HYDROLOGICAL, GEOLOGICAL AND CHEMICAL ASSESSMENT OF BOUINENC CATCHMENT, SOUTH OF FRANCE

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ABSTRACT

Bouinenc catchment assessment has been carried out during field work in the South of France. This catchment assessment consists of field surveying, data collection, measurement, processing, and analysis based on hydrology, geology and chemistry condition. Moreover, EC routing has been done in this catchment along the Bouinenc. Result shows that during the observation period (June 1st until June 8th, 2010), the discharges are decreasing both in Upstream (Chap village) and in the Downstream. EC values at measurement location in downstream are increasing and have diurnal cycle depend on temperature. The potential evapotranspiration varies from above 4 to 7 mm/day during the measurement. Based on the geology map and survey, the majority of this study area is black marls and limestone formation from the Jurassic period. The springs are mainly located in the contact zone of the different layers and also in some cases due to faults. Water type in this area primarily is calcium bicarbonate from the marls and limestone formation. EC routing result shows that there is no significant interaction between surface water and groundwater. In addition, discharges from tributary rivers are not sufficient to influence the main river.

Keywords: *Catchment assessment, hydrology, geology and chemistry.*

ABSTRAK

Analisis di DAS Bouinenc telah dilakukan selama kerja lapangan di Selatan Prancis yang terdiri dari survei lapangan, pengumpulan data, pengukuran, pengolahan data dan analisis berdasarkan kondisi hidrologi, geologi dan kimia dari DAS tersebut. Penelusuran EC telah dilakukan juga di sepanjang sungai Bouinenc. Hasil analisis menunjukkan bahwa selama pengamatan (1 juni sampai 8 juni, 2010), debit sungai menurun baik di hulu (Chap) maupun di hilir. EC di lokasi pengukuran, hilir Bouinenc, meningkat dan membentuk siklus harian bergantung kepada suhu. Potensial evaporasi bervariasi dari 4 hingga 7 mm/hari selama pengukuran. Berdasarkan peta geologi dan survei, DAS Bouinenc mempunyai formasi geologi "black marls"dan "limestone" dari jaman jurasic. Mata air pada umumnya terdapat di bidang kontak dari lapisan batuan yang berbeda dan beberapa terdapat pada bidang patahan. Tipe air pada DAS Bouinenc pada umumnya adalah kalsium bikarbonat yang berasal dari formasi "marls" dan "limestone". Hasil dari penelusuran EC menunjukkan bahwa tidak ada interaksi antara air permukaan dan air tanah. Selain itu debit dari anak sungai tidak memberikan pengaruh yang besar ke sungai utama.

Katakunci: *Analisis DAS, hidrologi, geologi, dan kimia.*

INTRODUCTION

In order to make an assessment of the water resources for a certain area, it is necessary to understand the hydrological behavior of that area, for which in turn a large amount of information has to be collected (Foppen et al. 2010). Hydrological characteristics, chemical analysis and geological description are important and essential in order to assess the catchment for a better understanding of its behavior.

Hydrological analysis can show the catchment response to rainfall events, chemical analysis can indicate the quality of the water resources as well as the interaction between the soil and water, furthermore geological description can help us to validate the chemical analysis and interpretation for the sources of the chemical characteristics of the water. Kirchner et al. 2004 stated that the measurement of chemical behavior will yield novel insight into many key questions in catchment hydrology including:

1) How long do catchments store water in the sub surface, and by what combination of flowpaths does this water reach the stream?
2) What are the mechanism connecting catchment (relatively long) time scales of water storage and their (much shorter) time scale of hydrological response to rainfall inputs?
3) How do the time scale and flowpaths of sub surface transport change with flow regime and antecedent condition?
4) How do hydro-geological conditions and thus flowpath routing, affect the chemical interaction of porewaters with soils, bedrock and biological processes within the catchment?
5) How should model aggregate catchments' intrinsic complexity and heterogeneity, in order to represent catchment behavior adequately across a range of time scale?

A preliminary assessment for the Bouinenc catchment has been undertaken from June 1st to June 8th, 2010 (located at 44°08'12"N; 6°17'18"E) based on the three analyses above mentioned. This assessment answers some of those questions stated by Kirchner in general with several limitations such as time is too short, catchment is too big, transportation is not sufficient, etc. It is recommended to have long time measurement in order to have a detail interpretation but this study was limited by time.

The assessment consists of not only area surveying but also data measurement, collecting and analysis. Discharge measurements and water chemical analyses have been done in some locations. Cross sections and describing the geological characteristic have been made in one of the spring location. Additionally, geological interpretations are also shown in this study. Moreover, EC routing along the main river has been carried out to have a better understanding about the contribution of tributaries discharge and groundwater interaction to the main river.

The aim of this study is to analyze the Bouinenc catchment area based on hydrology, chemistry and geology condition. The objective of this study is to obtain a catchment characteristic in general related to source of discharge, evapotranspiration in this catchment, geology effect in the river, and interaction between groundwater and surface water. Location of study is at Bouinenc catchment, one of the main Bleone river tributary. This catchment is located in the upstream of Digne les Bains city in South of France with area 38 km^2 (see Figure 1).

MATERIAL AND METHODS

Surveying in the catchment area was done using topographic map from Institut Geographique National number 3440ET (scale 1:25.000) and geologic maps from Ministere De L'industrie et De L'amenagement Du Territoire, Service Geologique National number 918 (scale 1:50.000). Topography map was also used to delineate the catchment area and to identify the spring's locations. Geology map was used to identify the geology formation in the area of interest.

The chemistry data were analyzed from the samples taken in the main tributaries by measuring EC, pH, the main anion and cation which are: SO_4^{2-}, HCO_3^-, NO_3^-, Cl^-, Ca^{2+}, and Mg^{2+}. EC, and pH have been analyzed using EC and pH meter. SO_4 was determined turbidimetrically by using spectrophotometer (De Lange) at 890 nm. HCO_3^-, Cl^-, Ca^{2+}, and Mg^{2+} were analyzed using a Hatch digital titration kit. NO_3^- was analyzed using paper nitrate test. Na^+ and K^+ were assumed by the deficit in the ion balance. Chemical analysis was done in 24 hours after the samples were taken.

The method for Sulfate analysis using spectrophotometer is described below:

1) Fill a clean sample cell with 10 ml of sample, add the contents of one sulfaVer4 sulfate reagent powder pillow to the sample cell. Cap the cell and invert several times to mix.
2) Press timer enter, a five minutes reaction period will begin. Allow the cell to stand undisturbed.
3) After the timer beeps, fill a second sample cell with 10 ml of sample (blank)
4) Place the blank into the cell holder; tightly cover the sample cell with instrument cap.
5) Press zero, the cursor will move to the right, and then the display will show 0 mg/L SO4.
6) Within five minutes after the timer beeps, place the prepared sample into cell holder. Tightly cover the sample cell with the instrument cap.
7) Press read and the result will be displayed.

The limitation of this equipment is 70 mg/L. If the sample has concentration more than that, the sample needs to be diluted first.

The method to use Hatch digital titration kit is explained below:

Alkalinity (HCO_3^-)

Fill the measuring cylinder with 25 mL sample, transfer to flask. Add 2 drops bromocresolgreen-methylred. Titrate with cartridge (0.2M H_2SO_4) from green to pink/red color. Reading:

100 digits = 2.00 meq HCO_3^-/L = 122 mg/L = 100 mg/L as $CaCO_3$

Calcium (Ca^{2+})

Fill the measuring cylinder with 25 mL sample, transfer to flask. Add 10 drops 6M NaOH and 10 drops murexide. Titrate with cartridge (0.2M Na_2EDTA) from purple to blue. Reading:

100 digits = 2.00 meq Ca^{2+}/L = 40 mg/L = 100 mg/L $CaCO_3$

Magnesium (Mg^{2+})

Fill the measuring cylinder with 25 mL sample, transfer to flask. Add 10 drops of buffer, add 5 drops of Eriochrome-black T. Titrate with the cartridge (0.2M Na_2EDTA) from wine-red to blue. Reading:

(digits Mg^{2+} - digits Ca^{2+})*0.243 = mg Mg^{2+}/L

Chloride (Cl^-)

Fill the measuring cylinder with 25 mL sample, transfer to flask. Add 10 drops of 5% K_2CrO_4. Titrate with the cartridge (0.2M $AgNO_3$) from yellow to red. Reading:

mg/L = [(digits/100)*35.5]-13

Discharge measurements were performed using area-velocity and instantaneous salt method. Velocity was measured in the stream using a propeller made by Eijkelkamp and the discharge was calculated using the mid section method. Moreover, two Schlumberger divers in the Bouinenc upstream Chap (44°07'59.9"N; 6°22'15.8"E) and in the downstream area (near the big road, 44°08'12.5"N; 6°17'27.48"E) were installed. Instantaneous method was used for small stream using 1 kg and 500 mg of salt and EC meter. EC calibration was done using 10 g/L salt solution.

The basis of instantaneous salt method is the measurement of the passage of an upstream continuously or instantaneously injected known amount of tracer substance. The most important demand of this method is a salt completely mixing with the water and assuming that the entire tracer will pass the site during observation period. The discharge is determined with:

$Q = Mt0t1C1 - C0dt$ ....(1)

Where:

Q : stream discharge (m^3/s)

M : mass of injected tracer (mg)

C_1 : tracer concentration downstream (mg/m^3)

C_0 : background concentration downstream (mg/m3)

t_0 : time of first arrival of the tracer downstream (s)

t_1 : time of disappearance of the tracer downstream (s)

In discrete form, equation (1) becomes:

$Q = Mt0t1(C1 - C0)\Delta t$ ....(2)

Which can easily solved in spreadsheet. The relation between tracer concentration and EC reading is almost linear and given by:

C = k(EC)+a ....(3)

Where:

k : calibration constant

EC : electrical conductivity (μS/cm)

a : intercept

Rating curves in Bouinenc upstream (Chap) and downstream have been developed using Manning's equation (see equation 4). Due to the absence of rainfall, instead of obtaining a discharge-water depth relationship directly, a previous use of Manning's equation to calculate the slope, assuming a roughness coefficient of 0.04 (Boiten, 2008) was needed. Evapotranspiration was calculated using climatology data obtained from the temporary meteorological station located in the camping site.

Manning formula introduced by Ven Te Chow, 1964 to calculate discharge in the river is described below:

Q = $A * \frac{1}{n} * R^{\frac{2}{3}} * S^{\frac{1}{2}}$ ....(4)

Where:

Q : discharge (m^3/s)

n : Manning coefficient

R : hydraulic radius

S : River slope

A : cross section area (m^2)

EC routing was done along the Bouinenc River starting from Bouinenc and Cougnes junction until downstream of Bouinenc. The EC values were measured before and after the river tributaries, in the middle of two main tributaries, and in areas of interest.

RESULT AND DISCUSSION

Hydrology Assessment

Bouinenc catchment has a river length ±10.8 km from the Bouinenc-Cougnes junction until the downstream area under the old bridge and area approximately 38 km^2. The lowest elevation is ±696 m NTF (National Transfer Format, British National Grid Coordinate System) and the highest is ±2282 m NTF. The predominant land cover of this catchment consist of Oak and Pine forest in the upstream and middle area, agriculture and cattle in the middle and downstream area, in the middle area near Draix an open area can be seen with marls rock, and small housing settlements. The original source of water for this river is springs around the mountains, a same configuration can be observed for the main tributaries also, although the origin and geological characteristics of the springs are not the same among each other. Major sub-catchments in this area are Ravin du Vabre, Riou du Couard, and Ravin des Cougnes (see Figure 1). The average heavier rainfall recorded by the experimental station in Draix took place from June 26 to November 15 is 30 mm a day with moderate rainfall intensity (Mathys et al. 2005). Mean annual rainfall is 940 mm with daily maxima of 80 mm (Cosandey et al. 2005).

Discharges in the Bouinenc at the two locations have been measured using Divers. The downstream area (see Figure 1) has a CTD diver which measured water level and EC values. Discharges in the upstream of the Bouinenc catchment is 0.132 m^3/s and in the downstream area of Bouinenc is 0.187 m^3/s. Discharges in the main tributaries river are 0.07 m^3/s for Bouinenc upstream, 0.015 m^3/s for Cougnes, 0.004 m^3/s for Couard and 0.03 m^3/s for Vabre (see Figure 4 for tracer break curve graph example). These tributaries discharges were measured using salt instantaneous method while discharges at main rivers were measured using propeller. Rating curves at those two locations have been made based on Manning's formula. Manning coefficient assumed in this calculation is 0.04 for Mountain River with gravel bottom and few boulders (Boiten, 2008). Slopes obtained from Manning calculation are 0.0069 for Bouinenc Chap and 0.0012 for Bouinenc downstream. Rating curve constructed on those areas can be seen at Figure 2.

Discharges at Bouinenc Chap and Downstream can be constructed based on these rating curves. Time series of water level data from the divers in the observation period were plotted using these rating curves after the water level data are corrected. Pressure-elevation correction and water level correction needed to be made in order to have actual water level. Discharges from Bouinenc River and EC-temperature values are shown at Figure 3.

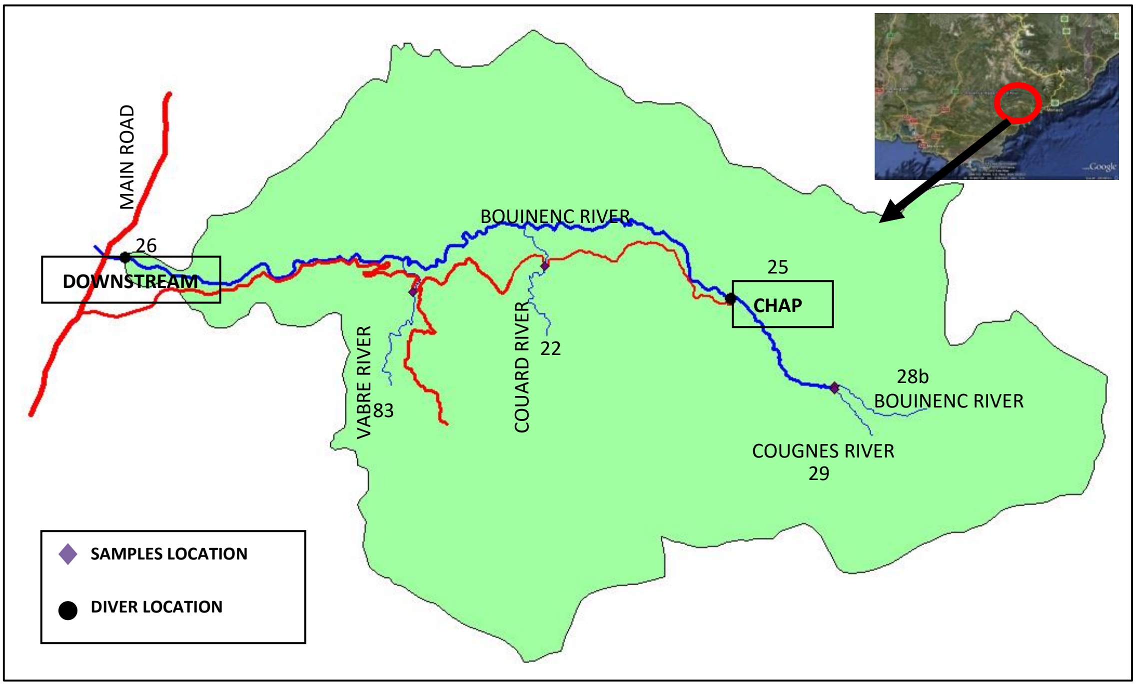
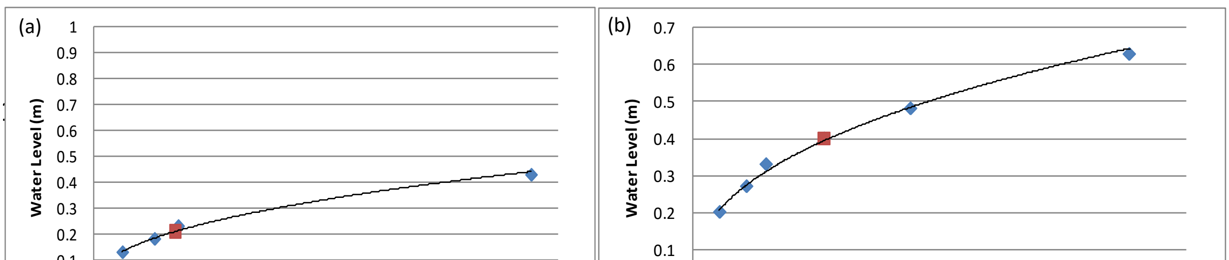


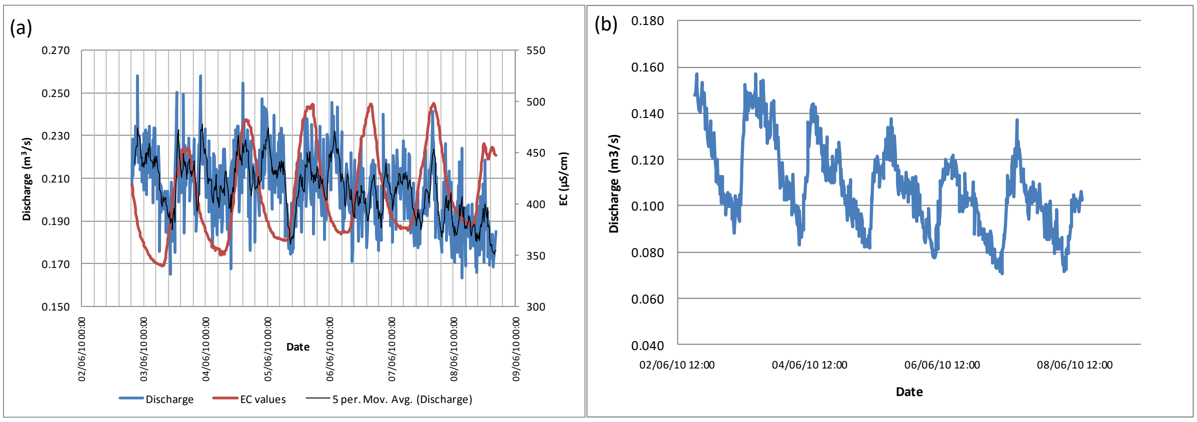
Figure 1 Location of study area



(a) Bouinenc upstream (Chap)

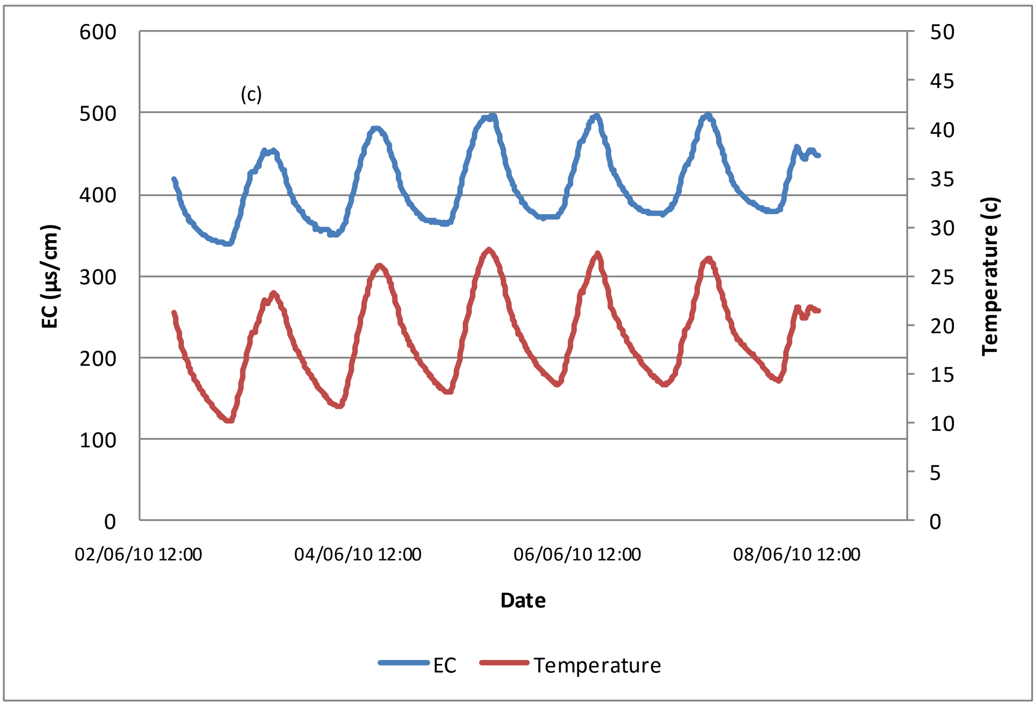
(b) Bouinenc downstream

Figure 2 Rating curves at Bouinenc River



(a) Discharges and EC at Bouinenc downstream

(b) discharge at Bouinenc upstream (Chap)



(c) EC and temperature at Bouinenc downstream

Figure 3 Discharges, EC and Temperature at Bouinenc River

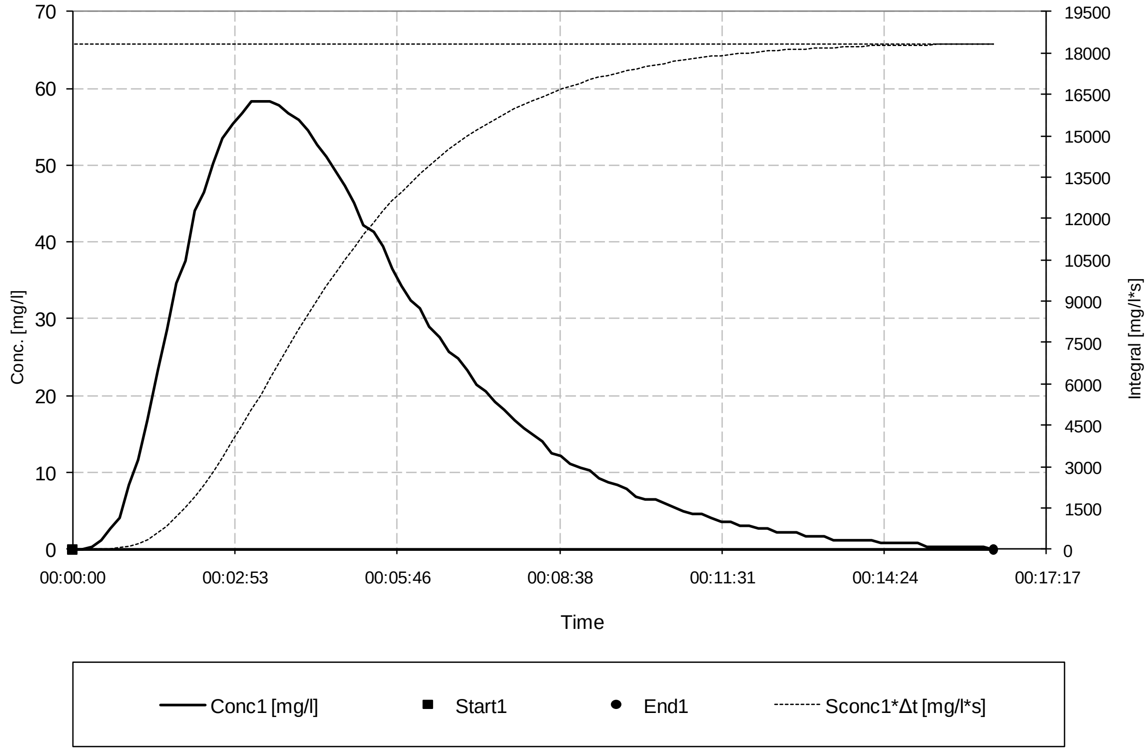


Figure 4 Tracer break curve at Vabre

Discharges at Bouinenc Chap and downstream area are decreasing slowly because it was a rain two days before we started measurement. We can assume that the measured discharges are discharges which have source from spring and sub-surface water. Maximum discharge is 0.16 m^3/s and minimum discharge is 0.07 m^3/s at Chap while maximum discharge is 0.258 m^3/s and minimum 0.163 m^3/s at downstream. EC values at Bouinenc downstream show diurnal fluctuation and has the same pattern with temperature. This diurnal cycle is a result from the effects of evapotranspiration (Kirchner et al, 2004). When the temperature increases, evapotranspiration also increase. Calles, 1982 also stated that evapotranspiration seems to be the most important agent even if certain examples give unlikely results. However in the downstream area the EC value and the discharge do not show a consistent relationship as it was expected. The highest and lowest values of the parameters should show a direct relationship, but it was observed that during the daily variation, some unexpected peaks occurred (between 21:00 and 4:00 hours approximately). The observed graphic (see (c) EC and temperature at Bouinenc downstream

Figure) cannot explain the hydrological characteristics of this catchment. A possible reason for this abnormal situation might be an erroneous calibration of the diver used in the continuous measurement.

A portable climate data logger system was set up with interval of 15 minutes to record meteorological data in order to calculate the evapotranspiration during the period. That climate equipment consists of solar panel, typing bucket rain gauged, sunshine recorder, thermometer, and anemometer. The station located at the camping place with the altitude of 625 m. There was a small gap of unmeasured data in June 4th (10:58 to 15:28) due to solar power problem, so the missing data were in-filled using linear interpolation method. The evapotranspiration was computed base on the Penman-Monteith method (see Figure 5).

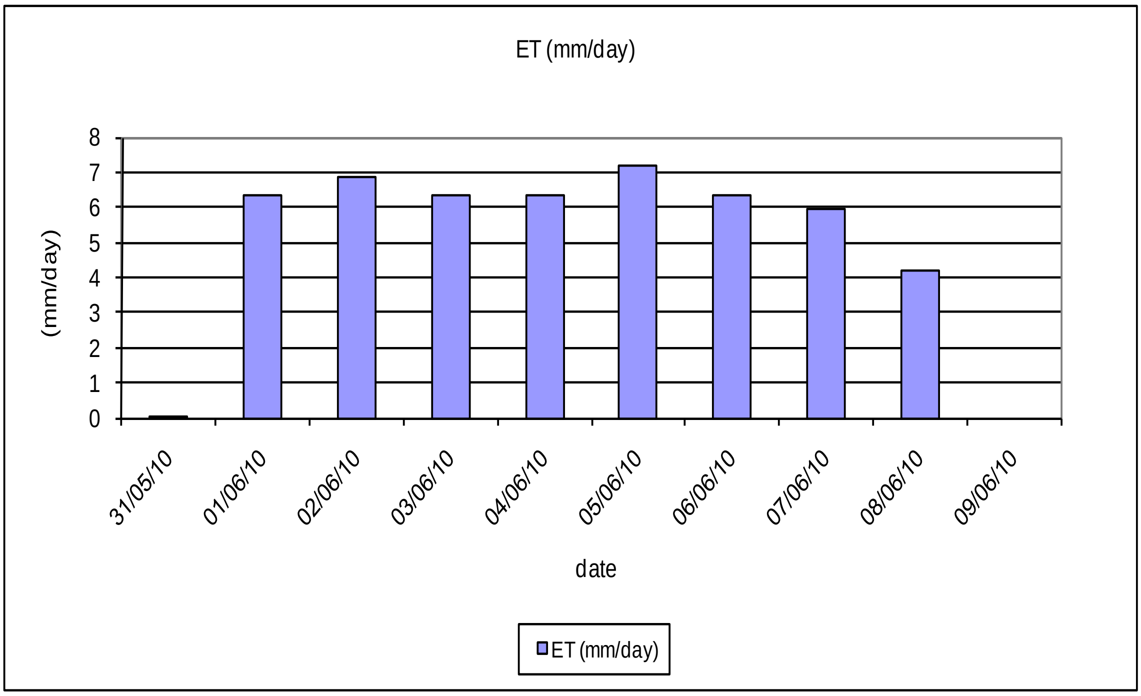


Figure 5 Daily potential evapotranspiration calculated for the Bouinenc catchment from June 1st to June 8th, 2010

Figure 5 shows that the daily potential evapotranspiration varies from above 4 to 7 mm/day except the first day (May 31st) just some hour measurement and the day June 8th. At June 8th the value is only approximately 4 mm/day because there was considerable amount of clouds during the whole day. Overall, there was a small rainfall (0.1 to 0.2 mm in 4th June) recorded during the measurement days. This might be fog in the morning.

Geology Assessment

The geology of the Bouinenc catchment along the Bouinenc River is mainly composed of black marl facies badlands. These black marls hill slopes are prone to weathering processes and landslide generation which can be seen in steep slopes. Bedrock is mainly covered by overlying weathered materials. The fieldwork area was divided to four main sub-areas, downstream and upstream of the Draix village and two main branches of the river at uppermost of the main river.

The geology along the Bouinenc River downstream of the Draix area is rather homogenous with sequence of loose silty clay colluviums (C). In the northern part of the river there is a layer of black marls from the Upper Toarcian (L_8), very dark marl-limestone including phosphatic cords from the last stage of the early Jurassic period (J_{0a}), the well developed layers of limestone and marls prone to slumping from the early Jurassic (J_1), the composition of rarely hardened gray, dark marl from Mid-Jurassic epoch ($J_{2\text{-}4}$).

Upstream of the Draix area is the continuing of the Mid-Jurassic ($J_{2\text{-}4}$) formation up to the intersection between two main upstream branches (Bouinenc and Cougnes) with small part of cryoclastic rock falls associated with the falling of large limestone blocks. Cougnes branch continues its way upstream to the springs "Sce Cab de la Cine" and "Sce des Cougnes" in south-east of the catchment. Geology of this part is rather heterogenic with the sequence of $J_{7\text{-}9}$, J_1, $J_{2\text{-}4}$, $J_{5\text{-}6}$ from the Jurassic epoch and marl limestone (N_1, N_2, N_3) from the Cretaceous period. The main springs are located in the contact of the different layers except "Sce des Cougnes" which is in the fault. The schematization of the geology formations along the main river can be seen at Figure 6.

Bouinenc branch passes heterogeneous layers of black marls of different Jurassic period including $J_{7\text{-}9}$, J_1, $J_{2\text{-}4}$, $J_{5\text{-}6}$, and the composition of calcite, marl and conglomerate from cretace epoch (N_1) and it finishes its way at the springs Sce des Fontounes, du Cheval Blanc and les Croquets formed in the contact layers. In the western valley of the du Cheval Blanc several faults exist (see Figure 7 and Photo 1). The geological checking was done using acid liquid and hammer to test the rock type in some parts.

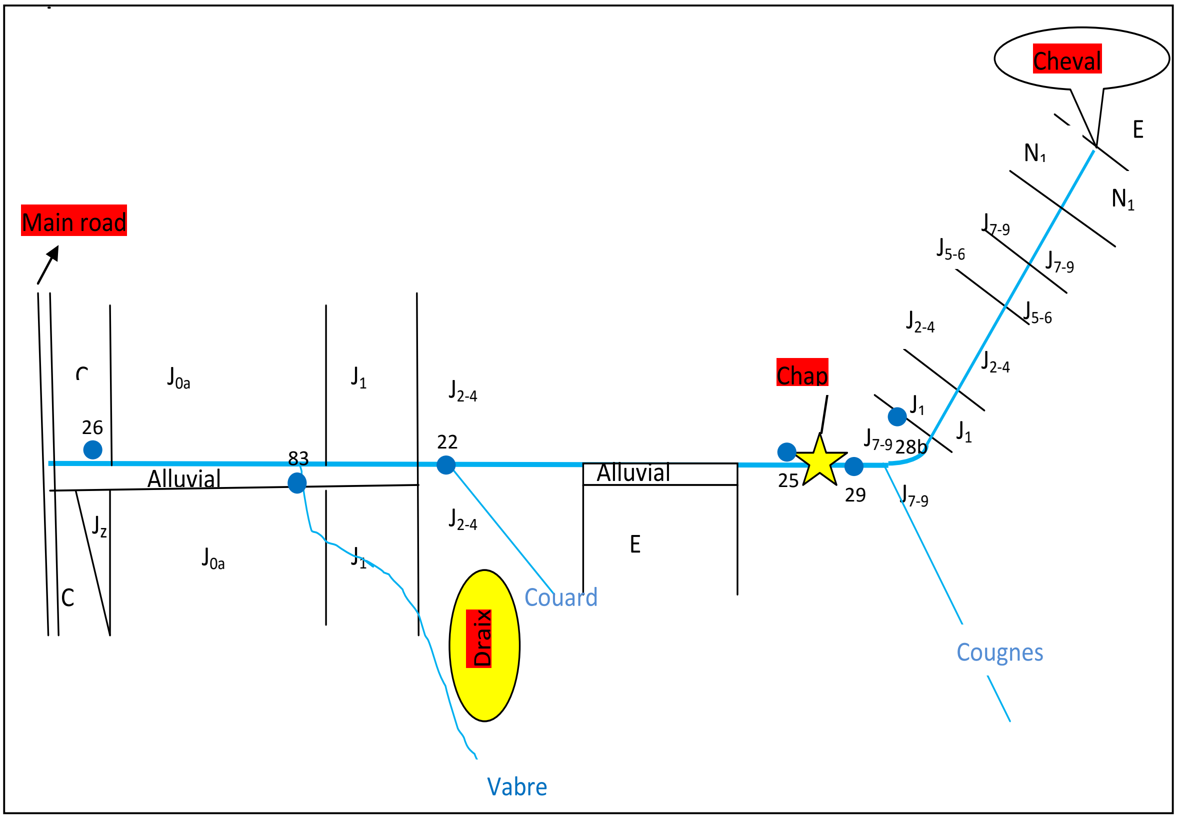


Figure 6 Schematization of the geology formations along the main river

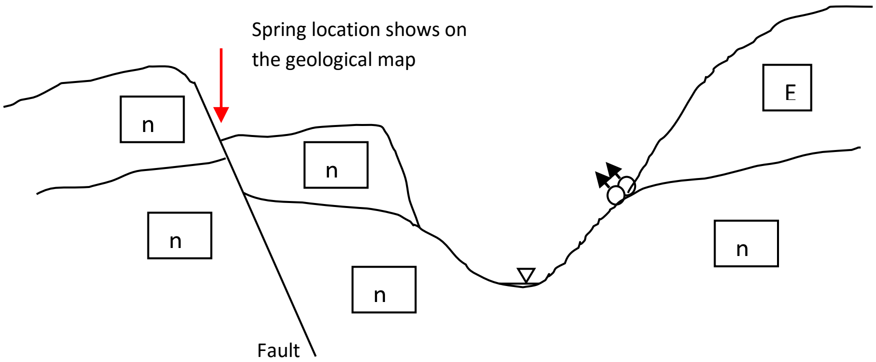


Figure 7 Cross section of the springs du Cheval Blanc

Legend:

C : Quaternary formation, spreading silty clay colluvium

E : Quaternary formation, Scree old or fixed

L_8 : Upper Toarcian, black marls with nodules of phosphate

J_{0a} : Early-Jurassic, marl-limestone including non-mappable facies in the area

J_1 : Early-Jurassic (Bajocian), alternation of marl and gray limestone with ammonites

$J_{2\text{-}4}$: Mid-Jurassic (Bathonian, Callovian, Oxfordian), "muck"

$J_{7\text{-}9}$: Late- Jurassic (Tithonian and Berriasian), limestone for a flint conglomerates and beams circumvents

$J_{5\text{-}6}$: Late-Jurassic (Middle and Upper Oxfordian), alternation of marls and limestone with yellow patina

N_1 : Cretaceous (Berriasian), marly limestone and conglomerates has edge beams

N_2 : Cretaceous (Valanginian), marl and marl-limestone leaflet yellow patina

N_3 : Cretaceous (Hauterivian), marl-limestone bundles was around, red sandstone glaucontic

Photo 1 Springs du Cheval Blanc

Chemistry Assessment

The combination of chemistry and geology analysis can give a better understanding about where the water comes from. In addition, hydrochemistry as well as geophysical surveys are important in unraveling the hydrologic systems and the geological subsurface structures (Bogaard et al, 2000). Samples were taken in the main stream and major tributaries stream. Samples analysis is shown at Table 1.

Table 1 shows that the source of the Bouinenc River from the spring has EC 259 µS/cm, pH 8.36, and dominant water type $CaHCO_3$. Cougnes River which is flowing to the Bouinenc has EC 988 µS/cm, pH 7.17, and dominant water type $CaHCO_3$. Sulfate concentration is higher in this River (192 mg/L) compared with Bouinenc itself. This sulfate comes from the gypsum formation in the mountain upstream this river. Higher $CaHCO_3$ is coming from the Marls and Limestone formation (Appelo and Postma, 2005). After the water from Cougnes and Bouinenc are mixing, the EC is 388 µS/cm with water type $CaHCO_3$ and the sulfate concentration decreases to 106 mg/L at Bouinenc Chap. Two major tributaries, Couard and Vabre, have EC 665 µS/cm and 411 µS/cm respectively. The water from Couard has higher Sulfate concentration and has Mg^{2+}, but water from Vabre doesn't have Mg^{2+}. We guess that the present of higher SO_4^{2-} in these sub-catchments is related with the possibility that the black marls contain transformed Gypsum. Couard has a higher concentration of SO_4^{2-} compare with the Vabre sub-catchment, because the stream path of the Couard sub-catchment is completely located in the black marls ($j_{2\text{-}4}$) while Vabre is located in the black marls and marly-limestone (j_1). Comparatively, the stream path of the Couard sub-Catchment is shorter than the Vabre in $j_{2\text{-}4}$. Water in the Bouinenc downstream area has EC 440 µS/cm, pH 8.26 and water type dominant $CaHCO_3$. A piper diagram from main river and tributaries can be seen at Figure 8.

A piper diagram shows that mainly water in this catchment is calcium bicarbonate type ($CaHCO_3$). The strong calcium bicarbonate type is in the Bouinenc upstream and the rest is calcium bicarbonate with high sulfate concentration except at Couard. Water type at Couard is sodium sulfate with high calcium concentration.

EC routing along the main river was done to have the idea about the tributaries contribution to the main river and the interaction between groundwater and surface water. EC routing started from Bouinenc-Cougness junction to the downstream Bouinenc under the old bridge. EC routing was done in two days by walking along the river. The result of EC routing can be seen at Figure 9 and 10.

Table 1 Samples analysis at Bouinenc catchment

No	Item	Rivers					
		Bouinenc Upstream (28b)	Cougnes (29)	Bouinenc Chap (25)	Couard (22)	Vabre (83)	Bouinenc Downstream (26)
1	EC (µS/cm)	259	988	388	665	411	440
2	pH (-)	8.36	7.17	8.28	8.05	8.3	8.26
3	Temperature (°C)	12.3	15.7	13.8	20.3	23.5	21.7
4	Ca^{2+} (mg/l)	48.4	134.4	57.6	54	98	53.2
5	Mg^{2+} (mg/l)	0	16.28	11.66	30.62	0	17.98
7	$HCO3^-$ (mg/l)	131.76	234.4	220.82	185.44	235.46	187.88
8	Cl^- (mg/l)	0	6.39	5.68	6.03	13.85	2.48
9	SO_4^{2-} (mg/l)	11	192	106	512	128	90
10	Discharge (m^3/s)	0.07	0.015	0.132	0.004	0.03	0.187

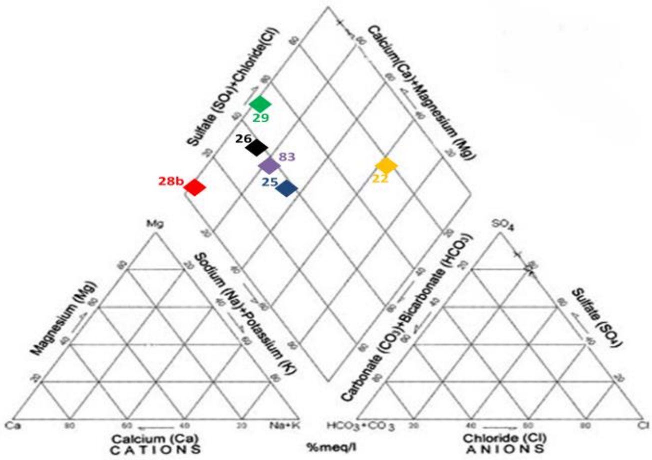


Figure 8 Piper diagram Main River and tributaries

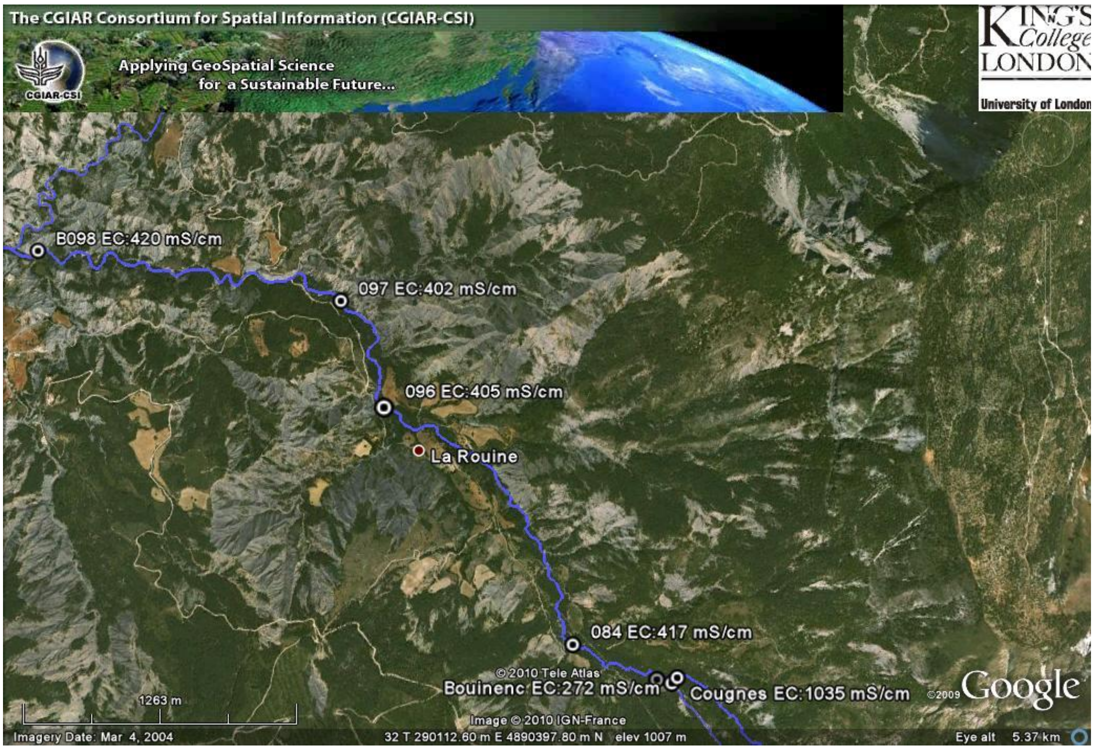


Figure 9 Location of EC measured upstream. Stream flow direction is from right to left

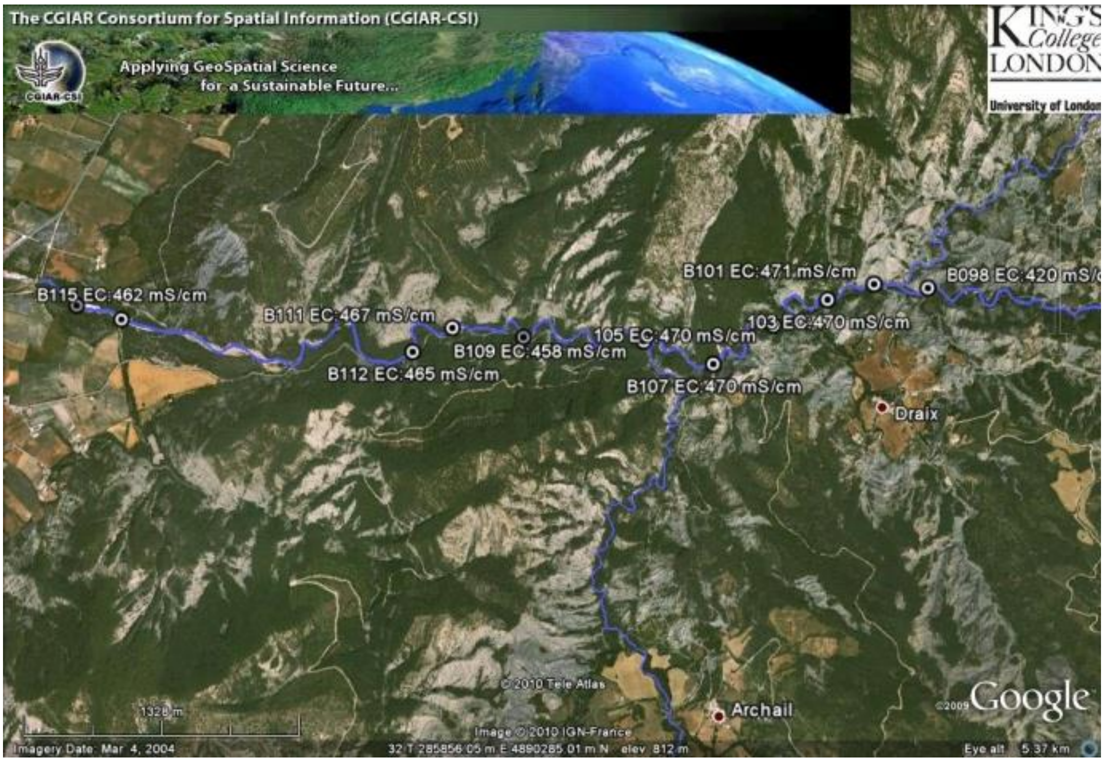


Figure 10 Location of EC measured downstream. Stream flow direction is from right to left

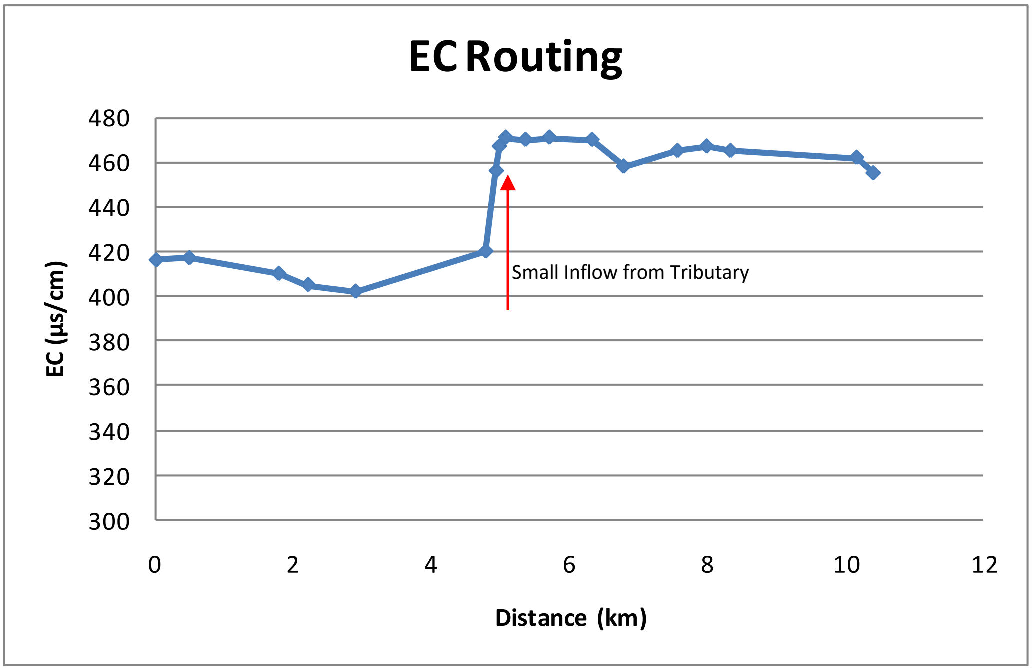


Figure 11 Longitudinal section of EC routing along the main river (from left to right is upstream to downstream)

Figure 9 and 10 show the location of EC measured in two parts. First part (Figure 9) is upstream area and second part (Figure 10) is downstream area. EC values along the main river are almost same in every segment. EC values are between 402 µS/cm and 471 µS/cm. EC measured in the final location of the first day and in the beginning of the second day are different. This can happen because EC in the river is not constant (see (c) EC and temperature at Bouinenc downstream

Figure). The increasing EC from the upstream to the downstream area is caused by inflow from tributaries which have a higher EC (chemical concentrations) such as Couard and Cougnes. To have a better overview about this EC routing, longitudinal EC routing graphic has been made (see Figure 11). The longitudinal section of EC routing starts from Bouinenc upstream after Bouinenc-Cougnes junction.

At distance ± 5 km from upstream, the EC value increases sharply because the tributary rivers flown to the Bouinenc have higher EC value (700-900 μS/cm). Furthermore, these tributaries have a sufficient discharge to influence the main river. From the EC routing we can indicate that there was no significant interaction between surface water and groundwater. We found very small springs in the river bank but these small springs cannot influence the main river.

CONCLUSION AND RECOMENDATION

This study has shown that during the observation period (June 1st until June 8, 2010) the discharges are decreasing both in Chap and in the downstream. The minimum and the maximum discharges in this year are still unknown due to the limitation of observation period. EC values in this river are increasing and has diurnal cycle depended to temperature also. The increasing of EC values might be caused by evapotranspiration. The daily potential evapotranspiration varies from above 4 to 7 mm/day. Based on the geology map and survey, the majority of this study area is black marls and limestone formation from the Jurassic period. The springs are mainly located in the contact zone of the different layers and also in some cases due to faults. Water type in this area primarily is calcium bicarbonate type ($CaHCO_3$) from the marls and limestone formation except Couard. Water type at Couard is sodium sulfate. Sulfate and magnesium are found in some tributaries, this chemical concentration is from Gypsum formation in the mountain. There is no significant interaction between surface water and groundwater since the difference between discharges in downstream (0.187 m^3/s) and sum of tributaries discharges (0.166 m^3/s) is small. The gap between those values is caused by many unmeasured small tributaries. Moreover, EC routing shows that the discharges from tributary rivers are not sufficient to influence the main river except tributary at distance ± 5 km from upstream.

The hydrology data obtained in this study are not sufficient to give a better view of this catchment. Because of it, we recommend that we should collect those data from the experimental basin located in Draix. We assume they have data with long time series record.

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