DESIGNING RIVERBANK PROTECTION SYSTEMS: MACRA DESIGN VS HEC-RAS

September 5th, 2023

MACCAFERRI

WEBINAR AGENDA

5'	*Introduction*
10'	*Features of our software MacRa Design*
25'	*MacRA Design vs HEC-RAS: a live demo*

Live Q&A Session

Speaker

P. Di Pietro - DT Business Unit Senior Specialist & Know-how Manager

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The integration of hydraulic engineering systems into the natural environment is a crucial aspect of sustainable development


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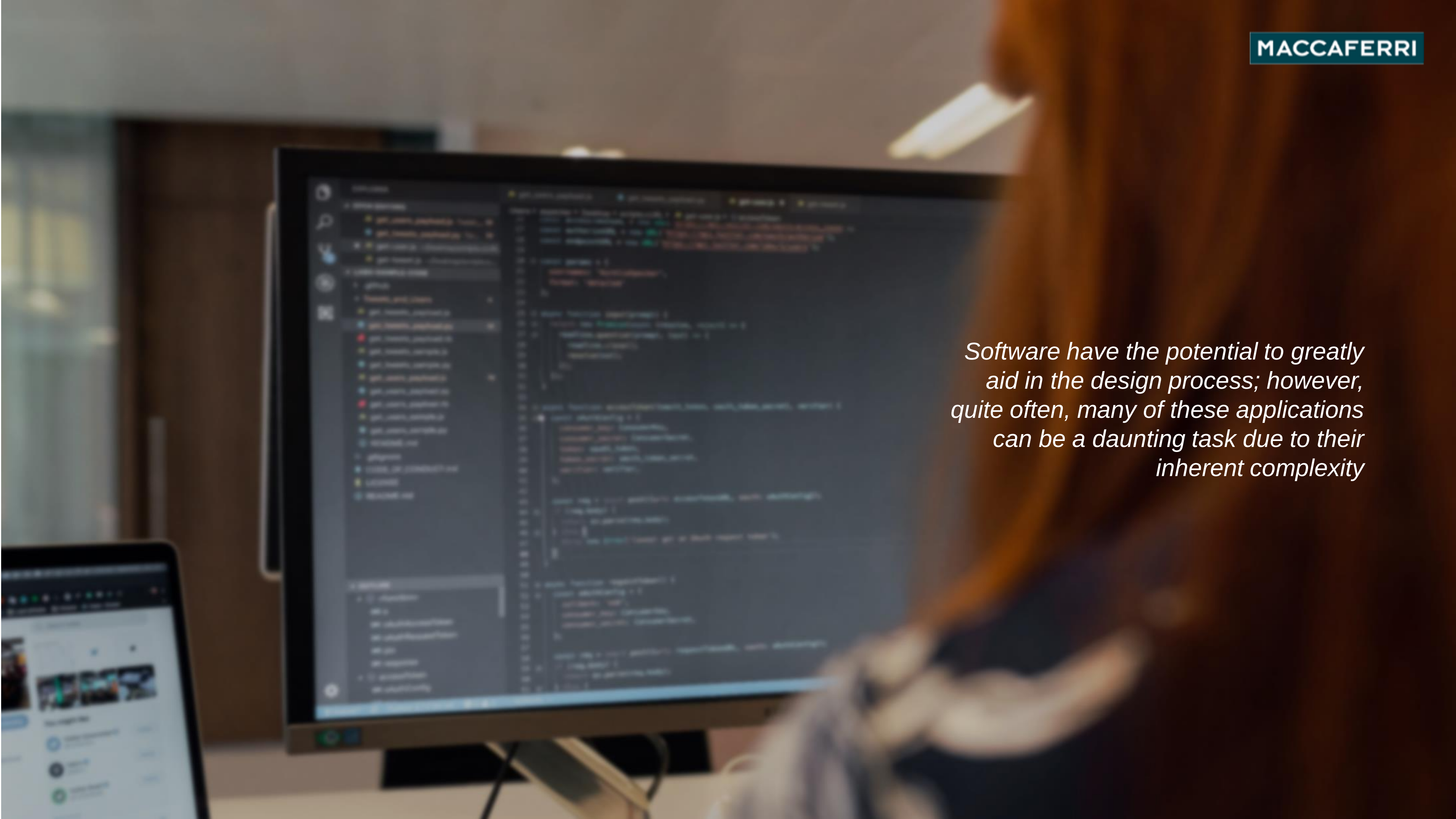
However, the complexities involved in designing hydraulic solutions often present challenges to engineers



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Software have the potential to greatly aid in the design process; however, quite often, many of these applications can be a daunting task due to their inherent complexity

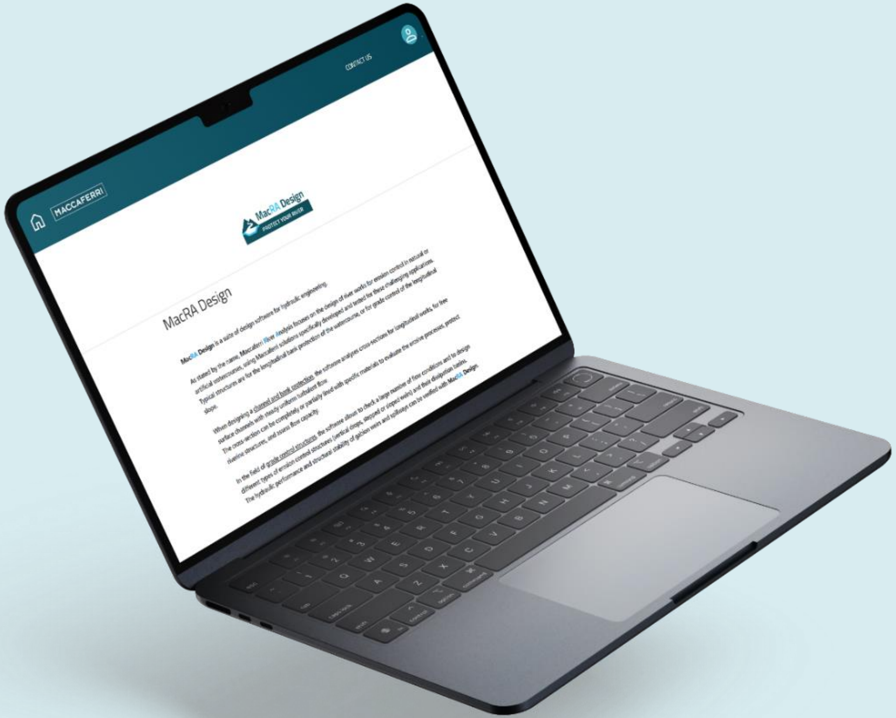
A SOFTWARE FOR COMPLEX HYDRAULIC SIMULATION

HEC-RAS SOFTWARE

HEC-RAS is a commonly used software for hydraulic analysis, able to evaluate unsteady flows with complex geometries.

It implements very sophisticated algorithms, capable of reproducing virtually any hydraulic condition, and for this requires a big amount of data as input.

A BRAND-NEW ALTERNATIVE



MacRA Design
PROTECT YOUR RIVER

Maccaferri **R**iver **A**nalysis is a suite of design software for hydraulic engineering, which focuses on the design of river works for erosion control in natural or artificial watercourses, using Maccaferri solutions specifically developed and tested for these challenging applications.

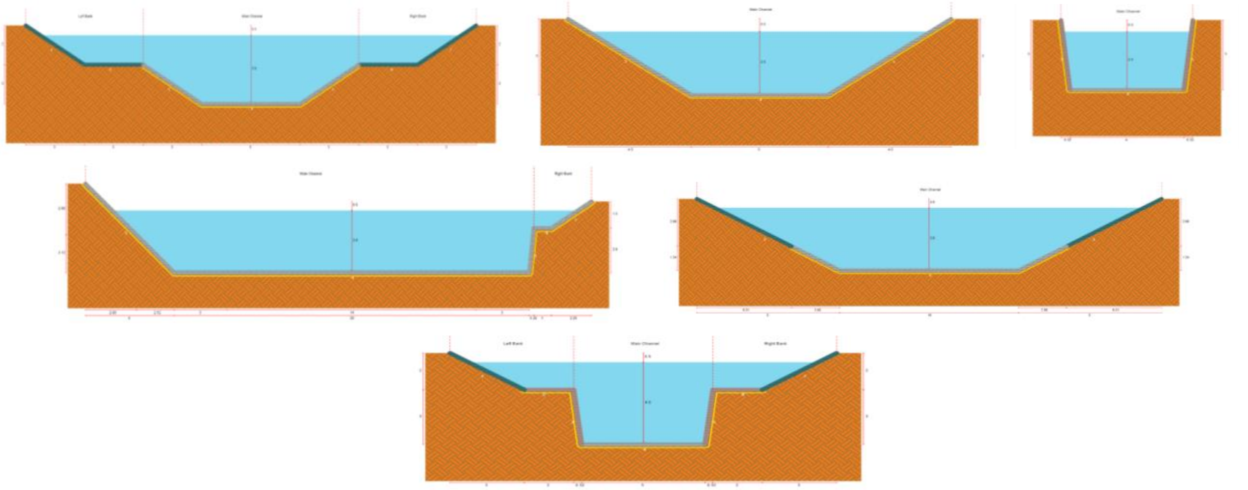
PROJECT TYPE ANALYSIS

CHANNEL AND
BANK PROTECTION

PROJECT TYPE ANALYSIS

When designing a channel and bank protection, the software analyses cross-sections for longitudinal works, for free surface channels with uniform flow.

CHANNEL AND
BANK PROTECTION



- Rectangular section
- Simple and double trapezoidal sections
- Sections with subsectors
- Sections with vertical banks

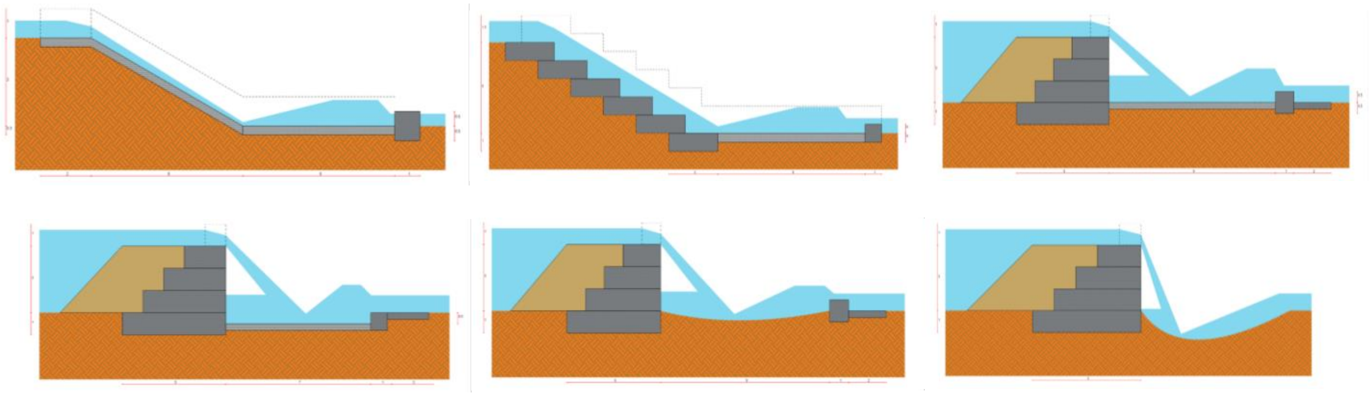
PROJECT TYPE ANALYSIS

GRADE CONTROL STRUCTURES

PROJECT TYPE ANALYSIS

The software allows to check many flow conditions and to design different types of erosion control structures and their dissipation basins.

GRADE CONTROL STRUCTURES



- Sloped weir
- Stepped weir
- Weir with vertical drop

KEY FEATURES OF MACRA DESIGN

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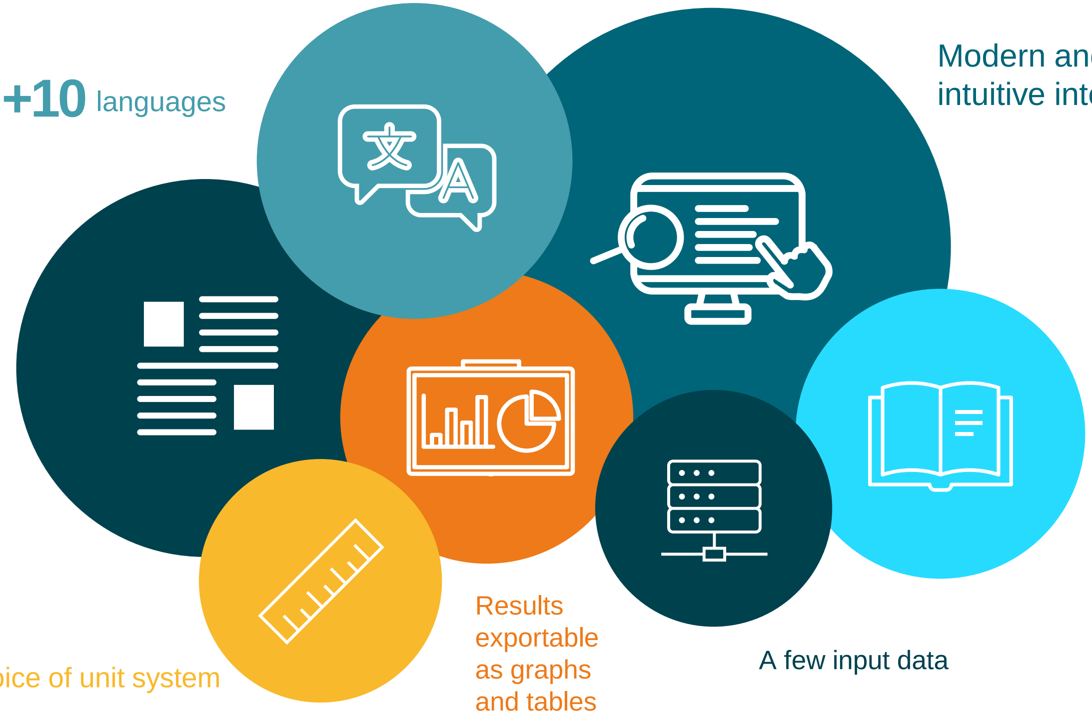


CHANNEL AND BANK PROTECTION

A few input data

Geometry

Cross-section templates

Hydraulic

Discharge
Slope

Materials

Shear stress and roughness of erosion protection available from a database

CHANNEL AND BANK PROTECTION

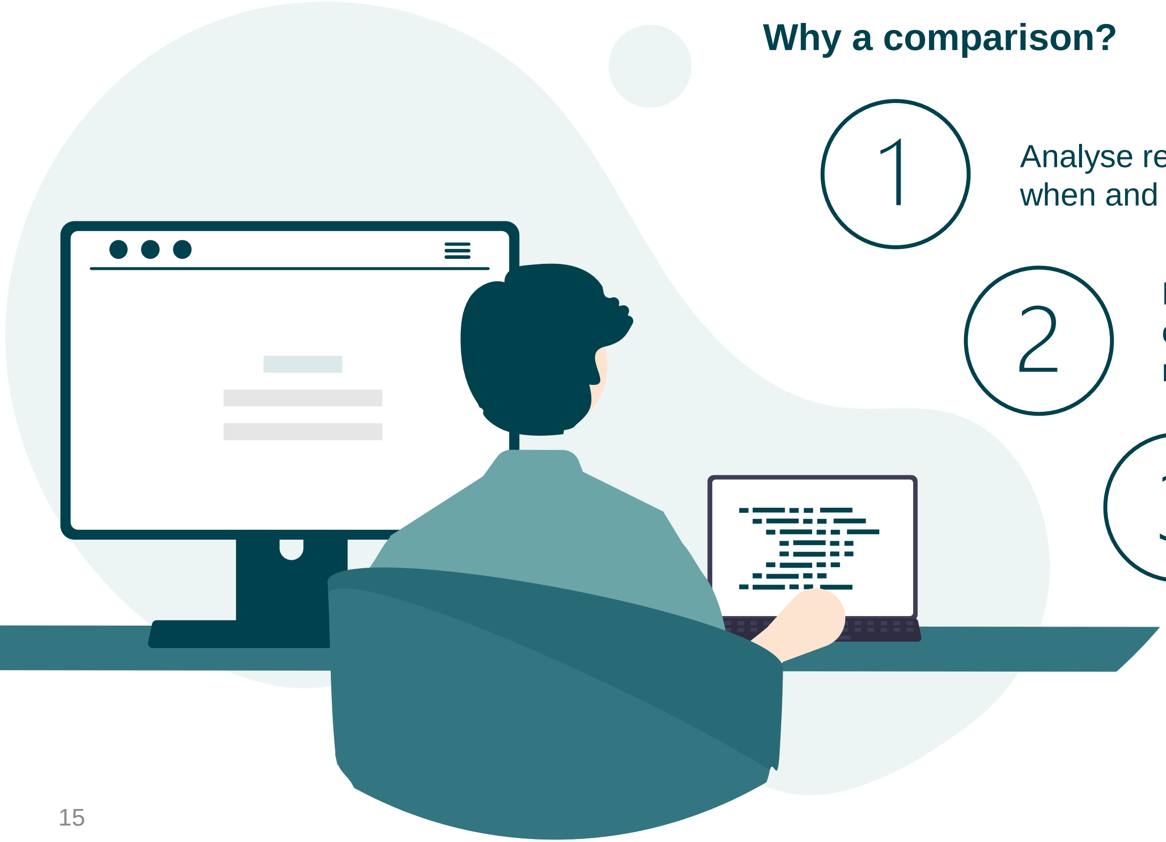
Materials

Protection systems

Soil bioengineering and natural vegetation

Natural soils

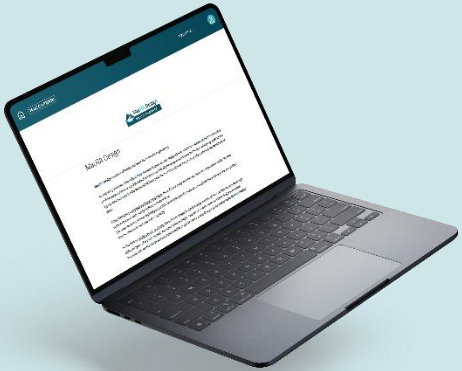
A HEAD-TO-HEAD COMPARISON



Why a comparison?

1. Analyse results of the two software and see when and how they provide similar results.
2. Define the accuracy level for each case, and define boundaries of a reliable response.
3. Identify the most suitable sections and geometries where results of MacRa Design are in alignment with HEC-RAS.

A HEAD-TO-HEAD COMPARISON



MacRA Design
PROTECT YOUR RIVER

VS

HEC-RAS SOFTWARE

A HEAD-TO-HEAD COMPARISON

MACCAFERRI

1 **Straight** river stretch with **constant** section

2 **Straight** river stretch with **varying** section and bed slope

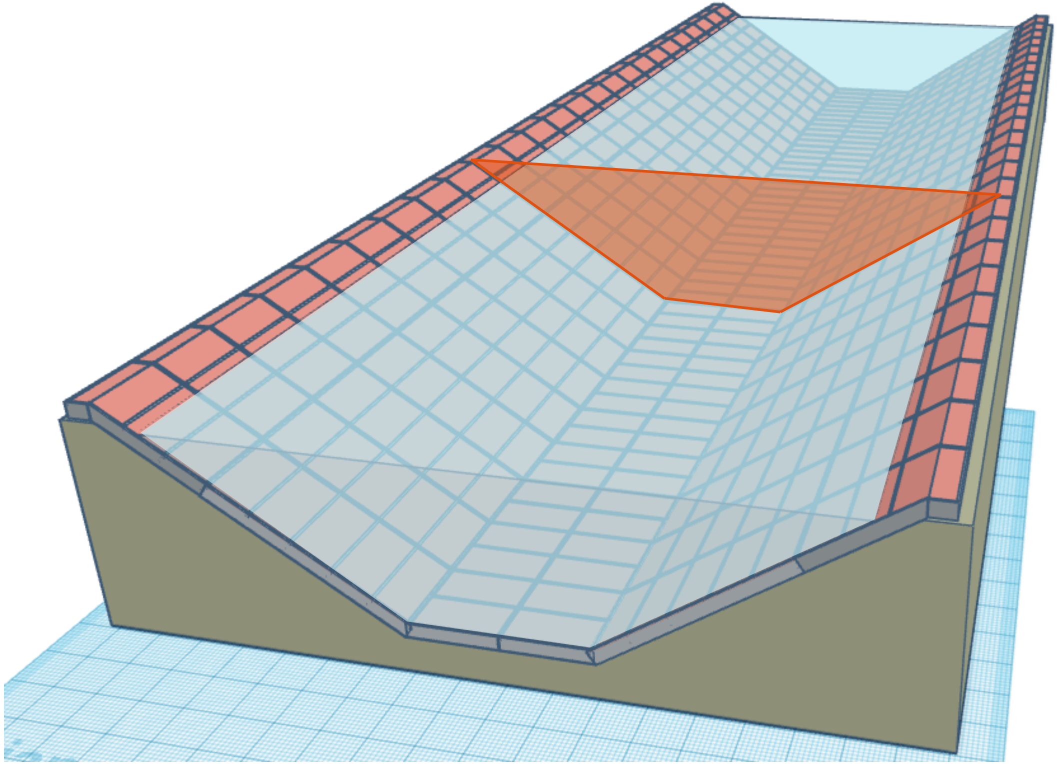
3 **Bending** river stretch with **varying** section and bed slope

INCREASING LEVEL OF SOPHISTICATION

A HEAD-TO-HEAD COMPARISON: FIRST CASE

1

Straight river stretch
with **constant** section



A HEAD-TO-HEAD COMPARISON: FIRST CASE

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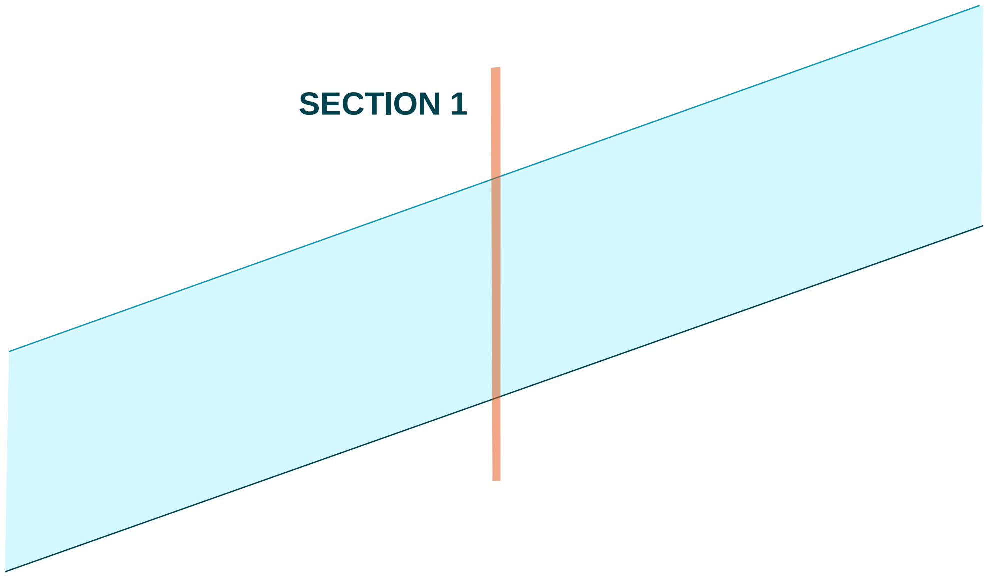
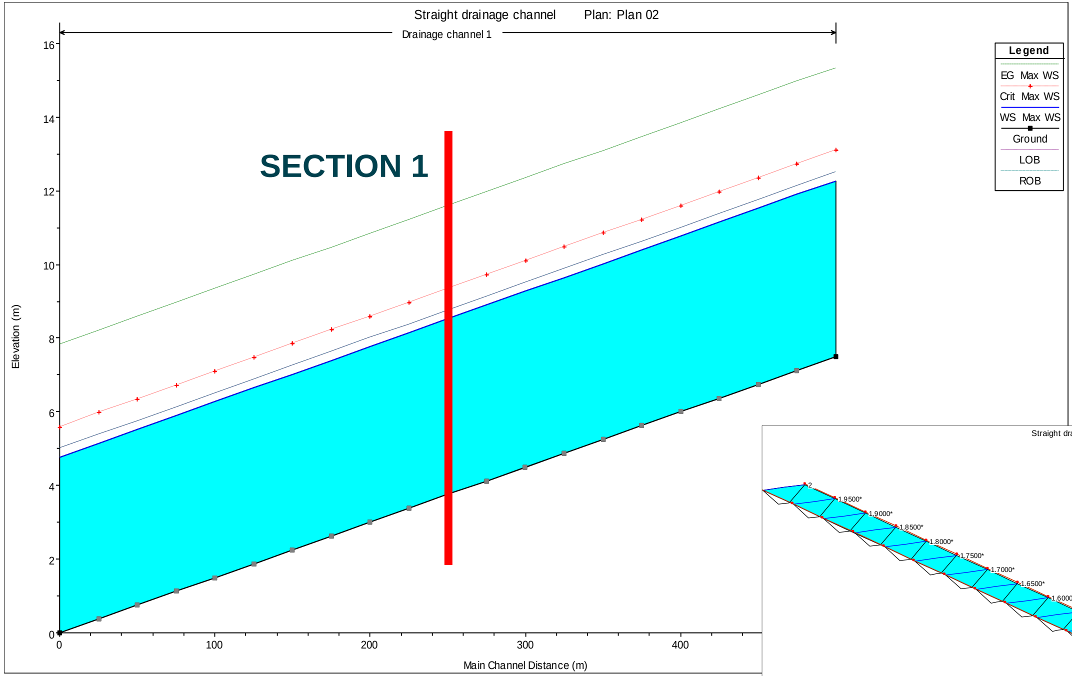
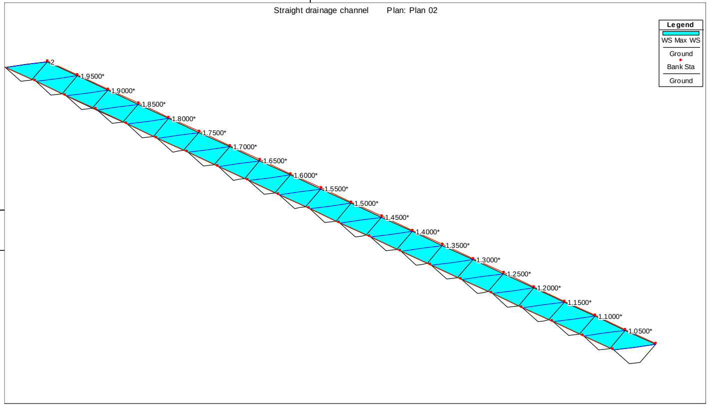


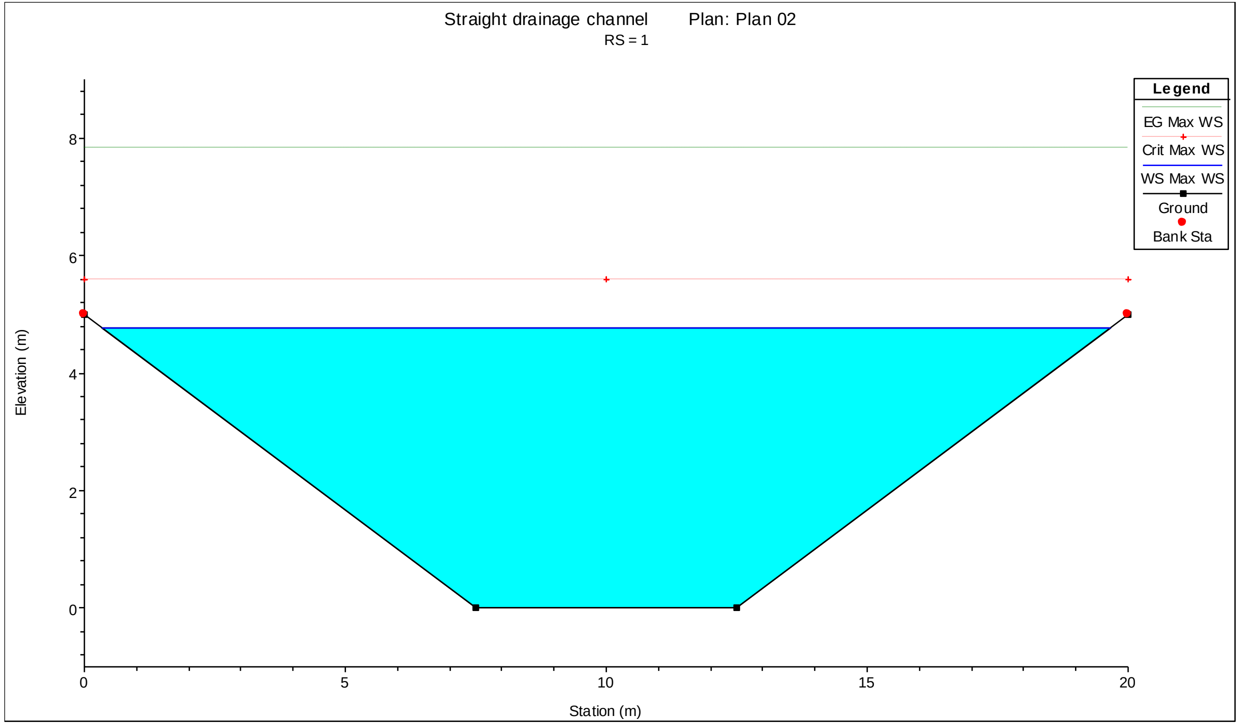
CALCULATION WITH HEC-RAS





HEC-RAS

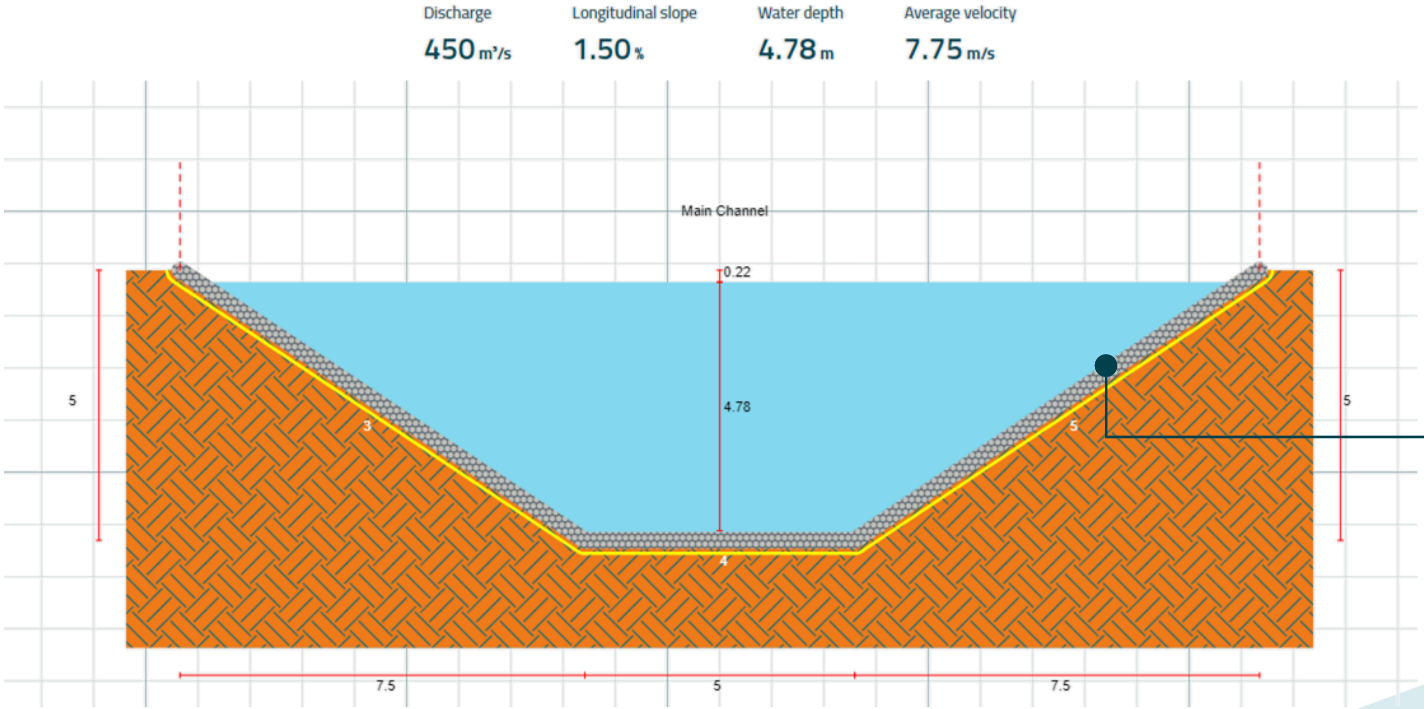
CALCULATION WITH HEC-RAS

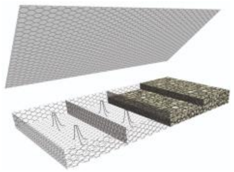


HEC-RAS

CALCULATION WITH MACRA DESIGN

MACCAFERRI





Reno Mattress Plus

MacRA Design
PROTECT YOUR RIVER

FIRST CASE: OUTPUT ANALYSIS

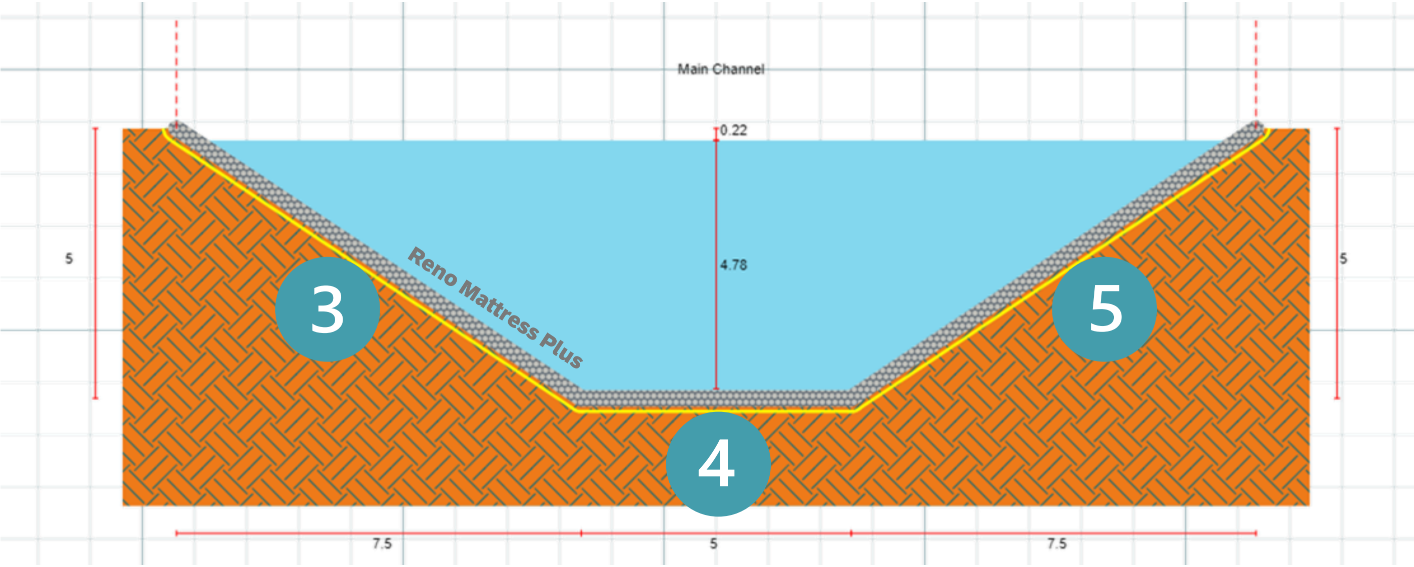
	WS elev. [m]	Δ	Velocity [m/s]	Δ	Shear Stress [N/m^2]	Δ
MacRA Design PROTECT YOUR RIVER	4.77		7.75		392.08	
HEC-RAS Steady	4.78	0.21%	7.73	- 0.26%	382.96	- 2.33%
HEC RAS Unsteady	4.77	0.00%	7.75	0.00%	384.86	- 1.84%

1 Difference in shear stress results between MacRA Design and HEC-RAS are approximately 2%

FIRST CASE: OUTPUT ANALYSIS

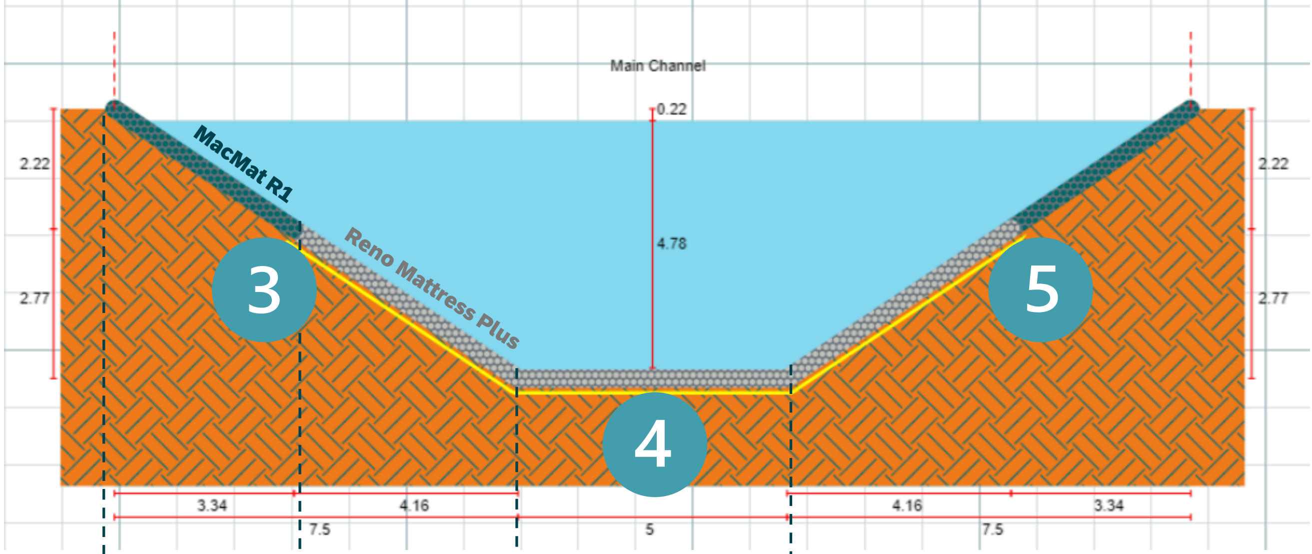
MACCAFERRI

2 **HEC-RAS** calculates the shear stress of the overall cross section, as opposed to **MacRA Design** where the shear stress can be obtained for each sector, including the sloped ones.



FIRST CASE: OUTPUT ANALYSIS

2 **HEC-RAS** calculates the shear stress of the overall cross section, as opposed to **MacRA Design** where the shear stress can be obtained for each sector, including the sloped ones.



Shear Stress [N/m²]	227.57	294.39	392.08

A HEAD-TO-HEAD COMPARISON

MACCAFERRI

1 **Straight** river stretch
with **constant** section

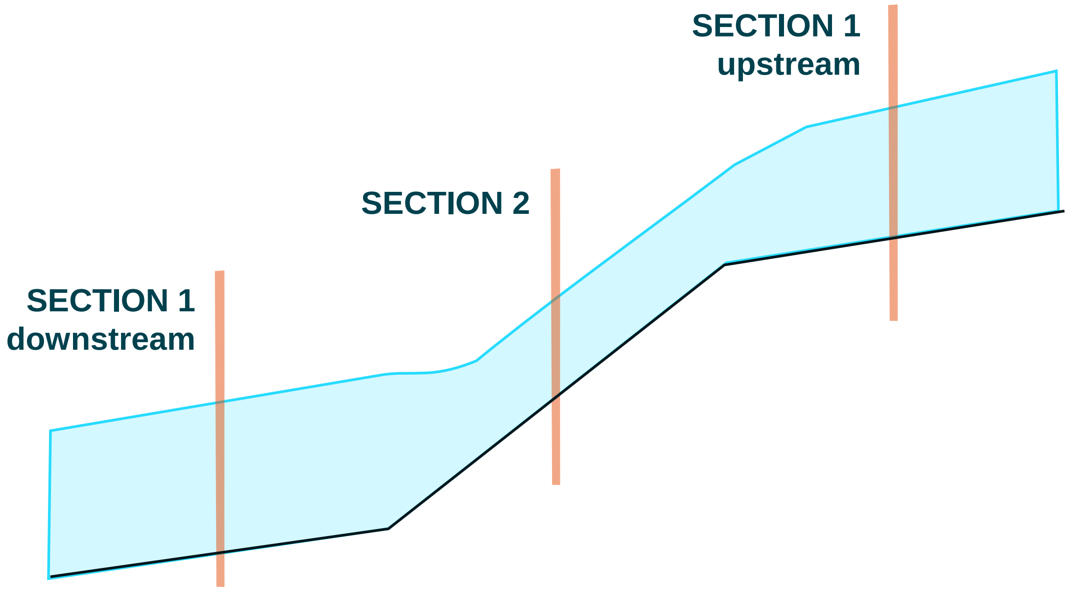
2 **Straight** river stretch
with **varying** section
and bed slope

INCREASING LEVEL OF SOPHISTICATION

A HEAD-TO-HEAD COMPARISON: SECOND CASE

2

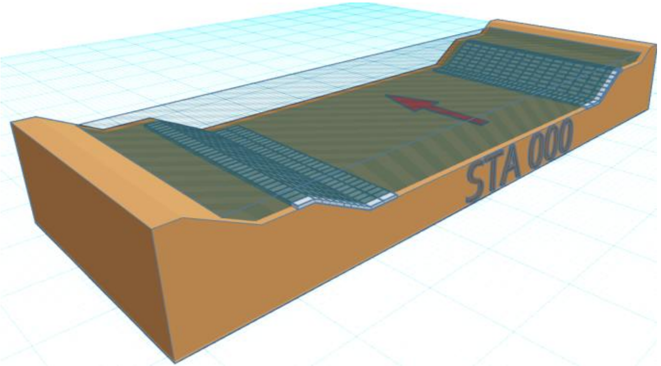
Straight river stretch
with **varying** section
and bed slope

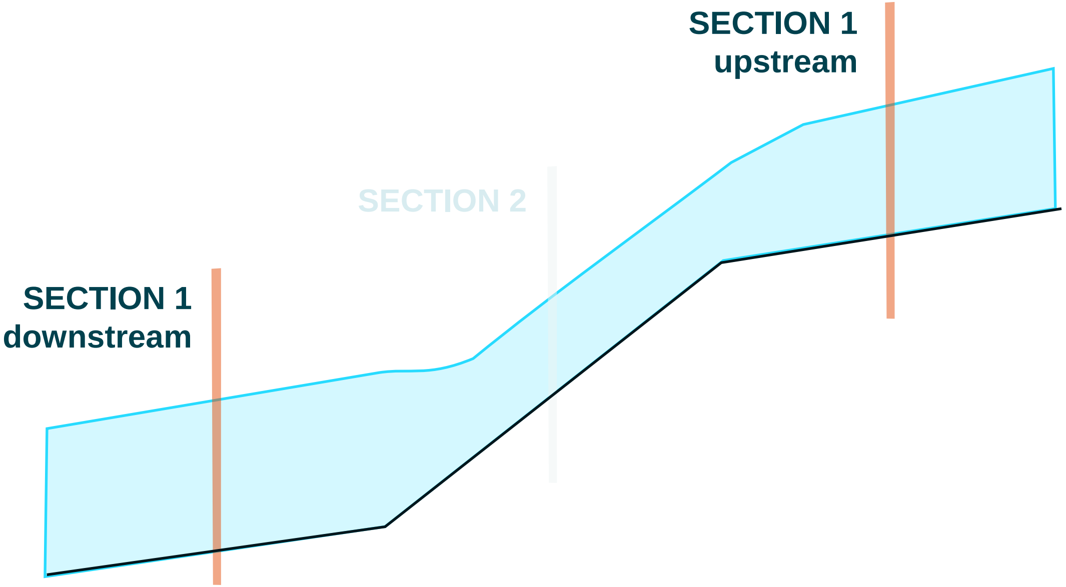


A HEAD-TO-HEAD COMPARISON: SECOND CASE

2

Straight river stretch
with **varying** section
and bed slope



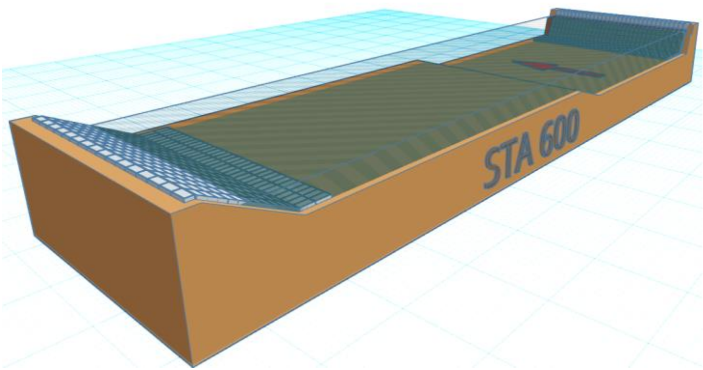


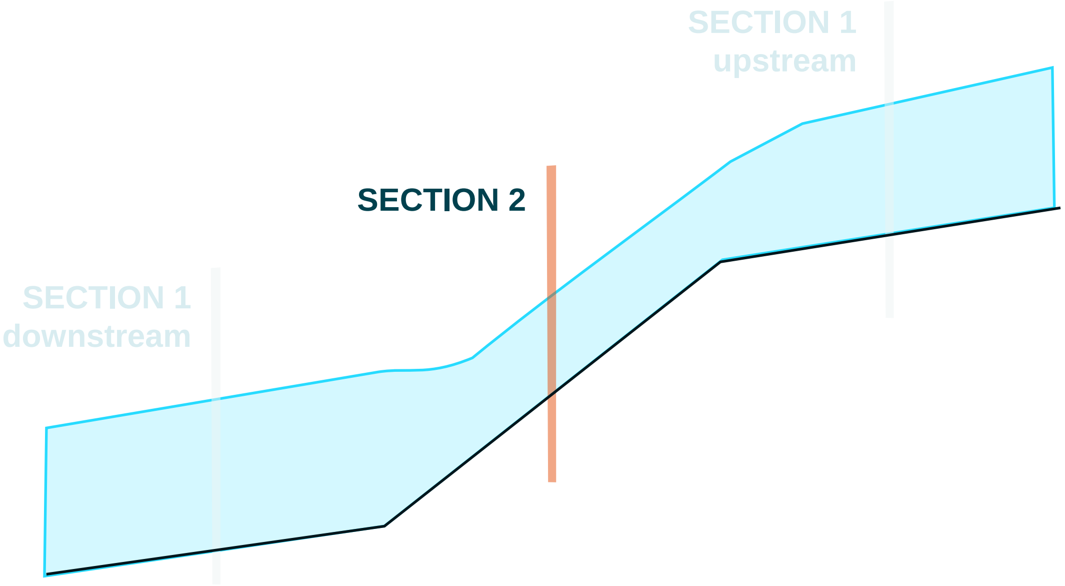
A HEAD-TO-HEAD COMPARISON: SECOND CASE

MACCAFERRI

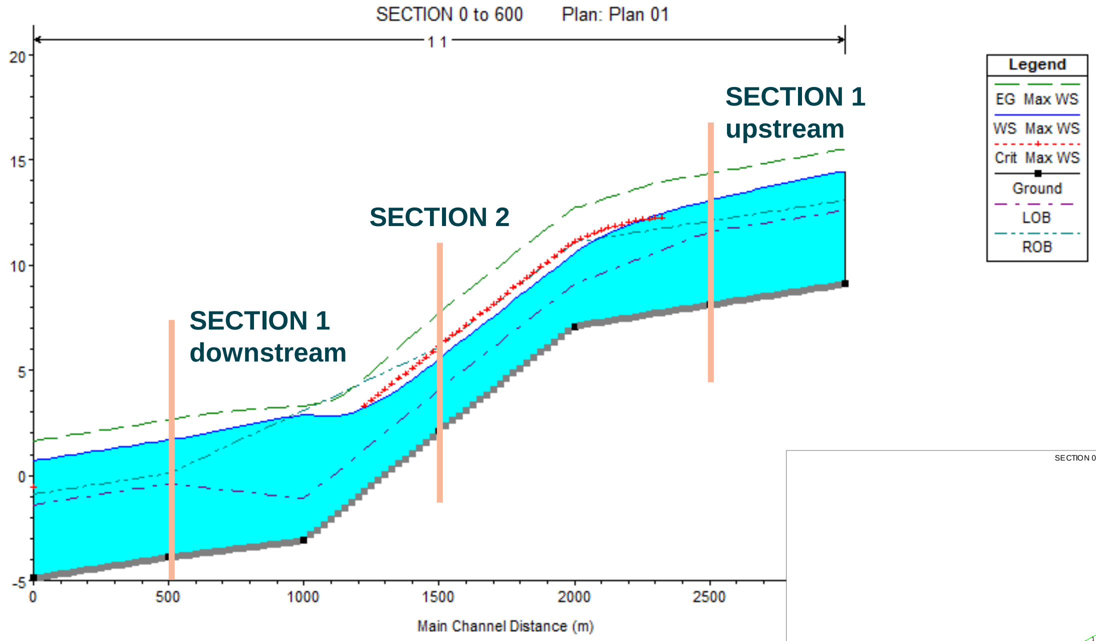
2

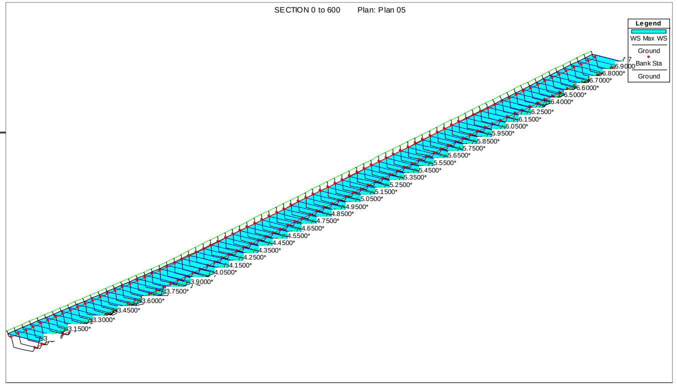
Straight river stretch
with **varying** section
and bed slope





CALCULATION WITH HEC-RAS





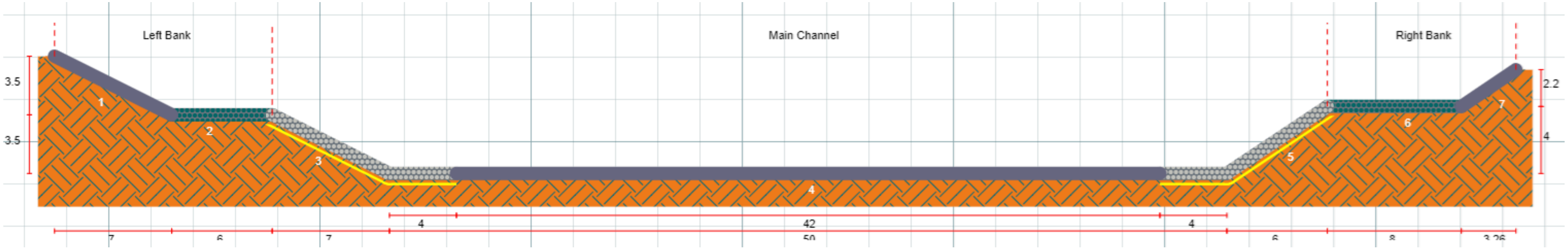
HEC-RAS

CALCULATION WITH MACRA DESIGN

MACCAFERRI

SECTION 1
downstream
and upstream

2000 m^3/s

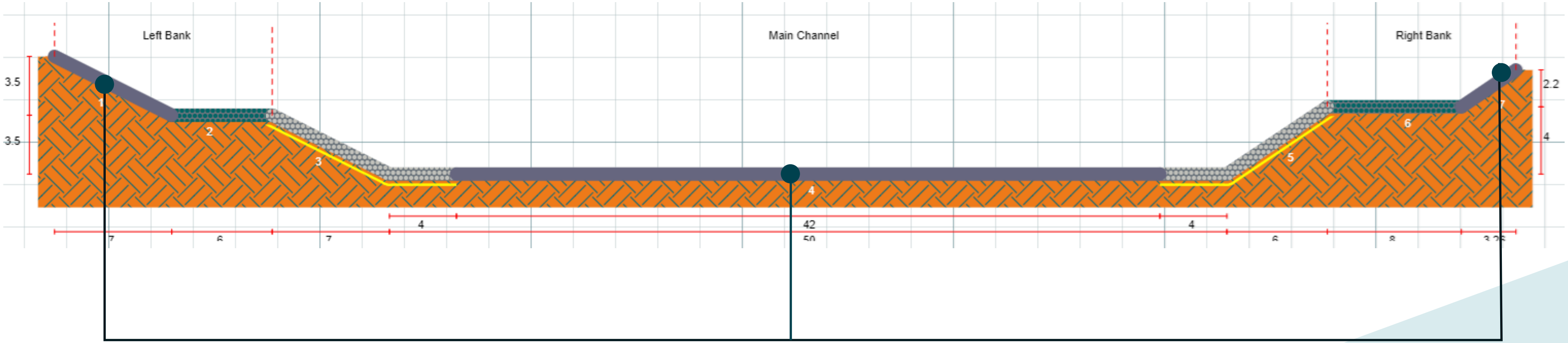


MacRA Design
PROTECT YOUR RIVER

CALCULATION WITH MACRA DESIGN

SECTION 1 downstream and upstream

2000 m^3/s

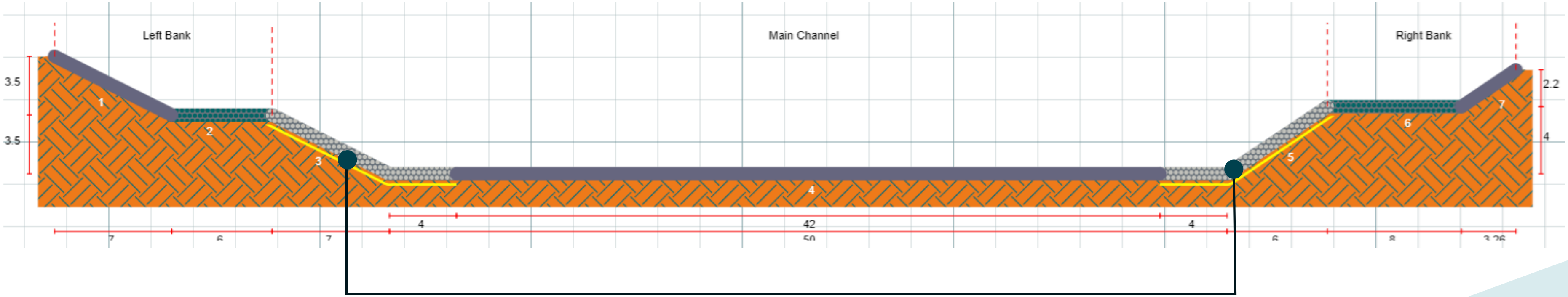


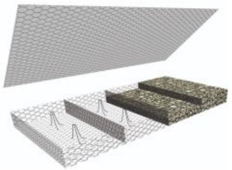
Natural soils

CALCULATION WITH MACRA DESIGN

SECTION 1 downstream and upstream

2000 m^3/s



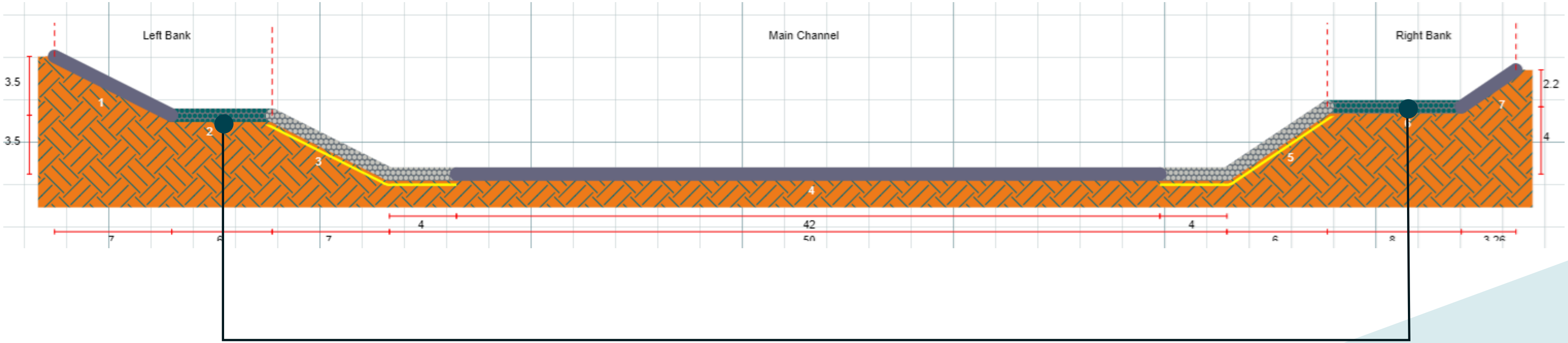


Reno Mattress Plus

CALCULATION WITH MACRA DESIGN

SECTION 1 downstream and upstream

2000 m³/s



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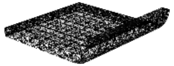
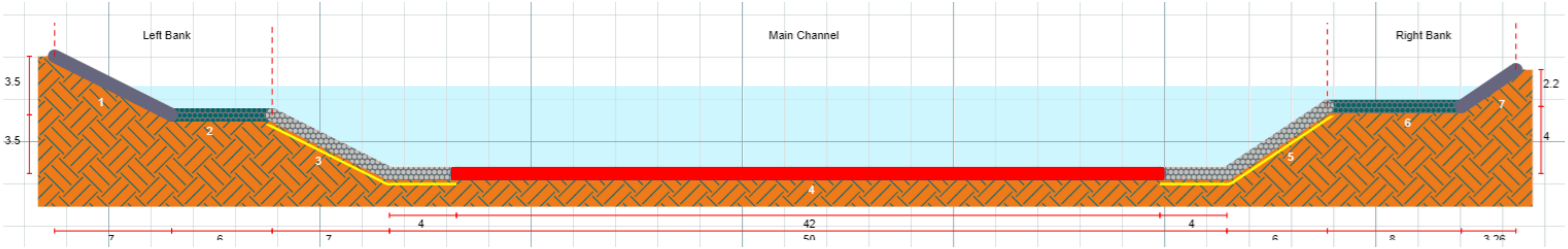


CALCULATION WITH MACRA DESIGN

MACCAFERRI

SECTION 1 downstream and upstream

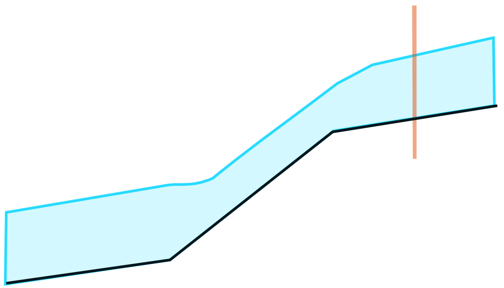
2000 m^3/s



MacRA Design
PROTECT YOUR RIVER

SECOND CASE: OUTPUT ANALYSIS

MACCAFERRI

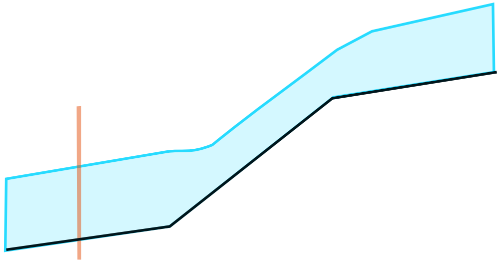


SECTION 1 UPSTREAM

	WS elev. [m]	Δ	Velocity [m/s]	Δ	Shear Stress [N/m^2]	Δ
MacRA Design PROTECT YOUR RIVER	5.12		6.51		229.34	
HEC-RAS Steady	5.16	0.78%	6.45	- 0.92%	220.72	- 3.76%
HEC-RAS Unsteady	5.08	- 0.78%	6.58	1.08%	230.66	0.58%

SECOND CASE: OUTPUT ANALYSIS

MACCAFERRI



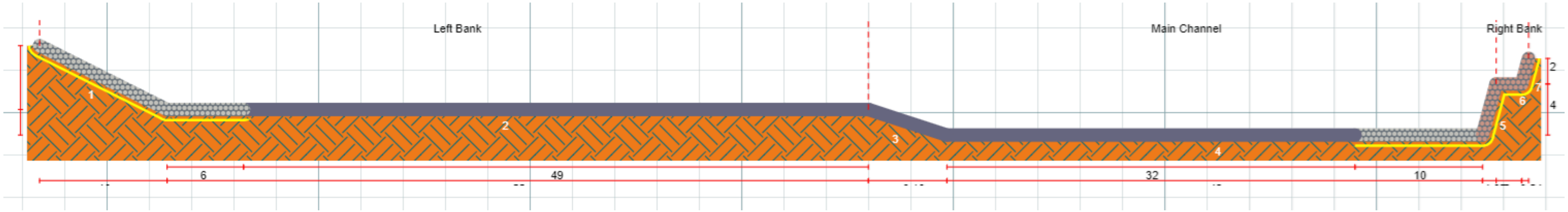
SECTION 1 DOWNSTREAM

	WS elev. [m]	Δ	Velocity [m/s]	Δ	Shear Stress [N/m²]	Δ
MacRA Design PROTECT YOUR RIVER	5.12		6.51		229.34	
HEC-RAS Steady	4.96	- 3.13%	6.44	- 1.08%	220.74	- 3.75%
HEC-RAS Unsteady	4.94	- 3.52 %	6.46	- 0.77%	222.45	- 3.00%

CALCULATION WITH MACRA DESIGN

SECTION 2

2000 m^3/s

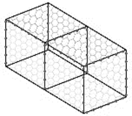


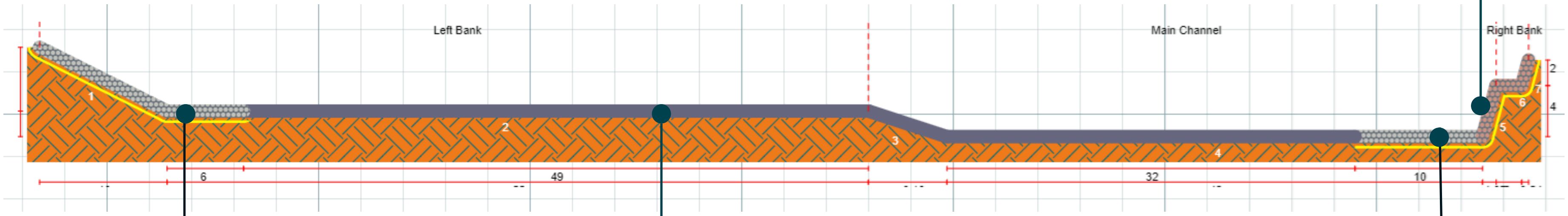
CALCULATION WITH MACRA DESIGN

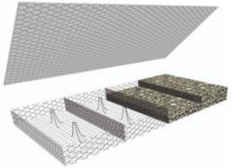
SECTION 2

2000 m^3/s

Gabions







Reno Mattress Plus

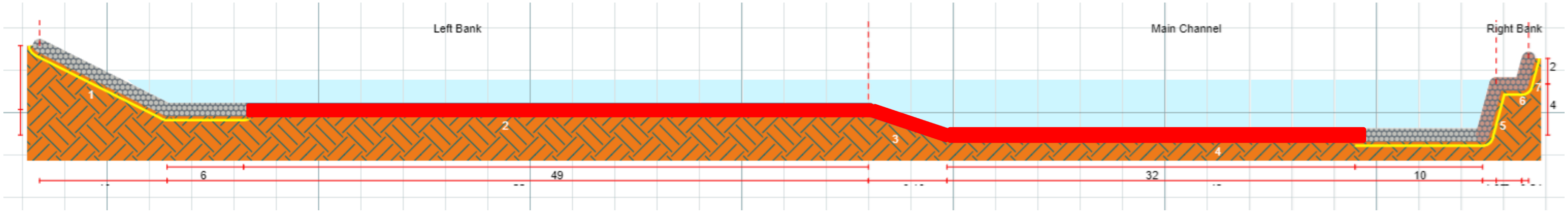
Natural soils

MacRA Design
PROTECT YOUR RIVER

CALCULATION WITH MACRA DESIGN

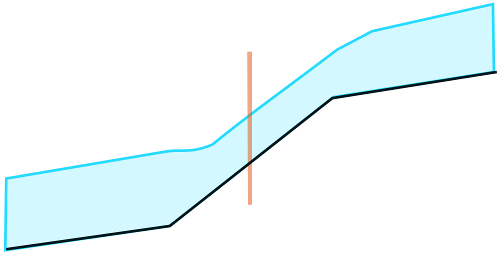
SECTION 2

2000 m^3/s



SECOND CASE: OUTPUT ANALYSIS

MACCAFERRI



SECTION 2

	WS elev. [m]	Δ	Velocity [m/s]	Δ	Shear Stress [N/m²]	Δ
MacRA Design PROTECT YOUR RIVER	3.86		8.00		381.90	
HEC-RAS Steady	3.95	2.33%	7.72	- 3.50%	344.68	- 9.75%
HEC-RAS Unsteady	3.95	2.33%	7.72	- 3.50%	345.17	- 9.62%

SECOND CASE: CONCLUSIONS

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Choose the correct cross-sections:

→ In the middle of a homogeneous reach

→ NOT at the section or slope change

RESULTS:

→ About **3%** difference between **MacRA Design** and **HEC-RAS** in straight sections

→ Less than **10%** difference between **MacRA Design** and **HEC-RAS** in middle reaches, with slope and cross-section change

→ **MacRA Design** returns results more conservative than **HEC-RAS**

A HEAD-TO-HEAD COMPARISON

MACCAFERRI

1 **Straight** river stretch with **constant** section

2 **Straight** river stretch with **varying** section and bed slope

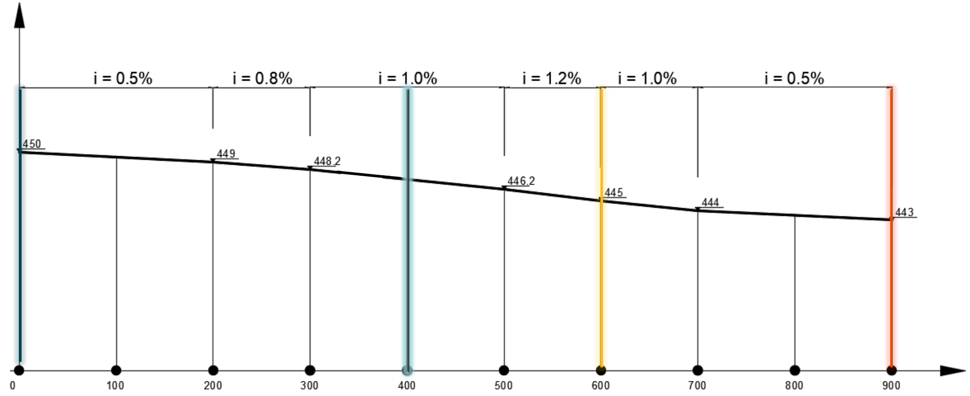
3 **Bending** river stretch with **varying** section and bed slope

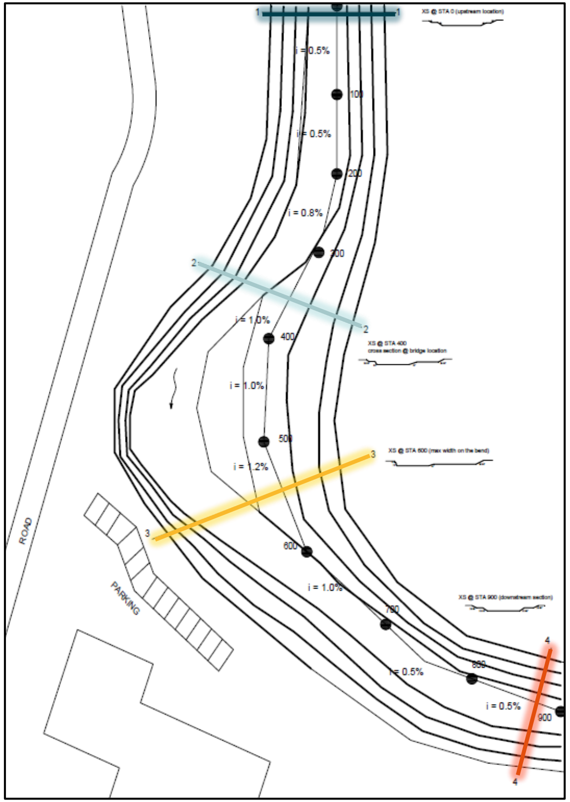
INCREASING LEVEL OF SOPHISTICATION

A HEAD-TO-HEAD COMPARISON: THIRD CASE

3

Bending river stretch
with **varying** section
and bed slope





A HEAD-TO-HEAD COMPARISON: THIRD CASE

MACCAFERRI

3

Bending river stretch
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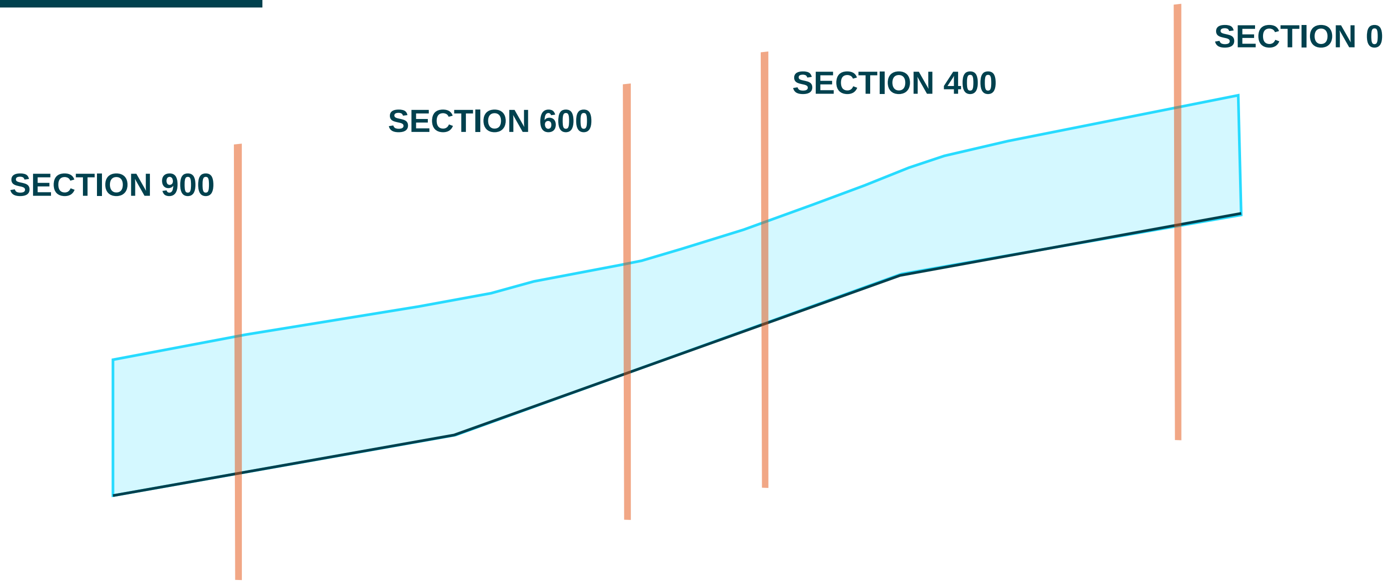

A HEAD-TO-HEAD COMPARISON: THIRD CASE

MACCAFERRI

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Bending river stretch
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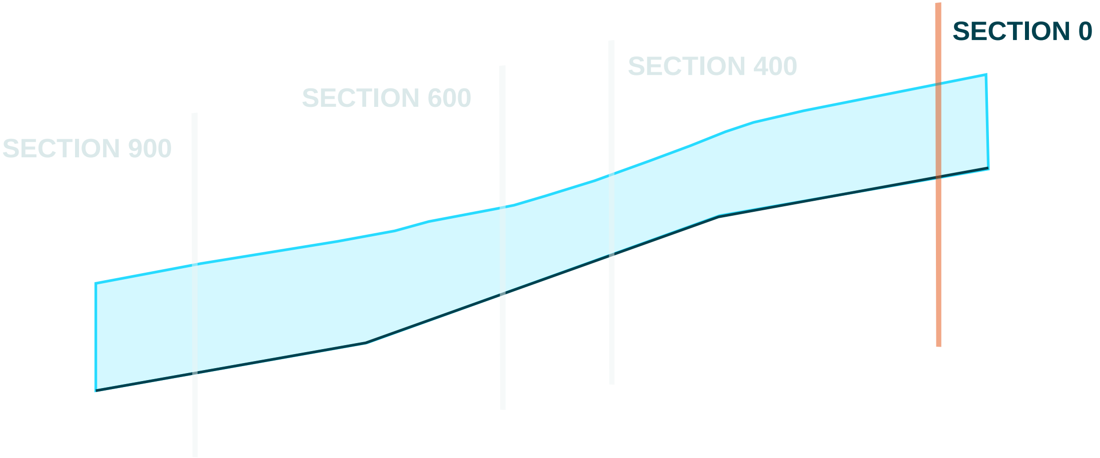
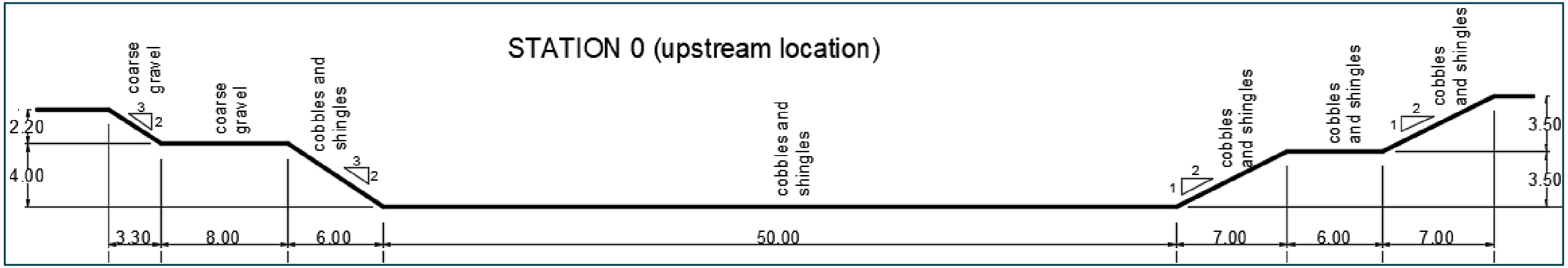
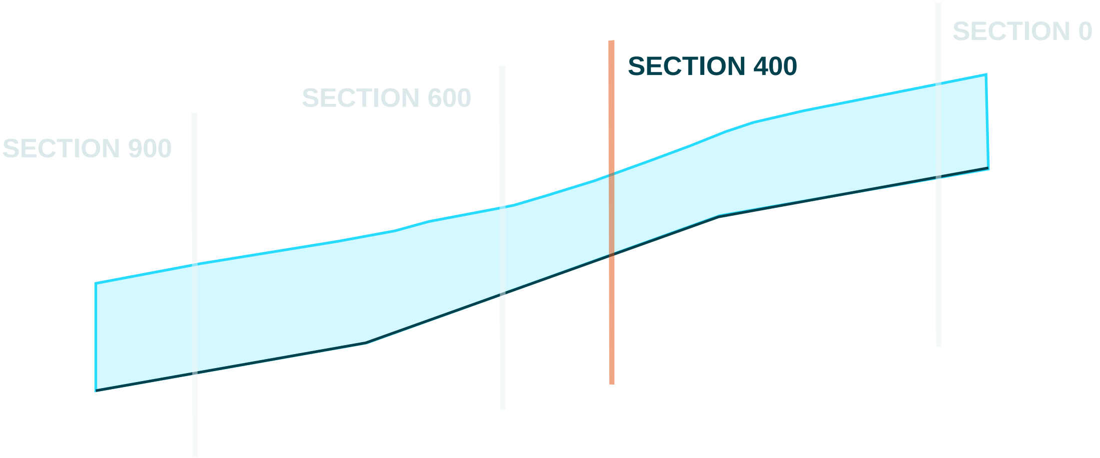


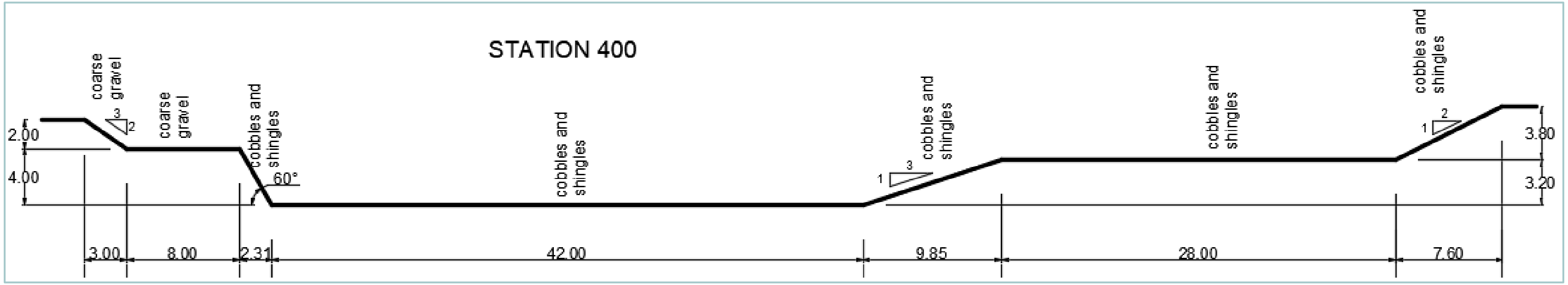


A HEAD-TO-HEAD COMPARISON: THIRD CASE

MACCAFERRI

3 **Bending** river stretch with **varying** section and bed slope





A HEAD-TO-HEAD COMPARISON: THIRD CASE

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Bending river stretch
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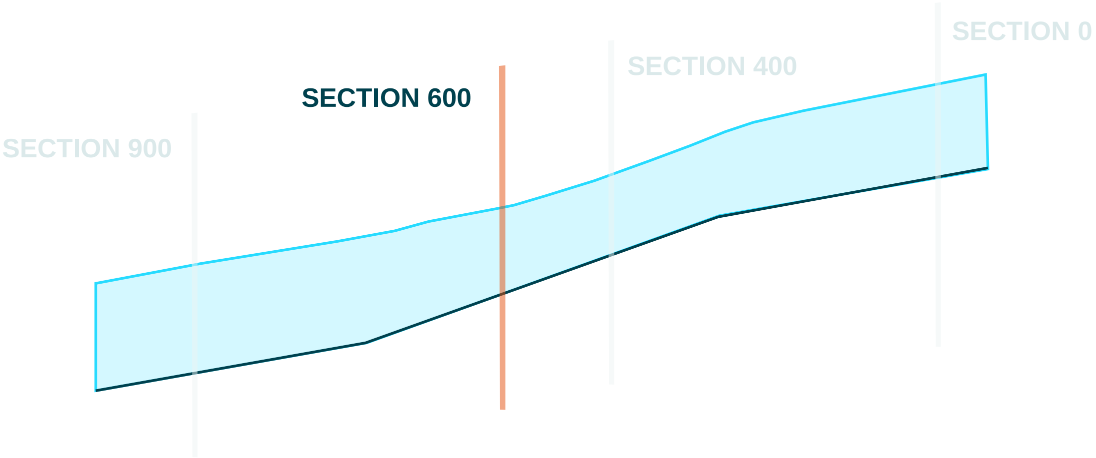
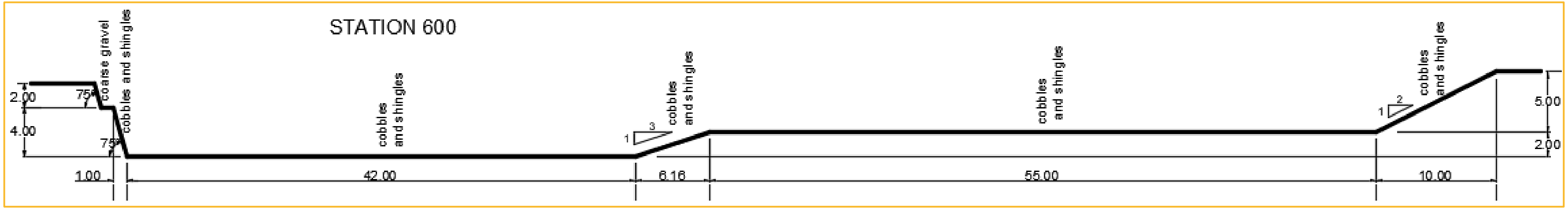


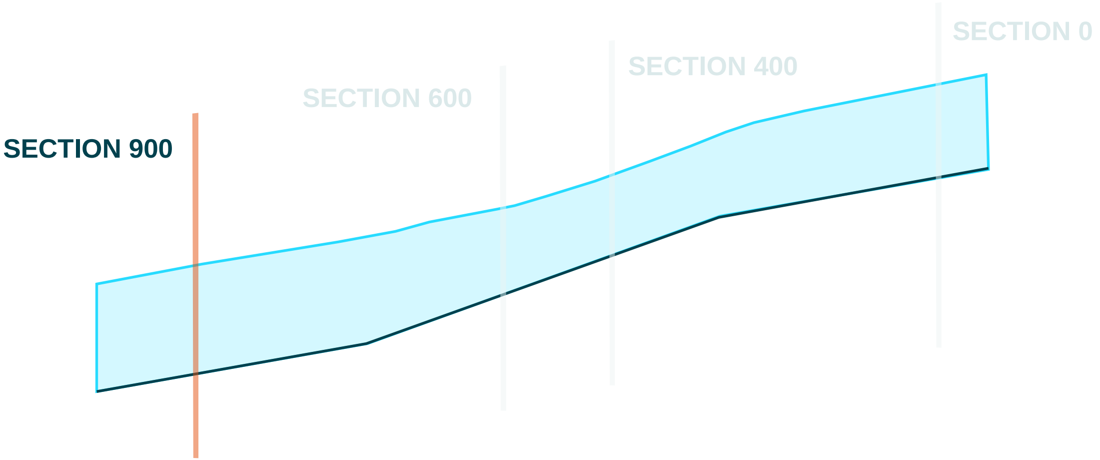


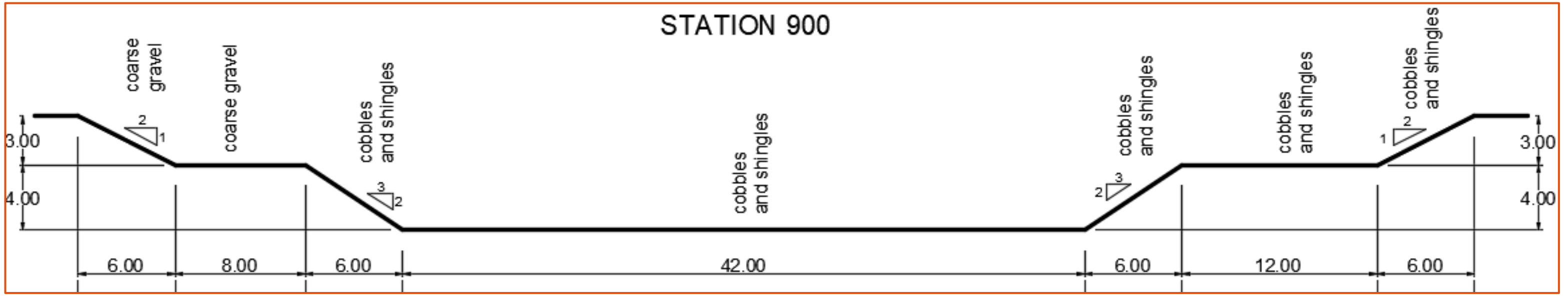
A HEAD-TO-HEAD COMPARISON: THIRD CASE

MACCAFERRI

3

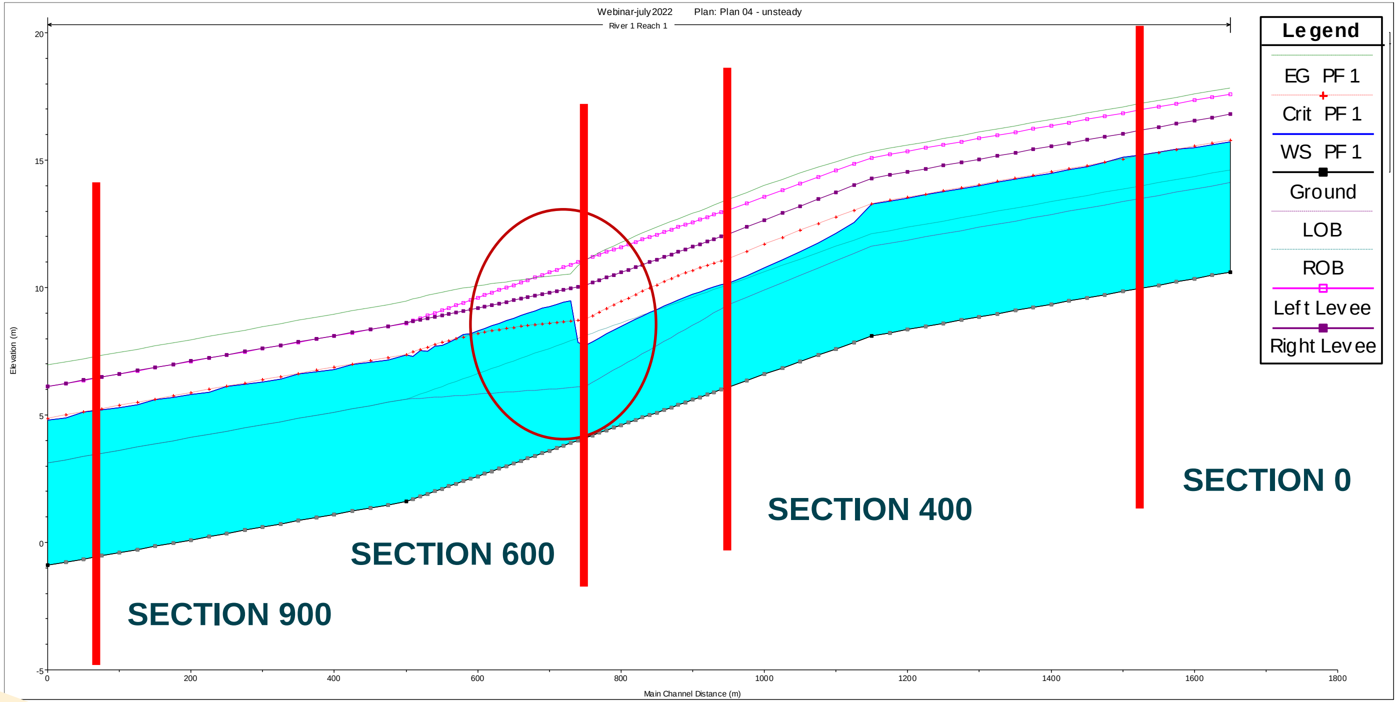
Bending river stretch with **varying** section and bed slope





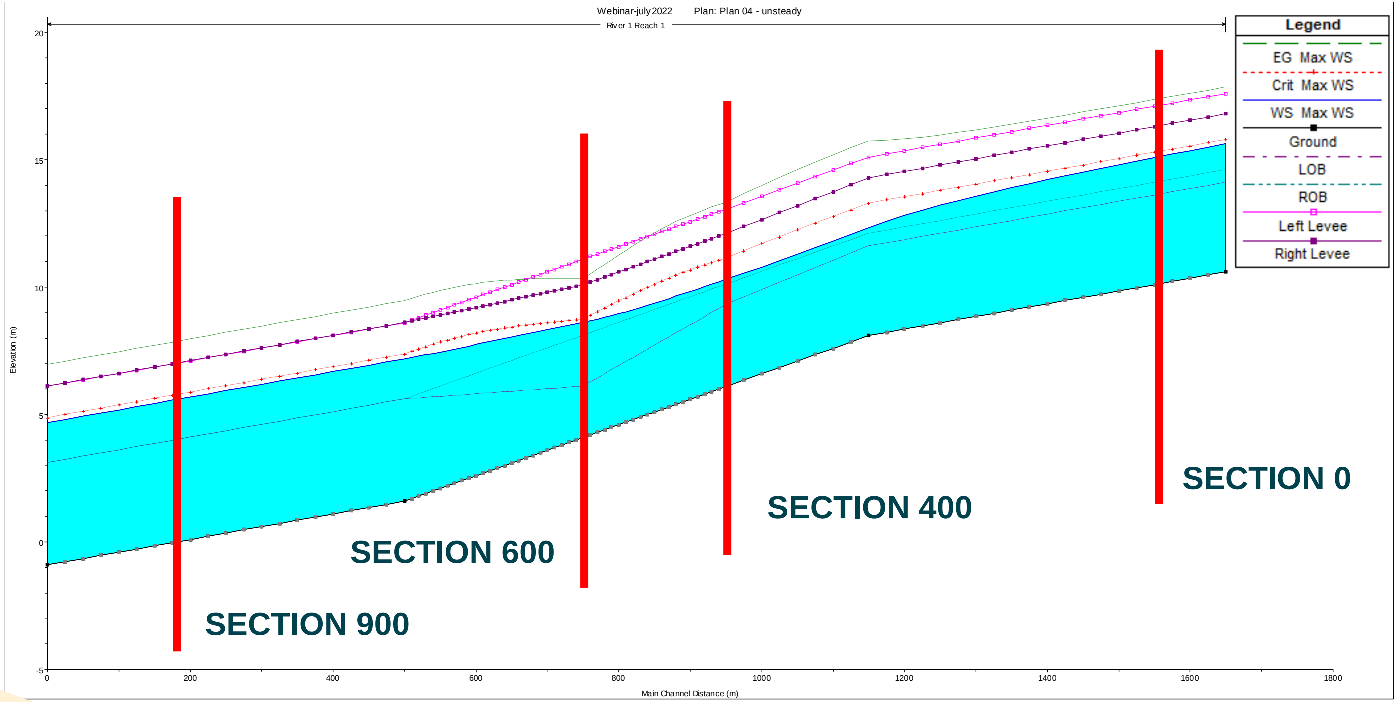
CALCULATION WITH HEC-RAS

MACCAFERRI



HEC-RAS
Steady flow

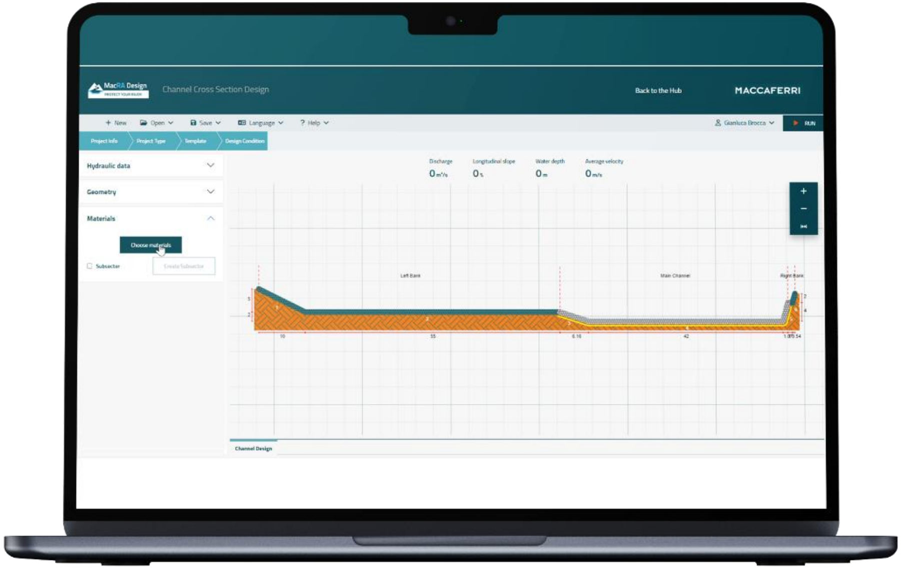
CALCULATION WITH HEC-RAS



HEC-RAS
Unsteady flow

CALCULATION WITH MACRA DESIGN

MACCAFERRI

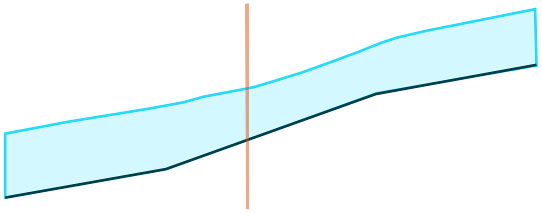


LIVE DEMO

MacRA Design
PROTECT YOUR RIVER

THIRD CASE: OUTPUT ANALYSIS

MACCAFERRI

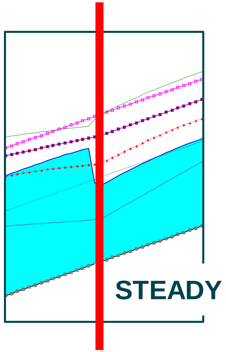


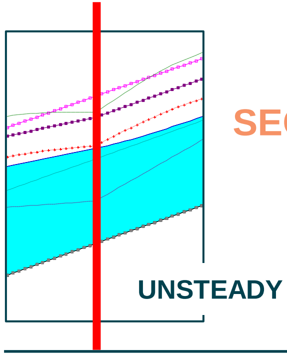
SECTION 600

	WS elev. [m]	Δ	Velocity [m/s]	Δ	Shear Stress $[N/m^2]$	Δ
MacRA Design PROTECT YOUR RIVER	3.86		8.02		381.90	
HEC-RAS Steady	3.63	- 5.96%	8.82	9.98%	462.60	21.13%
HEC-RAS Unsteady	4.27	10.62%	7.67	- 4.36%	332.56	- 12.92%

THIRD CASE: OUTPUT ANALYSIS

MACCAFERRI





SECTION 600

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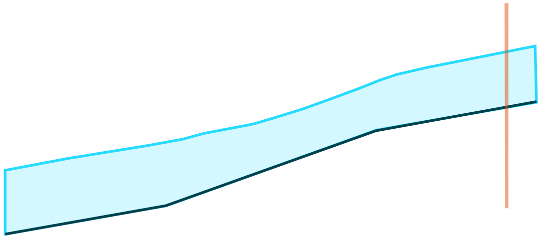
THIRD CASE: OUTPUT ANALYSIS

MACCAFERRI

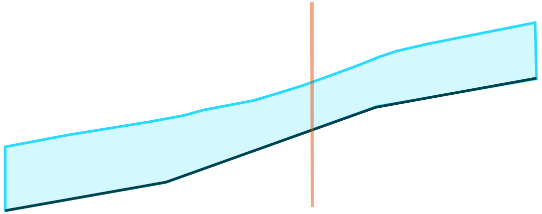


SECTION 0

	WS elev. [m]	Δ	Velocity [m/s]	Δ	Shear Stress [N/m^2]	Δ
MacRA Design PROTECT YOUR RIVER	5.12		6.51		229.34	
HEC-RAS Steady	5.14	0.39%	6.48	- 0.46%	222.42	- 3.02%
HEC-RAS Unsteady	4.91	- 4.10%	6.85	5.22%	252.87	10.29%

THIRD CASE: OUTPUT ANALYSIS

MACCAFERRI

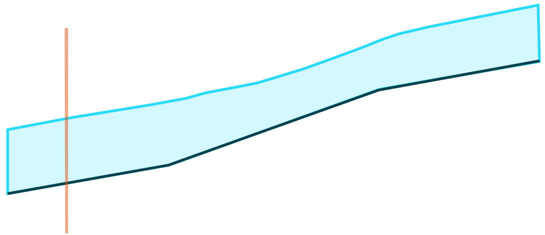


SECTION 400

	WS elev. [m]	Δ	Velocity [m/s]	Δ	Shear Stress [N/m^2]	Δ
MacRA Design PROTECT YOUR RIVER	4.50		8.30		392.83	
HEC-RAS Steady	4.06	- 9.78%	8.11	- 2.29%	379.45	- 3.41%
HEC-RAS Unsteady	4.20	- 6.67%	7.78	- 6.27%	344.69	- 12.25%

THIRD CASE: OUTPUT ANALYSIS

MACCAFERRI



SECTION 900

	WS elev. [m]	Δ	Velocity [m/s]	Δ	Shear Stress [N/m²]	Δ
MacRA Design PROTECT YOUR RIVER	5.54		6.78		243.84	
HEC-RAS Steady	5.75	3.79%	6.57	- 3.10%	221.31	- 9.24%
HEC-RAS Unsteady	5.59	0.90%	6.82	- 0.59%	241.33	- 1.03%

A HEAD-TO-HEAD COMPARISON

MACCAFERRI

+1

1 **Straight** river stretch with **constant** section

2 **Straight** river stretch with **varying** section and bed slope

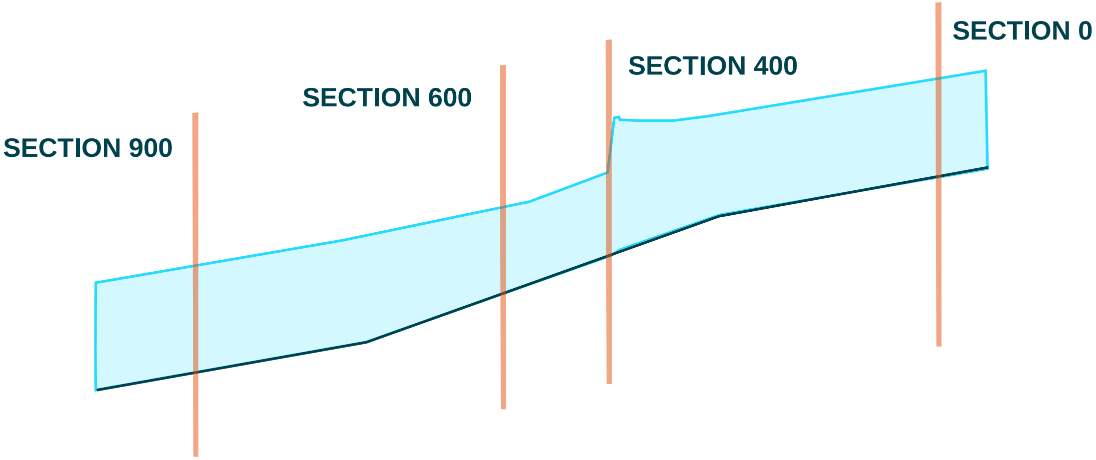
3 **Bending** river stretch with **varying** section and bed slope

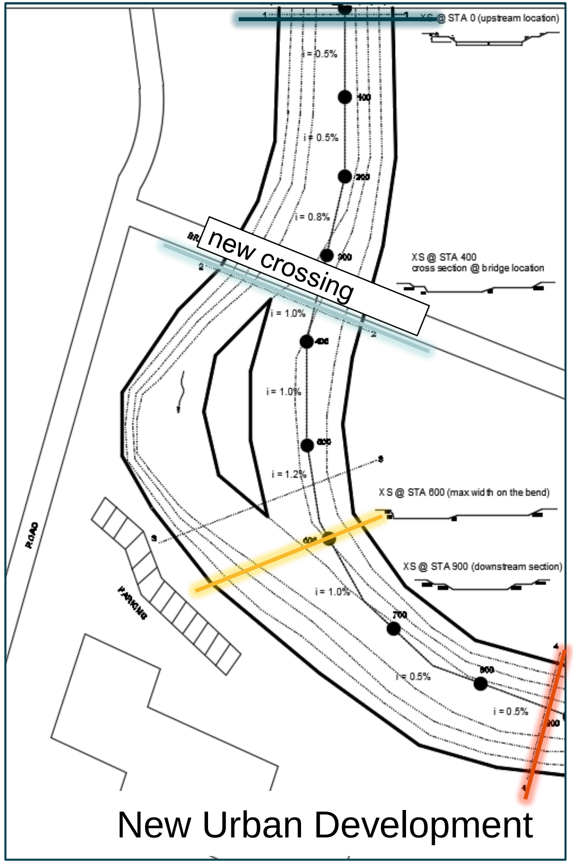
INCREASING LEVEL OF SOPHISTICATION

A HEAD-TO-HEAD COMPARISON: THIRD CASE +1

+1

Bending river stretch
with **varying** section,
bed slope & **bridge**



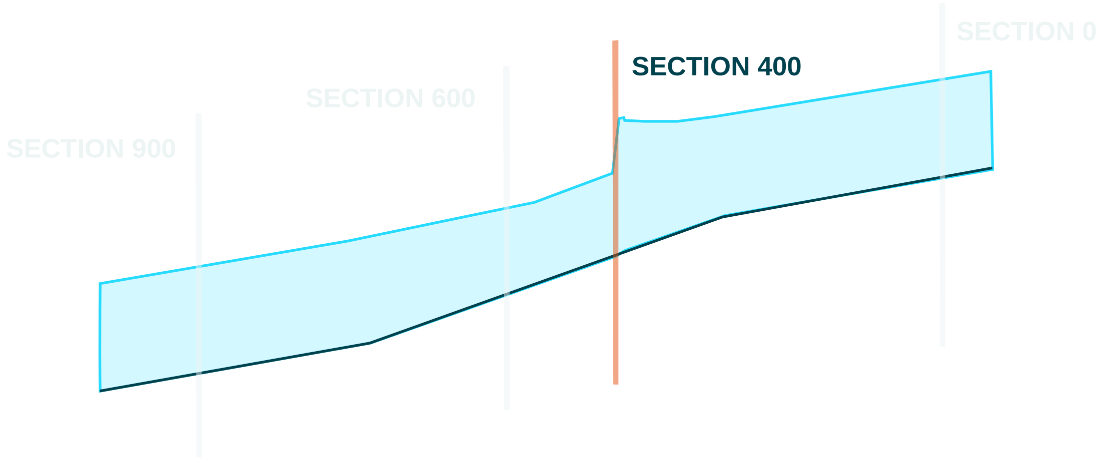


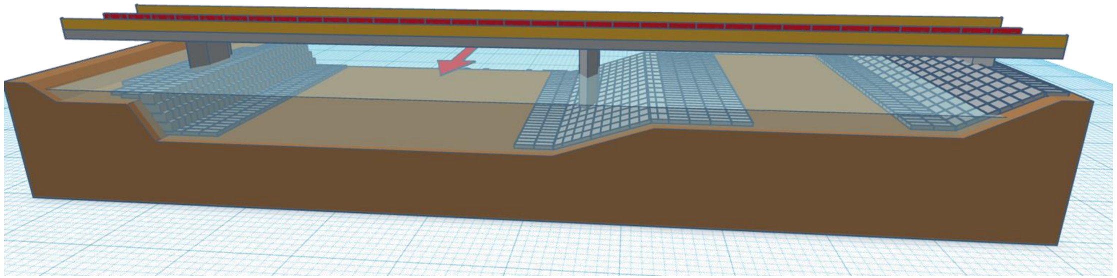
A HEAD-TO-HEAD COMPARISON: THIRD CASE +1

MACCAFERRI

+1

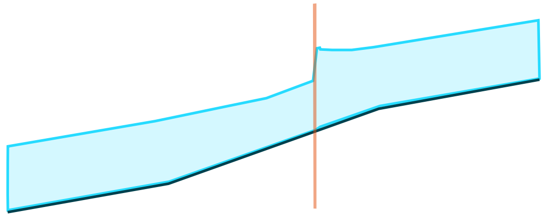
Bending river stretch
with **varying** section,
bed slope & **bridge**





THIRD CASE +1: OUTPUT ANALYSIS

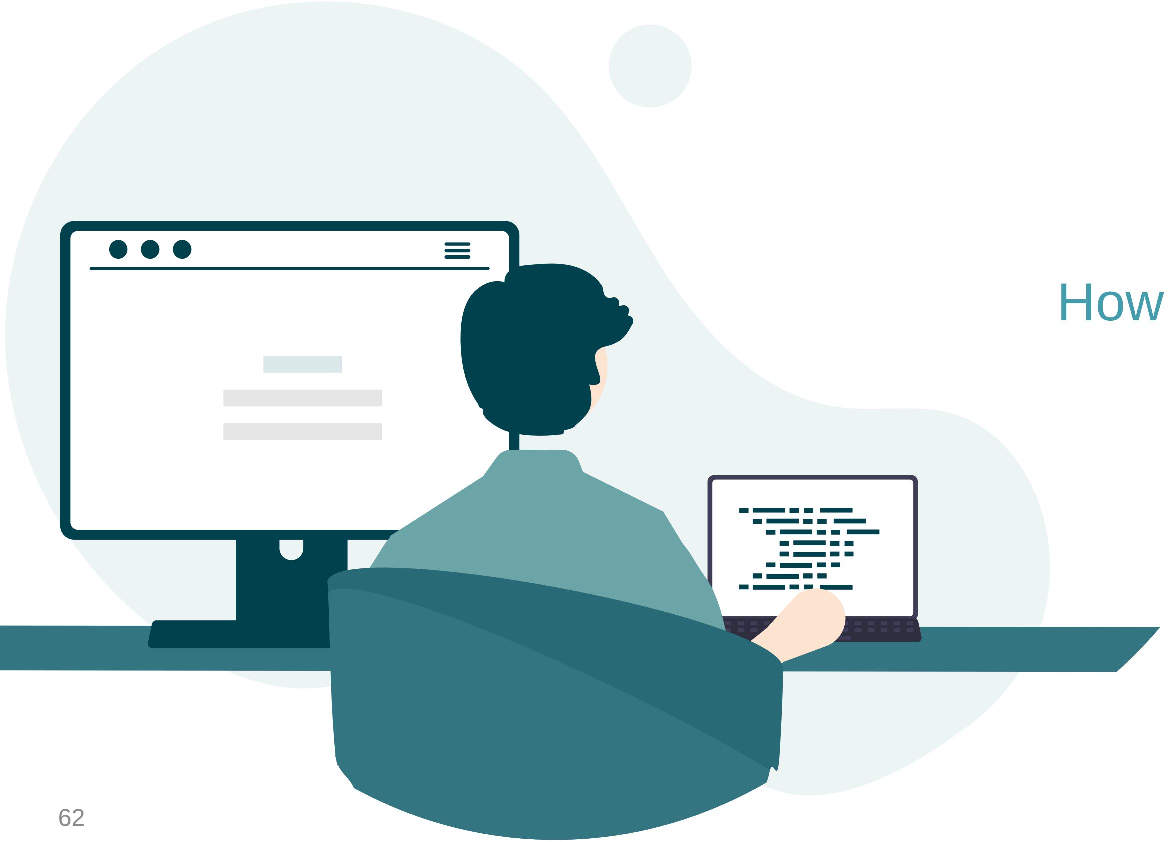
MACCAFERRI



SECTION 400

	WS elev. [m]	Δ	Velocity [m/s]	Δ	Shear Stress [N/m²]	Δ
MacRA Design PROTECT YOUR RIVER	4.50		8.30		392.83	
HEC-RAS Steady	4.67	3.78%	7.85	-5.42%	340.07	-13.43%
HEC-RAS Unsteady	4.37	-2.89%	8.61	3.73%	419.05	6.67%

FINAL CONCLUSIONS



How did the comparison go?

A SOFTWARE THAT IS ACCURATE AND RELIABLE

1

Analyse results of the two software and see when and how they provide similar results

MacRA Design returns very similar results to the HEC-RAS steady flow simulations without incurring in unrealistic results, such as the presence of the hydraulic jump in example 3

MacRA Design returns very similar results to the HEC-RAS unsteady flow simulations, if the cross-sections are chosen properly.

In presence of a hydraulic structure (bridge, etc.) **MacRA Design** can not simulate the variation of hydraulic conditions due to the structure, but the results can be used as a starting point for a local hydraulic and scour analysis.

2

Define the accuracy level for each case, and define boundaries of a reliable response

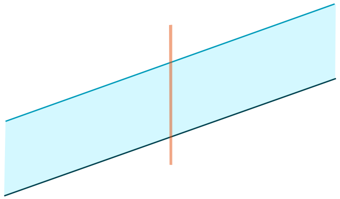
For steady flow, differences in the order of **1-5%**

For unsteady flow, differences in the order of **1-10%**

MacRA Design generally returns **conservative** results!

3

Identify the most suitable sections and geometries where results of MacRA Design are in alignment with HEC-RAS

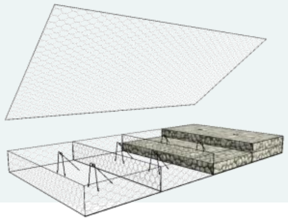


Choose the correct cross-sections: in the middle of homogeneous reaches and NOT where the section or slope is varying

A SOFTWARE THAT DESIGNS THE BEST SOLUTION

MACCAFERRI

	SECTION	MAX SHEAR STRESS [N/m²]	THICKNESS [m]	ALLOWABLE SHEAR STRESS [N/m²]
1 **Straight** river stretch with **constant** section	1	392,08	0.23	385 - 534 ✓
2 **Straight** river stretch with **varying** section and bed slope	1	230.66	0.23	385 - 534 ✓
	2	381.90		
3 **Bending** river stretch with **varying** section and bed slope	0	252.95	0.23	385 - 534 ✓
	400	392.83		
	600	381.90		
	900	243.84		

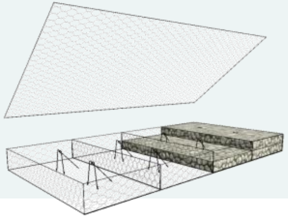


+ Reno Mattress Plus with X-Ties

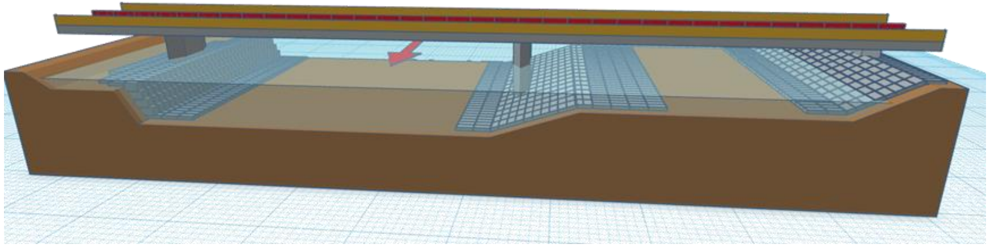
A SOFTWARE THAT DESIGNS THE BEST SOLUTION

MACCAFERRI

	SECTION	MAX SHEAR STRESS [N/m²]	THICKNESS [m]	ALLOWABLE SHEAR STRESS [N/m²]
+1 **Bending** river stretch with **varying** section, **bed slope** & **bridge**	0	229.34	0.30	459 - 637
	400	419.05		
	600	381.90		
	900	243.84		



Reno Mattress Plus with X-Ties



STATION 400