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OUED M'ZAB'S I.R.S DEVELOPMENT POPULATION AND FLOOD, LIFE IN HARMONY PART 2: DESIGN AND OPERATION

L'AMENAGEMENT I.R.S D'OUED M'ZAB LA POPULATION ET LA CRUE, LA VIE EN HARMONIE PARTIE 2 : CONCEPTION ET FONCTIONNEMENT

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ABSTRACT

This paper discusses, for the first time, flood management in the Ghardaïa oasis. A thousand-year-old hydraulic development has been implemented by the Mozabites on the M'zab River for more than 7 centuries. During the period: 1996-2020 we carried out several missions at the rate of two to three per year. Investigations and inquiries were carried out with the Ksourian population and the Oumana El Ma (management committee). The M'zab River was divided into three ways that is the originality of this project. In order of priority, track 1 called Tardja N'Bouchemdjane transports the first floodwaters for the irrigation of the eastern palm grove of Ghardaïa. The second seguia is used to transport part of the flood water to the Bouchen dam. These waters are intended for recharging the water table. The excess flood water flows directly into the third lane of the M'zab River; it's a safety security. This original layout, we called it "IRS Dvelopment". Part 2 of this study is devoted to the design and operation of the IRS Development at M'zab River.

Keywords: M'zab River, IRS Development, flood, Irrigation, Eat Palm Grove.

RESUME

Le présent papier évoque pour la première fois, la gestion des crues dans l'oasis de Ghardaïa. Un aménagement hydraulique millénaire a été mis en œuvre par les Mozabites sur l'oued M'zab depuis plus de 7 siècles. Durant la période : 1996-2020 nous avons effectué plusieurs missions à raison de deux à trois par année. Des investigations et des enquêtes ont été menées auprès de la population ksourienne et les Oumana El Ma (comité de gestion). L'oued M'zab a été aménagé en trois voies telle est l'originalité de ce projet. Par ordre de priorité, la voie 1 appelée Tardja N'Bouchemdjane transporte les premières eaux de la crue pour l'irrigation de la palmeraie-Est de Ghardaïa. La deuxième voie est consacrée au transport d'une partie des eaux de la crue vers le barrage de Bouchen. Ces eaux sont destinées à la recharge de la nappe phréatique. Le surplus des eaux de la crue s'écoule directement dans la troisième voie de l'oued Mzab ; c'est une voie de sécurité. Cet aménagement original, nous l'avons baptisé « Aménagement IRS ». La partie 2 de cette étude est consacrée à la conception et le fonctionnement de l'aménagement IRS d'oued M'zab.

Mots clés : Oued M'zab-Aménagement IRS-Crue-Irrigation-Nappe-Palmeraie.

GLOSSARY

Amlaga: Meeting point of two Rivers
Chaabat: Tributary
Khottara: Animal-drawn well
Koua: Realized rectangular opening in the wall of a garden
N': of
Tardja: open channel
Oumana El Ma: Management Committee
Oumana Esseil: Management Committee
Ahbas: Dam
Seguia: open channel
Tissanbadh: Underground gallery

INTRODUCTION

Raws, floods, two scary words. Often the flood when it occurs in arid regions, it causes material and human damage. Flash floods have increased in number in recent years, especially in the early fall. This phenomenon often occurs in the arid regions of the Algerian Sahara. However, often the population of the north perceives the floods as a misfortune; conversely the Mozabites consider the floods as a gift from the sky. Only the Mozabite population who can speak to the flood. For her, the flood was never a danger, you only have to live higher and cultivate the wadi. A submersion of the palm grove by one to two floods per year is essential for its development. The waters of a flood are loaded with clay particles and nutrients that are beneficial to the plant. Also, the arrival of a flood causes a general leaching of the palm grove while sweeping away the quantities of salts accumulated during one to two years. The only reservoir available in the M'zab Valley was the water table. Its recharge by flood water infiltration once or twice a year becomes essential to ensure permanent irrigation of 5 to 7 years of drought. So how do you take advantage of the flood? To answer this question, hydraulic installations were carried out in the oases of the M'zab valley which we called: IRS development. In each oasis, there is an IRS Development specific to the geomorphology of the environment. This is how we find that the studies we conducted on the oases of Metlili, El Guerrara, Berriane and Ghardaïa Est (Remini, 2020; Remini, 2019; Remini, 2018; Remini and Ouled Belkhir, 2019; Khelifa and Remini, 2019). This study follows that on the Touzouz River (Remini, 2020). This paper focuses on the largest IRS development project carried out on the M'zab River for the irrigation of the eastern palm grove of the Ghardaïa oasis. In Part 2 of this article, we will examine the design and operation of IRS development of M'zab River.

STUDY REGION AND SURVEYS

Study area

The study area is the Ghardaïa oasis; capital of the M'zab valley. A city with a tourist vocation par excellence. Very well known for its millennial Ksourian architecture. Located 600 km southwest of Algiers, Ghardaïa sits today on one of the largest aquifers on the planet. This is the tablecloth of the Intercalary Continental (fig. 1). Before the discovery of the aquifer of Intercalary Continental in the early 1940s, the entire M'zab valley was fed by the water table. Unfortunately, today the waters of this aquifer are polluted. The Ghardaïa

oasis has today become a large metropolis where there is a great commercial, agricultural and tourist activity. Ghardaïa is crossed by the M'zab River, well known for its devastating floods. With a flow exceeding 1200 m^3/s, the 2008 flood caused a lot of material and human damage (Ouled Belkhir and Remini, 2016, Bouamer et al, 2019; Zegait et al, 2018; Remini et al, 2012).

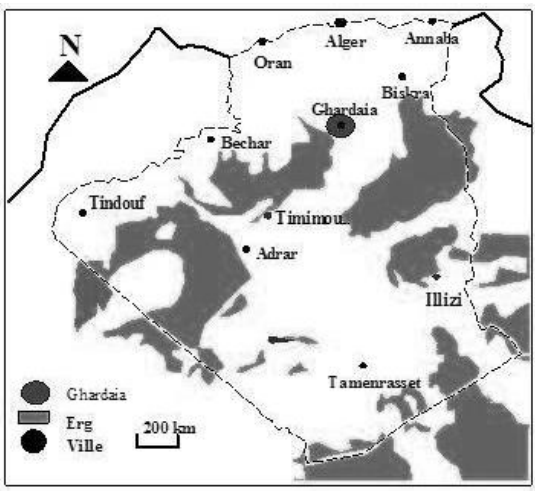


Photo 1. A view of the M'zab valley (Remini, 2020)

Photo 2. 2. A view of the legendary Ghardaïa market (Remini, 2018)

Figure 1: Situation of the study region (Remini, 2020)

Methodology of work

Ghardaïa; a rocky region with a hyper-arid climate known for low rainfall and a temperature that can exceed 50 °C in summer. In M'zab River, sporadic floods occur once or twice a year but which can drain significant amounts of water. Make a development in the Mzab River to annihilate the floods and make the most of these waters loaded with solid particles.

Interested in the floods in the M'zab River in the mid-1990s, once on site we were impressed by the extent of the development carried out over the past 7 centuries. We liked a city and everything that the Ksourian population has achieved in terms of hydraulics and architecture. With each mission, we discover new elements of the layout. This is how this work has lasted for more than 20 years of research.

RESULTS AND DISCUSSIONS

Presentation of the IRS Development of M'zab River

Based on the idea that any drop of water that falls on the catchment area of the M'zab valley is captured. All the tributaries that lead to the palm grove have been arranged so that all the runoff water is used and drained towards the gardens. For this purpose, a large original and unique hydraulic installation in the world has been designed in the M'zab River for more than 7 centuries. We called: I.R.S Development. It consists in annihilating the floods and making the most of these waters. In this case, the flood is divided into 3 parts according to the priority: Irrigation, Recharge of the water table and the evacuation of the surplus water towards the M'zab River downstream of the oasis (Security) (fig. 2).

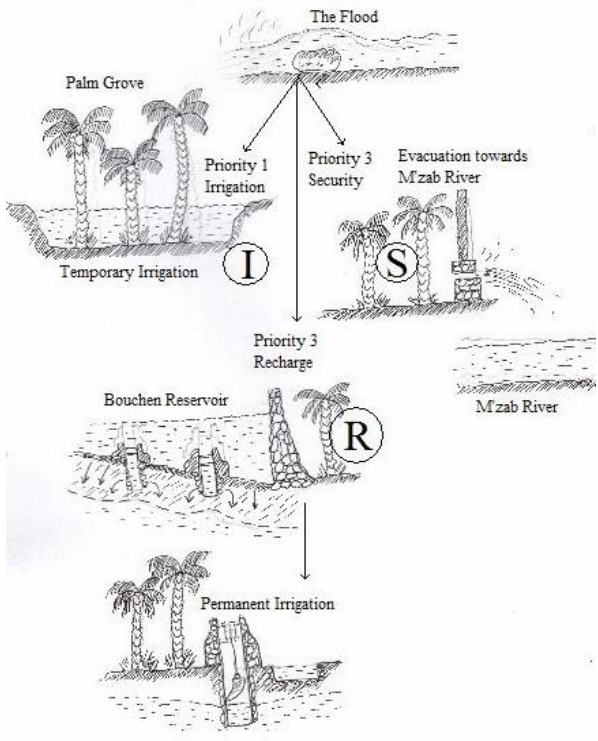


Figure 2: IRS Development concept (Remini, 2020)

Irrigation of the East palm grove of Ghardaïa by flooded waters

Covering an area of 2 km^2, the ancient palm grove of Ghardaïa stretches from Ahbas Ajdid to Ahbas N'Bouchen (from south to north). The M'zab River divides the palm grove into two parts: East and West. The West palm grove with an area of 1 km^2 is irrigated by flooding of Touzouz River (Remini, 2020). The palm grove - East with an area of 1 km^2 is irrigated by the floods of the M'zab River (fig. 3). With each flood, the gardens of the palm grove of Ghardaïa are flooded with water loaded with materials. For Mozabites, such an operation is essential for the soil and for the plant. The flood makes it possible to clean the soil of salt deposits. The fine materials provided by the flood are of great interest for the soil and the plant. It is for these reasons that IRS development gives priority to spread irrigation. To this end, the Rivers of M'zab has undergone a specific arrangement so that the first waters of the flood will be transported directly to the gardens of the eastern palm grove of Ghardaïa.

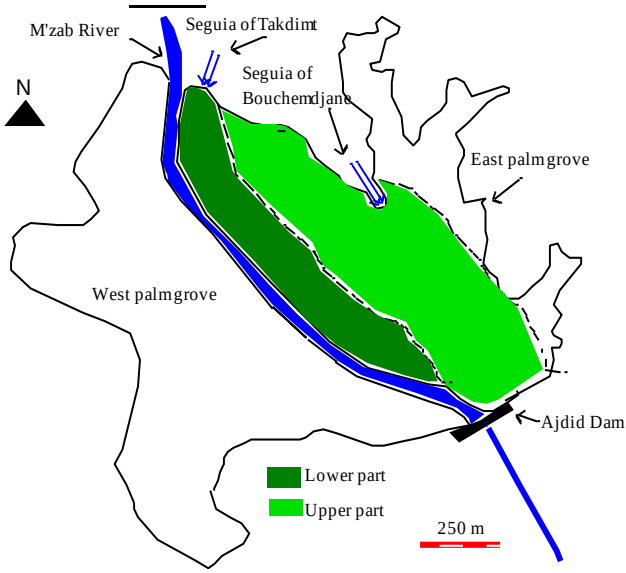


Figure 3: Délimitation de l'ancienne palmeraie de Ghardaïa (Remini, 2020)

Distribution of the M'zab River into three seguias

The M'zab River begins from the meeting point of the Laadira and Labiod Rivers called Amlaga, to Sebkhate Sefioune for a distance of 400 km. The M'zab River is very well known for its devastating floods since it drains appreciable amounts of water exceeding 1000 m^3/s. To take advantage of these

waters, an ingenious millennial development was built upstream of the palm grove on a section of 3.8 km from the M'zab River (fig. 4). The main part of this arrangement is a rock wall. In a loop form, the wall starts 750 m from Amlaga and closes 1100 m from Amlaga (fig. 5 (a and b) and 6). Since the M'zab River is very wide, the water flows from the left bank to the right bank. In this case, the wall also plays the role of an 80 cm high weir, since the water flows from the seguia of Bouchemdjane to the seguia of Bouchen and then to the seguia of M'zab. However, the height of the water must exceed that of the wall, which is equal to 80 cm (fig. 7 and 8). With a total length of 6.5 km, an average width of 60 cm and an average height of 80 cm, the loop wall is made of double layers of rock with an intermediate layer of aggregates. The arrangement made by this loop wall divides the M'zab River into three seguias (Fig. 9 and 10):

- Seguia of Bouchemdjane who transports flood water for the irrigation of the eastern palm grove.
- Seguia of Bouchen for the artificial recharge of the water table.
- Seguia of M'zab to evacuate the surplus of the flood towards the downstream of the palm grove.

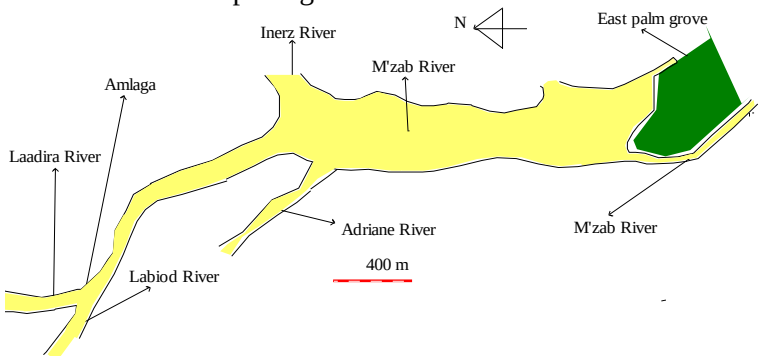


Figure 4: Site chosen for the design of IRS development of M'zab River (Schema, Remini, 2020)

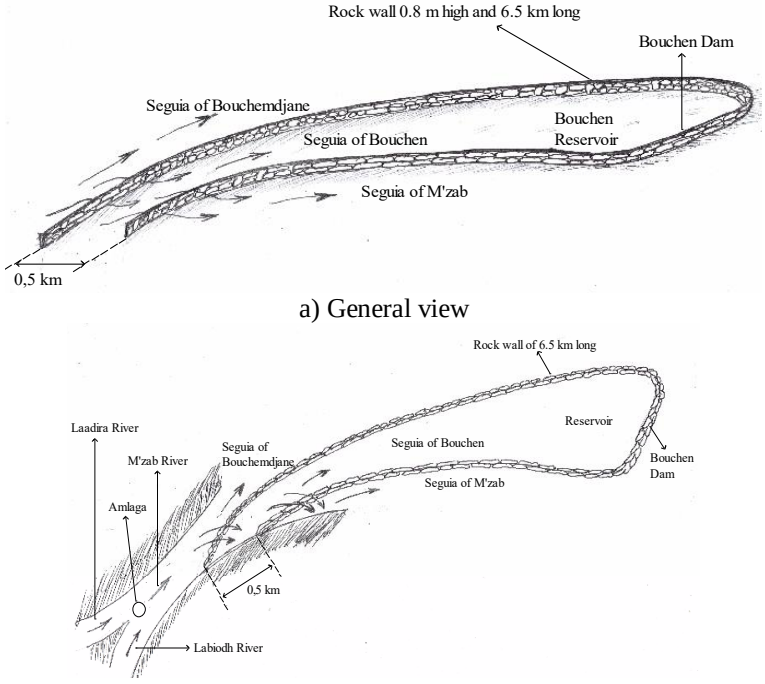


Figure 55: Diagram of the rock wall built on a section of the M'zab River (Diagram, Remini, 2020)

Figure 6: The wall dividing the M'zab River into three seguias (Photo. Remini, 2014)

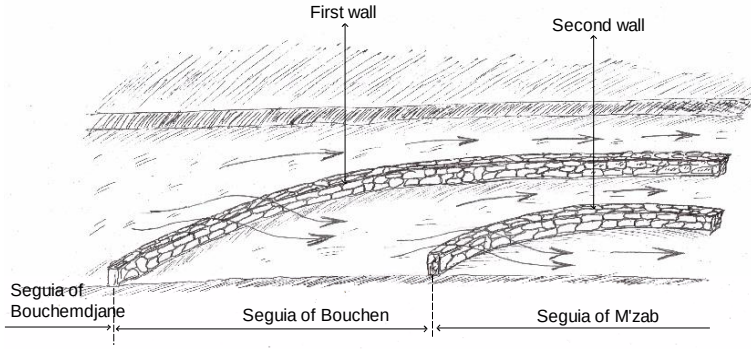


Figure 7: The wall starts and ends on the right bank of M'zab River

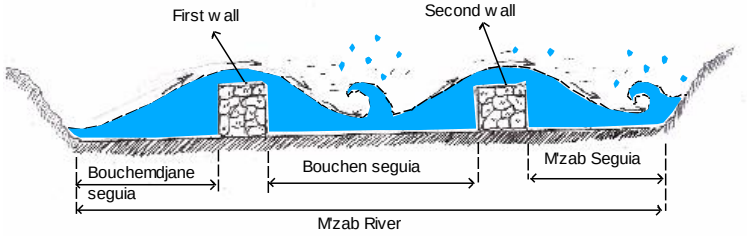


Figure 8: Flow along the width of M'zab River

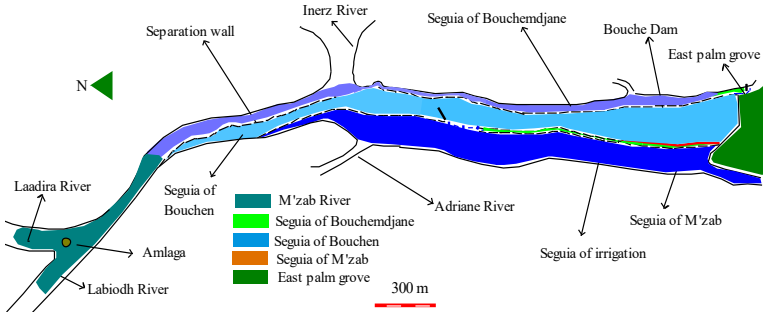


Figure 9: Division of M'zab River into 3 seguias (Schema, Remini, 2020)

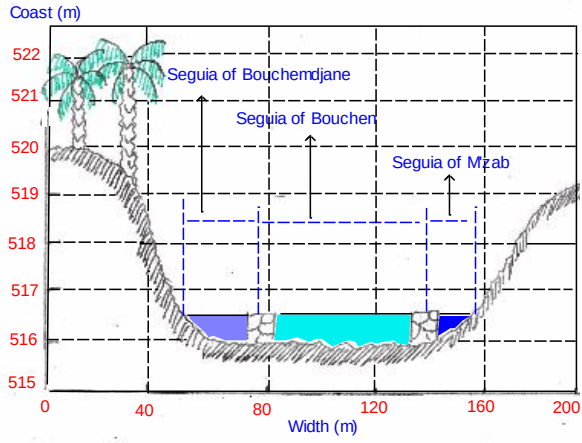


Figure 10: The IRS Development produces 3 sections; Bouchemdjane, Bouchen and M'zab

For the proper functioning of the IRS development of M'zab River, 18 hydraulic structures have been designed in M'zab River upstream of the palm grove. These are regulation dams, galleries, wells, reservoir and spillway (fig. 11). The IRS Development of M'zab River is managed by a committee called Oumana El Seil (management committee) which is made up of a group of people recognized by their competence in hydraulic know-how. The IRS Development is equipped with a surveillance network equipped with 2 towers and 6 surveillance chambers. It makes it possible to follow and control the floods along the River until the division of water between the gardens of the palm grove.

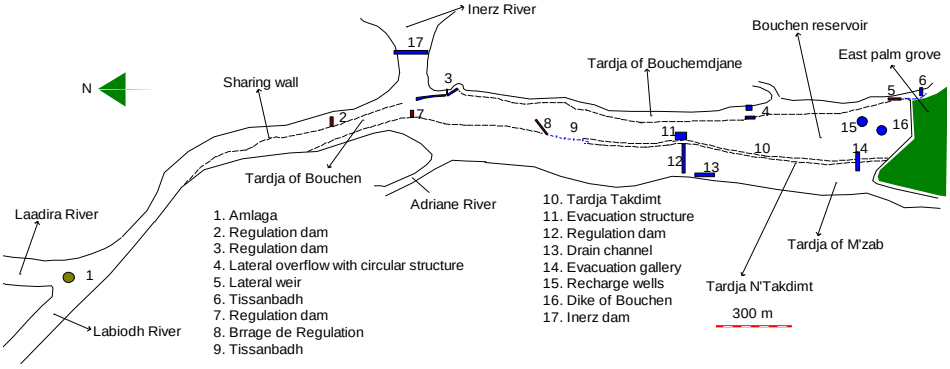


Figure 11: The hydraulic structures built in the M'zab River upstream from the Ghardaia palm grove (Schema Remini, 2020)

Functioning of the IRS Development of M'zab River

The wadis of arid regions such as the Sahara, are known by the size of its length which can exceed 100 km and its width which can reach 1 km. Obviously, these geometrical parameters have a consequence on the importance of the drained flow which can exceed 1000 m^3/s. With a length of 400 km, from Amlaga to Sebkhate Sefioune, the M'zab River with a width exceeding 400 m on certain sections can drain a flow of 1200 m^3/s like the October flood 2008 (Ouled Belkhir and Remini, 2016). A similar wadi with such a large space can have a flow not only along its length but also along its width (fig. 7). Taking advantage of the geomorphology and topography of the wadi, a mega hydro agricultural development was carried out on the M'zab River. It is intended to manage floods and take advantage of these waters. We called it "IRS Development" by M'zab River. In order of priority, IRS means: Irrigation, groundwater Recharge and oasis Security. In this case, the M'zab River was divided into three channels using a form of wall of a loop of 6.5 km (Fig. 5 (a and b)). The first channel called Seguia of Bouchemdjane which carries a quantity of flood water for the irrigation of the palm grove-East. The second channel called Seguia of Bouchen which transports water to Ahbas of Bouchen to recharge the water table. The third channel corresponds to the M'zab River to transport excess water downstream from the oasis. We're talking about the security of the oasis. To fully understand the functioning of the IRS Development of M'zab River, we have schematized in Figures 12, 13 and 14, the 3 rivers of the IRS development of M'zab River as well as the location of 18 hydraulic structures. We also located 7 cross sections in very specific places in the development.

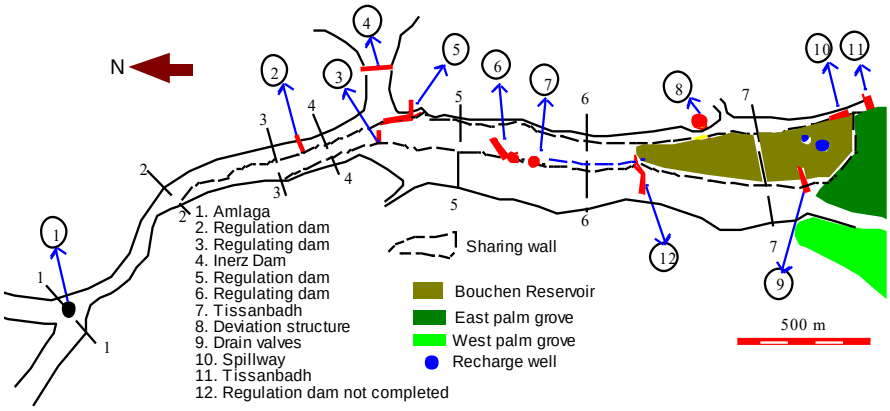


Figure 12: Diagram of the 3 ways of IRS development on M'zab River (Schema Remini, 2020)

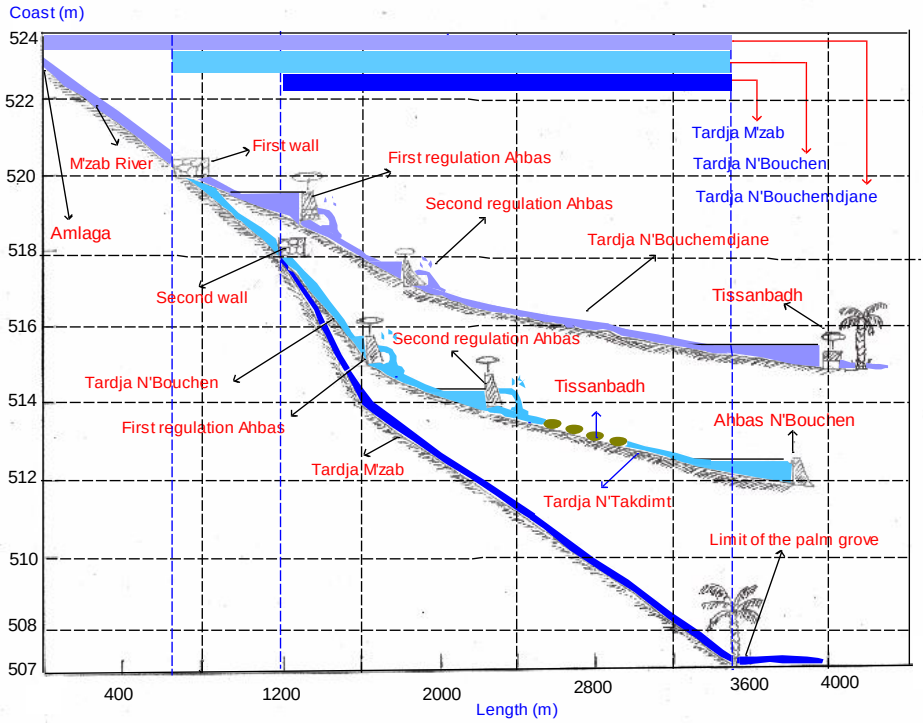


Figure 13: Longitudinal sections of the 3 watercourses of the IRS Development of M'zab River (Schema Remini, 2020)

Figure 14: Seguia of Bouchemadjane and the first regulation Dam (Photo. Remini, 2013)

Figure 15: Seguia of Bouchen and second regulation Dam (Photo. Remini, 2013)

The arrival of a flood at Amlaga (meeting point of Laadira and Labiodh wadis) is managed according to the importance of its flow. For a low flow rate and thanks to the 0.8 m high wall, the water flows directly into the seguia of Bouchemedjane. The flow continues as long as the sheet of water does not exceed the height of the wall (equal to 0.8 m). It is according to the geomorphology and topography of M'zab River that an adequate development has been carried out. The builders of a large hydro agricultural project raised the peculiarities of the site. Thanks to their know-how in terms of hydraulics and the knowledge of their environment, a section of the M'zab River with a length of 4 km from Amlaga to the beginning of the palm grove was divided into 3 ways. Each of the 3 tracks has its slope and its cross section (fig. 12 and 13). As we mentioned earlier, this sharing was highlighted by the creation of a 6.5 km wall in the form of a loop. We baptized this project "IRS Development" which means: Irrigation of the palm grove, the recharge of the water table and the security of the oasis by the evacuation of the excess water towards the M'zab River. The three channels developed are represented as follows:

The first canal corresponds to the seguia of the left bank nicknamed the seguia of Bouchemdjane. It transports the first waters of a flood for the irrigation of the upper part of the eastern palm grove of Ghardaïa. The second channel corresponds to the central seguia called seguia of Bouchen. It carries the flood water once the water level exceeds the height of the first wall (0.8m). These waters are stored in the Bouchen reservoir to recharge the water table. The third

channel begins once the water level in the Bouchen seguia exceeds the height of the second wall (0.8 m). It corresponds to the M'zab seguia which transports the excess flood water. Even the water evacuated by the drain valves of the Bouchen dam and those from the floods of the gardens are transported by the seguia of M'zab. The third channel is the security seguia. These three canals are equipped with a 6.5 km riprap wall and 18 hydraulic structures. For good management of the irrigation operations in the upper part of the eastern palm grove, the seguia of Bouchemadjane is equipped with two control dams, 5 spillways, a diversion structure and a gallery sharing system underground (Tissanbadh). The meeting at the point of Amlaga of waters coming from the wadis of Laadira and Labiod marks the beginning of M'zab River. After a flow of 600 m, the first wall channels the water into the seguia of Bouchemdjane (figs. 16 and 17 (a and b)). These waters go directly to Tissanbadh, a 4km route. Obviously, these waters must first pass through the two regulatory dams and the diversion structure to reach its point of arrival (Tissanbadh).

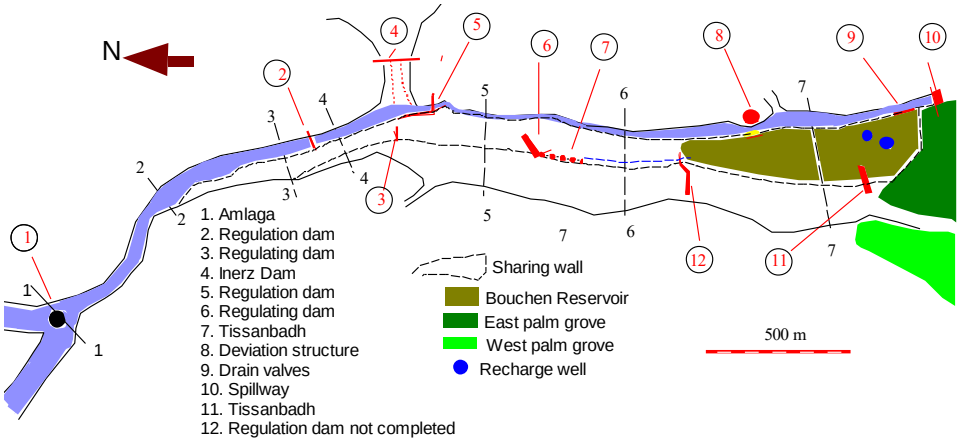
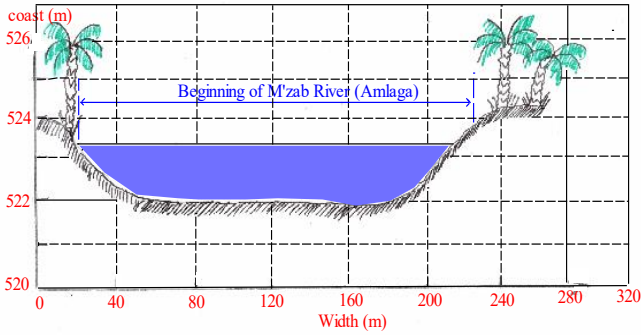
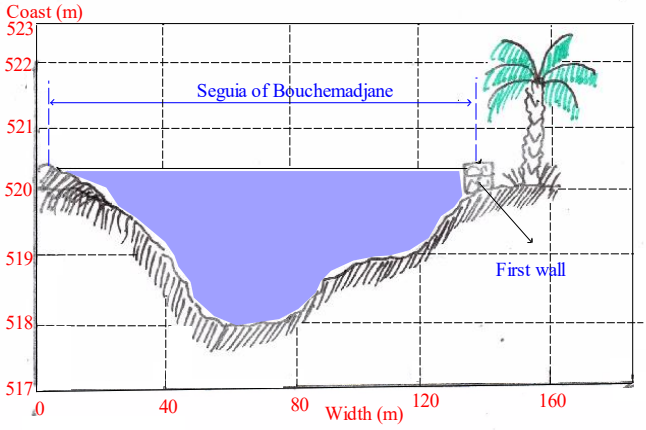


Figure 16: IRS Development: The first waters of a flood flow into the Bouchemdjane channel (purple color in the figure) (Schema Remini, 2020)



a) Before the partition wall (section: 1-1)



b) At the beginning of the Bouchemdjane seguia (Section: 2-2)

Figure 17: Cross sections of the M'zab River before the three-lane distribution. The first waters flow directly into the seguia of Bouchemdjane for the irrigation of the upper part of the eastern palm grove of Ghardaïa (Schema Remini, 2020)

It should also be added that all the runoff from the Inerz River tributary is controlled by a control dam. Initially, these waters are diverted directly to flow into the seguia of Bouchemdjene thanks to a system of weirs (fig. 7). These waters are added to the waters from Amlaga to flow to Tissanbadh. In a second step, the closing of the valves of the second dam gives access to the water coming from the Inerz River to flow over the weirs to reach the seguia of Bouchen. The Tissanbadh valve maneuvers allow water to pass through the 5 underground galleries to reach the seguias-alleys of the palm grove. Through the Koua (openings arranged tangentially at the bottom of the garden walls),

flood water floods the upper part of the eastern palm grove of Ghardaïa. In this case, the irrigation operation is completed; the alert will be given to the team of Oumana El Ma of Tissanbadh for the closure of the valves. Channeled by the two walls, the Bouchen seguia has a double function: irrigation of the lower part of the palm grove-East and filling of the Bouchen reservoir in order to recharge the water table. For a good management of these two functions; the Bouchen seguia was equipped with two control dams, a foggara, a seguia, a gallery, two recharge wells and a reservoir equipped with drainage outlets. If the water level exceeds the height of the wall (0.8 m) at the start of the first wall (600 m from Amlaga), the water flows over the weir (the wall) and goes to the seguia of Bouchen. After passing through the first regulating dam (which is 1600 m from Amlaga), the water flows through the vents (6 valves) from the second regulating dam (which is 2000 m of Amlaga) to reach the foggara of a 900 m gallery. At the exit of the foggara, the water is conveyed by the Tardja N'Takdimt, 1600 m long, to reach a second gallery with adjustable valves (figs. 18 and 19).

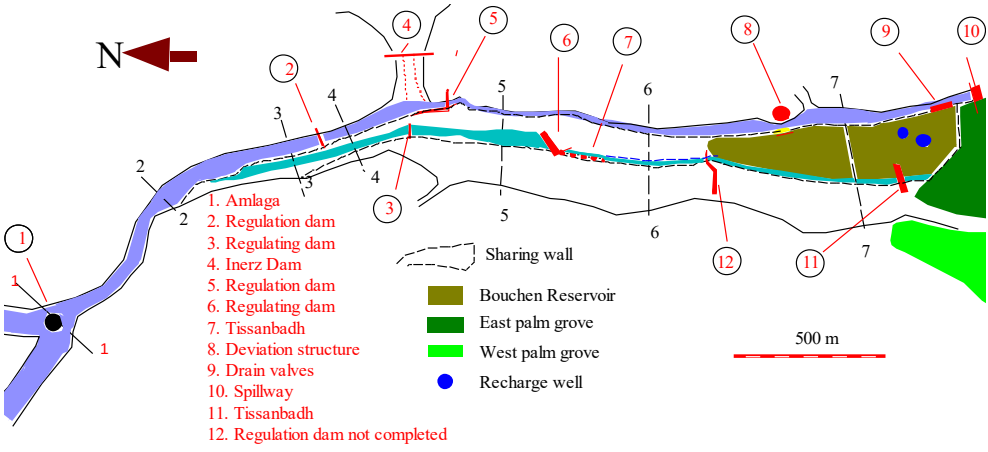


Figure 18: IRS Development: As a second priority, the water flows into the Bouchen seguia, then it borrows Tardja N'Takdimt to irrigate the lower part of the eastern palm grove (blue color on the figure) (Schema Remini, 2020)

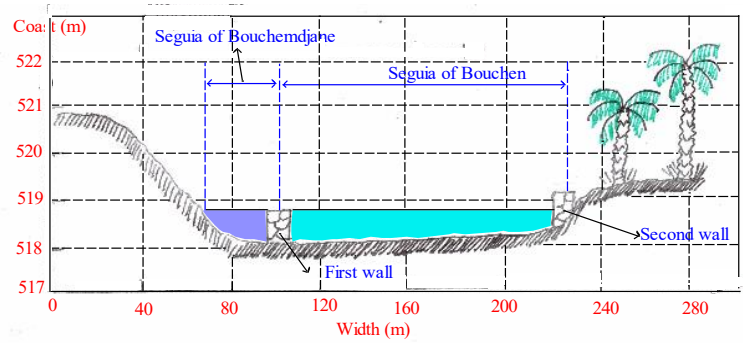


Figure 19: Section (3-3), at the start of the second wall. Beginning of the Bouchen seguia (Blue color) (Schema Remini, 2020)

The opening of these holes allows the water to reach the seguias-alleys. Through the Kouas arranged at the bottom of the walls (foundations), each garden receives its quantity of water evaluated according to the number of palm trees. Once the lower part of the eastern palm grove has been completely flooded, the gallery gates will be completely closed. The alert will then be given to the team at the second dam for the closure of the drainage outlets (6 valves). This allows the dam spillway to drain water to fill the Ahbas of Bouchen (Fig. 20). We are talking about the second priority of the IRS Development which is the artificial recharge of the aquifer thanks to the storage of water in the lake of Ahbas of Bouchen.

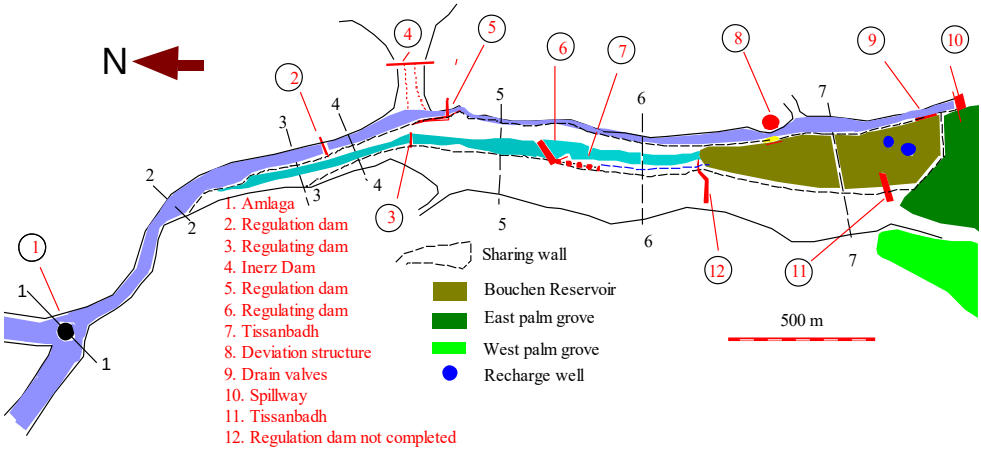


Figure 20: IRS Development: As a second priority, the water flows into the Bouchen seguia, then it borrows the seguia from the Bouchen reservoir to recharge the water table (blue color on the figure) (Schema Remini, 2020)

The recharge of the water table is carried out by the indirect method thanks to the infiltrations which are carried out through the bottom of the reservoir. The direct method is carried out by the two wells which are located in the center of Ahbas of Bouchen. A good recharge of the water table during a flood can take years of drought. More than 1,000 animal-drawn wells (called khottaras) have been produced in the palm grove of Ghardaïa. After the passage of a flood, the water level rises in the wells of the palm grove. In times of drought, permanent irrigation is carried out by the water drawn from these wells. Once the water level in the Bouchen seguia exceeds the height of the second wall (80 cm), the water takes the direction of the third path which corresponds to the M'zab River itself (fig. 21 and 22 (a, b, c and d)). It is a safety route intended to transport the excess water of a flood as well as the surplus of water evacuated by the drainage outlets and the overflow of the gardens of the palm grove of Ghardaïa.

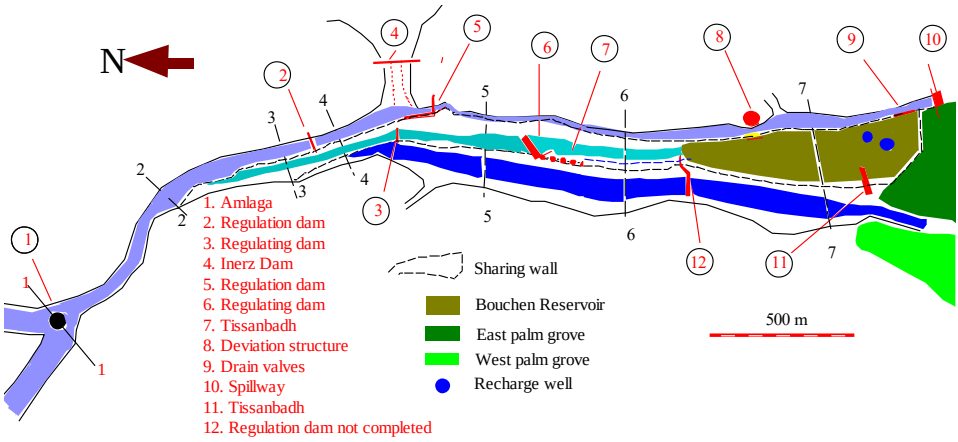
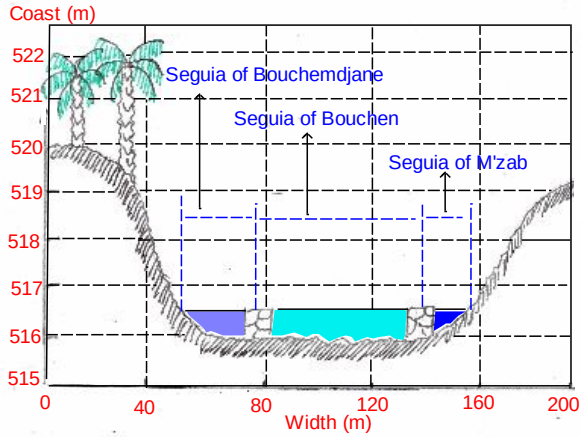
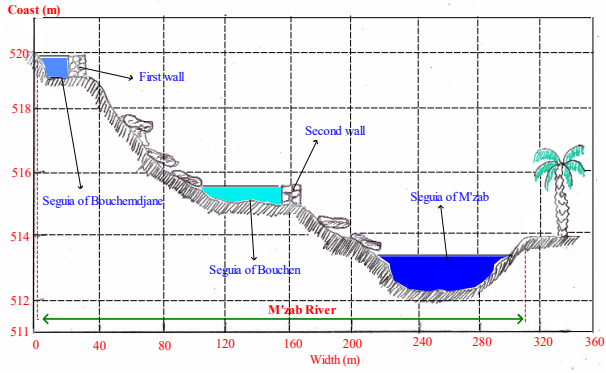


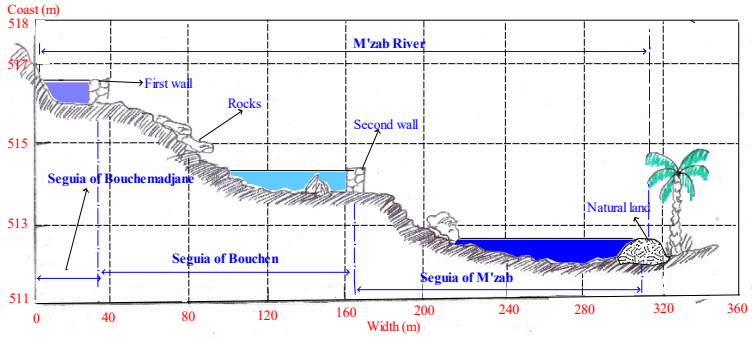
Figure 21: Furnishings IRS: Third priority, water flows into the irrigation channel of Mzab to reach the limit of River (Sebkhate Sefioune). This is the way of security. (Dark blue color in the figure) (Schema Remini, 2020)



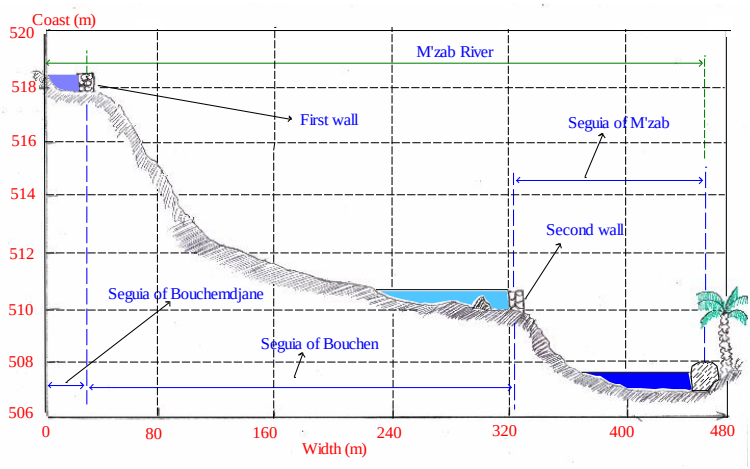
a) Section (4-4). Beginning of the third seguia- Seguia of M'zab (Dark Blue color) (Schéma Remini, 2020)



b) Section (5-5). Three seguias in full flow (Schéma Remini, 2020)



c) Section (6-6). Three Seguias in full flow (Schema Remini, 2020)



d) Section (7-7). Three seguias in full flow (Schema Remini, 2020)

Figure 22: The flood in the M'zab River - The three seguias of the M'zab River in full flow: Bouchemdjane, Bouchen et M'zab

DISCUSSIONS

Impressed by the grandeur of a layout. Impressed by all that has been achieved by the Mozabites in terms of hydraulics and architecture. If today, the architecture of the ksours in the M'zab valley is known throughout the world, however, the Mozabite hydraulic heritage remains little known despite an invaluable know-how in flood control. It is the climate of the region which has imposed the relationship: population-flood. A rocky region and a hyper arid climate. The Mozabite over time has learned that effectively in such a region without floods, man will not be able to survive. It is the sporadic floods that recharge the underground tank. Wait for drought to draw water from the water table using the khottaras. Mozabites practice two types of irrigation. Temporary irrigation which consists of flooding the gardens with flooded water; compulsory irrigation since very beneficial for the soil and for the plant. Freshwater irrigation to allow the plant to grow. To live in harmony with the floods, the Mozabite in matters of habitat applied the rule: live higher and cultivate the gardens in the wadi bed. Ksar on the hill and develop the wadi flood to destroy and make the most of these waters. IRS Development consists of dividing the M'zab River into three rivers to ensure in order of priority:

irrigation, recharging of the water table and security of the oasis by evacuating the surplus of the flood downstream.

CONCLUSIONS

A rock wall in the shape of an unclosed loop with a total length of 6.5 km was built on a section of M'zab River 4 km long. What genius? Called IRS, the 0.8 m high wall divides the M'zab River into three rivers. In order of priority, the stream of Bouchemdjane, located on the left bank, is intended to transport the first flood waters for the irrigation of the eastern palm grove of Ghardaia. The central watercourse which bears the name of Tradja of Bouchen has a dual function: irrigation and groundwater recharge. Irrigation is carried out by the water transported by Tardja of Takdimt and the recharge of the water table is affected by the infiltration of the water stored in the Bouchen reservoir. The stream on the right bank which is part of the M'zab River carries the excess of the flood and the overflow of the Bouchen dam.

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