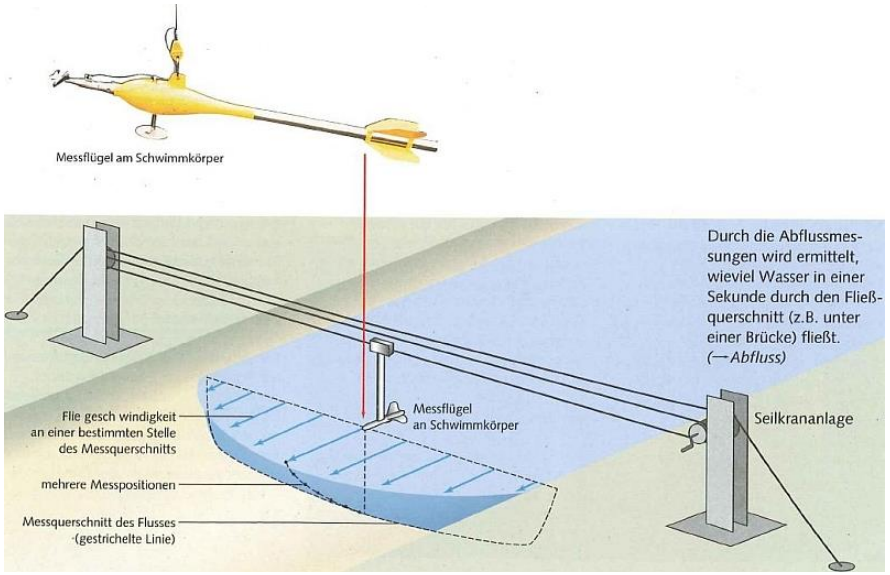
Name	Langform	Wert	Zeitbezug
km	Kilometer des Pegels an der Wasserstraße RHEIN	814 km	
Lage	Koordinaten des Pegels	51° 38.769' N 6° 36.409' E	
PNP (m. ü. NHN)	Pegelnullpunkt (Meter über Normalhöhennull)	11,218 m	gültig ab 01.11.2017
HSW	höchster Schifffahrtswasserstand	1060 cm	gültig ab 01.01.1950
M_I	Marke I	870 cm	gültig ab 01.01.1995
M_II	Marke II	1060 cm	gültig ab 01.01.1995
NNW	niedrigster bekannter Wasserstand	111 cm	01.10.2003
GlW	gleichwertiger Wasserstand	177 cm	gültig ab 01.01.2015
TuGLW	Tiefe unter GlW	280 cm	gültig ab 01.01.2000
MNW	mittlerer niedrigster Wert der Wasserstände in einer Zeitspanne	180 cm	01.11.2000 - 31.10.2010
MW	Mittelwert der Wasserstände in einer Zeitspanne	378 cm	01.11.2000 - 31.10.2010
MHW	mittlerer höchster Wert der Wasserstände in einer Zeitspanne	850 cm	01.11.2001 - 31.10.2010
HHW	höchster bekannter Wasserstand	1231 cm	03.01.1926

Data Pre-Analysis

Time Series

- upstream – Ruhrort
  h(t) and Q(t)
- downstream – Wesel
  h(t) and Q(t)





reference: Bayerisches Landesamt für Umwelt

Data Pre-Analysis

Time Series Meta Data

```
water level : values 157776 NaN: 0 0.0%
Wesel 814.0            min  110.00 cm
                       max  1116.00
                       mean 373.93
                       sd   153.87"
```

year	1989	1990	1991	1992	1993	1994	1995	1996	1997 …
NA	0	0	0	0	0	0	0	0	0
NA %	83.30	0.00	0.00	-0.27	0.00	0.00	0.00	-0.27	0.00
min	141.00	148.00	120.00	141.00	215.00	197.00	190.00	179.00	145.00
max	684.00	896.00	860.00	722.00	1092.00	938.00	1116.00	657.00	886.00
mean	296.57	320.49	295.14	343.50	342.05	423.07	454.44	307.14	325.23
sd	166.07	135.84	143.84	135.66	144.77	157.76	179.47	98.28	122.23

Data Pre-Analysis

Time Series Analysis

- low water scenario
- mean water scenario
- high water scenario
- identification of specific events
- statistical analysis -> return period
- rating curve for different time windows (e.g. 10 years)

Data Pre-Analysis

Velocity

Manning-Strickler equation

$$v_m = k_{st} R^{\frac{2}{3}} \sqrt{S} = 34\ 6{,}1^{\frac{2}{3}} \sqrt{0{,}014\%} = 1{,}34 \frac{m}{s}$$

Measurements

known Q and h -> unknown v

$Q = v\ A(h)$ -> $v = \frac{Q}{A(h)}$

Q_{mean} = 2267 m^3/s h_{mean} = 3,74

A (3,74+11,22) = A (14,96) -> 1700m^2 (from Crossection analysis)

v = 2267/1700 = 1,33 m/s = 4,8 km/h

Data Pre-Analysis

Normal Depth (uniform flow)

Manning-Strickler equation

$$v_m = k_{st} R^{\frac{2}{3}} \sqrt{S}$$

$$Q = k_{st}\, A(h)\, R(h)^{\frac{2}{3}} \sqrt{S}$$ Q(h) -> non linear equation A(h), $R_h(h)$

Q_{mean} = 2267 m^3/s

k_{st} = 34 -> h_n -> can be solved by iteration

S = 0,014 %

see https://www.weather.gov/aprfc/NormalDepthCalc

Data Pre-Analysis

Courant Number Courant–Friedrichs–Lewy (CFL) condition

- necessary condition for convergence (FDM)
- $C = v \frac{\Delta t}{\Delta x} \leq C_{max}$

„Courant“ – Number

v -> velocity
Δt -> time step Δx -> space step
C_{max} -> might be 1 for explicit schemes

- Consequences ?

velocity -> river behaviour
Δx -> cross section distance

$$\Delta t \leq 1 \frac{\Delta x}{v}$$

Data Pre-Analysis

Courant Number Courant–Friedrichs–Lewy (CFL) condition

$$\Delta t \leq 1 \frac{\Delta x}{v}$$

Δx -> 100 m, v = 1,3 m/s -> $\Delta t \leq$ 76 sec

Δx -> 100 m, v = 2,5 m/s -> $\Delta t \leq$ 40 sec

Δx -> 500 m, v = 2,5 m/s -> $\Delta t \leq$ 200 sec

20 years simulation Δt = 60 sec: 10.512.000 time steps

344 cross sections two values -> 53 GB result data !!

Data Pre-Analysis

Simulation Key Numbers

cross section distance -> Δx

time step -> Δt

simulation scenario -> number of time steps

result storage freqency -> resolution of result
size of result file