Managing materials across the Isere river and “Isere amont” works

O. Manin
Symbhi (Syndicat Mixte des Bassins Hydrauliques de l’Isère), Grenoble, France

J.-F. Frezet & L. Boutonnier
Egis, Seyssins, France

ABSTRACT: The « Isère Amont » project is based on the implementation of « expanding flood areas » all along the 50 km long Isère valley and aims to protect the urbanized areas from a bicentennial flood, from Pontcharra to Grenoble. The project launched in the early 2012 is worth 112 million euros. A first construction phase extends to 2016 for the downstream 10 km of river, and costs 52 million euros. The first hydraulic works consisted in decreasing gravel banks and partially clearing the vegetation to improve the water-carrying capacity and facilitate the transit of sands and gravels up to deposit areas. Afterwards material extractions occurred to settle two deposit areas.
Different types of materials were extracted :
- Silty materials, or fine sands, reused to fill ponds ;
- Gravelly materials, stored and reused to achieve levees confortments ;
- Materials infested with invasive and other kinds of wastes.

1 OVERVIEW OF THE PROJET

The “Isère Amont” project is a flood control project on the Isère river upstream from Grenoble. It aims to protect the urbanized areas of the Gresivaudan valley from floods (the length of the river involved is about 50 km).
The Isère river watershed is mostly located in the highest parts of the French Alps. Therefore, sedimentation control is also an important part of the flow control.
The flow control part consists in :
- Enhancing existing embankment in selected areas along the river ;
- Settling new embankment in the flood plain to create so called “Champ d’Inondation Controlée” (CIC), ie expanding flood areas ;
- Removing partially or completely the banks inside the river channel.

The other topics of the project are :
- Environmental restoration of sand and gravel quarries ;
- Two deposit areas in the main river channel.

The project is phased according to three steps :
- The first step at the downstream part of the valley and currently under works : “Tranche 1”
- The second step mainly at the upstream part of the valley : “Tranche 2”
- The last step : in the middle of the project area : “Tranche 3”

Some key figures of the project are mentioned in the following table.

Table 1. Key figures for earthworks of the Isère Amont Project

Length of structure (ml)	Tranche 1	Tranche 2	Tranche 3
Embankment rehabilitation	19 000	9 900	8 300
Confinement merlons	4 500	9 800	7 100
Bank removal	5 200	6 900	
Sedimentation pit	4 900		

This paper aims to present the different types of materials extracted from the Isère river, their characteristics, how they will be reused, and to explain the principle of a deposit area for the further maintenance of the river.

2 DETAILS OF THE EARTHWORKS

2.1 *Sources*

There are two main sources of materials, from the main channel : deposit areas and bank removals.

Figure 1. Extractions from a bank removal in Grenoble along the Isere river.

Figure 2. Extractions from the deposit area of Domene along the Isere river.

The resource distribution (including top soil) is shown in the following table.

Table 2. Resource distribution from the main river channel (forecasted)

		Type	Estimated total volume (m3)
Tranche 2	Bank 1	Mainly Emerged	20000
Tranche 2	Bank 2	Mainly Emerged	61000
Tranche 2	Bank 3	Mainly Emerged	50300
Tranche 2	Bank 4	Mainly Emerged	67900
Tranche 2	Bank 5	Mainly Emerged	71400
Tranche 2	Bank 6	Full river width	104200
Tranche 2	Bank 7	Mainly Emerged	40300
Tranche 2	Bank 8	Mainly Emerged	38100
Tranche 2	Bank 9	Mainly Emerged	16900
Tranche 2	Bank 10	Mainly Emerged	50700
Tranche 2	Bank 11	Mainly Emerged	35900
Tranche 2	Bank 12	Mainly Emerged	57600
Tranche 1	Sedimentation pit 1	Full river width	35000
Tranche 1	Sedimentation pit 2	Full river width	65000
Tranche 1	Bank 1	Mainly Emerged	33000
Tranche 1	Bank 2	Mainly Emerged	7200
Tranche 1	Bank 3	Mainly Emerged	5500
Tranche 1	Bank 4	Mainly Emerged	5000
Tranche 1	Bank 5	Mainly Emerged	15000
Tranche 1	Bank 6	Mainly Emerged	18000
Tranche 1	Bank 7	Mainly Immerged	15000
Tranche 1	Bank 8	Mainly Immerged	8000
Tranche 1	Bank 9	Mainly Immerged	41000
Tranche 1	Bank 10	Mainly Immerged	36000
Tranche 1	Bank 11	Mainly Immerged	49000
TOTAL			947000

The sum of all the bank removals and sedimentation pit diggings is just shy of 1 million cubic meters of various soils.
At the end of 2013, almost two thirds of Tranche 1 earthwork has been carried.

2.2 *Needs*

Rehabilitation works, which consist in embankments and confinement merlons building, consume a lot of materials.

For example, on confinement merlons the needs as described at the end of the design phase is depending of the height of the levee :

- Lower than 1.20 m : no special recommendation, pending forecasted material extracted from the river (ie silty sand and silty gravel are usable) ;
- Between 1.20 and 2 m high, D1/D2 and D3 materials, according to “GTR” standards (ie coarser fraction of sandy gravel), Kenney and Lau criterion should be verified ;
- Higher than 2 m the use of materials extracted from the river could not be planned. Soil were proposed to be sourced from local stone quarries (see table 5 for geomechanical properties)

For the embankment rehabilitation it was planned that most of the works will be managed with materials extracted from the river.

2.3 *Earth movement*

Materials extracted from the river are screened and sorted on site.
<u>Soils polluted by invasive plants</u> are transported in dedicated abandoned sand and gravel pits in the flood plain. These dedicated flooded pits are equipped with special devices in order to limit invasive infestations.
There is one pit on Tranche 1, but it is located upstream of main works in Tranche 2 area indeed.
There is also 1 for each other Tranche, not ideally located and generating a lot of trucking.
<u>Reusable soils</u> (mainly silty gravel and sandy gravel) are carried and stored on so called “Station de Lavage Concassage Criblage” (SLCC) where they can be later processed for reuse, ie crushed and screened.
At this stage 4 SLCC are planned : 2 on Tranche 1 already in use, and 2 on Tranche 2. No SLCC is planned for Tranche 3, but it should change with the feedback of Tranche 1 work phase.
<u>Other soils</u>, non polluted and which are not needed for reuse, are carried to other abandoned sand and gravel pits, for environmental rehabilitation. Vertical banks of the abandoned flooded pits limit biodiversity. The aim is to create shallow water with soils extracted in the river and not reused or reusable. These shallow water will be modeled to become reed beds for example.
On each Tranche there are 3 rehabilitated gravel pits, including the invasives disposal sites.

3 NATURE OF EXCAVATED SOILS

3.1 *Silty sands : “sablons”*

It is the top layer in sand banks.
After each flood, layer as thick as 50 cm to 1 m meter can be seen on the upper parts of sand banks.
These silty sands are mainly A1 according to the French GTR classification system, ie fine soil with low plasticity. The max diameter is less than 5 mm.
This top layer is usually contaminated with invasives and processed as such. If not, it is used as topsoil for seeding at the end of the work phase.

3.2 *Silty gravels : “Limons tout venant ”*

This layer is not well defined, as it is a transition between the top layer of silty sand, and the bottom layer of sand and gravel.
Those silty gravels contain a good fraction of sand and are A1, A2 or B1, B2 or B5 material according to the French GTR classification system.

3.3 *Sandy gravels : “Sables et graves”*

This layer is at the bottom of the banks and in the river main channel. These sandy gravels can have a marginal fraction of fine, and are B3, B4. Indeed most of them are D2 or D3.

Figure 3. Silty gravels extracted from the Isere river.

Figure 4. Sandy gravels extracted from the deposit area.

Figure 5. Sandy gravels extracted from the bank removal.

3.4 *Proposed geomechanical properties*

Pending analysis of direct shear test and triaxial test, the geomechanical properties of Isère deposit /soil are detailed in the following tables :

Table 3 : Isère deposit in situ geomechanical properties

Nature	Unit weight (wet) kN/m3	Friction angle Φ' (°)	Cohesion C' (kPa)
Silty sand (Sablons)	16	28	4
Silty gravel	19	31	4
Sandy gravel	19	34	0

Table 4 : Isère deposit geomechanical properties after processing in SLCC and compaction

Nature	Unit weight (wet) kN/m3	Friction angle Φ' (°)	Cohesion C' (kPa)
Silty gravel	19	31	4
Sandy gravel	19	37	0

To complete the earlier tables, other materials needed for the building are :

Table 5 : Other material sourced outside the river bed

Nature	Unit weight (wet) kN/m3	Friction angle Φ' (°)	Cohesion C' (kPa)
Crushed stone (merlons 2-4 m)	21	42	0
Coarse raw material 0/400 mm (merlons higher than 4 m)	22	45	0
Rip rap	20	45	0

4 OPTIMIZATION OF SOILS REUSE

4.1 *Optimizations during design phase*

In the initial design phase, no reuse of soils extracted from the river was planned. Those soils were simply stored on SLCC and sold to building companies. It was later assessed that this choice will not be cost and environmentally efficient.

So, during detailed design phase, the reuse of soils extracted from river banks and sedimentation pit has been studied.

The first change was to consider that the extraction phase could be significantly shorter than the rest of the building phase. So, through SLCC already needed in the no reuse scenario, temporary storage was made possible.

The second change was to define designs that can help to increase the reuse of soils.

The scheme of reuse is :

<u>Silty sands :</u>

- Topsoil for seedings ;
- Soils for quarries rehabilitation :

<u>Silty gravels :</u>

- Merlons less than 1.2 m high ;
- Access ramps to embankment from the flood plain ;
- Soils for quarries rehabilitation.

<u>Sandy gravels</u>

- Subgrade of trails of road on the confinement merlons of embankment ;
- Merlons between 1.2 and 2.0 m ;
- Drainage toes on embankment rehabilitation are made of 20/80 gravel screened from sandy gravel on SLCC.

If needed, silty sands treatment has been successfully tested.

Reuse of soils extracted from the Isère river on merlons higher than 2 m was not selected. The key criterion of this decision was the use of an homogenous levee design.

4.2 *Optimizations of design during building phase*

When this article was written, those optimizations were being measured.
The goal is to allow reuse on merlons up to 4 m high instead of sourcing materials from outside areas. It is possible thanks to a change in the design, to zone levee design from an homogenous design.
Initial testing on compacted gravel D3 according to GTR tends to show that friction angle is higher than the 42° requested for confinement merlons up to 4 m. In fact it seems that geomechanical properties of sourced “crushed stone” can be matched, leaving only the internal erosion to cope with. It can be done with an internal core of silty sand.
It tends to improve the reuse of sandy gravel and to open a new use for silty sand. Until this optimization, silty sand were not used in merlons or embankments.

4.3 *Reuse of materials from other projects*

The Symbhi contracts another major project in building phase too, on the Romanche river. It is 20 to 30 km away from the Isère Amont Tranche 1 works. The Romanche river is more torrential than Isère and the river bed is made of pebbles. These peebles extracted from the river for the need of the project are trucked to Isère amont Tranche 1 works and use to fill the gabion mattress on embankments.

5 CHALLENGES

5.1 *Soil polluted with invasive vegetation*

<u>Quantities</u>
The thickness of the contaminated layer has been difficult to forecast. At some point during Tranche 1 works up to 3 m of contaminated soil has been discovered. Some human activities tend to have huge impacts on the thickness of this layer, especially unofficial BMX grounds laid on sand banks and implying a lot of earthworks without any care concerning invasive plants.
For Tranche 1, the quantity of contaminated soil has been underestimated, leading to a loss of reusable soils. Indeed it appears that only one disposal site available for these soils didn’t clearly permit any flexibility to adapt and re-optimize earth movement.
For Tranche 2 and 3, it has been decided to allow disposal in all rehabilitated quarries. The cost of the invasives control device at each quarry (presented further) is easily repaid by the flexibility to adapt ear movements and its efficiency proved.
<u>Control device at disposal site</u>
The control device is a floating barrier with a 70 cm deep net under the water level. This device is set in the vicinity of the unloading area. The goal of this device is to catch all the part of the invasive plants that are floating at the surface.
This device is sometimes cleaned.
A visual inspection of the banks and, if necessary a manual cleaning, provide more security.
During Tranche 1 works, the control device has proved its efficiency, paving the way for using each quarry on Tranche 2 and 3 for invasives disposal.

5.2 *Waste in urban sections*

On bank 9 in Tranche 1, in the urbanized area of Grenoble, more than 20 tonnes of tires have been extracted from the sand bank.
So wastes can be a real problem in urban sections.

5.3 *Sand bank extraction*

The time between the design phase and the building phase can reach several years, especially if you consider that topographic data are always among the first surveys carried.
As the river is still deposing a lot of silty sand and sandy gravel, sand bank volume is hard to estimate accurately at the tender phase.
Furthermore, floodings of the excavation area did occur during excavation phase, overtopping cofferdams. It leads to deposit sandy silts and silty gravel on fresh layer of sandy gravel. When excavations works resume, a part of the sandy gravel is mixed with new deposits leading to a loss of sandy gravel volume.
As a feedback for this analysis, we can consider that we have tended to underestimate sand bank volume about 10 to 20 % average, and sometimes more on the smallest sand banks. But sandy gravel volume may be lower than forescasted, partly due to floodings during excavation.

5.4 *Screening of gravel*

Indeed, even if it was anticipated as a challenge, it was not. The fine fraction of the sandy gravel doesn’t present any problem on reuse.
The whole process to the reuse from the sandbank involves a lot of loading / unloading :

- First temporary storage on the sandbank ;
- Loading and trucking to SLCC ;
- Unloading on temporary storage on SLCC ;
- Loading and mixing of crude gravel (D3, C1B3 according to GTR) with less crude gravel (sandy gravel) leading to lessening the fine fraction ;
- Processing if necessary ;
- Unloading on temporary storage ;
- Loading and trucking to reuse site…

Figure 6. Reusing materials all around gravels.

The majority of the reuse soil are in fact D3 soils, which are very low fine fraction (less than 12% passing at the 80 µm sieve, and Dmax more than 50 mm).

5.5 *Servicing of SLCC*

One unexpected issue was the nesting of the Beeater (Guêpier d'Europe) on the slopes of topsoil storage. It is a protected species according to the decree of April 17th, 1981. We had to stop exploitation of the topsoil storage till the end of the nesting period.

5.6 *Servicing of deposit area*

One challenge with deposit area is to secure access to the river bed from the embankment. A minimal amount of excavation is needed so that the longreach excavator can create a 8 m wide temporary fill in the river bed. This fill is used by truck to move around the excavator for loading operations.
So minimal average excavation depth is 1 m. If average excavation is less, there not enough material to build the temporary fill.
Moreover, during servicing and maintenance of the deposit area, the dredged channel can move from one bank to the other. An access to the river bed from both banks is therefore needed.
Annual excavated volume will be in the 40 000 – 120 000 m^3 range. Gravels from this maintenance phase will be sold, and should more than repay for the cost of excavation.

6 CONCLUSION

The « Isère Amont » project is an innovative project based on expanding flood areas because it uses systematically all the natural and agricultural areas along the Gresivaudan valley to store flows over the 30-year return period flood. The plan has been optimized for the 200-year return period flood.
It is a large-scale project which enables to reuse all the materials extracted from the Isere river : no material contribution from other locations is necessary and each type of materials has a special use in the Gresivaudan valley (levees, gravels…).
These arrangements were optimized during long studies and designs. The dialogue with all the administration services, but especially with the elected representatives and the inhabitants, finally allowed the technical optimization and the best acceptability of these arrangements : the link between people and the river will appreciably evolve in the coming years.
The rhythm of the works is fixed by the budgetary capacities : a 12 million euros budget is fixed every year.
After the first two years of intervention with 20 million euros of works realized, the schedules are maintained and the costs also.
The arrangements are realized according to the rules. A more complete feedback will be able in 2016 at the end of the first construction phase, then at the end of the project, around 2022-2025.

7 THANKS

The contracting authority thanks all the technical engineers who have participated in the conception of the « Isère Amont » project, but also all the elected representative, the associations of the valley (environment, leisures…) and the inhabitants who participated in the dialogue around the elaboration of this project, during more than 300 working meetings and 35 public meetings. The contracting authority thanks all the companies in charge of these works and their participants.

8 REFERENCES

Egis, Hydrétudes. 2009. *Travaux d'aménagement hydraulique, environnemental et paysager de l'Isère à l'amont de Grenoble. Maîtrise d'œuvre tranche 1. Etudes de projet.*

Egis, Hydrétudes. 2011. *Travaux d'aménagement hydraulique, environnemental et paysager de l'Isère à l'amont de Grenoble. Maîtrise d'œuvre tranche 1. Dossier de consultation des Entreprises.*

Sogreah, BRL Ingénierie, Gay Environnement, 2008. *Elaboration de la phase AVP du projet intégré « Isere Amont ».*