

Two interconnected water transfers for irrigation and drinking water, a structuring project for the high plains of Setif

Deux transferts d'eau interconnectés pour l'irrigation et l'eau potable, un projet structurant pour les hautes plaines sétifiennes

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Abstract. The “High Plains of Setif” is a mega water transfer project located in Northern Algeria and is divided into two systems: the Western system and the Eastern system. The Western system consists of a new dam and a water transfer of over twenty kilometres and aims at providing irrigation and drinking water for the Setif region. The Eastern system consists of two new dams and a water transfer of more than fifty kilometers, and aims to transfer water between the dams of Tabellout (Oued Djendjen) and Draa Diss for irrigation and drinking water in the El-Eulma region. The whole project concerns a volume of 310 million m³ water per year transferred for the irrigation of 40,000 hectares, and drinking water for more than 1,300,000 inhabitants by 2040. The aim of this report is to present the mega project of the “High Plains of Setif”, which constitutes a first experience in Algeria ensuring the interconnection of several reservoirs in the territories to be irrigated. Some design adaptations as well as the multi-use of water in the project will also be discussed.

Résumé. Les « Hautes Plaines Sétifiennes » est un méga projet de transfert d'eau situé dans le nord de l'Algérie, réparti en deux systèmes : le système Ouest et le système Est. Le système « Ouest » qui se compose d'un nouveau barrage et d'un transfert d'eau de plus de vingt kilomètres reliant le barrage existant d'Eghil Emda au barrage de Mehaoune, vise à fournir l'irrigation et l'eau potable pour la région de Setif. Le système « Est » se compose de deux nouveaux barrages et d'un transfert d'eau de plus de cinquante kilomètres, et vise à transférer l'eau entre les barrages de Tabellout (Oued DJendjen) et

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de Draa Diss pour l'irrigation et l'eau potable à la région El-Eulma. L'ensemble concerne un volume d'eau transféré de 310 millions de m³ par an pour l'irrigation de 40 000 hectares et l'eau potable pour plus de 1 300 000 habitants à l'horizon 2040. Le projet aux dimensions hors norme, constitue une première en Algérie assurant l'interconnexion de plusieurs réservoirs dans les territoires à irriguer. Quelques adaptations de conception ainsi que le multiusage de l'eau dans le projet seront également discutées.

1 Introduction

The High Plains Setif Transfer Project, for which first studies were carried out by EDF-Somival in 2003, led ANBT in 2009 to rely on the Safege-Tractebel consortium of engineering firms for the construction of the three dams and the transfers. In 2011 SGI Ingenierie Studied the drinking water supply of both systems for ADE (Algerian Public Water Company).

The work and studies, worth more than €1.5 billion, took place over more than a decade and involved numerous engineering firms and companies.

This article describes the project and presents some of the specific design or adaptation features that had to be realized to face difficulties, limit the costs and make the system more resilient.

2 Project's context

2.1 The High Plains Setif Transfer Project

The Algerian national program has the challenging ambition to overcome the deficiencies in supply of drinking water and irrigation water in Algeria, particularly by the implementation of inter-basin transfer projects. The High Plains Setif Transfer Project is one of these projects. This project is located in Eastern Algeria, and represents a major part of a phased development national program managed by the National Agency for Dams and Transfers (ANBT) under the aegis of the Algerian Ministry of Water Resources and Environment.

Development of the water storage and transfer in the Setifian Highlands is essential to meet the gradual increase in water needs (domestic and industrial uses) of the Setif department and the objective of agricultural intensification through irrigation.

The main purpose of the High Plains Setif Transfer scheme is to transfer 310 million m³ per year for the irrigation of 40,000 hectares and to supply with drinking water to more than 1,300,000 inhabitants by 2040.

The two components of the High Plains Setif Transfer Project are:

- The Western Setif Transfer which consists in pumping the water from the existing Ighil Emda dam reservoir, located in Bejaia Wilaya, towards the recently built Mahouane dam.
- The Eastern Setif Transfer which consists first of a gravitational transfer from the existing Erraguene dam reservoir towards the recently built Tabellout dam and then of a pumped water conveyance system from Tabellout reservoir to the Draa-Diss dam also built recently

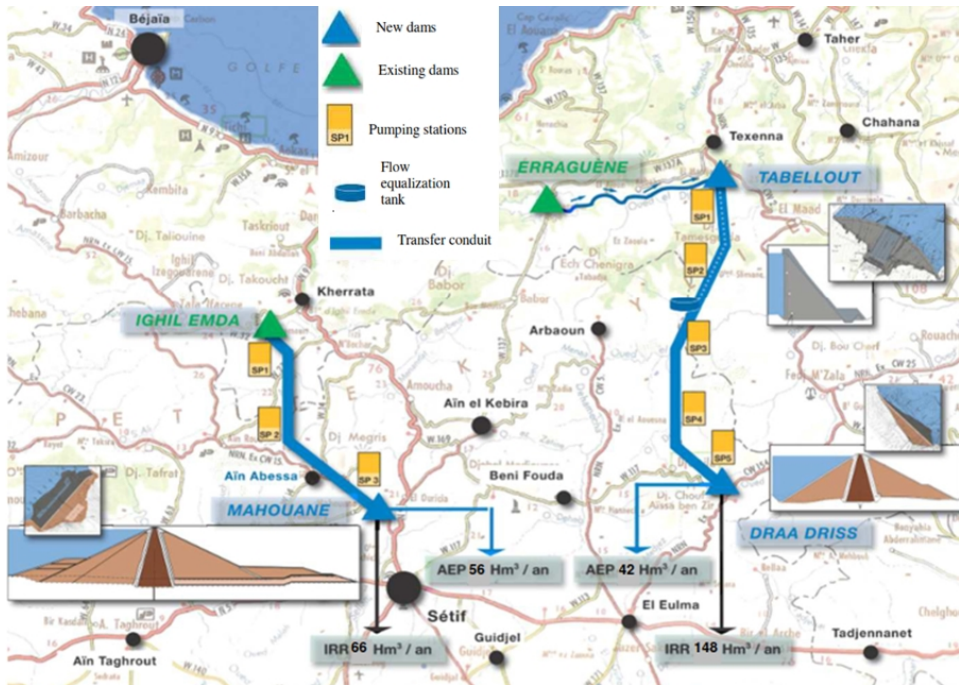


Fig. 1. Map showing the initial diagram of the High Plains Setif Transfer Project.

2.2 Western Setif Transfer

2.2.1 Western Transfer

The Western System from Ighil Emda reservoir to Mahouane reservoir is designed to transfer an annual volume of 119 million cubic meters (hm³), of which 30 hm³ (i.e. 25.2%) is for water supply and 89 hm³ (i.e. 74.8%) for irrigation. This transfer has the peculiarity to divert the water dedicated to hydropower for the needs of drinking water and irrigation water.

- 3 pumping stations (4+1 groups 16 000 kW/ global capacity 6 m³/s / HMT 30bars)
- steel pipes DN1800 (22 km)

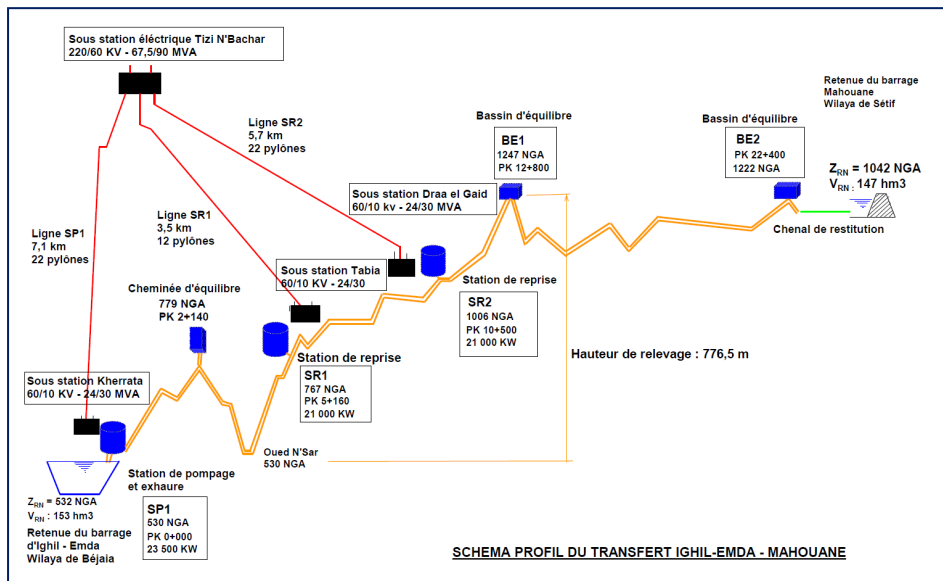


Fig. 2. West system profil.

2.2.2 Ighil Emda Dam

This dam is located east of Algeria in the little Kabylie, 60 km from Béjaïa. The Ighil Emda dam stores a large quantity of water (156 hm³ - current useful capacity of 60 hm³) at an elevation of 532 m above sea level. Water is provided by the Wadi Agrioun. Its impounding began in September 1953. It supplies two hydroelectric power plants (installed capacity 24 MW). Its catchment area of 63,900 ha is located between the Massifs of the little Kabylie and the continental highlands.

2.2.3 Mahouane Dam

This dam is located northeast of Mahouane village, 8 km northwest of Setif city. The dam is a clay core rockfill dam which allows the creation of a reservoir of 133.6 hm³ below the Full Supply Level (1148.72 m NGA). Its maximum height on natural ground is 76 m (88 m on foundation), the crest length is 884 m.

The following variations to the construction contract were implemented during the construction of the dam:

- The diameter of the drinking water supply pipe was increased from 600 mm to 1000 mm (water needs greater than initially estimated)
- The dam was provided with additional upstream and downstream shoulders to guarantee the stability under the revised seismic loading (0.39 g instead of 0.26 g in the initial Detailed Design for Mahouane).

2.3 Eastern System

2.3.1 Eastern transfer

The East System from Tabellout reservoir to Draa Diss reservoir is intended to transfer annually a volume of 189 million cubic meters (hm³). With the contributions of the Draa Diss watershed (1.5 hm³), the project will provide downstream 39.5 hm³ (20%) for drinking water and 151 hm³ (80%) for irrigation.

- 5 pumping stations (5+1 groups 20 000 kW/ global capacity 7,2 m³/s / HMT 40bars)
- steel pipes DN1800-2500 (65 km)
- galleries
 - diameter 3.5 m (4,5 km)
 - diameter 2.5m (754 m)

2.3.2 Erraguene Dam

This dam is located in the department of Jijel. It was constructed from 1955 to 1961 on the Djendjen River. Its catchment area is 133 km². It is a multiple arch dam (35m-span for each arch) in pre-stressed concrete. The height of Erraguene dam is 83 m and its crest length is 543 m with a storage capacity of 250 hm³. It is equipped with a spillway (1500 m³/s) and 2 bottom outlets. It supplies two hydroelectric power plants (installed capacities of 13.5 MW at the toe of the dam and 100 MW at the extremity of the headrace tunnel).

2.3.3 Tabellout Dam

Tabellout is a Roller Compacted Concrete dam located in northern Algeria in the region of Jijel. With a height of 121 m and a crest length over than 360 m, Tabellout dam will represent one of the leading works of Setif High Plain Water Supply Project with a reservoir capacity of 294 million m³. It creates an intermediate reservoir before transferring the water to the Draa-Diss reservoir to supply El-Eulma district for drinking and irrigation water.

A potentially seismic fault was identified about 200 m upstream of the dam axis and its identification led to re-evaluating the project site seismic hazard.

The project design has been adapted to ensure the stability of the dam in such highly unfavorable seismic conditions (0.47 g instead of 0.2 g in the initial Detailed Design for the Tabellout dam). Several measures have been adopted to adapt the Tabellout dam's shape to the highly seismic context ensuring stability and safety. The design of the RCC dam was revised from a straight shape to an arched shape without affecting the initial RCC volume. The monolithic behaviour of the dam is ensured by vertical grouted joints, shear boxes and a seismic belt placed at the crest of the dam.

2.3.4 Draa-diss Dam

The site is located on the Oued Medjez, 11.5 km north-east of El Eulma, east of the commune of Tachouda. The dam is a clay core rockfill dam which allows the creation of a reservoir of 137.3 hm³ below the Full Supply Level (1138.20 m NGA). Its maximum height on natural ground is 67 m (76 m on foundation), the crest length is 956 m.

The following variations to the construction contract were implemented during the construction of the dam:

- Deepening of the grouting gallery
- Modification of the water tight blanket with more unsorted material (cheaper alternative)

3 Multi-purpose transfers – focus on the Water Supply needs

L'Algérienne Des Eaux (ADE) is the Algerian National Agency in charge of the implementation of the National Policy related to the access of the water supply to the population throughout the national territory. ADE is responsible for the management of production, treatment, storage, conveyance and distribution of the water supply. It is under this mandate that ADE has launched a study in order to take advantage of the High Plains Setif Transfer Project towards planning future investments for the supply of drinking water to most of the Setif Wilaya (Algerian Administrative Region). The Study was carried out from 2009 to 2011.

3.1 Background and purpose of the study

The objectives of the study is to identify the future needs in terms of water supply and to ensure that they are satisfied for the urban areas and settlements located along the transfers. Indeed, the socio-economic evolution of the region is conditioned by the availability of sufficient water resources to meet the long-term needs of the domestic sector and various activities (administrations, industry, agriculture). Even though the study mainly focused on investment related to water supply, the whole program has a multi-purpose dimension – combining irrigation and water supply considerations.

In a country with a generally dry climate such as Algeria, it appeared that the water resources is rather heterogeneous by regions. Higher water resources availability in the North (due to topographical conditions and proximity with the Mediterranean Sea) contrasts with the Southern part. Considering this background, the Algerian Government has implemented a policy of large inter-regional water transfers of which the Setif project was an integral part.

SGI Ingénierie based in Geneva, Switzerland, then carried out the study together with the consulting Algerian firm Progress. The study has considered both East and West Transfers.

3.2 Scope of the investments to be designed

The study area considered both East and West systems:

- The Eastern system: the transfer that ends in the Draa Diss dam reservoir is to provide supply water to the Easter part of the Wilaya, including El Eulma, the major city of the area with an estimated population of 113 000 inhabitants at the 2040 horizon;
- The Western system: the transfer between the existing Ighil Emda reservoir and the planned Mahouane dam is to provide water supply from Mahouane reservoir to the Western par of the Wilaya including the major city of Setif which is expected to have an estimated population of 154 000 inhabitants at the 2040 horizon.

The investments have included the intake, treatment, storage, pumping and conveying of the water supply to the different settlements for both systems

The drawing below provides an overview of the main conveyance systems designed at that time for the two independent systems.

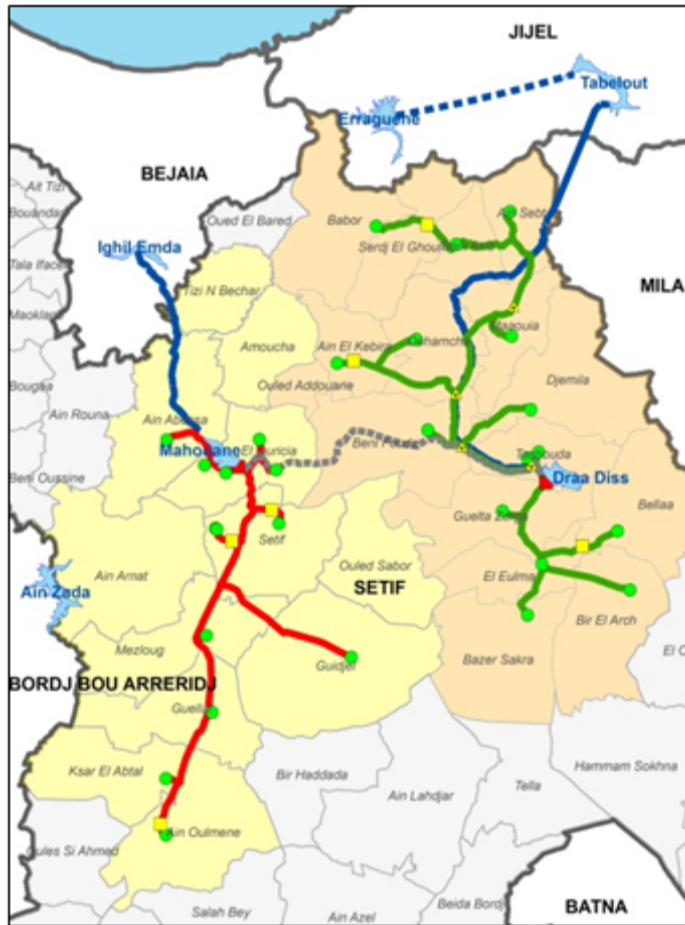


Fig. 3. Map of the main conveyance systems and connection between the two reservoirs.

The investments have been designed to offer the overall possibility of transferring a volume of 313 million m³ intended to supply drinking water to approximately 1,400,000 inhabitants of the cities of Sétif, El Eulma and their neighbouring towns, as well as to irrigate approximately 40,000 hectares of agricultural land.

SIG Ingénierie assignment aimed at delivering studies from a preliminary stage of identifications of possible scenarios towards the preparation of the Detailed Design and Tender Documents for the selected works. It has been decided that the design horizon of the study will be in 2040.

3.3 Demographic and water demand trends

A socio-economic was carried out to estimate the evolution of the population and thus the water demand. This step was an essential step of the study and a major input for the design of the future systems. Important outputs are presented hereunder:

- The total population of the study area is estimated to be 1,855,200 inhabitants by 2040;

- The average daily water demand within the study area is estimated to be around 300,000 m³/d by 2040.

Even though the study was solely focused on water supply investments mobilising the water from Dra Driss and Mehouane reservoir, the Consultant had to consider several transversal major parameters that made this assignment a strategic study, such as:

- Preservation of the existing water resources (mainly boreholes) for the future vision. Even though groundwater resources are of limited potential, by preserving the operation of the existing boreholes, ADE will ensure diversification of the water resources for water supply needs- diversification being a parameter in terms of securing the resources and the supply of drinking water. Furthermore, operating costs being lower for groundwater, this orientation helps in minimising operation and maintenance costs. Finally this approach helps at optimizing the use of existing investments.
- Ensuring that the multi-purpose concept of the project is considered throughout the study. At the time of the study the Consultant had to ensure that both transfers would allow irrigation of more than 40,000 hectares representing a demand of approximately 240 hm³/year.

The fact that diverse existing water resources were already mobilized, the Consultant had to consider in his approach different scenarios of water resources mobilization. The study had concluded at a preliminary stage the preservation of existing schemes as well as the preservation of existing groundwater resources with a lowering of the capacity in order to consider climate change issues and to remain in a conservative approach.

The figure belows provides an overview of the evolution of the average daily water demand of the study area from 2010 to 2040. The water demand being nearly doubled in 30 years time. The population growing from one million inhabitants in 2010 to an estimated population of nearly 1.9 million inhabitants in 2040.

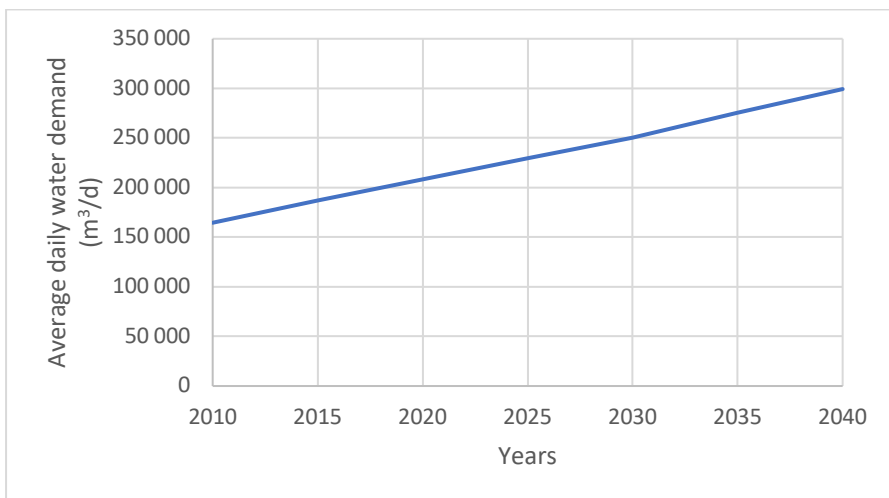


Fig. 4. Average daily water demand.

Considering the higher water demand during dry season, a peak coefficient was applied. Subsequently the total maximum daily water demand has been estimated to be nearly 327,000 m³/d to be delivered by the new scheme.

The mobilisation of the transfers for the drinking water supply needs is presented hereunder for the average daily case:

		Mobilisation of transfers for water supply (m ³ /day)			
		2010	2020	2030	2040
Average	Western system	73'886	96'657	115'204	154'356
	Eastern system	52'147	71'881	89'105	113'458
	Both systems	126'033	168'538	204'309	267'814

3.4 Focus on the East system

This Eastern system was designed to supply:

- Drinking water to El Eulma and several agglomerations along the transfer and conveyance pipes (750,000 inhabitants - 100,000 m³/d in average demand);
- Irrigation of the El Eulma plain (20,000 ha - 148.5 Hm³/year).

Possible scenarios for conveyance of the water supply system:

Different scenarios were considered. The scenarios did not differ on socio-economic criteria as the willingness remained to supply water to the whole population. It could only differ in terms of technical, engineering or financial criteria.

The crossing of the mountainous chain that stretches on the North and East sides of the future Draa Diss reservoir provided a sole option in terms of positioning of the conveyance pipes. Thus, a single route for all the proposed scenarios had to be considered.

However, the spatial allocation of water supply delivery allowed the possibility for the Consultant to consider two scenarios technically very different- namely scenario 1 and scenario 2 summarized hereunder.

Scenario 1: consisted in:

- Using water resources solely at the Draa Diss reservoir (end reservoir of the East system);
- Building a Water Treatment Plant of 100'000 m³/d centralised at the level of the Draa Diss reservoir, before supplying the various agglomerations to the North and South of the Draa Diss reservoir;
- Treated water was then to be conveyed by gravity or through pumping – ultimately stored in existing or new water storage. An important pumping station at Ouled Lahoua is to be designed to ensure water in the northern part of the system.

Scenario 2: was developed to consider the possibility in reducing the capacity of lift up of treated water at Ouled Lahoua. To this end Scenario 2 consisted in:

- Building a new intermediate reservoir at Sidi Yahia which would be fed by the transfer system. The town of Sidi Yahia and the surrounding towns could be supplied by gravity from this basin.

- Building a second Water Treatment Plant at Sidi Yahia reservoir (supply to the northern agglomerations - 33,000 m³/d). Draa Diss Water Treatment Plant would then be reduced to 67,000 m³/d.

Comparison of the scenarios:

Scenario 1 had a lower investment cost than Scenario 2 (- 5%). However, Scenario 2 had a lower operating and maintenance cost than Scenario 1; which brings the total cost per m³ calculated slightly lower for Scenario 2 (9.30 DA/m³ against 9.48 DA/m³ for Scenario 1). Difference in terms of financial comparison on a 15-year operating period is minor – less than 2% difference on the m³ sold. Subsequently Scenario 1 was defined as the best scenario and was retained because only one Water Treatment Plant was to be operating and maintained over the years, ii. Scenario 2 would need a solid agreement between ANBT and ADE. The following overview shows the selected variant for the East system.

3.5 Proactive approach during the study

In order to ensure that the study fulfilled the set objectives, and even beyond, the Client and the Consultant had to have proactive and flexible approaches. Indeed, during the study major amendments were made to the initial scope of services, such as:

- Design horizon: initially settled for 2030, it had been decided to carry out the socio-economic analysis and subsequently the design in order to meet the future water demands up to the year 2040.
- Interconnection between the western and eastern systems: in order to secure the supply of drinking water to the whole region, a back-up interconnection system was added and considered during the study. The principles of the interconnection were as follows:
 - The interconnection concerned the treated water between the two treatment sites, East (Draa Driss) and West (Mahouane), in order to guarantee a secured supply of treated water in the event of a treatment plant shutdown;
 - The interconnection was designed in the two directions in order to be able to transfer water from Mahouane to Draa Diss and vice-versa. The layout of the treatment sites was planned to integrate any required pumping station;
 - The interconnection required the laying of a new transfer/adduction pipeline. Two alternative routes were considered:

The southern route was selected for its lower construction and operating costs (total power of the Pumping Stations is higher for the northern route) and for technical aspects (significantly lower pressure in the pipes, less powerful pumping stations, less difficulties to access and less winding road infrastructure).

4 East Transfer - Adaptation of the route due to a geological hazard

4.1 Initial hydraulic Design

In the original project, the water of the East transfer system, coming from the Tabellout reservoir (RN 324.75 NGA), is pumped up to the level of 600 NGA, then flows by gravity through a gallery of 3.5 m internal diameter and 13 km length towards the Oued Halib basin (RN = 583 NGA) before being taken back by 3 stations in series (SP2, SR2 and SR3) and flowing into the Draa Diss dam.



Fig. 5. Tabellout Reservoir's Intake.



Fig. 6. Pipes of diameter 1800 mm to 2500 mm.

4.2 Geological hasard

The tunnel was built in a complex geological context characterized by Kabyl's flysch (Numidian nappe). During the execution phase, a strongly tectonized thrust zone was identified and led to additional geological studies. The conclusions of these studies led to modify the route of the East transfer.

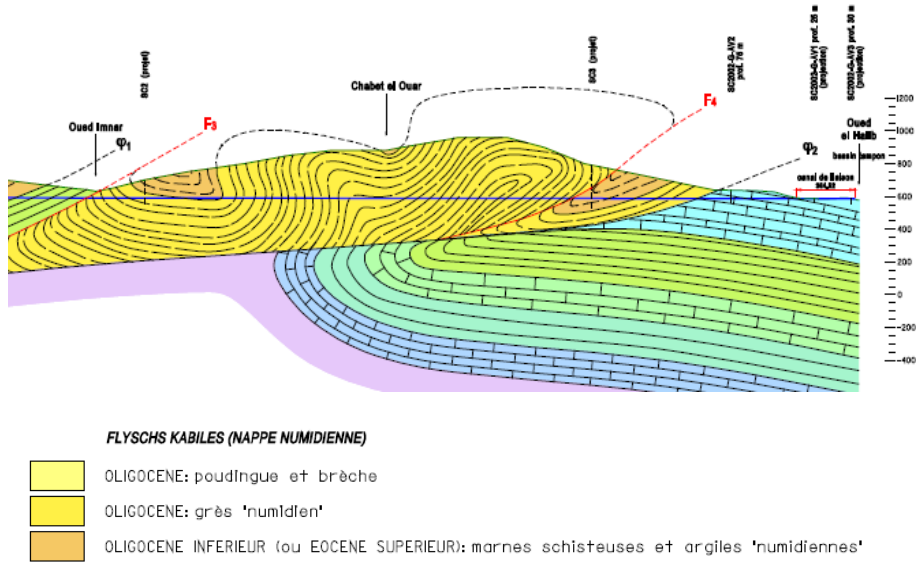


Fig. 7. Geological section of the Tabellout tunnel [EDF APD 2003].

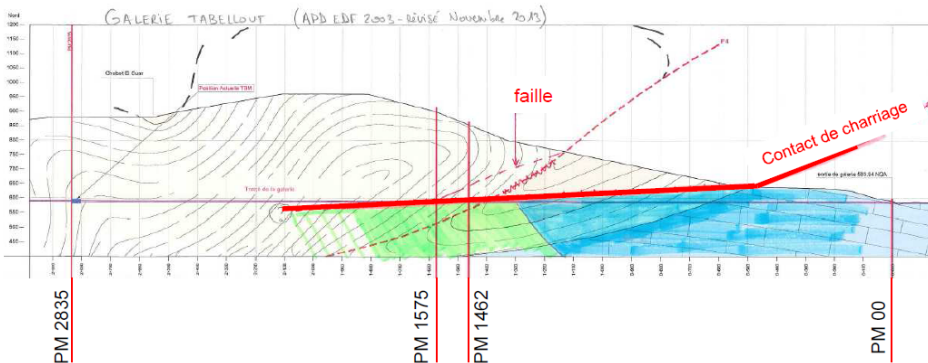


Fig. 8. Updated Geological section of the Tabellout tunnel - 2013].

4.3 New hydraulic design

At the request of the ANBT, SAFEGE studied solutions allowing, at a lower cost, to re-establish the route while preserving the transfer capacities and limiting the additional costs of the operation.

The solution adopted consists in recovering the SP2 pumps to equip an SR1bis pumping station located at an identical altitude but closer to the Tabellout reservoir. The hydraulic design of the new route consisted, for a given HMT pumping capacity (40 bars), in identifying the altitude of the high point and the pipe diameters in order to guarantee a gravity supply of SR2.

At this hydraulic altitude, a 754 m gallery had to be dug above the Tamentout pass.

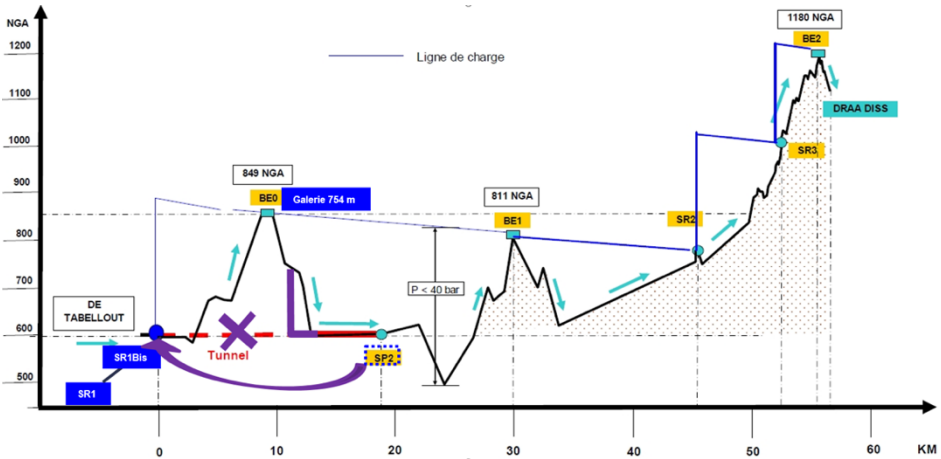


Fig. 9. Updated hydraulic profile of the transfer.

4.4 Pipe thicknesses

Pipe thicknesses have been justified according to AWWA [1] recommendations. A specific comparison study with CODETI [2] recommendations did not make it possible to reduce the thicknesses given the fact that the pipes are in trenches.

Particular attention has been paid to the risks of pipe ovalization.

4.5 Reuse of the tunnel

In order to recover the tunnel boring machine, the route of the original tunnel was modified to pass under the wadi Imnar and thus limit the depth of the well to be dug to allow recovery.

The precise determination of the location of the tunnel head required detailed topographical calculations to limit the accumulation of errors along the 4 km route and allow precise location of the access shaft and the sizing of the portal at the bottom of the well.

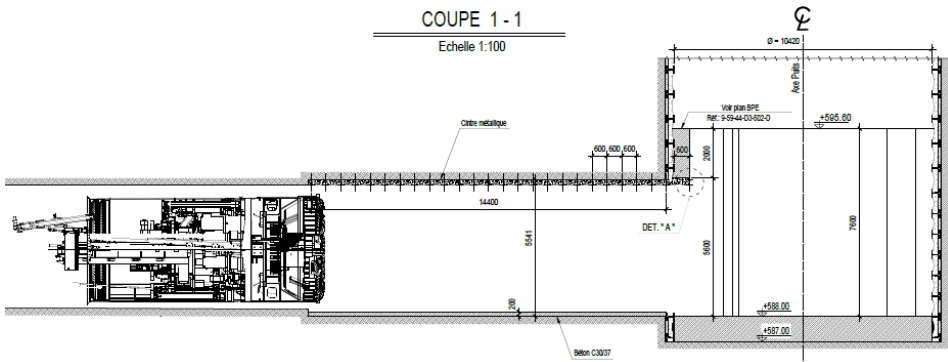


Fig. 10. Well 60 m deep and 10.80 m diameter.

References

1. AWWA American Water Works Association <https://www.awwa.org/>
2. CODETI Code de Construction des Tuyauteries Industrielles
<http://codes.snctpublications.com/fr/content/fiche-codeti%C2%AE-division-1-2013>