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B – data collection
C – statistical analysis
D – data interpretation
E – manuscript preparation
F – literature search

Evolution of the flow of drainage waters in the Oued Righ canal, Algeria

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Abstract

The channel of the Oued Righ valley plays an important role in draining the drainage waters of the palm groves of 47 oases. This article evaluates and offers a simple relationship calculation of flow of drainage water carried by the channel of Oued Righ. Several work missions were carried out in the Oued Righ Valley during the period: 2010–2018. Investigations and surveys were conducted among the local population. Data and information were collected from the National Hydric Resources Agency (Fr. Agence Nationale des Ressources Hydrauliques) of Touggourt (capital of the Oued Righ Valley). Samples of bottom material and flow velocity measurements were performed at 10 gauging stations located along the canal with a length of 130 km. A simple formula for evaluating the flow rate in the channel has been highlighted. It is a practical quantification tool that will be useful for channel managers. Calculated rate exceeded 5 $m^3 \cdot s^{-1}$ of wastewater and drainage flow into the nature 10 km before reaching the Chott Merouane; the place of discharge.

Key words: *canal, drainage water, flow, gauging, Oued Righ*

INTRODUCTION

For centuries, man has learned to live in dry environments like the Sahara. Thanks to his know-how acquired over time, the man has highlighted hydraulic techniques to draw water in the depths of the ground. Rudimentary means, a harsh climate, the man was able to dig wells up to tens of meters. However over time, humans have improved these capture techniques to increase their yield. Thus he designed the foggaras system in the regions of Touat, Gourara and Tidikelt [KOBORI 1982; REMINI 2016; 2017; REMINI *et al*. 2011; 2012]. Born in ancient Iran for more than 3,000 years [GOBLOT 1963; 1979; HUSSAIN *et al.* 2008; KAZEMI 2004], the foggara called qanat has completely changed groundwater abstraction patterns. Another genius hydraulic system that was invented in the Saoura Valley. This is khottara; a well with multi-balance made in the oases of the Saoura which makes it possible to increase the flow of drawing [REMINI, REZOUG 2017]. In the Oued Righ valley, it is rather the animal-drawn wells and the rocking wells that have been used. Unlike the other regions of the Sahara, the Oued Righ valley is practically the only region that has a network of canals equipped with a main collector channel to evacuate the drainage water that comes from the return irrigation. Today, this ancestral hydraulic system continues to play an important role in safeguarding the regional environment. Aware of its importance in the economic development of the region, the quantification of the volumes of water transported becomes an essential operation before any project of rehabilitation or maintenance of the main collector.

This is the main objective of this paper which is to implement a simple and practical relationship to evaluate the flow rate at any station.

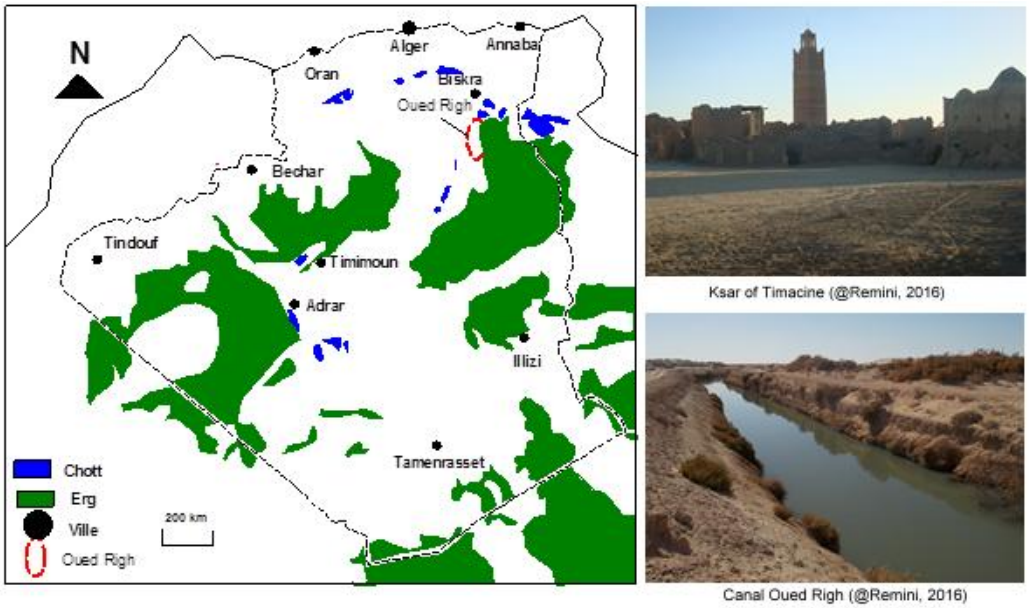

Fig. 1. Geographical location of the Oued Righ canal; source: own elaboration

REGION OF STUDY, METHODS AND MATERIALS

REGION OF STUDY

An arid region, Oued Righ Valley is a group of oases located on either side of a canal over 130 km in length. This valley is located between two Wilayas: El Oued and Ouargla. Located 450 km approximately as the crow flies South-East of Algiers, the climate of the Oued Righ valley is typically Saharan characterized by very low rainfall and high temperatures that can reach 47°C (Fig. 1).

The Oued Righ valley is made up of 47 oases of which Touggourt is the capital which is called the city of seven ksour [CHAOUCHE 2008]. Like the Souf valley, the Oued Righ valley exploits the Continental Intercalary aquifer. The Oued Righ valley is fed by 331 boreholes, which generally give a flow of about 9000 $dm^3 \cdot s^{-1}$ [BOUZNAD *et al*. 2016].

MATERIALS AND METHODS

To achieve our objective, a bibliographic search was started on the premises of the National Hydric Resources Agency of Touggourt (Fr. Agence Nationale des Ressources Hydrauliques – ANRH). Archives and documents dealing with the canal were consulted. All the data on the canal as well as the measurement and granulometry equipment were made available to us by the National Hydric Resources Agency (ANRH) of Touggourt.

- **Measuring materials used**

For the flow measurements in the Oued Righ channel, we used the propeller-type windmill: A – OTT C 31N° 41184, equipped with an F4 counter N° 128542 (Photo 1, 2).

The calibration of the reel gave us the following relation:

$$V = 0.1300n + 0.019 \quad (1)$$

Where: V = velocity of the current ($m \cdot s^{-1}$), n = number of propeller revolutions per second.

Photo 1. Type of reel used in gauging (phot. *M. Sayah Lembarek*)

Photo 2. Counter used in gauging (phot. *M. Sayah Lembarek*)

- **Relationships used**

For the determination of velocity, we used Strickler's universal relation [CARLIER 1972]:

$$V = K \cdot R_h^{2/3} \cdot I^{1/2} \quad (2)$$

Where: V = average velocity ($m \cdot s^{-1}$); K = roughness coefficient (from Strickler, Meyer–Peter and Müller and Raudkivi); R_h = hydraulic radius (taken from gauging); I = slope of the stretch of watercourse (slope of the bottom).

The roughness coefficient is determined by the empirical formulas: $K = 21 \cdot d_{50}^{-1/6}$ (Strickler), $K = 26 \cdot d_{90}^{-1/6}$ (Meyer–Peter and Müller), $K = 24 \cdot d_{65}^{-1/6}$ (Raudkivi).

- **Gauging stations**

For velocity measurements and sampling of bottom material, ten hydrometric stations were taken into account along the channel. These are the stations (Fig. 2): Kerdache (12 km), Ranou (24.5 km), Zaouia Labidia (34.5 km), Bourkhis (50 km), Sidi Slimane (55.9 km), Sidi Amrane (68 km), Zaouiet Riab (100 km), Tinedla Amont (111.25 km), Tinedla Aval (114 km), Boufeggoussa (125 km).

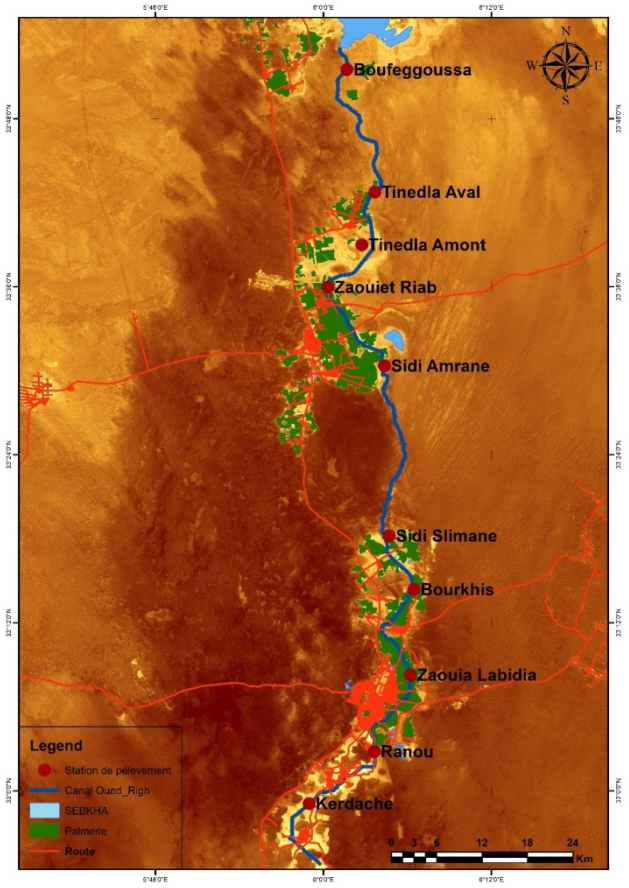

Fig. 2. Hydrometric stations at the canal level (sampling points); source: own elaboration

Photo 3. Flow velocity measurements near the left bank of the channel (phot. *M. Sayah Lembarek*)

For flow measurement, several gauging companions were organized. Three to four person are needed for the success of the measurements. The working conditions in the canal are extremely difficult, especially with the heat and the silt deposits at the bottom of the canal. Two people manipulate the reel and the counter for the third person records the measured values (Photos 3, 4).

Photo 4. Flow velocity measurements at the centre of the canal (phot. *M. Sayah Lembarek*)

RESULTS AND DISCUSSIONS

THE IMPORTANCE OF THE CANAL IN THE OUED RIGH VALLEY

Designed to evacuate domestic sewage and drainage, the Oued Righ canal with a total length of 132 km from the oasis of Goug to Merouane Chott; place of rejection (Photo 5). All palm groves (16,000 hectares) and settlements discharge their water (drainage and waste) along this canal running from south to north (Photo 6, 7). Executed in 1910 by the local population, the canal plays an economic and environmental role for the entire region of the Oued Righ valley. Without this structure, the entire region of the Oued Righ valley would be flooded today by the waters of the rising water table. As an example, we must look at the region of Souf, which suffered the consequences of the rise of the water table during the nineties [MILOUDI, REMINI 2016; 2018a, b; REMINI, KECHAD 2011; REMINI, MAINGUET 2003]. Nevertheless, on both sides of the canal, there

Photo 5. A general view of the magnitude of the channel of Oued Righ (phot. *B. Remini*)

Photo 6. A point of discharge of domestic wastewater in the canal (phot. *B. Remini*)

Photo 7. A point of discharge of drainage water in the canal (phot. *B. Remini*)

are about twenty water-lift sites that have made their appearances [BOUCHHAM *et al*. 2013].

EVOLUTION OF THE FLOW RATE ALONG THE CANAL

Due to the discharges of domestic wastewater and all drainage, the flow rate increases along the canal from South to North to Merouane Chott; the place of rejections. Ten gauging stations are located along this channel. The knowledge of this hydraulic parameter is of great use for the managers of this hydraulic structure. The values measured by the reel are shown in Table 1 and shown in Figures 3 and 4. It is interesting to note that the flow obtained at the Tinedela Aval station is 5.32 $m^3 \cdot s^{-1}$; such a high value which testifies to the importance of the discharges of the drainage water coming from the irrigation of the palm groves. However, approaching the last gauging station (Boufegoussa), a station located at the mouth of the Marouane Chott, the flow dropped to 3.24 $m^3 \cdot s^{-1}$, which seems illogical to us. We expected an increase in the flow or the boundary a constant value, since the segment Tinedla–Boufegoussa is a desert region with no agglomeration and the palm grove. This situation forced us to carry out an investigation mission in the region. It turns out that more than 2 $m^3 \cdot s^{-1}$ of water are thrown into the wild,

Table 1. Measured flow values

Station	Flow rate ($m^3 \cdot s^{-1}$)
Kerdache	0.13
Ranou	0.85
Zaouia Labidia	1.47
Bourkhis	1.68
Sidi Slimane	2.10
Sidi Amrane	1.91
Zaouia Riab	3.47
Tinedla Amont	4.22
Tinedla Aval	5.32
Boufeggoussa	3.24

Source: own study.

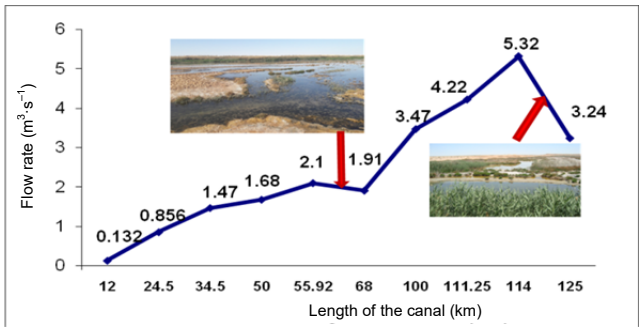

Fig. 3. Variation of the flow according to the length of the channel; source: own elaboration

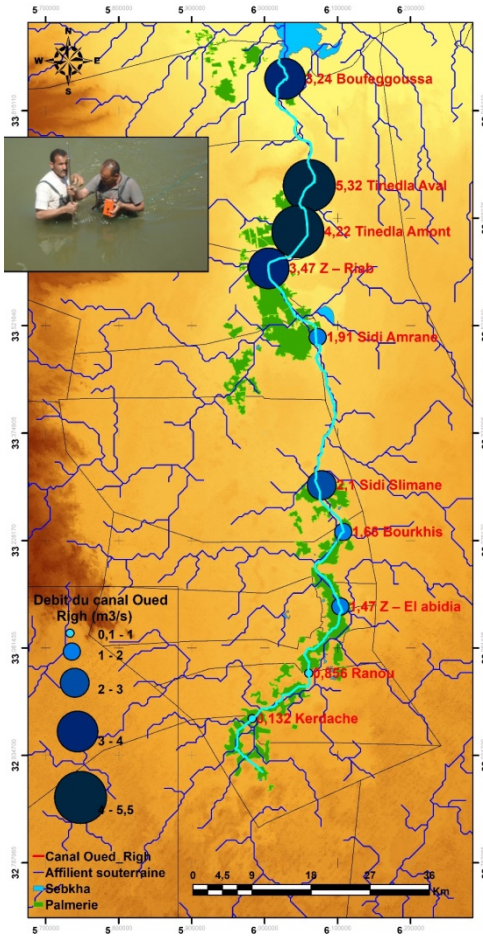

Fig. 4. Map of the Oued Righ canal with the evolution of the flow; source: own elaboration

forming a large lake because of the deterioration of the canal and the total absence of a skilful bank (Photo 8). In the same situation was observed along the section: Sidi Slimane–Sidi Amrane, the channel is leaking at a rate of more than 0.1 $m^3 \cdot s^{-1}$ of degradation of the channel (Photo 9).

Photo 8. Lake formed by losses of the canal in the section: Tinedla Aval–Boufeggoussa (phot. *M. Sayah Lembarek*)

Photo 9. Lake formed by losses of the canal in the section: Sidi Slimane–Sidi Amrane (phot. *M. Sayah Lembarek*)

IMPLEMENTATION OF A CALCULATION FLOW RELATIONSHIP

In order to make it easier for channel managers, we have identified a practical relationship that allows us to calculate the flow rate at each station. The relationship is inspired by Strickler. The roughness Strickler's coefficient must take parameters of the channel. Thus a particle size analysis is necessary for the determination of diameters: d_{50}, d_{90} and d_{65}. Samples with a mass of 1 kg of the bottom material were taken from the sections of 10 gauging stations. Once in the laboratory, the material was put in a tank and dried for 24 hours. Then it was put into a series of vibrating screens of different diameters. The results obtained are shown in Table 2.

Table 2. Diameter value d_{50}, d_{65} and d_{90}

Station	Diameter		
	d_{50} (mm)	d_{65} (mm)	d_{90} (mm)
Kerdache	0.26	0.31	1.23
Ranou	0.21	0.24	0.33
Zaouia Labidia	0.28	0.47	2.40
Bourkhis	0.16	0.24	2.70
Sidi Slimane	0.25	0.50	2.90
Sidi Amrane	0.28	0.48	3.30
Zaouiet Riab	0.20	0.17	1.20
Tinedla Amont	0.42	0.64	1.80
Tinedla Aval	0.13	0.15	0.31
Boufeggoussa	0.15	0.17	0.29

Source: own elaboration.

The resulting formula derives from Strickler's relationship whose roughness coefficient specific to the Oued Righ canal is $K = 16/(d_{65})^{1/6}$. In this case, the formula becomes:

$$Q = \frac{16}{d_{65}^{1/6}} R_h^{2/3} I^{1/2} S_m \tag{3}$$

To validate the new formula, we compared the results obtained by our formula with the measured values and calculated by the formulas: Manning–Strickler, Strickler, Meyer–Peter and Müller, Bazin and Raudkivi. The results obtained are shown in Figure 5. It is interesting to note that the results obtained by the Oued Righ formula are similar to the experimental results. Apart from the first three values, where there is a slight shift, the theoretical curve fits well with the experimental curve. For example, there is only a 4% error in the Tenedela Aval and Sidi Amrane stations.

CONCLUSIONS

As we mentioned at the beginning of this paper, the Oued Righ Canal plays an important role in the development of the Oued Righ valley. It is thanks to this collector that the domestic wastewater and drainage are evacuated towards the Merouane Chott. The quantification of the volumes of water flowing in this channel becomes a necessity for the managers of the structure. Flow gauges were made with the reel at 10 points along the 130 km long channel. A flow of more than 5 $m^3 \cdot s^{-1}$ was recorded at the Tinedla Aval station about 10 km from the outlet (Merouane Chott). However, because of the deg-

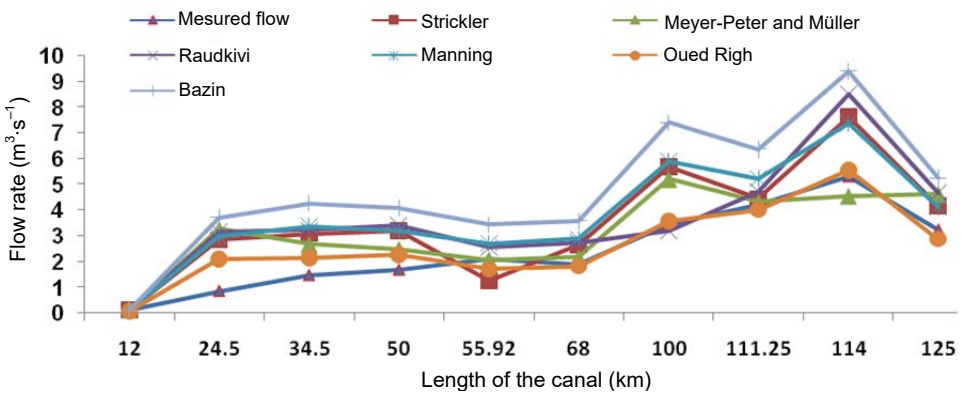

Fig. 5. Validation of the results obtained by the relation of Oued Righ; source: own study

radation of a section of the canal, 2 $m^3 \cdot s^{-1}$ of water is lost in nature by forming a lake of water.

A relationship for flow determination derived from the Strickler formula has been highlighted. Validated with the experimental results, the error committed does not exceed the value of 4%, it is a very encouraging result.

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Zmiany przepływu wód drenarskich w kanale Oued Righ w Algierii

STRESZCZENIE

Kanał w dolinie Oued Righ odgrywa ważną rolę w drenowaniu wód z gajów palmowych w 47 oazach. W pracy dokonano oceny na podstawie prostych obliczeń przepływu wód drenarskich niesionych przez kanał Oued Righ. W latach 2010–2018 wykonano kilka wyjazdów terenowych w rejon doliny. Badaniem i ankietowaniem objęto także lokalną społeczność. Dane i dodatkowe informacje pozyskano z Narodowej Agencji Zasobów Wodnych (fr. Agence Nationale des Ressources Hydrauliques) w Touggourt (miasta stołecznego doliny Oued Righ). W dziesięciu stacjach pomiarowych rozmieszczonych wzdłuż kanału o długości 130 km pobrano próbki osadu dennego i zmierzono prędkość przepływu. Wyprowadzono prosty wzór do oceny tempa przepływu w kanale. Wzór ten jest praktycznym narzędziem do wykorzystania przez zarządców kanału. Obliczona prędkość przepływu ścieków i wód drenarskich przekraczała 5 $m^3 \cdot s^{-1}$ w odległości 10 km od Chott Merouane, gdzie wody są odprowadzane do środowiska.

Słowa kluczowe: *kanał, Oued Righ, przepływ, punkty pomiarowe, woda drenażowa*