A combination of dredging/dewatering technologies to manage artificial reservoir sedimentation

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1. RATIONALE

Dam construction usually has an impact on river sediment transport, leading to erosion phenomena downstream the dam and along coastal areas, and to sediment deposition in the reservoir itself. This impact can be very important where the erodibility of the dam catchment basin is quite strong, and has to be duly considered in the dam management, to maintain a sustainable reservoir capacity and a correct efficiency of dam bottom outlets.

Different technologies are available for sediment removal from reservoirs, and the selection of the best one must be done taking into consideration several morphological and hydraulic parameters of the dam, of the relevant reservoir, and of the catchment basin as well (gross storage capacity, mean annual sediment inflow and mean annual runoff).

Most common technologies can be classified into three main categories: interventions on catchment basin (reforestation, check dams, etc.), deposition removal from reservoirs (flushing, hydrosuction, dredging and trucking), and sediment routing (sluicing, sediment by-pass, density current venting). When dredging or trucking technology has been selected, an additional activity has to considered, e.g. the final disposal of the sediments removed from the reservoir.

This paper deals with an interesting experience of sediment removal from a small reservoir located in the Northern part of Italy, on the worldwide famous Dolomites, the mountains that have been declared part of the human heritage by UNESCO. We are talking about Monguelfo dam, located in the lower part of Pusteria valley, north of Bozen city, where ALPERIA, the Public Company who is managing Monguelfo dam, and most of dams located in Bozen province, has its headquarter.

In 2018 ALPERIA launched a tender to select a Contractor able to propose a cost-effective technology to remove about 3,700 m^3 of sediments settled near the dam bottom outlets located on the right flank of the valley close to the dam.

The tender has been awarded to THETIS COSTRUZIONI, a Contractor which designed, supplied, installed, tested and managed a dredging system which allowed to complete the activity required by ALPERIA fulfilling contractual time and environmental constraints. In the following pages the reader will find in detail ALPERIA requirements considered to select the dredging system and to design the geotextile tubes where sediments have been pumped, jobsite organization, monitoring plan put in place by the Contractor, and finally the conclusions.

2. REFERENCE DATA AND CLIENT REQUIREMENTS

2.1. Reference data

Monguelfo dam has been built in 1957 - 1958 on Rienza stream, a tributary of Adige river, in the eastern part of the Dolomites (Bozen province). Monguelfo dam is a concrete dam, with the following characteristics (Figure 1):

Figure 1. Monguelfo reservoir

• Dam height:	51.00 m
• Free board:	1.00 m
• Normal operating water level:	1,055.00 m a.m.s.l.
• Maximum water level:	1,056.00 m a.m.s.l.
• Dam volume:	9,500 m^3 of concrete
• Crest length:	140.00 m
• Reservoir volume:	6.54 x 10^6 m^3
• Catchment basin surface (direct):	430 km^2
• Catchment basin surface (connected):	160 km^2
• Flood control volume:	0.44 x 10^6 m^3
• Flood discharge:	795 m^3/s

The dam is equipped with two bottom outlets, located in the right flank of the reservoir, with invert level of 1,026.00 m a.m.s.l., which drive the water to a tunnel, 5.0 m diameter, through two smaller tunnels, 4.0 m diameter.

2.2. Area to be dredged

ALPERIA, the Public Company responsible for management of Monguelfo reservoir, during the last years monitored the sedimentation in the reservoir and more in detail sedimentation rate close to the dam structure, through a comparison of topographic campaigns, to understand the evolution sedimentation phenomenon, and its impact to ancillary structures of the dam (dam bottom outlets and water intake), in terms of efficiency and safety.

On basis of this monitoring, ALPERIA noticed that the quantity of sediments, coming from the rain action on the ground of the catchment basin, was reaching an alert level especially nearby the intake of the two bottom outlets, generating a possible risk of bottom outlet clogging. Through the comparison of topographic surveys developed along several years, ALPERIA identified the area where the sediments have to be removed, and the relevant total amount.

Total area to be dredged (Figure 2) has a surface of 3,000 m^2 and is located at a water depth variable between 25 and 30 m, according to the water oscillation in the reservoir. Globally 3,700 m^3 have to be removed to assure a correct efficiency of bottom outlet structures, and the right safety factor. The average thickness of the sediment layer to be removed was ranging between 2 and 4 m.

In the following picture we can appreciate the area to be dredged (green area), which affects dam bottom outlets, located on the right side of the dam, the water intake located on the same side between two bottom outlets, through which the water is driven to Bruneck hydroelectric power plant, and the disposal area (blue area) where dredged sediments have been sent and incapsulated in geotextile tubes.

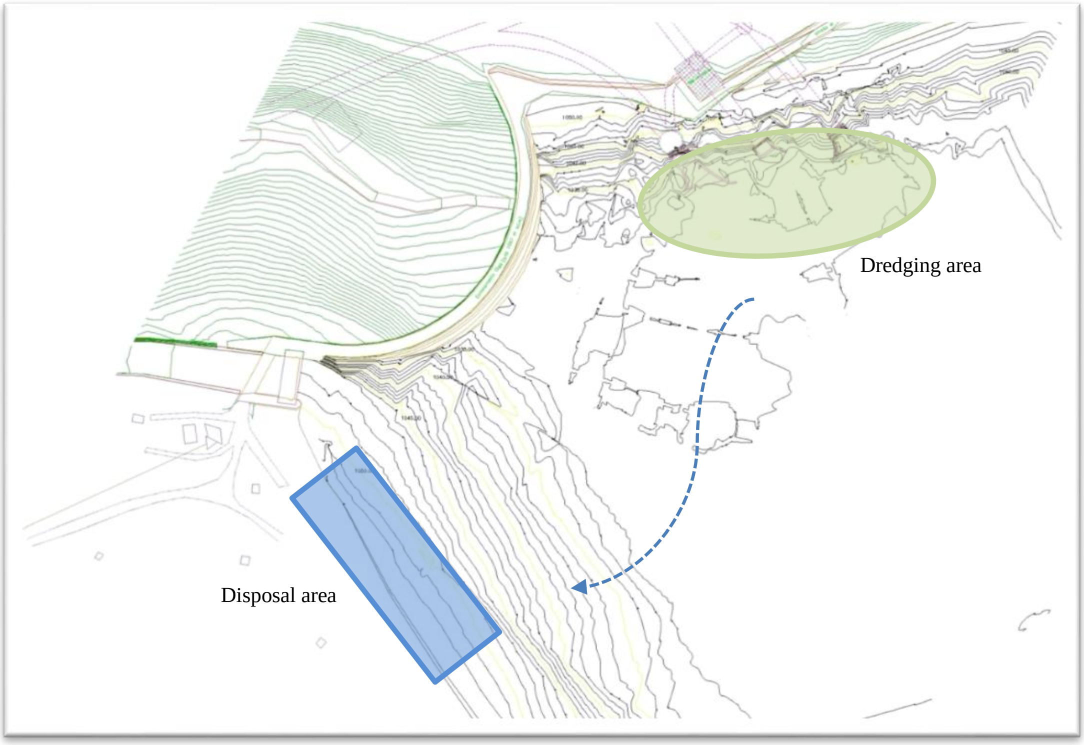

Figure 2. Area to be dredged & final disposal area

Dredging activity has been developed in front of concrete structures of the intakes of the bottom outlets, therefore the submersible pump operator had to carefully proceed between existing structures to avoid any damage and to collect the sediments exactly where required by the Client.

To correctly design dredging system and determine dredging efficiency of the submersible pump, ALPERIA supplied to the tenderers information on the sediments to be dredged, collected through a field campaign developed in the dredging area. Four boreholes have been driven, and for every borehole, an undisturbed sample has been taken and carried to a laboratory to determine grain size distribution and unit weight.

According to the grain size distribution analysis, the sediment to be dredged is a clayey silt with a small percentage of sand.

In the following table, main geotechnical parameters have been included; sediment to be dredged have a mean diameter of nearly 18 microns, and a wet density of 16.3 kN/m^3.

Table 1. Characteristics of sediment to be dredged

sample	D_{16} (microns)	D_{50} (microns)	D_{84} (microns)	Wet density (kN/m^3)
1	4	12	35	15.3
2	6	18	49	16.4
3	5	20	62	17.2
4	5	18	51	15.5

2.3. Client requirements

On basis of dam management plan, and on the environmental constraints, ALPERIA requested to fulfil following design criteria:

- Area to be dredged located in front of the bottom outlet intakes (3,000 m^2)
- total quantity to be dredged equal to 3,700 m^3
- Final disposal of dredged material in an area located on the left side of the reservoir
- sediment containment structure made with geotextile tubes laid in two layers
- Total duration of dredging activities (four months between May and August)
- No water level variation to be considered inside the reservoir.

3. PROPOSED SOLUTION

On basis of Client's requirements, and taking into consideration dam location and characteristics, and usual dredging solutions already experimented for similar projects, the Contractor decided to propose following technical solution:

- Submersible slurry pump located on a pontoon fully equipped, able to cover all the area to be dredged (3,000 m^2);
- Use of side excavators installed on both side of the submersible pump to improve pump efficiency when working with cohesive sediments;
- Submersible pipeline DN250, rubber made, to convey the slurry from the pump to the pontoon;
- Floating pipeline DN315, polyethylene made, conveying the slurry from the pontoon to the final disposal area, located on the left side of the reservoir, where geotextile tubes have been laid in two rows; total distance between dredging and disposal area was 200 m;
- Preparation of a sediment final disposal area where N. 6 geotextile tubes have been supplied, installed and filled with dredged sediments;
- Design and installation of a flocculant mixing plant where slurry discharge coming from dredging area have been mixed with a flocculant to avoid dispersion of sediments outside geotextile tubes during their filling;
- Service boat to allow the staff involved in the activity to reach the pontoon and to leave it at the end of the working shift.

Selected pump is a slurry hydraulic pump with a total power of 115 kW at 1,450 rpm, with a capacity of 500 – 600 m^3/h and a total head of 36 m. Hydraulic engine of the pump is driven by a power pack with a diesel engine able to supply a total power of 220 kW needed for all the equipment of the pontoon (winches, hoist, side excavators, cabin heating and conditioning, night lights, etc.).

In the Figure 3 general plan and cross sections of the final disposal area are depicted.

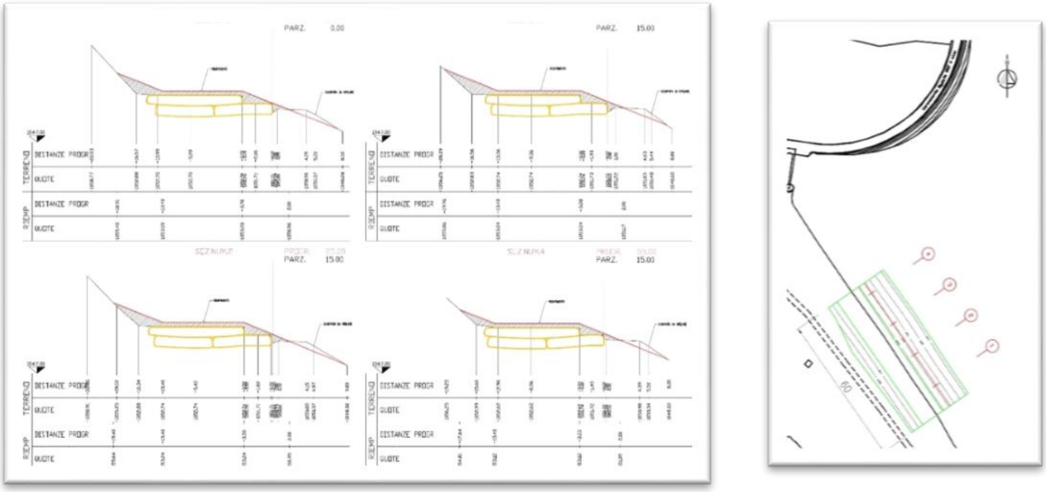

Figure 3. Final disposal area: general plan and cross sections

3.1. Dredging system

Considering the characteristics of the sediment to be dredged, and the total dredging time allowed by the Client, average slurry discharge has been equal to 500/600 m^3/hour, with a volumetric concentration of 7 – 10%, and discharged into geotextile tubes located roughly 200 m far from dredging area itself. The pump selected for this project has been DRAGFLOW pump HY85/160B; it’s a centrifugal slurry pump equipped with side excavators (Figure 4).

Figure 4. Centrifugal slurry pump with side excavators

As said before, most of the percentage of the sediment to be dredged is cohesive, therefore to assure the correct productivity requested by total project time allowed by ALPERIA, the pump has been coupled to two side excavators, specifically designed for cohesive materials (Figure 5).

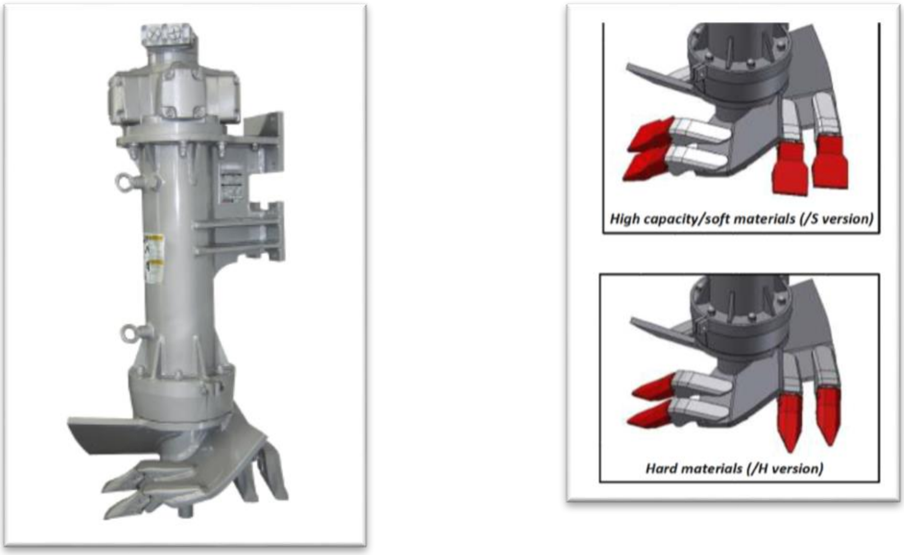

Figure 5. Side excavators for cohesive sediments

Submersible pump has been installed and managed through a pontoon specifically equipped (Figure 6). DRAGFLOW's pontoons follow a modular design that has been tested over the years in several projects all around the world. The submersible pumps adopted for this project allowed to use very compact pontoon, achieving at the same time quite large working depths requested by ALPERIA.

Figure 6. Pontoon

All DRAGFLOW’s pontoons are designed for an easy transportation either by container or by trucks. The pontoons are built with internal reinforcement structures and divided in different compartments. The pontoons follow a catamaran design with a steel tripod and hoist as main movement system for the submersible dredging pump. The pontoon is complete with handrails and skids under the floaters with an integrated high capacity fuel tank.

The pontoon is equipped with four mooring winches driven by individual electric motors, each one with cable length of up to several meters. The entire dredging equipment is easily controlled and operated from the central cabin were the operator manages all necessary controls to drive each component of the dredging system with indicators of working depths, current absorption and bathymetric survey system.

Figure 7. Aerial view of the dredging activity

3.2. Disposal area

Total quantity of sediments dredged in the area located nearby the inlets of the two bottom outlets, have been discharged inside N. 6 geotextile tubes located in a disposal area on the left side of the reservoir.

The disposal area has been excavated and levelled, and a layer of granular material has been laid over a geotextile to assure a correct drainage of the dredging water. Above the drainage layer, N. 4 geotextile tubes have been laid in two rows (2 tubes per row), and over them N. 2 bigger geotextile tubes have been laid (one row).

At the end of the filling activity, and once consolidation time has been completed, a soil coverage layer has been laid and compacted above geotextiles tubes, where a grass layer grew in a quite short time.

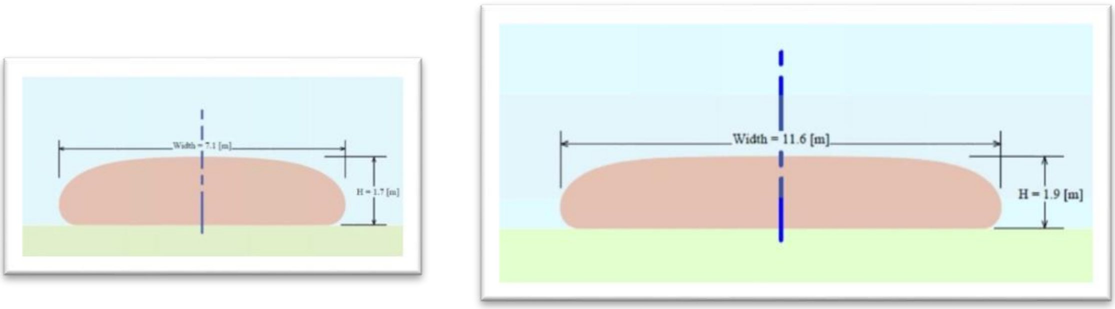

Figure 8. Geotextile tubes (lower layer on the left and upper layer on the right)

According to laboratory test developed on samples of sediments to be dredged, a total percentage of flocculant (anionic poly-electrolyte) equal to 100 ppm has been selected taking into consideration geotextile porosity, dewatering total time, mineralogy and grain size distribution of the sediments to be dredged.

In the following pictures, construction phases of the disposal area can be appreciated.

Figure 9. Final disposal area preparation (granular material over the geotextile)

Figure 10. Geotextile tube filling

Figure 11. Flocculant mixing plant

Figure 12. Dewatering of dredged sediments

Figure 13. Final covering of the geotextile tubes with soil

3.3. Monitoring activities

During dredging activity, a continuous check of the submersible pump position has been done, to be sure that dredging depth has been reached according to ALPERIA requirements. To do that, the Contractor had to know, during dredging activity, where the submersible pump actually is (x,y,z coordinates), which is the actual water depth where the pump is dredging, in relation with water level in the reservoir. For this purpose, a GPS device has been installed on board of the pontoon to know in every moment real time position of the submersible pump (x,y,z coordinates).

GPS coupled with topographic maps of the area to be dredged allowed to check if the dredging thickness required by the Client has been respected.

At the disposal area, total height of geotextile tube during the filling, and slurry discharge have been continuously checked to avoid damages at the geotextile tubes and to assure a correct quantity of flocculant.

Every geotextile tube has been equipped with three filling ports, connected through a pipeline to the main pumping line, needed to have a regular tube filling all along the tube.

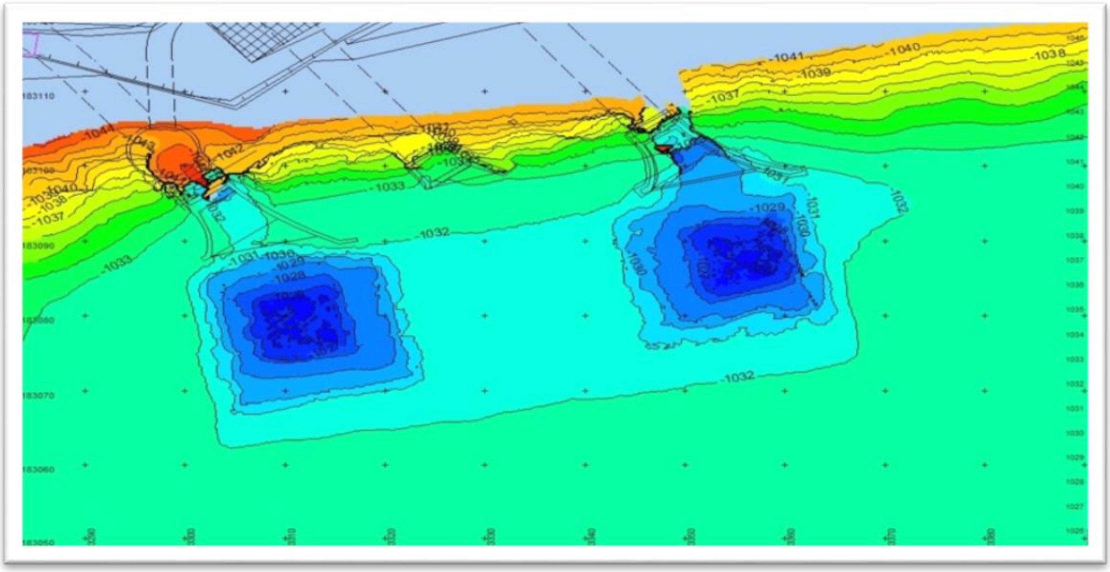

Figure 14. Multi-beam topographic survey after dredging

From the comparison between two multi – beam surveys, developed just before and just after dredging activity, Client's Project Manager has been able to check total quantity of the materials actually dredged from the reservoir and the relevant time needed to dredge.

4. CONCLUSIONS

Removal of sediments from intakes of bottom outlets has been concluded fulfilling ALPERIA requirements, taking into consideration supply and installation of the equipment, preparation of the final disposal area, installation and testing of the flocculant mixing plant, assembling and testing of the dredging system, maintenance of equipment itself, and finally the disassembly of the equipment, and the coverage of the final disposal area to allow grass growth.

A proper calibration of flocculant quantity per cubic meter of slurry allowed to develop de-watering process in a reasonable time, minimising the loss of fine sediments through the geotex-tile tubes.

Finally, the opportunity to dispose dredged sediments along reservoir perimeter allowed to save an important amount of water, because dewatering process gave back to the reservoir dredging water, allowing to use it to generate electric energy.

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