European Geosciences Union General Assembly 2023 Vienna, Austria & Online | 23–28 April 2023

NH3.13

EDI

Nature-based and bio-based solutions for geohazard mitigation on slopes and streambanks

Convener: Vittoria Capobianco[ECS] | Co-conveners: Alessandro Fraccica[ECS], Grainne El Mountassir, Gerrit Meijer[ECS], Anil Yildiz[ECS]

"NbS and combined techniques - Case studies of steep bank stabilizations in the Garonne water catchment area in France - Constructions in very close proximity to residential areas and infrastructures"

PPT virtual poster from Klaus Peklo Dipl.-Ing., graduate engineer
- Designer Soil and Fluvial Bioengineering and site manager expert -

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Be aware, an integrated design approach is necessary:

“Integrated design is a comprehensive holistic approach to design which brings together specialisms usually considered separately. It attempts to take into consideration all the factors and modulations necessary to a decision making process.”

(Victor Papanek (1972), "Design for the Real World: Human Ecological and Social CHange", Chicago: Academy Edition, p322. Extract of Wikipedia on Friday 23/04/21)

It consists of well-considered preliminary studies, then preliminary design, and not to forget the back-checking of your preliminary design, then continue by detailed execution design.

During your construction stage also frequent construction supervision and checks are obligatory.

Then you will get a reliable and sustainable integration of your “NbS/mixed techniques” construction into the existing ecosystem on your construction site.

>> Therefore see in next slide the « Workflow Pyramide of Soil and Fluvial Bioengineering constructions »!

- All pictures non credited are taken by K.Peklo -

Klaus Peklo Dipl.-Ing., graduate engineer
- Designer Soil and Fluvial Bioengineering and site manager expert -

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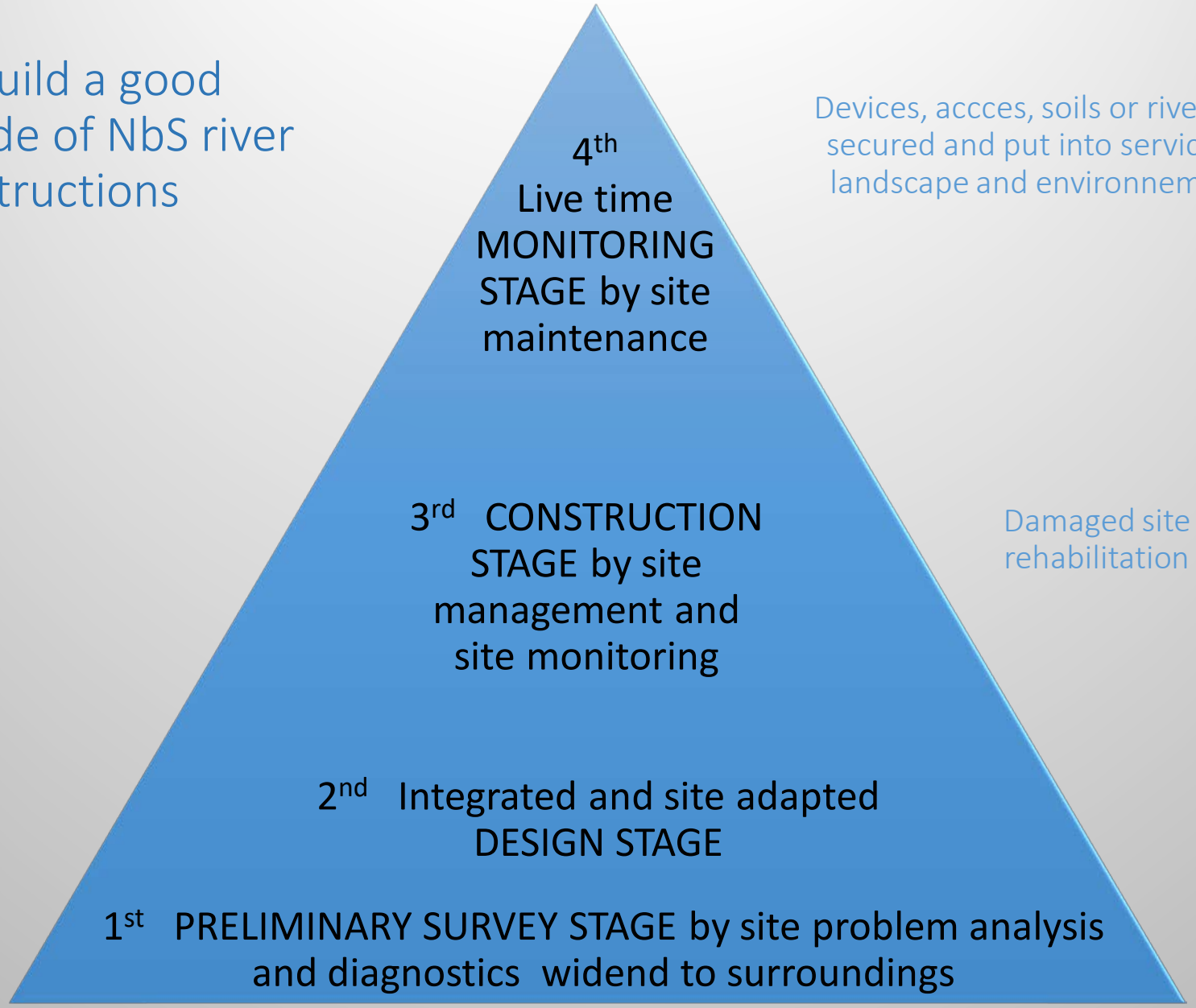
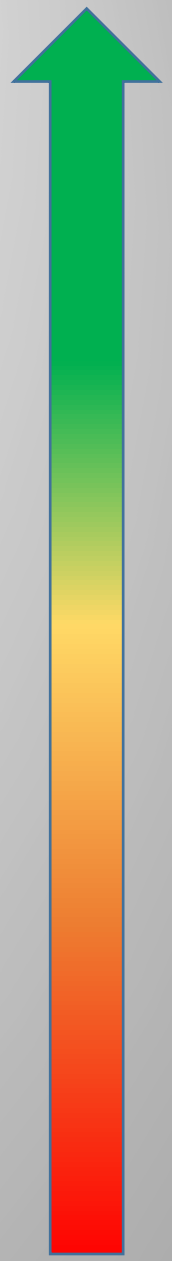
4 work steps to build a good workflow pyramide of NbS river engineering constructions



Devices, accces, soils or riverbanks are now secured and put into service by respecting landscape and environnement regulations

Damaged site is beginning his rehabilitation into the natural environment

Damaged site attending rehabilitation



- This PPT virtual poster would like to indicate you some extracts from river constructions designed and directed by Klaus Peklo from 1992 to 2022 within the Garonne catchment area, France -

I will try to show how severe bank slides, such as those following natural disasters, can be sustainably reintegrated into the river ecosystem in a modern, contemporary manner through the application of NbS and combined techniques.

Likewise I try also to explain, with the help of many pictures, the needs of integrated engineering approach to find out the causes of streambank slides before work is starting. Pointing out the workflow of NbS reconstruction process by determining an efficient analysing stage, construction stage and monitoring stage.

Klaus Peklo graduate engineer
- Designer Soil and Fluvial Bioengineering and site manager expert -

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INFRASTRUCTURE – Protection of main roads and bridges

Case study 1) 1999: Hers Vif River – 120m Rehabilitation work of River embankment
Construction time 3 months – Pre-tax costs 75.000 € (64.500 £ 10/2016 rate)

Damage case: Far advanced bed and bank erosion; imminent risk of undermined embankment collapse threatening public space and communal road

Preliminary studies carried out: Topographic and bathymetric data levys, hydrodynamical analyses…

Program mission: Project establishment, contract drafting and site monitoring in order to reduce risk of bank erosion

Geometric shape: Variable bed width 30/50m; bank height 6m, subvertical and variable slope gradient; design flood Q_{50} ~ 600m^3/s

Provided longitudinal construction: Horizontal willow fascine, live Log Cribwall, live Brush Mattress, Brush Layers, Log branch cutting

Provided transversal construction: 40 m wide 3D transversal Rough Ramp anchored in live RipRap

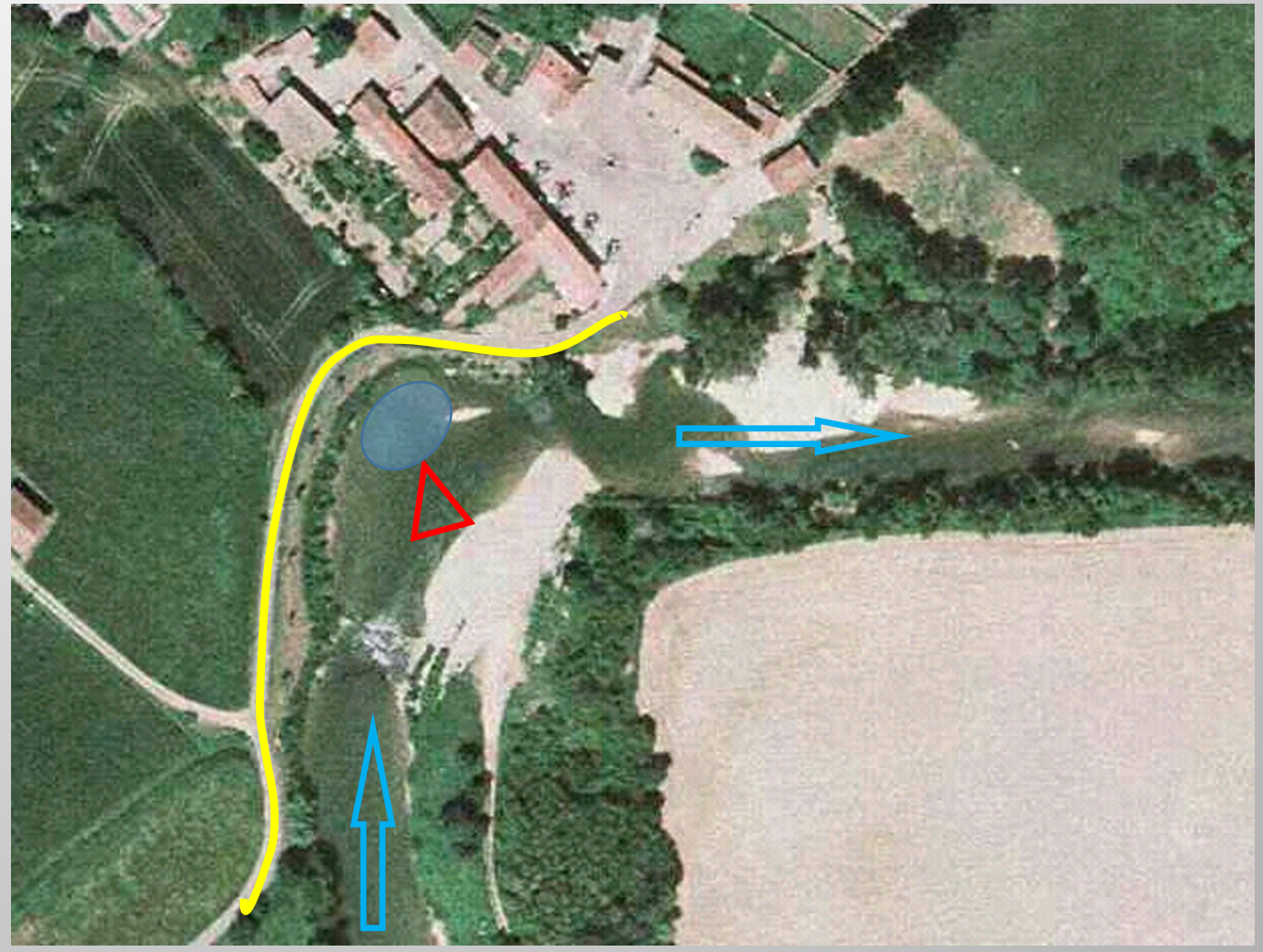


Image GoogeEarthPro

Case study 1) 1999: L'Hers Vif River – 120m Rehabilitation work of River embankment

Temporary riverbed shifting to right bank and Log Cribwall **construction stage** during the end of octobre 1999 on left bank

Case study 1) 1999: L'Hers Vif River – 120m Rehabilitation work of River embankment

Construction stage during winter 1999: Longitudinal left bank protection
as vegetated Log Cribwall

Anchoring depth =2,50m strengthend with local plant cuttings
in order to obtain a riparian Salix shrub stratum

Case study 1) 1999: L'Hers Vif River – 120m Rehabilitation work of River embankment

Construction stage during winter 1999: 3D transversal Rough Ramp works ongoing

Pile driving activity into river alluvium in progress >>

Einrammen der Larix decidua Pfähle ins alluvium

Case study 1) 1999: L'Hers Vif River – 120m Rehabilitation work of River embankment

State after the 1st stress-test

April 2000, 5 months after completion, a floodevent occuring of ~ 6,50m height

The yellow line indicates the position of the communal road also the highest floodlevel

April 2000 etwa 5 Monate nach Fertigstellung, Überschwemmung ~ 6,50m bis über die Strasse

Die gelbe Linie zeigt die Lage der Gemeindestrasse und den max. Hochwasserstand

Case study 1) 1999: L'Hers Vif River – 120m Rehabilitation work of River embankment

Detail of Log Cribwall – notice the off-centered position of wooden cross pieces

Picture taken after 600m3/s flood event in April 2000

Face of vegetated reinforced Log Cribwall constructed with Larix decidua felled in the highlands of the Pyrenees >>

Einwandige Holzstruktur aus Larix decidua gefällt in Höhenlagen der Pyrenäen

Case study 1) 1999: L'Hers Vif River – 120m Rehabilitation work of River embankment

Monitoring stage in 2005: Upstream picture towards 3D Hydraulic Rough Ramp anchoring into right bank

Background: Vegetated RipRap integrating anchoring on both Riversides >>

View towards upstream in 2005 of the 3D rough boulder ramp and the flanking vegetatively reinforced bank. The intended river bottom elevation in upstream to obtain velocity reduction through sediment deposition is clearly visible.

<< Front: Riparian Salix shrub stratum growing up of Log Cribwall after several cuttings

Case study 1) 1999: L'Hers Vif River – 120m Rehabilitation work of River embankment

Monitoring stage winter 2007: Upstream picture towards Rough Ramp anchoring into left bank

Always working in perfect condition, the Rough Ramp avoids erosion damage on LRB by deviating floods to RRB and provides free river oxygenation and supplies for bathing >>

Die gut funktionierende 3D Rip-Rap Blocksteinrampe erlaubt es die Hauptströmrichtung weg von der Gemeindestrasse ins rechtseitige Unterwasser zu lenken, damit die Erosionskräfte erheblich zu reduzieren und die Strasse nachhaltig zu schützen

Case study 1) 1999: L'Hers Vif River – 120m Rehabilitation work of River embankment

Monitoring stage in 2013: 4 years after completion date

View to lower left bank

Blick nach Unterwasser: Gesundheitszustand in 2013

View to upper left bank: no more undermining!

Blick nach Oberwasser: Gesundheitszustand in 2013
Keine Vortexerosion mehr im Mäanderzenith

Case study 1) 1999: L'Hers Vif River – 120m Rehabilitation work of River embankment

Monitoring stage in 2015

Satellite view indicates current state of construction: no more undermining as sedimentation now protects public road in the meander arch

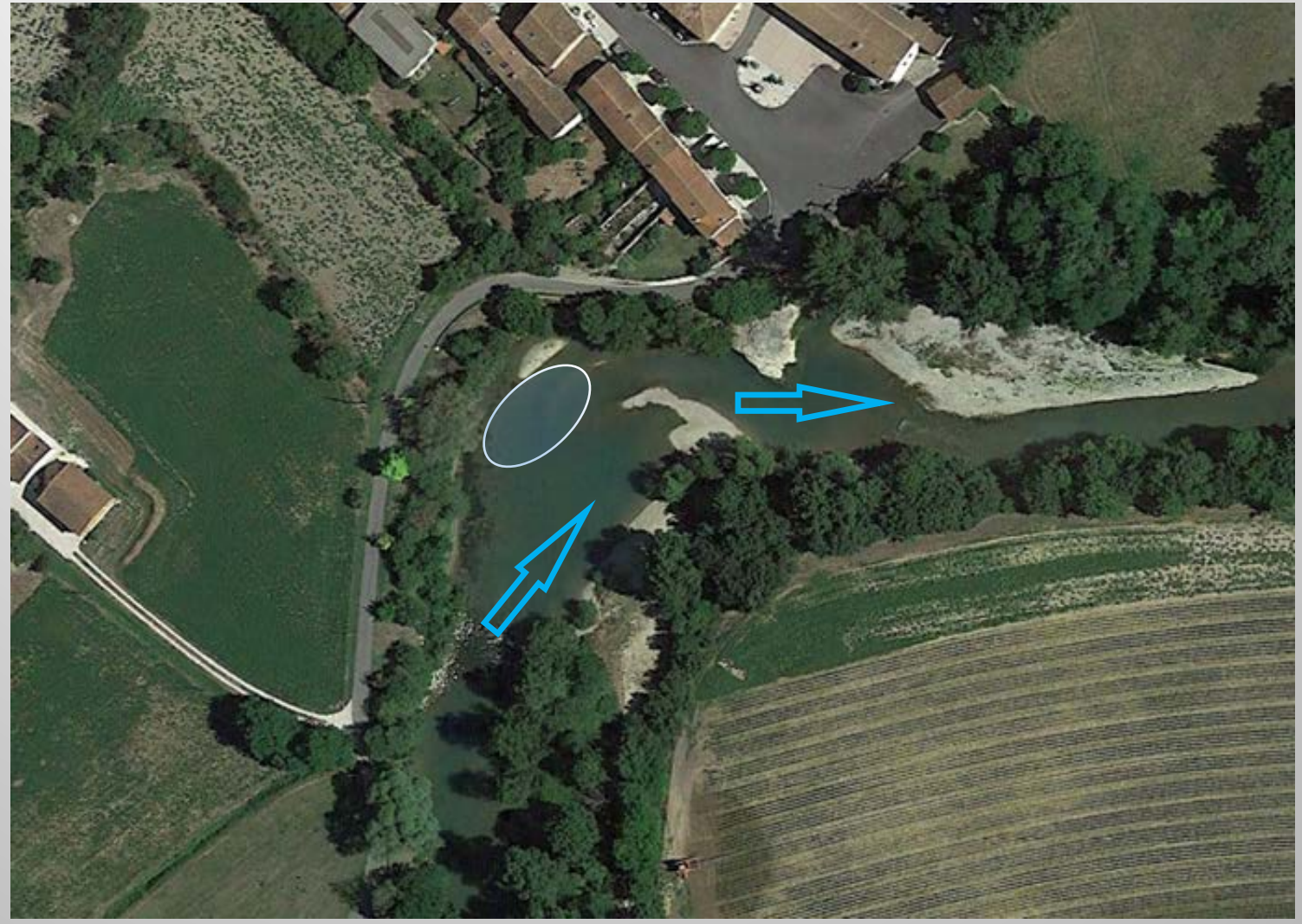


Image GoogeEarthPro

Satellitenfoto 2015: Sedimentation am Prallhang; keine Unterspülung der Strasse mehr

INFRASTRUCTURE – Protection of main roads and bridges

Case study 2a) 2020: L'Hers Vif River – 110m Rehabilitation work of river embankment at the bridgehead, along the flood wall protecting residential area and his access road – Construction time 5 months – Pre-tax costs 346.000 €

Both satellite view and X are indicating the most damaged right river bank in front of the resedential area.

Yellow rectangle is the site equipment position.

Blue arrow is the position of longitudinal construction provided.

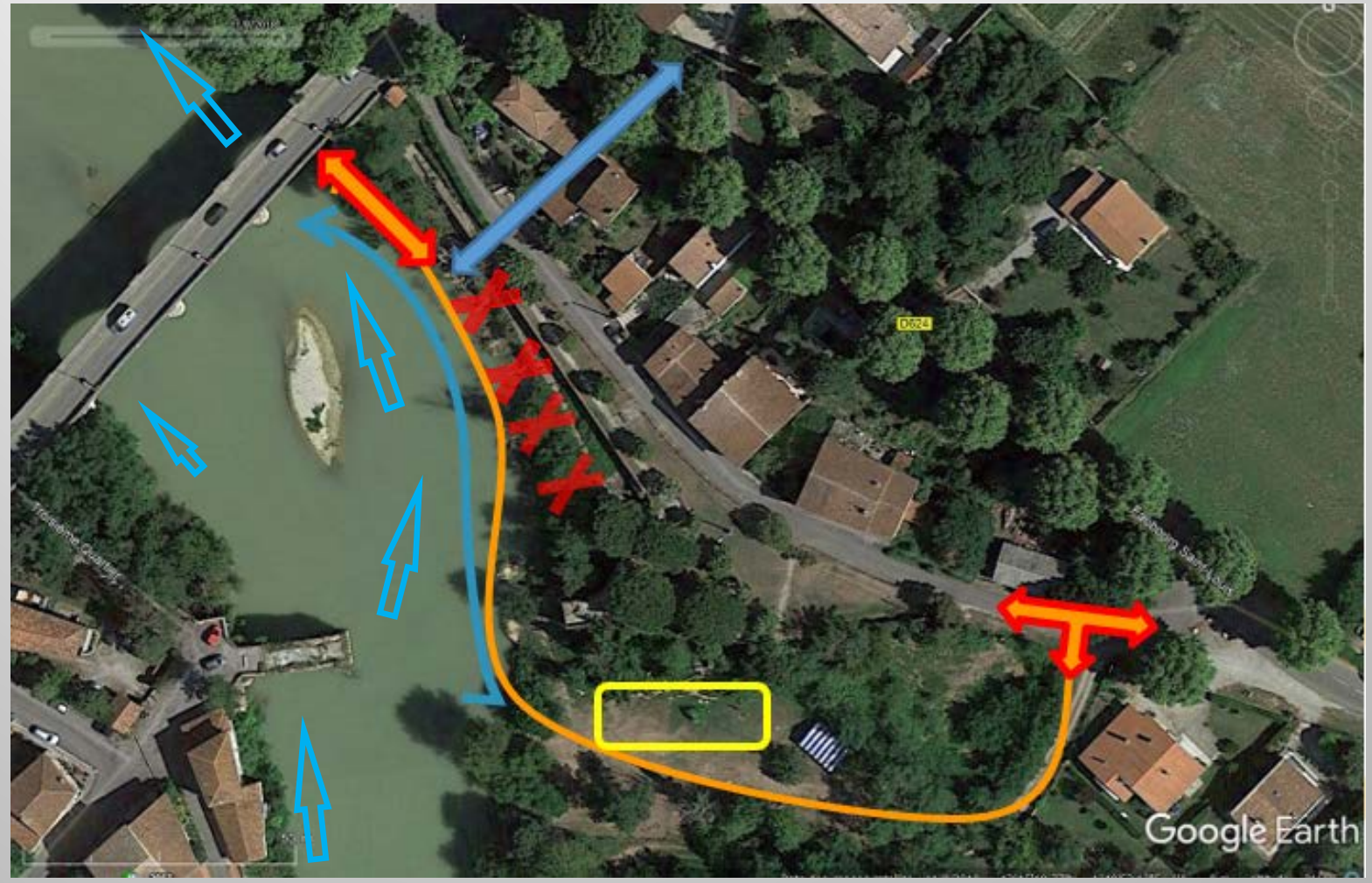
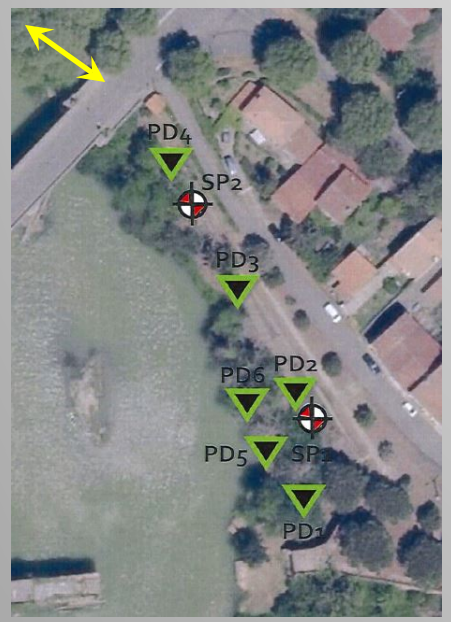


Image GoogeEarthPro

Case study 2a) 2020: L'Hers Vif River – 110m Rehabilitation work of river embankment at the bridgehead, along the flood wall and village road

Bathymetric investigation ongoing



Left and right: Images GoogeEarthPro

<< Left: Geotecnicla investigation

Below: Hydrodynamic investigation

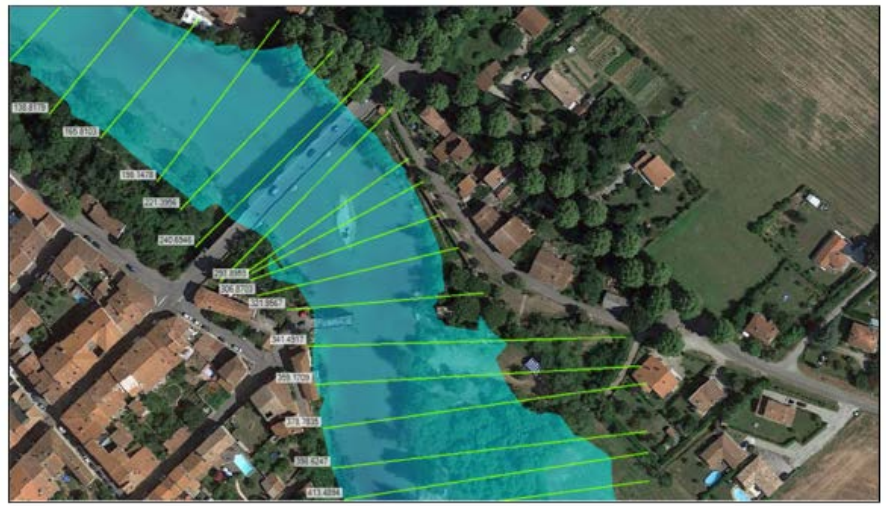
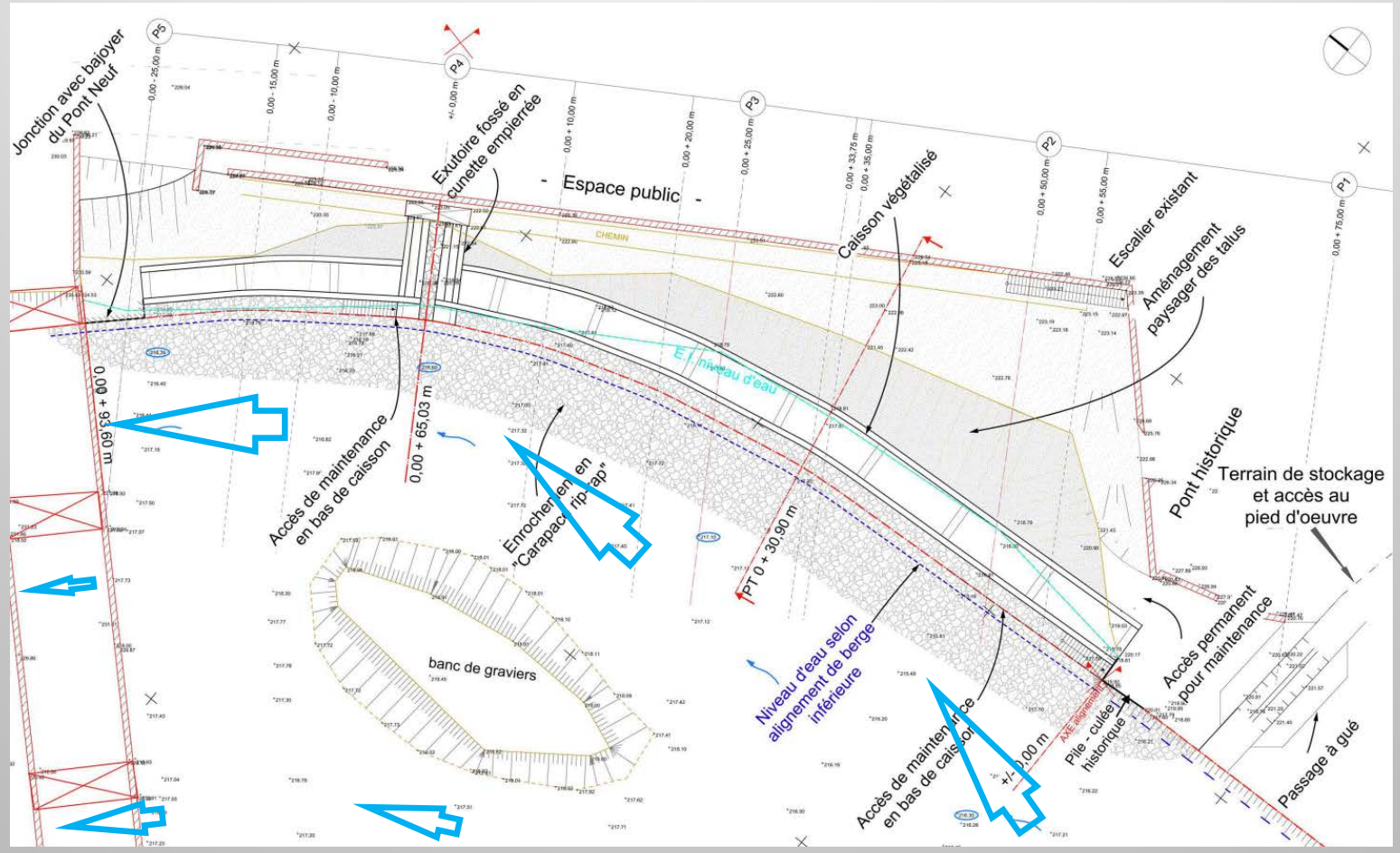


Figure 15 : Zone inondable pour T50ans

Case study 2a) 2020: L'Hers Vif River – 110m Rehabilitation work of river embankment at the bridgehead, along the flood wall and village road – Final design stage -

Design stage: The final exécution plan for public tender.



Case study 2a) 2020: L'Hers Vif River – 110m Rehabilitation work of river embankment at the bridgehead, along the flood wall and village road – Final design stage -

Design stage: The final outflow section for public tender.

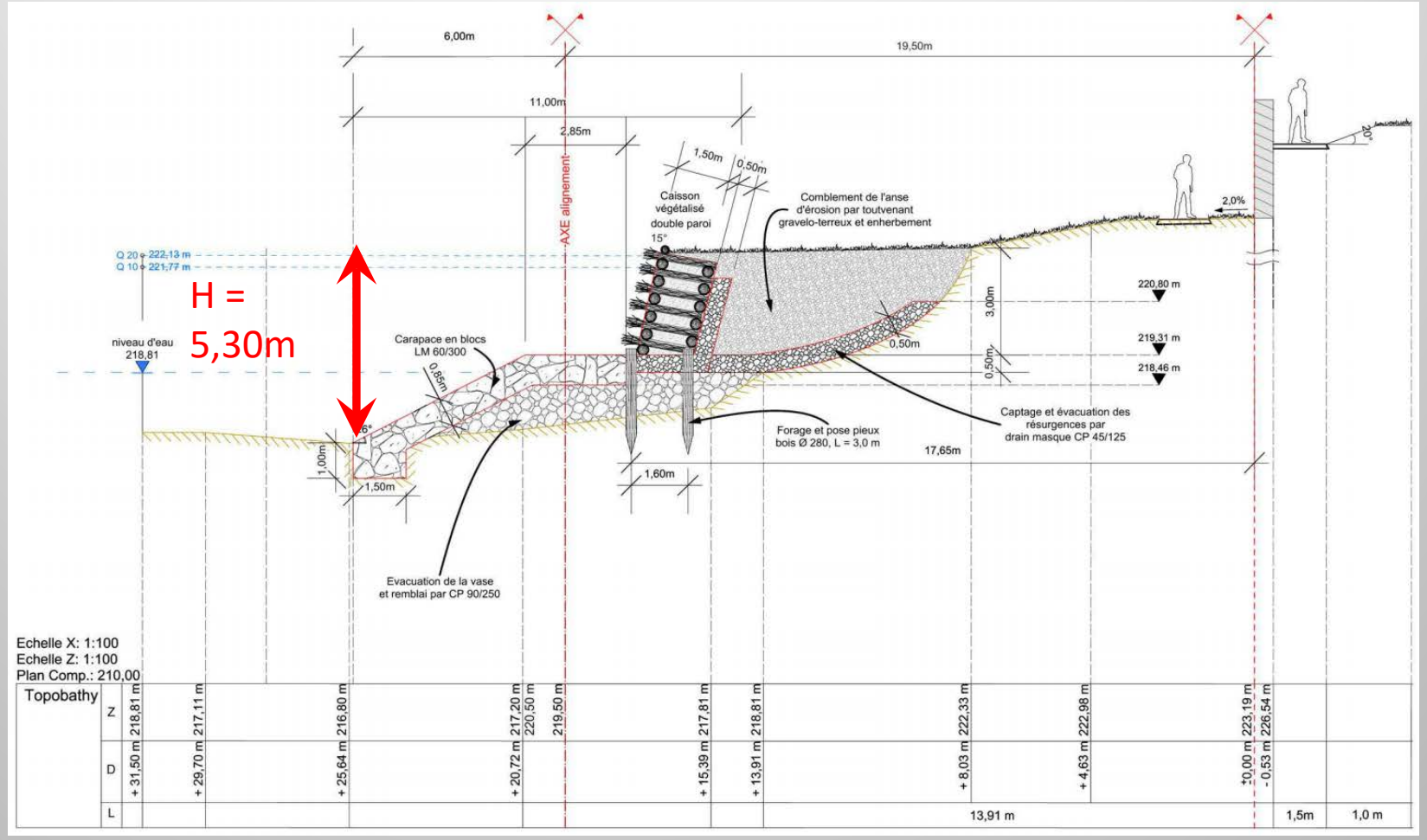
Right river bank re-construction

Soil refilled between flood wall and crib wall to obtain open space

Greened log crib wall

Hydraulic filter between crib wall and public open space

EN 13383 bloc-stone carapace



Case study 2a) 2020: L'Hers Vif River – 110m Rehabilitation work of river embankment at the bridgehead, along the flood wall and village road – construction stage -

<02/12/2019

11/12/2019>

< Saule drapé = Salix eleagnos, also called Salix rosmarinifolia >

< 12/2019 Plantage >

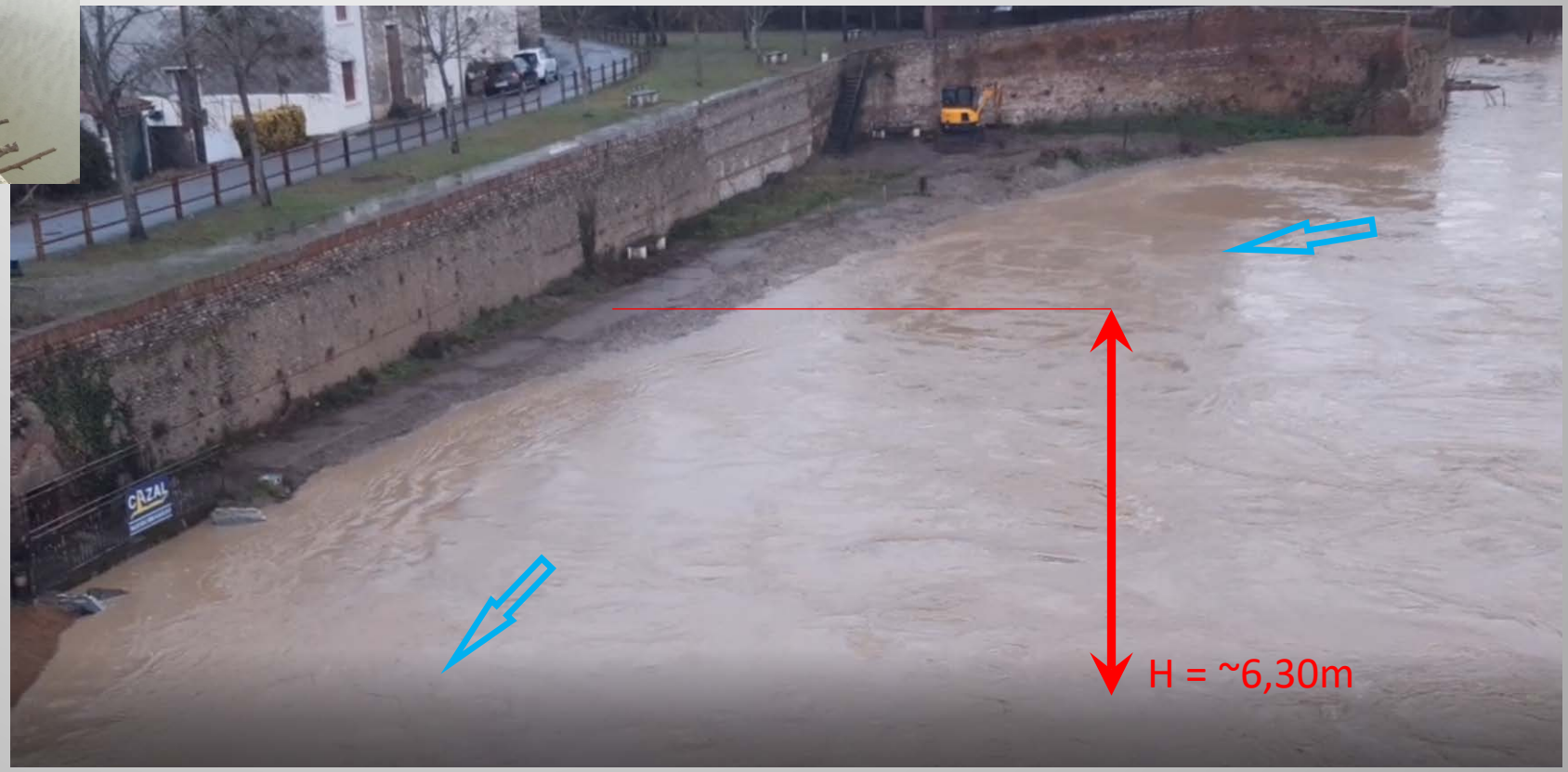
Our local natural « Woodland garden »

Case study 2a) 2020: L'Hers Vif River – 110m Rehabilitation work of river embankment at the bridgehead, along the flood wall and village road - construction stage -

Work in progress on 11/12/2019

Construction progress stopped in april due to 50 year flood

estimated about 650m^3/s



Case study 2a) 2020: L'Hers Vif River – 110m Rehabilitation work of river embankment at the bridgehead, along the flood wall and village road – Completion date -

Development of willow wood 4 months after the beginning of planting

Pictutre taken in 14/05/2020

Case study 2b) 2022: L'Hers Vif River –50m lower bank protection providing both erosion protection to the road bridge and safety access to public space

Current health state in march 2022

Detailed view to downstream:
Erosion progressed in close proximity to bridge pier

<< Frontview
Current health state in march 2022: 50m erosion process is ongoing in diretion to public space

Case study 2b) 2022: L'Hers Vif River – 50m lower bank protection providing both erosion protection to the road bridge and safety access to public space - completion date -

Completion date in april 2022: Current state of construction

View to upstream:
50m erosion process stopped by building a vegetated Log Cribwall

RESIDENTIAL AREAS – Protection of acess roads and residential buildings

Case study 3) 2012 to 2018: Garonne River – 500m Rehabilitation work of River embankment
Expected construction time 5 months – Pre-tax costs 950.000 €

Damage case: Far advanced bed shifting and bank erosion; imminent risk of embankment collapse threatening public space and communal road

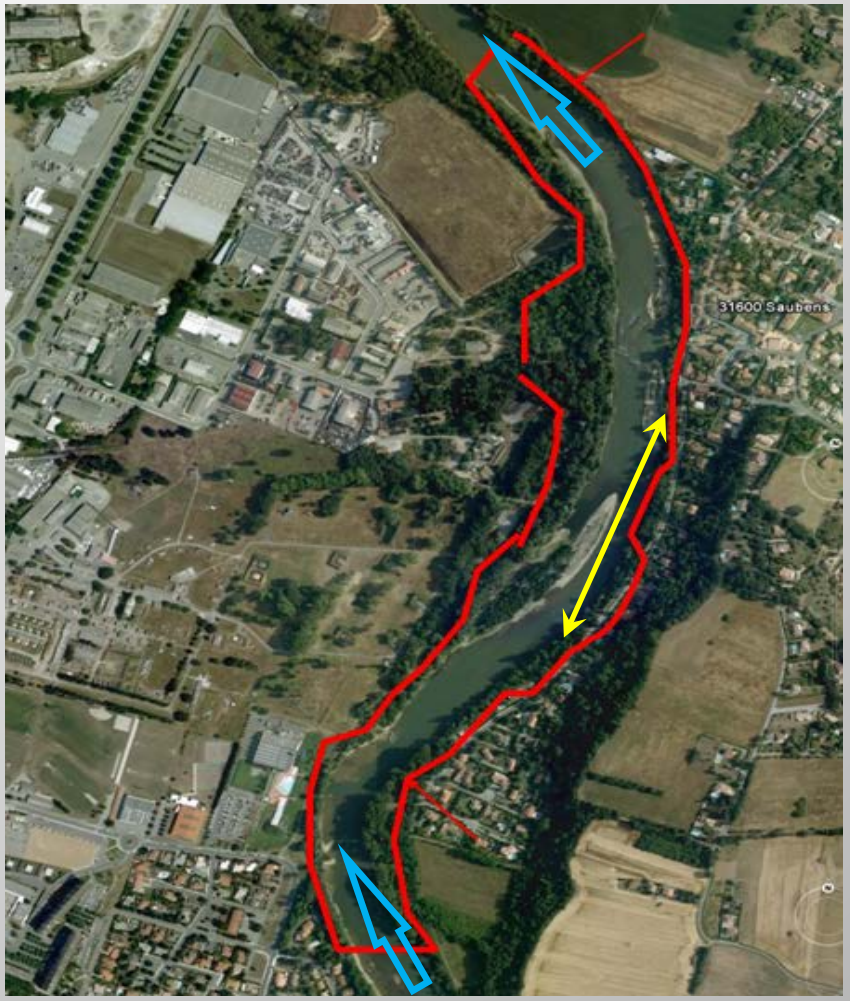
Preliminary studies: Topographic and bathymetric data levys, drillings in view of geotechnical assessment, diachronical and hydrodynamical analyses…

Program mission: : Project establishment, contract drafting and site monitoring In order to reduce risk of bank erosion

Geometric flow sector shape: Variable bed width 80/150/200/80m; bank height 10/12m, variable slope gradient 30/45/55;
design flood Q_{100} ~ 2.780m^3/s

Provided longitudinal works: live RipRap, Log Cribwall, live Brush Mattress, Brush Layers, combined drilled concrete injection anchors

Provided transversal works: absolutely necessary but not yet been authorised



Fond Image GoogeEarthPro

Case study 3) 2012 to 2018: Garonne River – 500m Rehabilitation work of River embankment

Preliminary survey stage: Diacronic analysis results in both bed shifting and bank erosion have progressed up to 6,5m over the last 50 years

2012: Far advanced bed deepening due to lack of bedload caused substratum outcrop

2014: Lateral movement continues and causes bank collapse close to the residential area access (position in yellow line)

2014 Die Flussverlagerung bewirkt, in zeitlichen Schüben, dauerhafte Uferabbrüche auf der gesamten Höhe von ca. 10/12m, die schützende Ripisylve/Auwaldreste sind nicht mehr vorhanden, gelbe Linie > Zufahrtstrasse

Case study 3) 2012 to 2018: Garonne River – 500m Rehabilitation work of River embankment

Important upper bank erosion in close proximity to residences (brown line is garden's border)

2015 Uferabbruch im Hausgarten; braune Linie ist das Mäuerchen im rechten Foto

Same propertie, garden border shown by brown line

2014 Uferabbruch im Hausgarten; braune Linie ist das Mäuerchen im linken Foto

Case study 3) 2012 to 2018: Garonne River – 500m Rehabilitation work of River embankment

GoogleEarthPro 2012: Yellow line indicates the most urgent job sections in NbS and combined techniques (total L ~ 500m)

GoogleEarthPro im Juni 2012: Gelbe Linie zeigt geplanten Wiederaufbau mittels ingenieurbiologischem und kombiniertem Uferschutz

Fond Image GoogeEarthPro

Case study 3) 2012 to 2018: Garonne River – 500m Rehabilitation work of River embankment

Design stage: Our first preliminary study, based on a terrestrial 3000m long DTM covering area of centennial flood Q_{100} ~2,780m³/s, was to compute the channel morphology (TELEMAC 2D software)

River bank reconstruction parameters

Flow rates:

Q_{min}=150 m3/s, Q_{max} 4.350 m3/s (1952)

Design base:

Slope $_{average}$ I = 0,0023

H_{max} = riverbed bottom + 10/12m

$V_{max\ channel}$ = 4,0m/s

HQ100 = 2.780 m3/s

Shearstress $T_{max\ bankborder}$ = 160N/m² > 220 N/m²

Hier das vorab erstellte DGM im HW Fall Q100 mit Hilfe von TELEMAC 2D auf Basis von 3000m terrestrischen und bathymetrischen Geländeaufnahmen

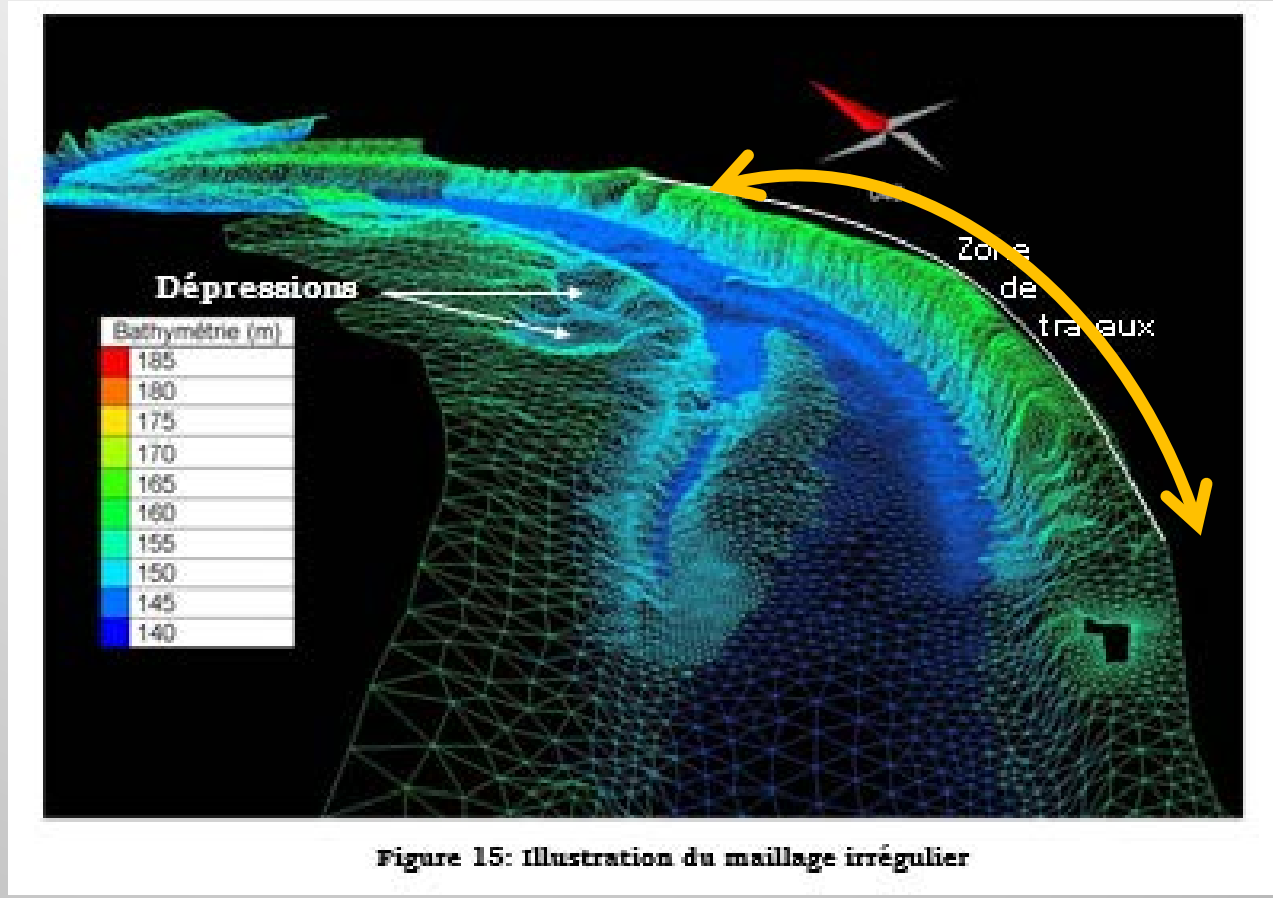
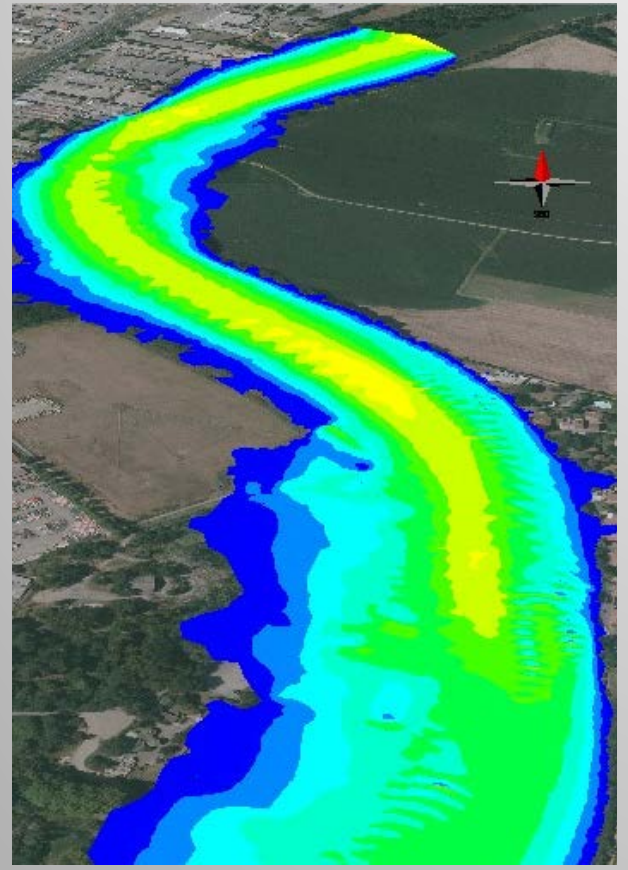


Figure 15: Illustration du maillage irrégulier

Auszug aus der Vorstudie « 2015 Hydrodynamisches Abflussgeschehen 2D des Flusses Garonne »

Case study 3) 2012 to 2018: Garonne River – 500m Rehabilitation work of River embankment

Design stage: Extract of this hydrodynamic 2D assessment (distance of 3000 m) with the aim of obtaining runoff characteristics to provide a basis for structural design of biological and mixed techniques

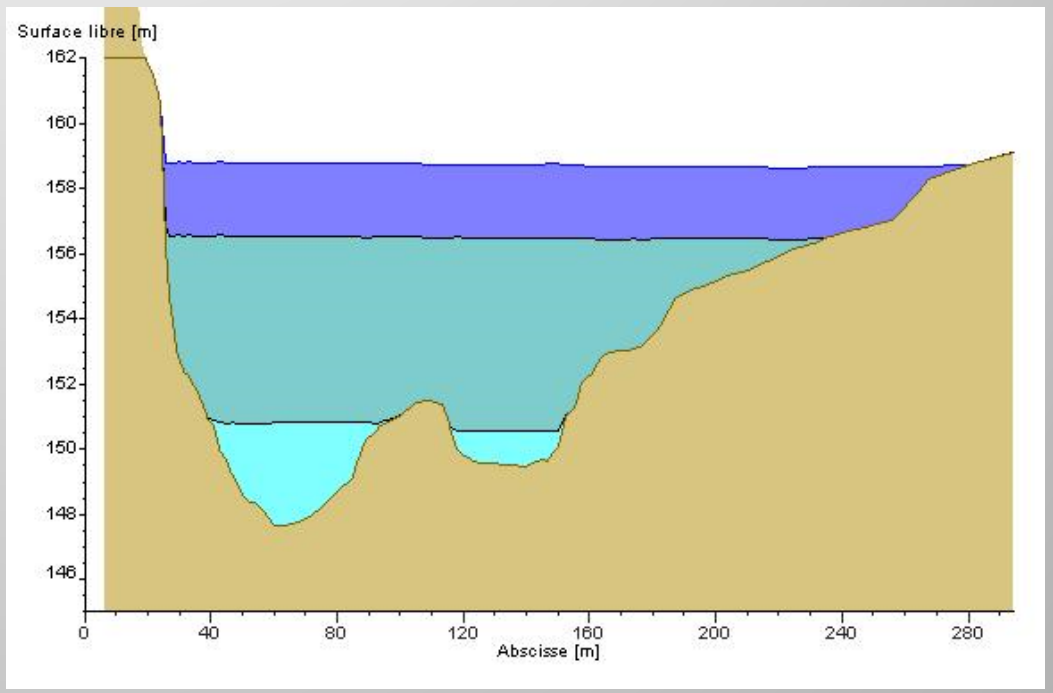


<< Velocity values are computed by TELEMAC 2D for required levels

Auszug der Vorstudie « 2015 I.C.E Hydrodynamisches Abflussgeschehen 2D des Flusses Garonne »

< Geschwindigkeits-verteilung

Flood cross-section values are computed by TELEMAC 2D for required levels



< Flussgrund und verschiedene HW Stände

Case study 3) 2012 to 2018: Garonne River – 500m Rehabilitation work of River embankment

Design stage: In the same time a subsoil geotechnical investigation was performed to obtain soil properties

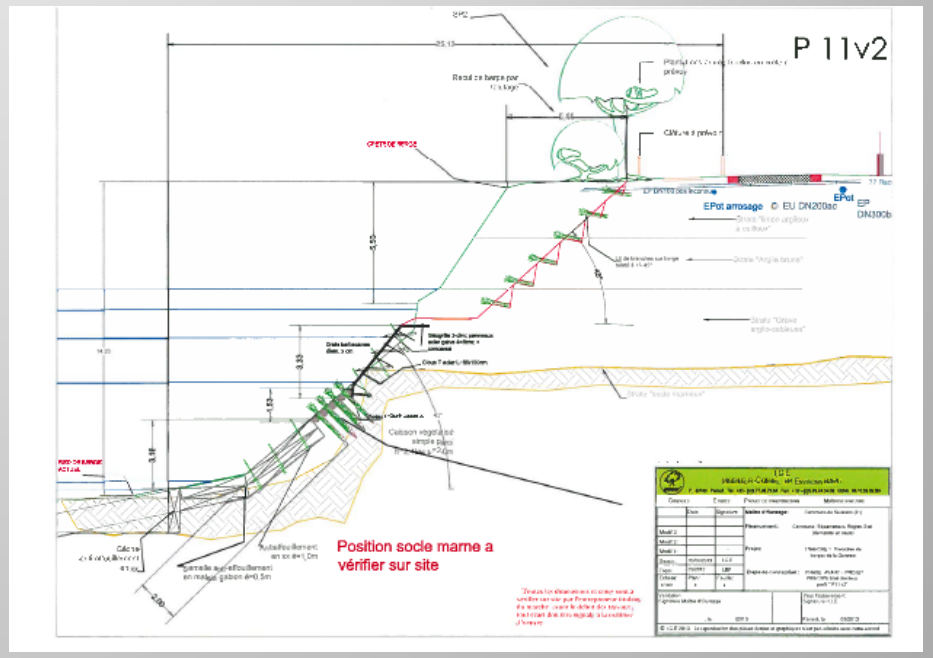
Yellow line indicates drilling positions

Gelbe Linie und Punkte sind die Positionen der geotechnischen Sondierbohrungen

Fond Image GoogeEarthPro

A preliminary design was made available for the geotechnical expert to verify Stability requirements

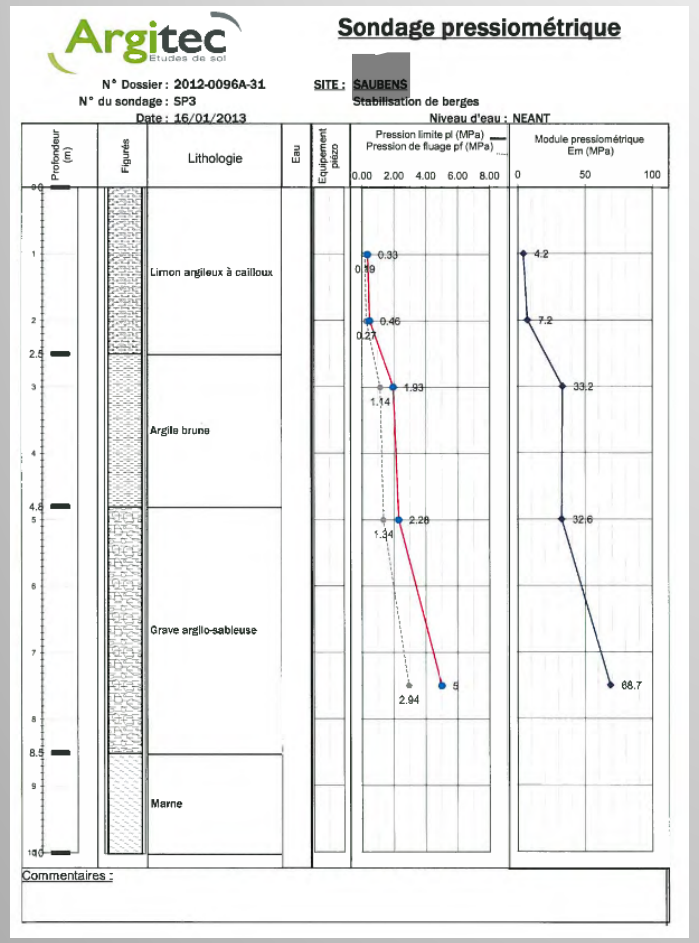
Daraus erstelltes geologisch/ bodenkundliches Profil und erste Lösungsüberlegungen



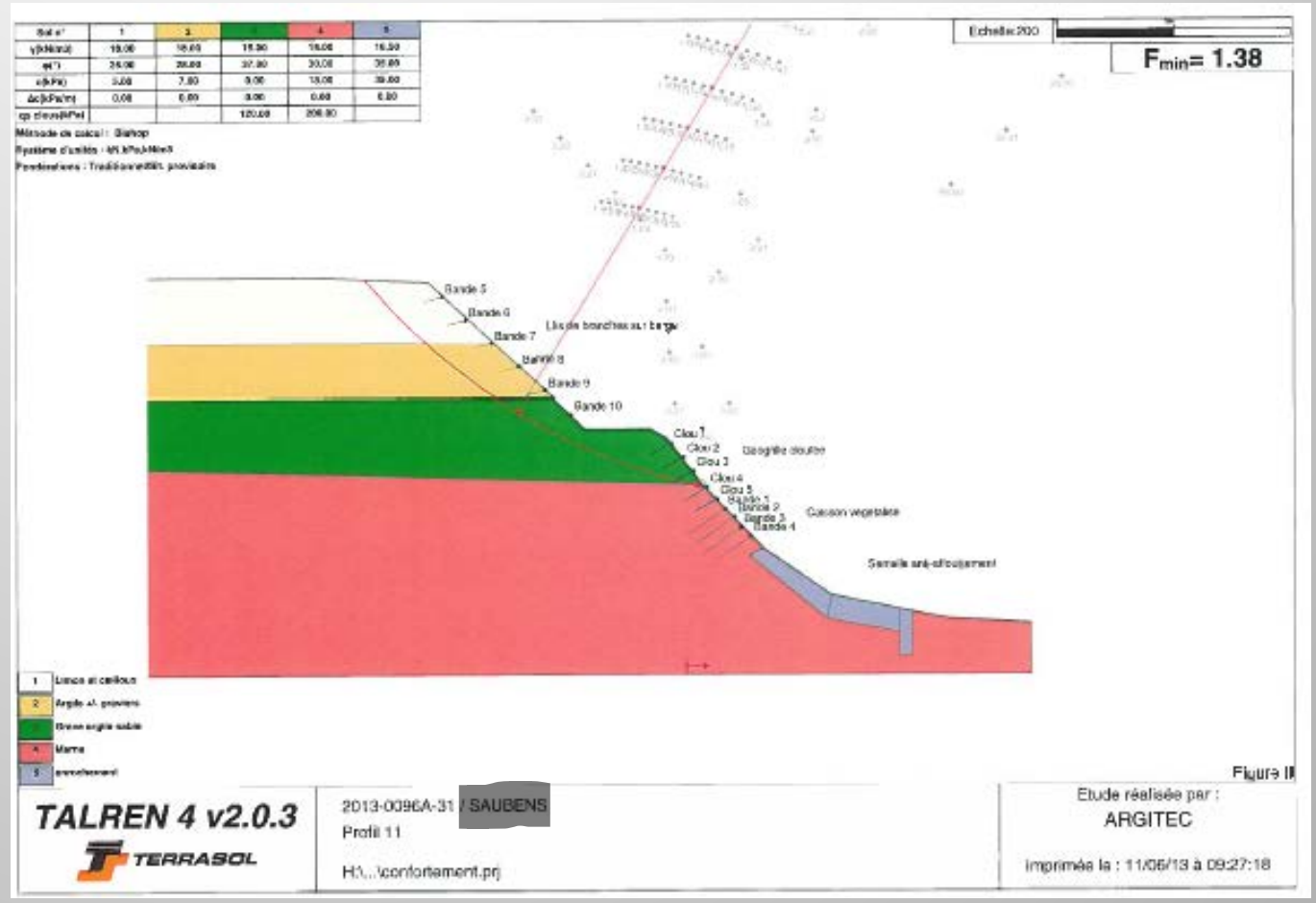
Case study 3) 2012 to 2018: Garonne River – 500m Rehabilitation work of River embankment

Design stage: Geotechnical assessment results based on a pre-design version of biological and mixed techniques intended in this design phase for protecting right river bank

Soil profile



Auszug aus der geotechnischen Vorstudie - Bodenprofil und Gleitkreis



Slip circle with integrated riprap and root layer protections

Case study 3) 2012 to 2018: Garonne River – 500m Rehabilitation work of River embankment

Design stage: Extract from the invitation to tender for public works – Finally selected execution profile on river position no. 11

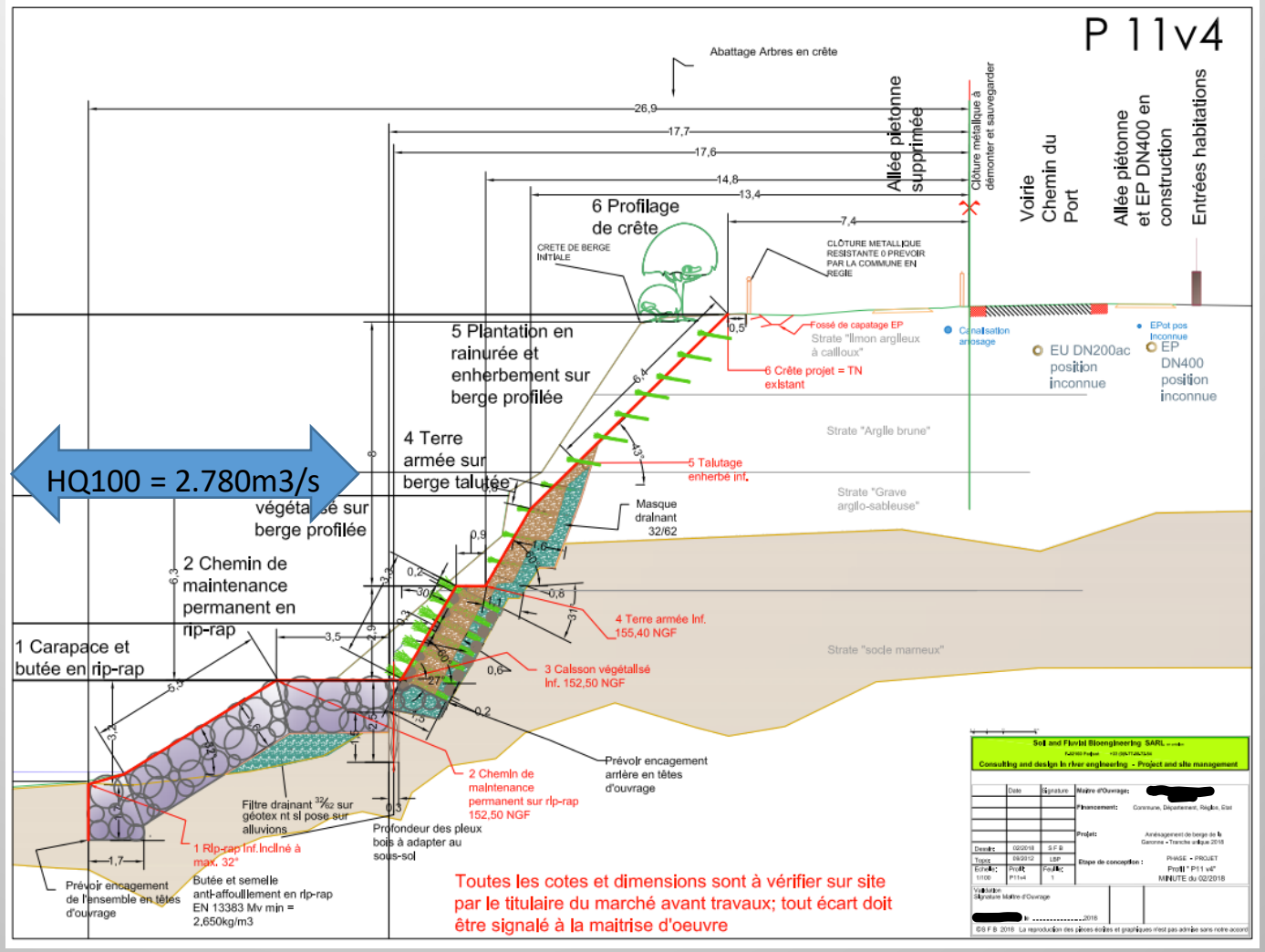
TOP bank: Multiple brush layer structures covered by 100% biodegradable coco geotextiles >>

UPPER: Dormant cuttings in 3D HMfree greened steel structure >>

MIDDLE: Greened Log Cribwall with integrated wedge filtering >>

BED: Machine-suitable maintenance strip >>blockstones according to EN 13383 Parts 1and2>>

BED: Rip-rap carapace blockstones according to EN 13383 Parts 1 and 2 >>



RESIDENTIAL AREAS – Protection of residential buildings

Case study 4) 2012: Longues Aygues river – 35m Rehabilitation work in close proximity of occupied flats
Construction time 2 months – Pre-tax costs 70.000 €

Damage case: Far advanced bed shifting and bank erosion; imminent risk of embankment collapse threatening residential area
Preliminary studies: Topographic data levys, drillings in view of geotechnical assessment and hydrodynamical analysis
Program mission: Project establishment, contract drafting and site monitoring In order to reduce risk of bank erosion

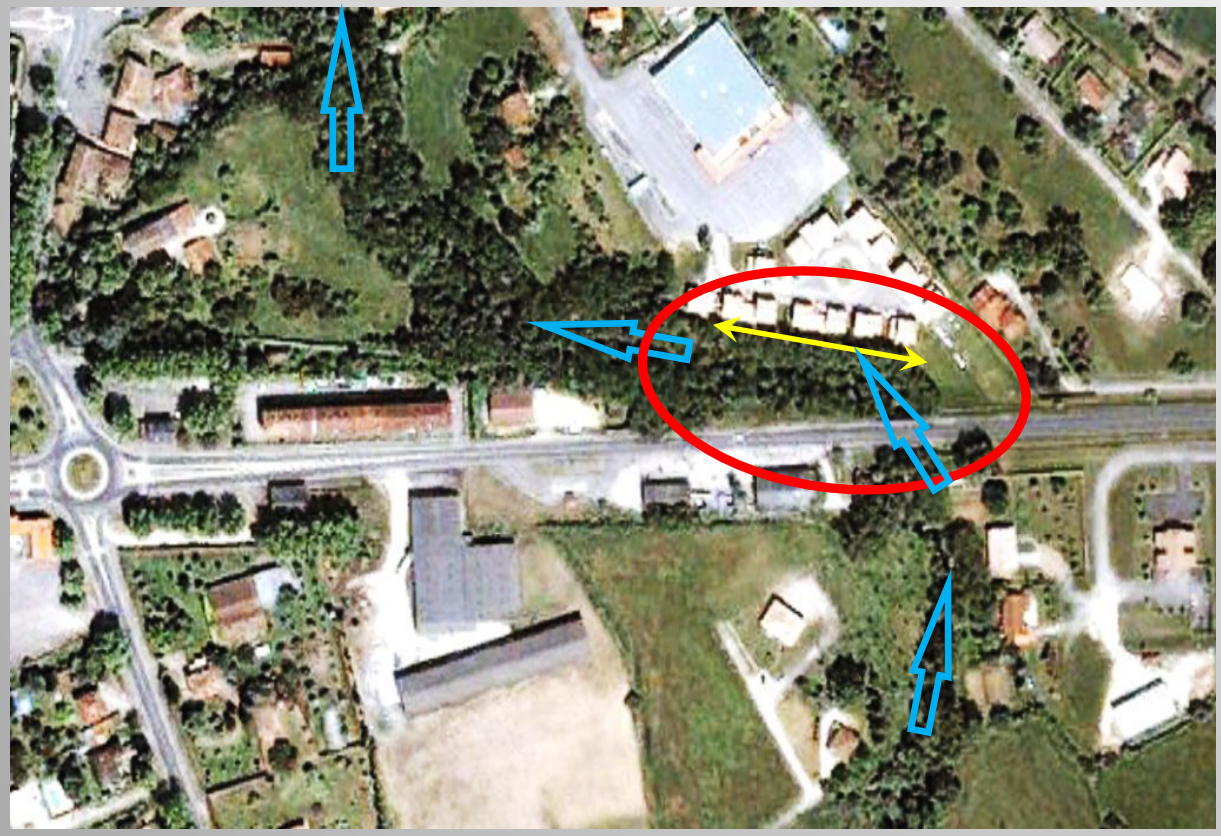


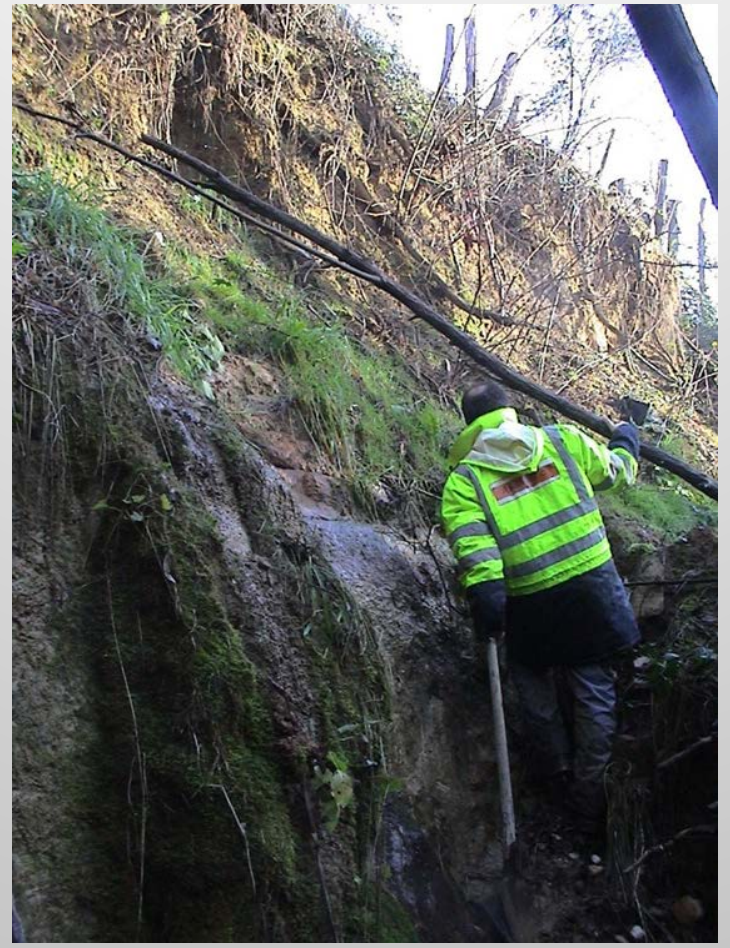
Image GoogeEarthPro

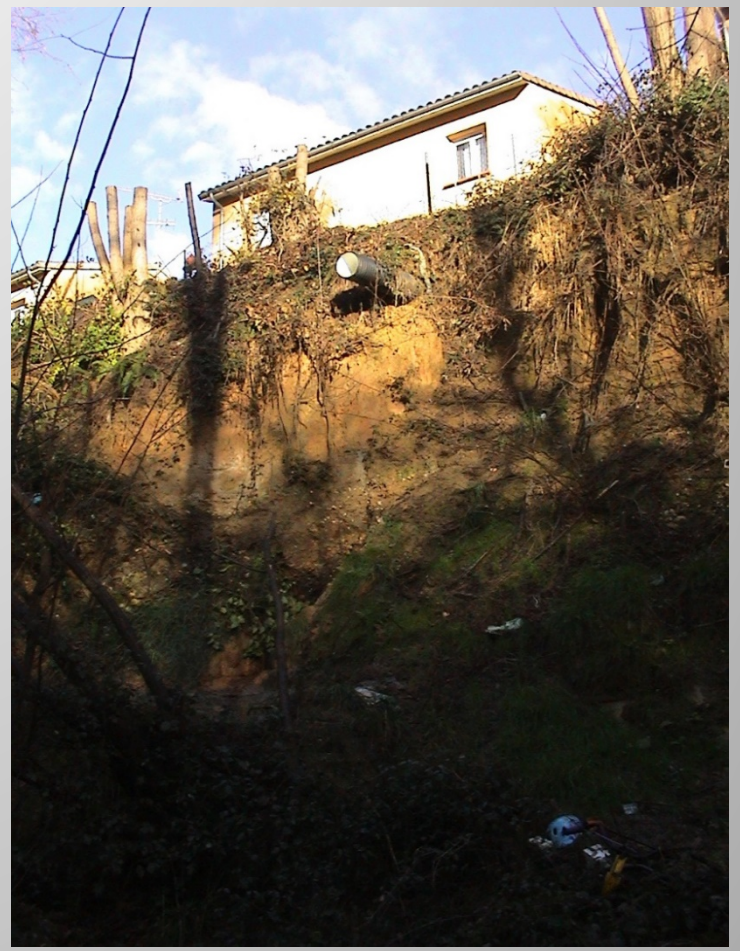
Case study 4) 2012: Longues Aygues river – 35m Rehabilitation work in close proximity of occupied flats

Preliminary studies ongoing

As usual a subsoil geotechnical investigation ongoing to obtain soil properties in proximity of buildings

After clearing work we discovered broken sewers, huge building rubbish and a pretty nice ☺ groundwater horizon





Case study 4) 2012: Longues Aygues river – 35m Rehabilitation work in close proximity of occupied flats

Construction stage ongoing

Catch and drainage of the groundwater discharges by means of drainage packings

Case study 4) 2012: Longues Aygues river – 35m Rehabilitation work in close proximity of occupied flats

Surprise in construction process ☹

Sudden emergence of a 10 year old wild construction waste site with significant volume to be disposed of

Case study 4) 2012: Longues Aygues river – 35m Rehabilitation work in close proximity of occupied flats

Construction stage starts up again

Preparing secured access to river bed by machines

Earthworks giving hydraulic shape in order to obtain flood impact reduction

Implementation of anchored 4m high 3D steel structure onto lower bank in order to obtain flood impact reduction

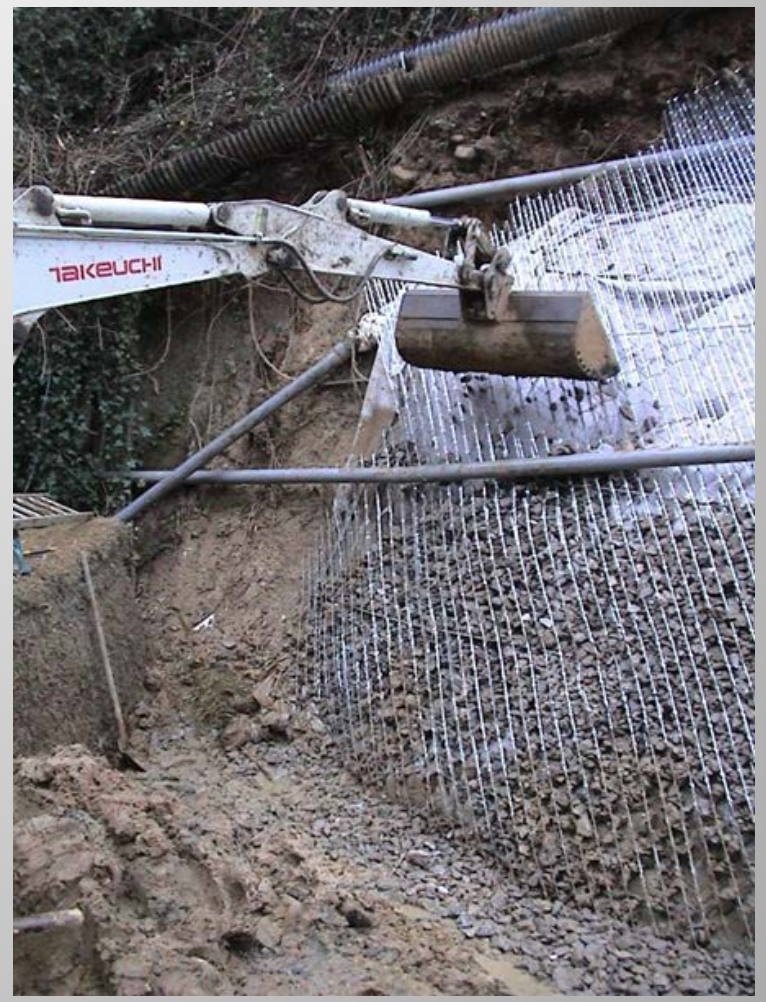
Case study 4) 2012: Longues Aygues river – 35m Rehabilitation work in close proximity of occupied flats

Construction stage

Groundwater capture on bedrock surface

Same work view from opposite bank

Before greening: Filling 3D steel structure with core grained gravel



Case study 4) 2012: Longues Aygues river – 35m Rehabilitation work in close proximity of occupied flats

Construction stage

After filling 3D steel structure with gravel, followed the insertion of dormant cuttings in the 3D steel grid structure

Pressing the willow stakes into remodelized lower bank

Case study 4) 2012: Longues Aygues river – 35m Rehabilitation work in close proximity of occupied flats

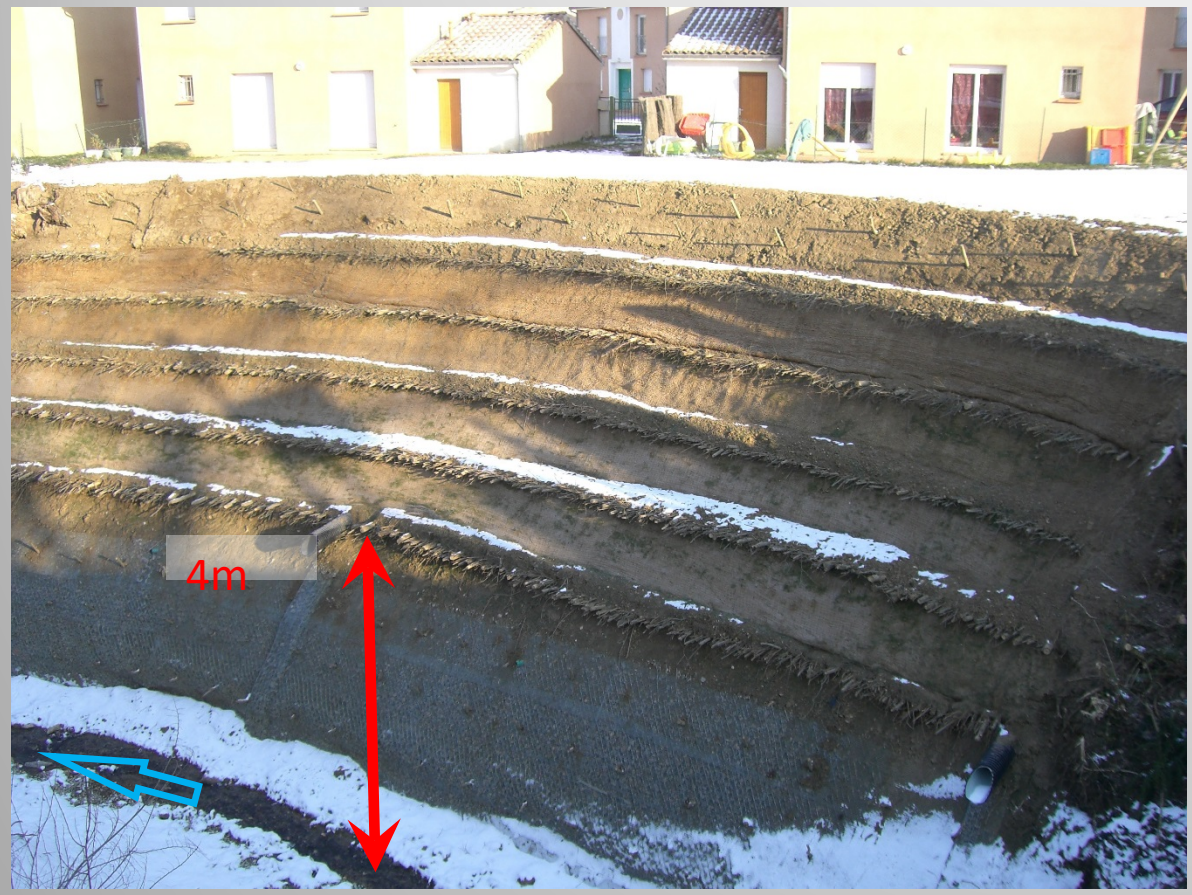
Construction stage

Storage facility close to the jobsite for live cuttings and wooden piles

Implementation of reconstruction work to center and top bank with log branch cuttings and dormant cuttings

Case study 4) 2012: Longues Aygues river – 35m Rehabilitation work in close proximity of occupied flats

Pictures taken in January /February 2012: Above the 3D Krismer vegetated metallic grid structure is visible the reconstruction of the right riverbank completed by brush layers using locally harvested willow cuttings and willow set stakes.



Case study 4) 2012: Longues Aygues river – 35m Rehabilitation work in close proximity of occupied flats

Completion date: Pictures taken March 2012

Picture to upstream right riverbank

Same position but picture to downstream right riverbank

Case study 4) 2012: Longues Aygues river – 35m Rehabilitation work in close proximity of occupied flats

Lifetime monitoring: Shrub stratum condition during a small 1.50m high flood one year after completion date in 2013

Image of shrub stratum captured on mai 2013

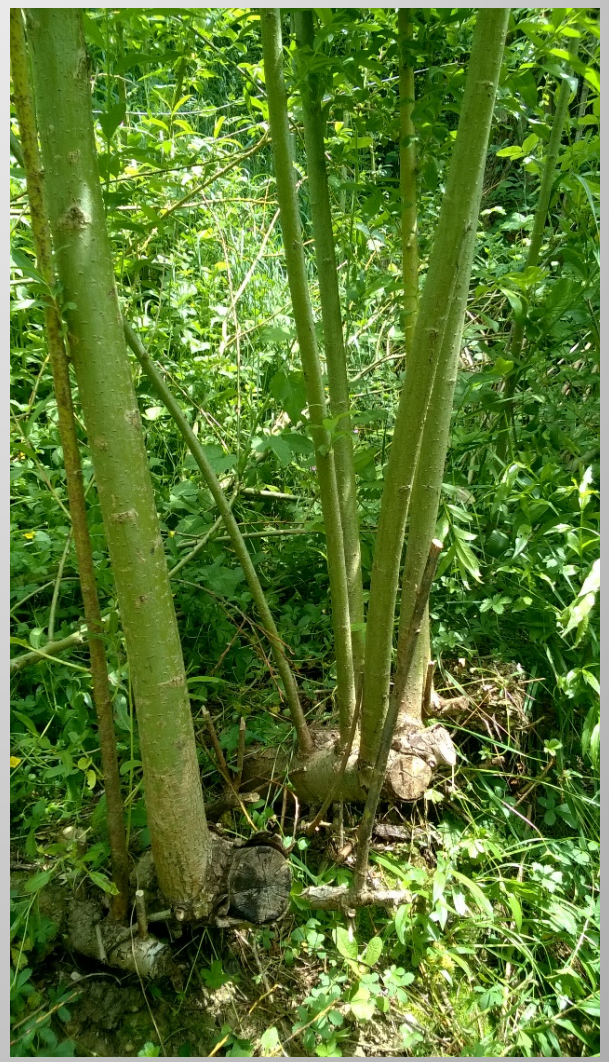
Vegetationsentwicklung im Mai 2013 während des ersten Hochwassers im 1ten Vegetationszyklus

Case study 4) 2012: Longues Aygues river – 35m Rehabilitation work in close proximity of occupied flats

Lifetime monitoring:

Detailed view of the willow stakes and willow cuttings in May 2016 in their 4th vegetation cycle with good maintenance care

Detailaufnahme der Weidenpfähle und Weidenstecklinge im Mai 2016 im 4. Vegetationszyclus bei guter Pflege



RESIDENTIAL AREAS – Protection of acess road and residential area by reduction of the riverbed displacement

Case study 5) 2008: Ariège river – Bed and lower cliff stabilisation by both 120m gabion and log live cribwall and 65m transverse structure by hydraulic rough ramp (3D hydraulische rauhe Rampe)

Construction time 4 months - construction pre-tax costs 505.000 €

Current state of riverbed shifting in 2000: You can clearly see the displacement towards the residential area

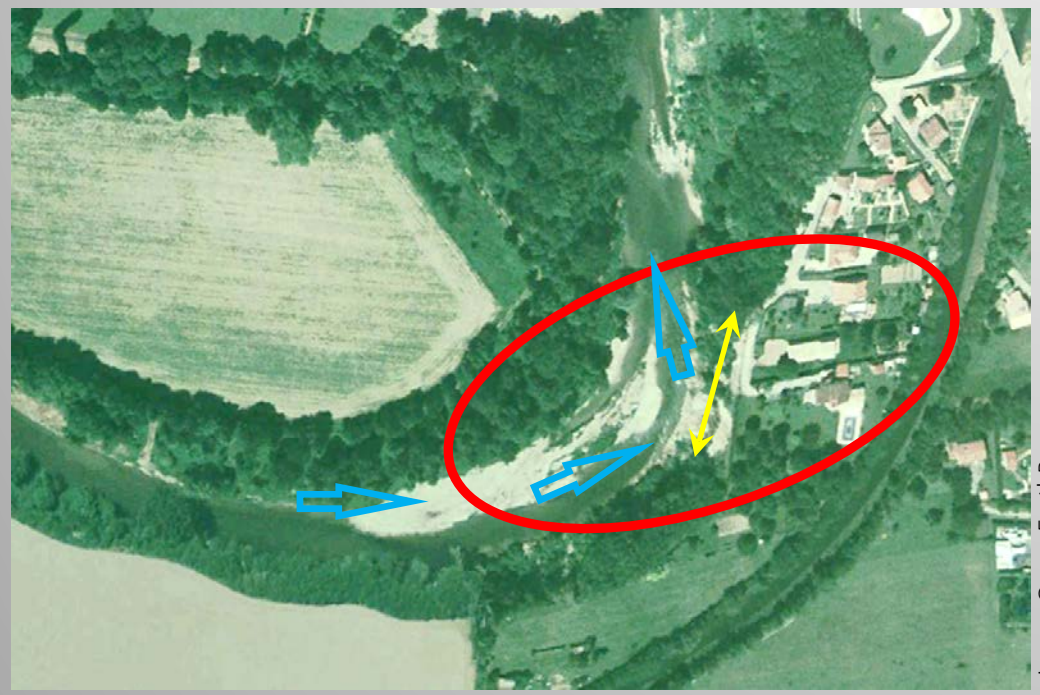
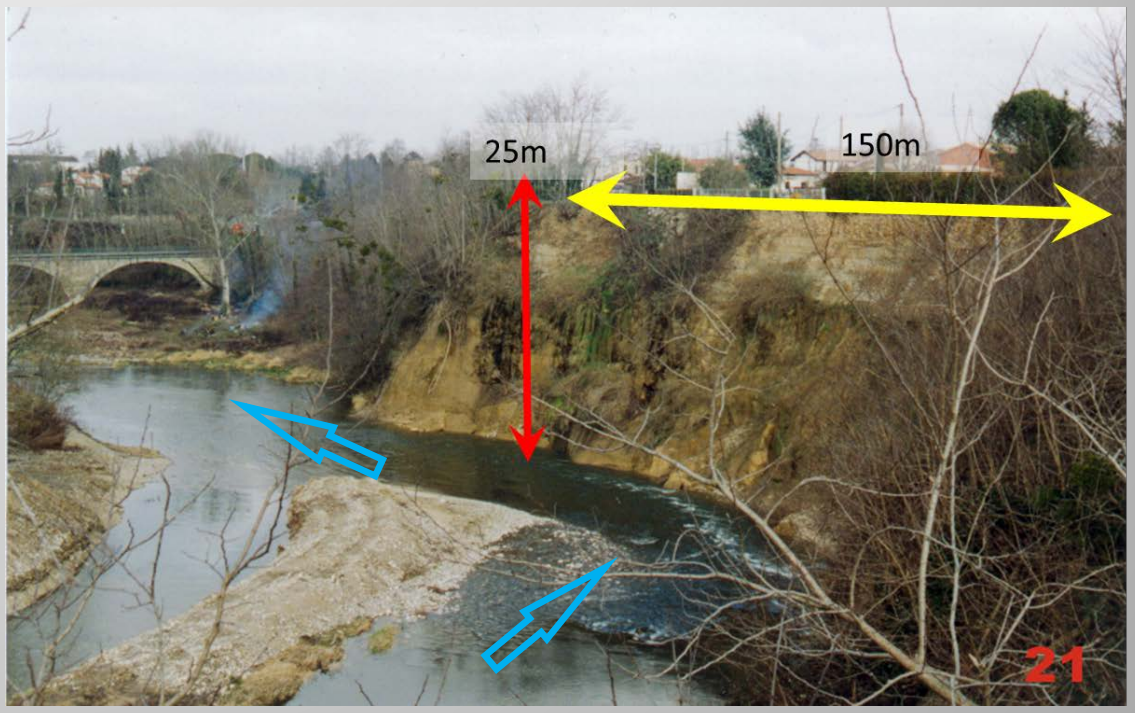


Image GoogeEarthPro

View to breaking steep wall due to riverbed shifting in immediate vicinity of houses and acces road in the year 2000

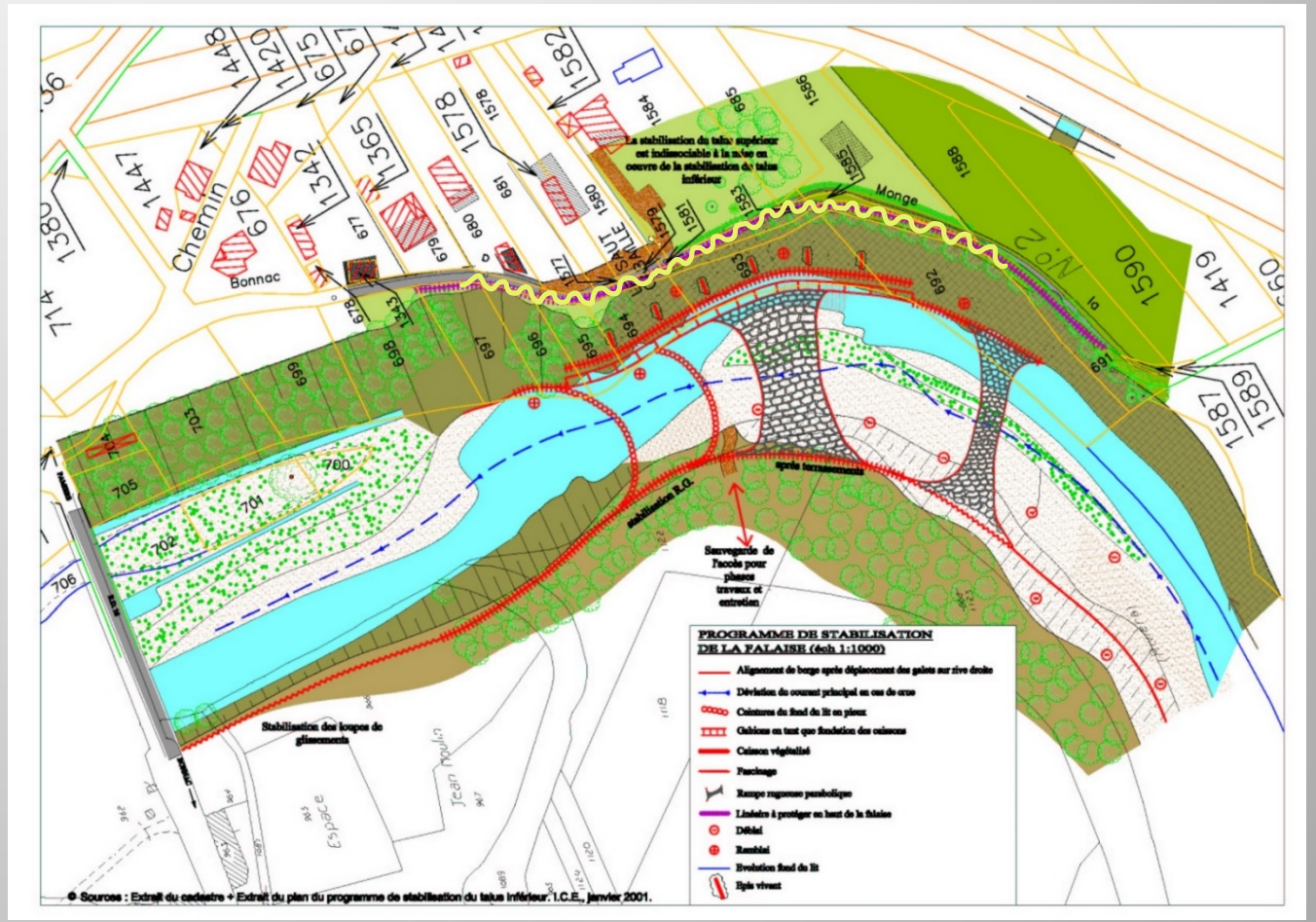


Case study 5) 2008: Ariège River 25m below the residential area – Bed and lower limestone cliff stabilisation by both 120m longitudinal live structure and 65m transverse hydraulic structure

Preliminary studies - Elevation of the river bottom by both transverse and longitudinal structures:

Hydraulic block ramps for the intended shift of the main stream direction; additional vegetative reinforced Krainer wall on gabions.
This has significantly reduced erosive forces and allowes limited restoration of the green riparian line.

Damage case: Large-volume steep wall demolition as well as the only access road; relocation of the access road partially into private property.
Mission: Reduction of sheer stress at the lower right river bank and reconstruction by both nature based green Soil and Water Bioengineering and mixed techniques.
No order: Upper steep cliff protection.
Design: Riverbed width variable from 40m over 90, then 50m; bank height 25m; discharge design floodflow HQ50 =+/- 500m3/s, lowflow NW 18m3/s
Preliminary studies: Diachronic and hydrodynamic analysis of riverbed shifting, terrestrial and bathymetric site surveys over 420m, sedimentological soil sampling
Longitudinal works on left and right bank: Scouring protection by vegetatif reinforced timber Krainer wall on gabion foundation, brush layers, willow piles, chemically untreated coconut fibre mesh
Transversal works: 3D rough blockstone ramp, timber ram belts



Case study 5) 2008: Ariège River 25m below the residential area – Bed and lower limestone cliff stabilisation by both 120m longitudinal live structure and 65m transverse hydraulic structure

Preliminary studies

Collapsed cliff edge in 2006

Pictures left and right: View to pathology of the access road on top of the escarpment in 2006.

Case study 5) 2008: Ariège River 25m below the residential area – Bed and lower limestone cliff stabilisation by both 120m longitudinal live structure and 65m transverse hydraulic structure

Preliminary studies

Our ongoing river bed survey in 06/2006 to obtain alluvium and subsoil parameters

Case study 5) 2008: Ariège River 25m below the residential area – Bed and lower limestone cliff stabilisation by both 120m longitudinal live structure and 65m transverse hydraulic structure

Preliminary studies

Design principle of the hydraulic blockstone Rough Ramp shown by longitudinal profile – Hydraulic assessment was made during preliminary-studies stage

Case study 5) 2008: Ariège River 25m below the residential area – Bed and lower limestone cliff stabilisation by both 120m longitudinal live structure and 65m transverse hydraulic structure

Construction stage

Background of right rviver bank : Greened Log Cribwall called « Krainerwand » construction work is ongoing

Foreground of right rviver bank :Hydraulic rough ramp construction work by timber pile driving is ongoing
Ariège runoff is shifted to left river bank !

Case study 5) 2008: Ariège River 25m below the residential area – Bed and lower limestone cliff stabilisation by both 120m longitudinal live structure and 65m transverse hydraulic structure

Construction stage

Work progresses in minor river bed from right bank to left bank

Pile setting is required for reinforcing RipRap blockstones

Case study 5) 2008: Ariège River 25m below the residential area – Bed and lower limestone cliff stabilisation by both 120m longitudinal live structure and 65m transverse hydraulic structure

Lifetime monitoring

Downstream picture taken in June 2013

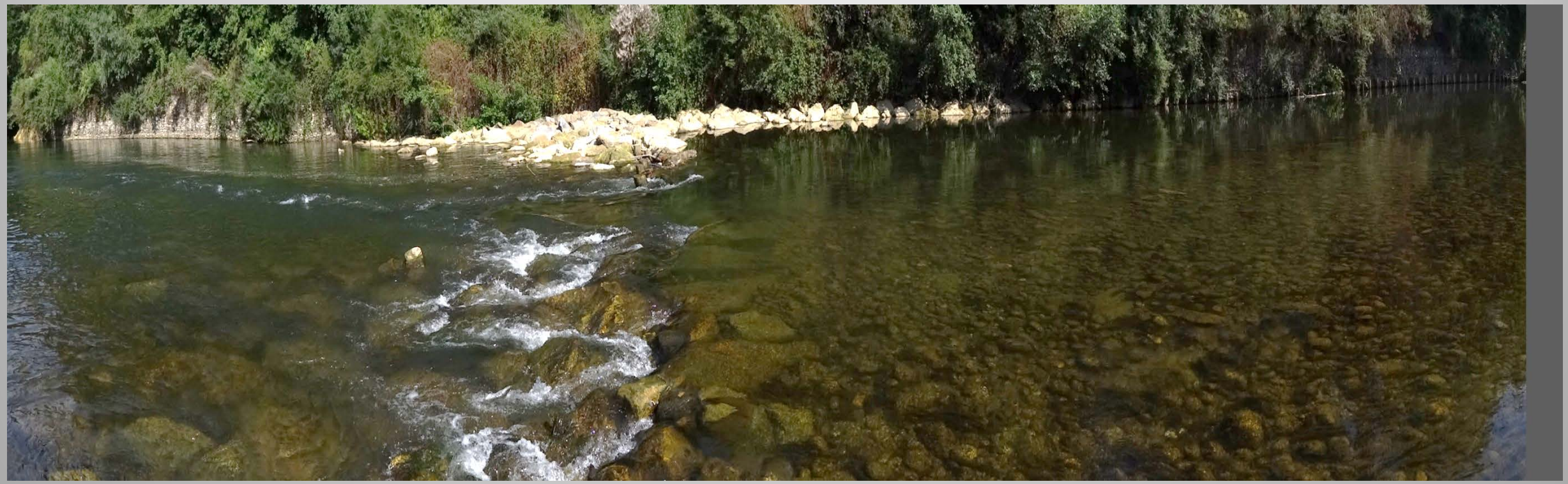
Gabions, timber cribwall and hydraulic rough ramp designed with a bypass for canoes/kayak sporting

Transversestream picture taken in October/November during low runoff

Case study 5) 2008: Ariège River 25m below the residential area – Bed and lower limestone cliff stabilisation by both 120m longitudinal live structure and 65m transverse hydraulic structure

Lifetime monitoring

Here panoramic view of the rough ramp in September 2016. The intended raising of the underwater river bottom by about 40cm in the upstream can be seen well from the gravel granulation



Case study 5) 2008: Ariège River 25m below the residential area – Bed and lower limestone cliff stabilisation by both 120m longitudinal live structure and 65m transverse hydraulic structure

Lifetime monitoring

State of health of the 65m wide hydraulic rough ramp in August 2014:
Fishing pleasure (>>free permanent O2 entry!)

Bathing pleasure and state of health of the rough ramp in September 2016: (in the background the row of wooden piles in front of the gabion wall).

Public spaces – Erosion protection of a city museum area

Case study 6) 2007: Hers Vif River – 1.000m² Steep cliff stabilisation and 50m Log Cribwall onto Gabions ensuring safety access to classified medieval buildings
Construction time 4 months – Pre-tax costs 290.000 € (249.400 £)

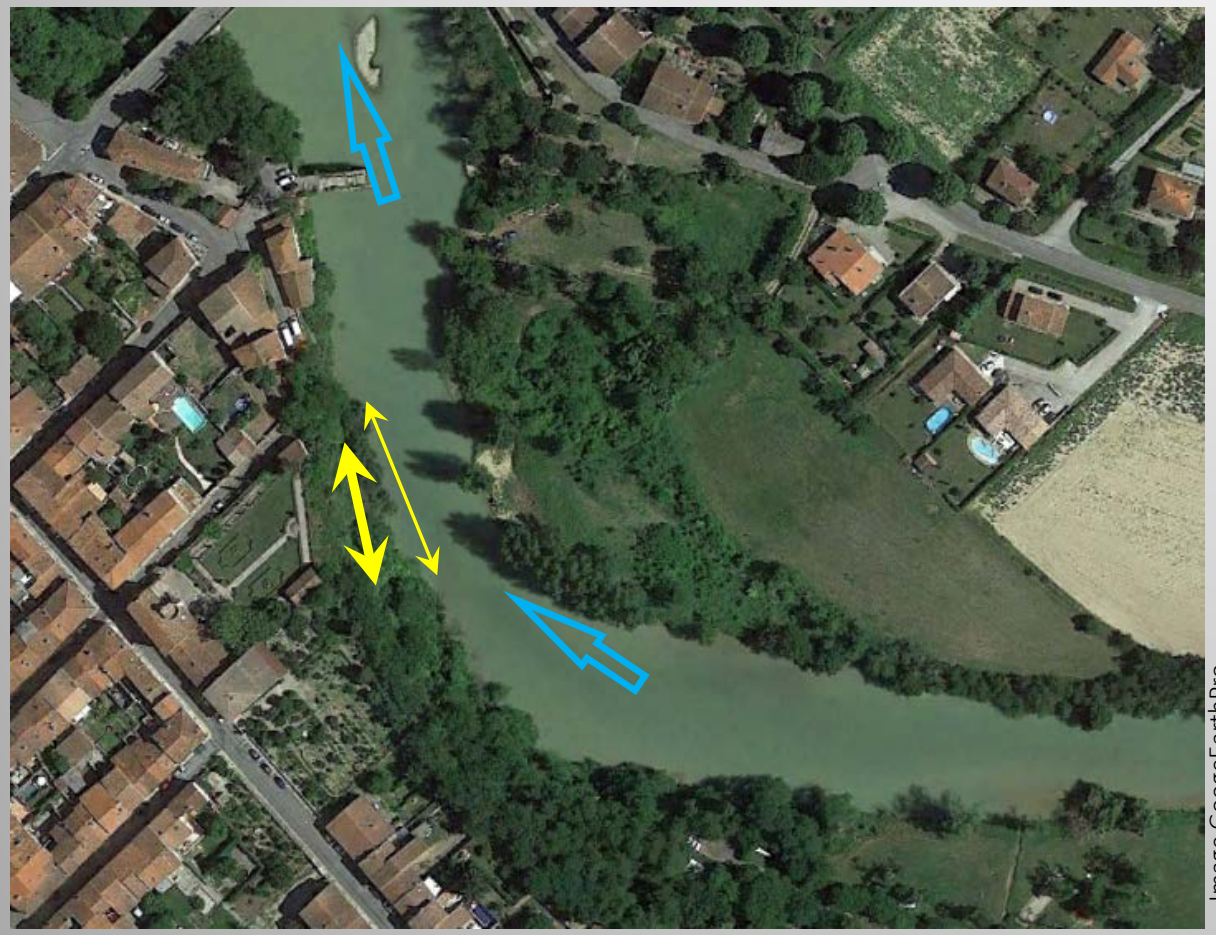


Image GoogeEarthPro

Damage case: Far advanced cliff erosion but less bank erosion problem; imminent risk of upper cliff edge collapse threatening public space

Preliminary studies: Historical, topographical and bathymetrical data levys, subaquatic river bed survey, hydrodynamical analyses…

Program mission: Project establishment, contract drafting and site monitoring in ordert to reduce erosion risk **Geometric shape:** Variable bed width 55/35/45m; protected bank height 23m by slope gradient roughly 60° and design flood Q_{50} ~ 600m³/s

Realised longitudinal works: Live Log Cribwall built onto submerged Gabion wall

Realised cliff works: Combined drilled concrete injection anchors on top bank and greenable 3D steel structure on cliff surface

Transversal works: Not required at this time

Case study 6) 2007: L'Hers Vif River – 1.000m² Steep cliff stabilisation and 50m lower bank protection ensuring safety access to classified medieval building and his garden

Preliminary studies

Condition of limestone cliff site in 2006: several detached areas and others with potential for collapse

Accessable public viewing platform >>

Direction of flood discharge

Case study 6) 2007: L'Hers Vif River – 1.000m² Steep cliff stabilisation and 50m lower bank protection ensuring safety access to classified medieval building and his garden

Preliminary studies

7m thick sand and gravel layer >>

At least 16m high limestone marl layer >>

Logging work in March/April 2007 to check the stability of the whole steep cliff

Case study 6) 2007: L'Hers Vif River – 1.000m² Steep cliff stabilisation and 50m lower bank protection ensuring safety access to classified medieval building and his garden

Construction stage

Ground anchor preparation for reinforcing upper cliff areas, sizing in accordance to geotechnical survey results

Implementation of 7-m-long ground anchors by drilling and concrete injection

Case study 6) 2007: L'Hers Vif River – 1.000m² Steep cliff stabilisation and 50m lower bank protection ensuring safety access to classified medieval building and his garden

Construction stage

Anchors for tightly placing the 3D steel structure onto the purged steep slope, sizing in accordance to geotechnical survey results

Implementing 3D KRISMER steel structure panels

Case study 6) 2007: L'Hers Vif River – 1.000m² Steep cliff stabilisation and 50m lower bank protection ensuring safety access to classified medieval building and his garden

Detail of embedded 3D KRISMER steel structure panel: fixing system by steel cables, themselve held by anchors

Case study 6) 2007: L'Hers Vif River – 1.000m² Steep cliff stabilisation and 50m lower bank protection ensuring safety access to classified medieval building and his garden

Construction stage

Installing steel structure in progress from upstream to downstream

Filling the 3D steel structure with ballast using a mobile hydraulic crane

Case study 6) 2007: L'Hers Vif River – 1.000m² Steep cliff stabilisation and 50m lower bank protection ensuring safety access to classified medieval building and his garden

Cliff condition **one year later after completion date** (picture taken in April 2008)

<<Growing vegetated log crib wall onto gabion wall

Case study 6) 2007: L'Hers Vif River – 1.000m² Steep cliff stabilisation and 50m lower bank protection ensuring safety access to classified medieval building and his garden

Cliff condition **5 years later after completion date** (picture taken in June 2013)

Conclusion of my presentation based to carrying out both NbS and mixed techniques works since more than 30 years

Reintegration into the river landscape of violent bank slides near residential areas and infrastructure with NbS techniques is feasible.

The prerequisites, however, are: Sufficient damage cause analysis by integrated engineering approach, good training and experience of the hired construction companies during construction stage. In addition, clients need to throw out some of their old ideas of exclusively mineral and similar attachment techniques in the actual context of climate changement ☺.

This presentation serves as a demonstration of the potential of sustainable NbS steep bank revegetation for infrastructure and residential area protection, based on an integrated workflow process and acompagnied by geotechnical analysis using some examples realized since 1992 in France.

Thank you for your interest and attention
Dankeschön für Ihr Interesse und Aufmerksamkeit
Merci de votre intérêt et de votre attention
Děkujeme vám za váš zájem a pozornost
Gracias por su interés y atención
Obrigado pelo seu interesse e atenção
Takk for din interesse og oppmerksomhet
Kiitos kiinnostuksestanne ja huomiostanne

☺ I WISH YOU MUCH JOY IN ENGINEERING NATURE-BASED SOLUTIONS AND MIXED TECHNIQUES ☺

PPT virtual poster from Klaus Peklo Dipl.-Ing., graduate engineer
- Designer Soil and Fluvial Bioengineering and site manager expert -