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# Monitoring River Flows : Cases of the Djiri River (Republic of Congo)

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**Abstract**

*The objective of this work is to conceptualize and carry out a tool for monitoring river flows with a simulation of the Djiri River data; the Djiri River is located in the Djiri watershed and to date has only one installed hydrological station. The Djiri watershed has an area of 980 km2, a length of 57 km. This watershed is located between 4 and 4-52' south latitude and 15 and 15-55' east longitude and the altitude between 600 and 760 m, its geology is mainly composed of Batéké sands. Most of our rivers in Africa and especially in Congo Brazzaville see their water levels drop, sometimes disappearing during dry periods. These natural stretches are often accentuated by the use of the water resource at a time when it is less available: drinking water supply, irrigation, watering of public gardens, etc. In Congo Brazzaville, for example, the majority of river flows occur during low water periods. In the face of these decreases in flows, it is necessary for daily hydrometric measurements to be carried out to monitor flows in order to facilitate the prevention, detection and resolution of any problems related to the drop in the water level of each streams. This work is carried out in the Hydrology Laboratory of the Institute for Research in Exact and Natural Sciences (IRSEN) as part of the doctoral thesis project carried out at the Faculty of Science and Technology (FST) of the Marien NGOUABI University of Brazzaville (Republic of Congo); This research is generally aimed at the design and implementation of an automated information system for tracking river flows in the Republic of Congo in order to facilitate the actors of national hydrology by acquiring a detection or prevention of possible situations observed on waterways in Congo-Brazzaville. To date, no similar monitoring tools have been implemented in the Republic of Congo and this work brings great added value in terms of automating water ecosystem management processes for national hydrology. To achieve this information system, the bibliographical knowledge of data management issues at hydrological stations allowed us to describe the process of acquiring river flows and to conduct systemic modelling of MERISE type leading to a national database on hydrometric stations, the rivers on which they are installed, daily measurements performed and the scale applied to each river. The tool put in place allows to track not only the flow of the Djiri River but also those of all the rivers of the Republic of Congo. The Djiri River data were used to simulate the tool and the analysis of this data reveals a decrease in flow over the entire period of 2017 and any season. This decrease in flow, characterized by a divergence index of 0.82344, highlights a hydrological situation for which national hydrology actors will absolutely have to implement remediation mechanisms to protect this against the possible disappearance.*

**Keywords:** Stream flow, MERISE and information system, Hydrological scale, Hydrological station.



## Introduction

Monitoring water levels in rivers is of undeniable necessity given the vital importance of water in humans, fish, animals and plants. Also, the monitoring of water levels in a river is extremely linked to the notion of flow and imposes discipline in the daily and regular collection of water height measurements ; on a river, at least two measurements per day allow an estimate of the average daily flow using a scale defined specifically for that river. According to the Environmental Encyclopedia (2018), measuring the flow of a river serves several purposes:

- Operational management of hydraulic structures (hydro-electric installations, irrigation systems, flood-cutting or stretch support tanks, etc.) ;
- The sizing of these structures, by knowing the characteristics of these streams ;
- Regulatory control, for verification of downstream flow return obligations (minimum flow to ensure fish survival, maintenance of other uses; non-aggravation of floods), declaration of calamity (droughts ...) ;

The protection of property and people by announcing floods; heritage, by establishing series of long-term observations, essential to know the evolution of river regimes, to raise awareness of natural hazards, to

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assign a probability to extreme events (floods, stretches). The interest of these measures is now reinforced by the current challenges posed by global warming, new demands for sharing water between different uses (recreational, energy, irrigation, drinking water), restoration or the preservation of natural environments and their biodiversity, the social demand for knowledge, the increased vulnerabilities of society (Encyclopedia of the Environment,2019). In this work, we will not take measurements of water heights to deduce flows, but we will simply exploit measurements already carried out to simulate automated monitoring of river flows.

This research work is being carried out at the Institute for Research in Exact and Natural Sciences (IRSEN) as part of a unique doctoral thesis project at the Faculty of Science and Technology (FST) of the Marien NGOUABI University in Brazzaville (Rep. Congo). This work responds to the problem of monitoring river flows in the Republic of Congo and thus allows national hydrology actors to acquire in the short and medium term the provision of research centres and students in hydrologies to have the provision of research centres and students in hydrologies to have the a tool to monitor river flows to prevent, detect and design river disappearance risk coverage scenarios.

The monitoring tool is conceptualized and carried out using the following approach :

- Design of the concept model of entity-association data ;

Physical model of data;

- Realization of the application interface.

The tool's features include :

- Codification of hydrometric stations ;
- Codification of rivers, rivers, seas, etc.;
- Codification of scales ;
- The daily entry and recording of measurements taken on the stations ;
- Development of dashboards for monitoring.

In the long term, we will deploy this tool on the web to allow in immediate time to have a view of all the operational stations installed on all the rivers of Congo Brazzaville so follow up all these rivers.

**Introducing the study area**

**Study period**

The study period chosen covers 2 years, from 2016 to 2017. It refers to the sampling period adopted the assessment of the health impacts of the pollution of the waters of the Djiri River.

**Area of study**

This research work is generally in the field of hydrometry (measuring the flow of a river) and specifically in the application of computer engineering to the realization of hydrometric data recovery for the monitoring of river flows. The results of this work are flexible as apply to all rivers, streams, rivers and seas of Congo-Brazzaville but the experimentation of the implemented system is based on data from the Djiri River as a water system of Tests.

**Materials and Methods**

**Materials**

The set of hardware and software useful to run this study are summarized in the following table :

Table 1

*Materials and Software*

| N° | BESOIN | TYPE DE BESOIN | USAGE |
|---|---|---|---|
| 1 | POWER AMC | OUTIL LOGICIEL | CONCEPTION DU SYSTÈME D'INFORMATION |
| 2 | POSTGRESQL | | IMPLEMENTATION BASE DE DONNEES |
| 3 | WINDEV 23 | | PROGRAMMATION |
| 4 | ORDINATEUR PORTABLE | MATERIEL INFORMATIQUE | OUTIL DE TRAVAIL |

**Comment : Hardware and software summary**

Table 2 summarizes the various hardware and software used for this work.

**Methods**

**Data collection**

The data collected at the Institute for Research in Natural Exact Sciences was used to simulate the monitoring tool : this is the data covering the period 2017 on the Djiri River.

**Description of river flow measurement**

Direct flow measurement is a complex operation that can only be carried out on an ad hoc basis. With the exception of a very specific species, direct and continuous tracking of the flow cannot be carried out. This is the water height that is measured continuously, after having it first connected to the flow by a drying curve (LALLEMENT Christian,2018). This is why hydrometry is a four-step process :

Continuous measurement of heights upstream of a hydraulic control, or in other places where a univocal height-flow relationship can be established;

The construction of periodic gauges to build this relationship (drying curve), allowing to convert heights into flows ;

The tracing of this tarage curve and the detection of its evolutions; Then, after converting heights into flow, critical analysis of spatial and temporal fluctuations, and then archiving them.

**Divergence Index and River Flow Monitoring Indicators**

- **Divergence Index (IDIV)**

**Note :**
**DE :**Estimated flow ;
**DRF :**River reference flow ;
The trend index is defined by :

**IDIV** $=\frac{\mathbf{DE}}{\mathbf{DRF}}$

This index is by definition strictly superior to the unit to express the normal evolution of the flow of a river and otherwise will require the implementation of remediation scenarios on the river.

- **Monthly average of estimated debits**

To facilitate monthly monitoring of river flows, estimating the monthly averages of flows deducted from the station and river scale from daily water heights is an appropriate approach :
For each station, each river and every month of a year we have :

$$\mathbf{Moyenne}_{\mathbf{DebitEstimé_i}} = \frac{\sum_{i=1}^{N} \mathbf{Debit}_{\mathbf{Estimé_i}}}{\sum_{i=1}^{N} \mathbf{i}}$$

N : Number of days of the month, i month and DebitEstimated the flow deducted by crossing the water heights and the scale. As a principle of increasing changes in river flows, it is known that :

$\mathbf{Debit}_{\mathbf{Estimé_i}}$>DRF month i.

**Alors :** $\frac{\sum_{i=1}^{N} \mathbf{Debit}_{\mathbf{Estimé_i}}}{\sum_{i=1}^{N} \mathbf{i}} > DRF$

Otherwise, it will mean a decrease in the flow of a river.

- **Moyenne annuelle des débits estimés**

To facilitate the annual monitoring of river flows, the estimate of the inter-year average of flows deducted from the known averages of the years on each station according to the following expression : For each station installed on a river, each year we have :
Fori=1…$i_{max}$ ,j=1…$j_{max}$ et m=1…$m_{max}$ do **:**

$$\boldsymbol{Moyenne}_{\boldsymbol{DebitEstimé}_{s_j}} = \frac{\sum_{i=1}^{i=i_{max}} \boldsymbol{Moyenne}_{\boldsymbol{DebitEstimé}_{r_m s_j a_i}}}{\sum_{i=1}^{i_{max}} \boldsymbol{i}}$$

Où $\sum_{i=1}^{i=i_{max}} \boldsymbol{Moyenne}_{\boldsymbol{DebitEstimé}_{r_m s_j a_i}}$ represents the estimated average annual flow on the river$\boldsymbol{r_m}$on the station$\boldsymbol{s_j}$during the year $\boldsymbol{a_i}$.

- **SQL Script of Divergence Assessment on river flow**

**Script 1 : Rating of divergence on the flow of a river**

```
SELECT Annee_Mesure,Mois_Mesure,Nom_Station,Debit_Reference,la_moyenne_Debit_Estime Debit_Moyen_Mensuel,
(la_moyenne_Debit_Estime/Debit_Reference)IDIV_Mensuel
FROM
(
SELECT
        Riviere.Nom_Riviere AS Nom_Riviere,
        Station.Nom_Station AS Nom_Station,
        Mesure.Annee_Mesure AS Annee_Mesure,
        Mesure.Mois_Mesure AS Mois_Mesure,
        Riviere.Debit_Reference AS Debit_Reference,
        AVG(Mesure.Debit_Estime) AS la_moyenne_Debit_Estime
FROM
        Riviere,
        Station,
        Mesure
WHERE
        Riviere.IDRiviere = Station.IDRiviere
        AND             Riviere.IDRiviere = Mesure.IDRiviere

GROUP BY
        Mesure.Mois_Mesure,
        Mesure.Annee_Mesure,
        Station.Nom_Station,
        Riviere.Nom_Riviere,
        Riviere.Debit_Reference
)X
WHERE Annee_Mesure={ParAnnee}
AND Nom_Riviere={ParRiviere}
ORDER BY 2 ASC
```

- **SQL Script of Average Monthly Estimated Debit**

**Script 2 : Monthly Average Estimated Debit Estimate**

```
SELECT
        Mesure.Annee_Mesure AS Annee_Mesure,
        Mesure.Mois_Mesure AS Mois_Mesure,
        Station.Nom_Station AS Nom_Station,
        Riviere.Nom_Riviere AS Nom_Riviere,
        Riviere.Debit_Reference AS Debit_Reference,
        AVG(Mesure.Debit_Estime) AS la_moyenne_Debit_Estime
FROM
        Riviere,
        Station,
        Mesure
WHERE
        Riviere.IDRiviere = Mesure.IDRiviere
        AND             Riviere.IDRiviere = Station.IDRiviere
        AND
        (
                Mesure.Annee_Mesure = {ParamAnnee_Mesure}
                AND     Riviere.Nom_Riviere = {ParamNom_Riviere}
        )
GROUP BY
        Mesure.Annee_Mesure,
        Mesure.Mois_Mesure,
        Station.Nom_Station,
        Riviere.Nom_Riviere,
        Riviere.Debit_Reference
ORDER BY
        Mois_Mesure ASC
```

**SQL Script of Annual Average Estimated Debit**

**Script 3 : Annual Average Estimated Throughput**

```
SELECT
Mesure.Annee_Mesure AS Annee_Mesure,
Station.Nom_Station AS Nom_Station,
Riviere.Nom_Riviere AS Nom_Riviere,
Riviere.Debit_Reference AS Debit_Reference,
AVG(Mesure.Debit_Estime) AS la_moyenne_Debit_Estime
FROM
Riviere,
Station,
Mesure
WHERE
Riviere.IDRiviere = Mesure.IDRiviere
AND             Riviere.IDRiviere = Station.IDRiviere
AND
(
Mesure.Annee_Mesure = {ParamAnnee_Mesure}
AND     Riviere.Nom_Riviere = {ParamNom_Riviere}
)
GROUP BY
Mesure.Annee_Mesure,
Station.Nom_Station,
Riviere.Nom_Riviere,
Riviere.Debit_Reference
ORDER BY
Mesure.Annee_Mesure ASC
```

- **SQL Script of Annual Differences Between Reference Water Volume and Estimated Water Volume**

The reference water volume is the volume corresponding to the amount of water that should flow normally and in accordance with the beginning of the river reference. In the case of the Djiri River, it is defined by :

$$Volume_{Reference} = Debit_{Reference} * 24 * 3600 * 365$$

$$=25\frac{m^3}{s} * 24 * 3600 * 365\ s$$

The estimated volume of water is deducted from the average daily flow estimated by the same principle :

$$Volume_{Estimé} = Debit_{Estimé} * 24 * 3600 * 365$$

And the gap of the two volumes of water would be :

$$ECART_{VOLUME} = Volume_{Estimé} - Volume_{Reference}$$

A negative deviation will mean a loss of water volume at an i.e. water decrease and the positive deviation will correspond to an increase in the volume of water on this river.

**Script 4: Evaluation of annual différences between reference water volume and estimated water volume**

```
SELECT Annee_Mesure,Nom_Station,Debit_Reference,la_moyenne_Debit_Estime Debit_Moyen_Mensuel,
(la_moyenne_Debit_Estime-Debit_Reference)*24*3600*365 ECART_VOLUME_EAU_ANNUEL,
CASE
WHEN (la_moyenne_Debit_Estime-Debit_Reference)*24*3600*365>0 THEN 'AUGMENTATION VOLUME EAU'
ELSE 'BAISSE VOULUME EAU'
END OBSERVATION
FROM
(
SELECT
Riviere.Nom_Riviere AS Nom_Riviere,
Station.Nom_Station AS Nom_Station,
Mesure.Annee_Mesure AS Annee_Mesure,
Riviere.Debit_Reference AS Debit_Reference,
AVG(Mesure.Debit_Estime) AS la_moyenne_Debit_Estime
FROM
Riviere,
Station,
Mesure
WHERE Riviere.IDRiviere = Station.IDRiviere
AND Riviere.IDRiviere = Mesure.IDRiviere
GROUP BY
Mesure.Annee_Mesure,
Station.Nom_Station,
Riviere.Nom_Riviere,
Riviere.Debit_Reference
)X
WHERE Annee_Mesure={ParAnnee}
AND Nom_Riviere={ParRiviere}
ORDER BY 2 ASC
```

- **Estimated average daily throughput (Estimated flow)**

After that, the average daily flow can be estimated from the water heights recorded at the hydrometric stations compared to the scale terminals.

```
i est un entier=0
HLitRecherchePremier(Bareme,IDRiviere,COMBO_Riviere)
SI HTrouve(Riviere) ALORS
        SI Mesure.IDRiviere=Bareme.IDRiviere ALORS
                HLitRecherchePremier(Station,IDRiviere,COMBO_Riviere)
                SI HTrouve(Station) ALORS
                        SI Station.IDRiviere=Bareme.IDRiviere ALORS
                                HLitRecherchePremier(Ligne,IDBareme,Bareme.IDRiviere)
                                SI HTrouve(Ligne) ALORS
                                        SI Bareme.IDRiviere=Ligne.IDRiviere ALORS
                                                //POUR i= 1 A TableOccurrence(Table_Bareme)/
                                                POUR TOUT Mesure  AVEC Mesure.IDMesure[i] = 0 À TableOccurrence(TABLE_Mesure)
                                                        SI SAI_Hauteur_Moyenne>=Ligne.Borne_inferieure[i]
                                                           ET SAI_Hauteur_Moyenne<=Ligne.Borne_superieure[i] ALORS
                                                           Mesure.Debit_Estime[i]=      Ligne.Debit_Bareme[i]
                                                        FIN
                                                FIN

                                        FIN

                                FIN


                        FIN
           FIN

        FIN
FIN
```

The implementation of this processing automatically deducts the estimated throughput from the scale.

**MERISE modelling of station management data**

Data modeling in the sense of MERISE is based on the mathematical theory of sets and relationships ; MERISE considers a whole as an object or entity and a relationship as an association or semantic link between objects (Hubert Tardieu, 1978 ; Jean Patrick MATHERON, Hubert TARDIEU, 2000).

Formalism is based on the following syntax :

Subject - Word - Complement where the subject and the complement are objects or entities and the verb is the association.

Schematically one has :

In the short to medium term, MERISE will provide the following results :

-Building the conceptual model of data : description of all the information on the process of managing health statistics;

-Building the logical model of data : describing the data without addressing the constraints of implementing the data, this model reflects the organizational choice of data (relational table, file etc.)

-Building the physical model of the data : the presentation of the data as it will be implemented ;

- Implementation of the database and implementation of the application tool: realization of the actual data structure and the application interface.

**Results and Discussion**

**Results**

**Simulation of River Flow Monitoring Indicator**

According to the process of acquiring the estimated flows by crossing the average water heights at each station and the lines of the scale, it is necessary to follow these estimated flows compared to their monthly averages and the reference flow of the river for a given river and in a given year. Applying this approach with Djiri River data yields results in the following table :

Table 1

*Determination of the estimated Debit Divergence Index (IDIV)*

| ANNEE | Debit moyen annuel | DEBIT DE REFERENCE | IDIV | VOLUME D'EAU INITIAL | VOLUME ECOULE ESTIME | ECART | OBSERVATION |
|---|---|---|---|---|---|---|---|
| 1983 | 26,09 | 25 | 1,043556132 | 788 400 000 | 822 739 654 | 34 339 654 | AUGMENTATION DU NIVEAU D'EAU |
| 1984 | 26,19 | 25 | 1,047654147 | 788 400 000 | 825 970 530 | 37 570 530 | AUGMENTATION DU NIVEAU D'EAU |
| 1985 | 26,21 | 25 | 1,048559901 | 788 400 000 | 826 684 626 | 38 284 626 | AUGMENTATION DU NIVEAU D'EAU |
| 1986 | 25,99 | 25 | 1,039785381 | 788 400 000 | 819 766 795 | 31 366 795 | AUGMENTATION DU NIVEAU D'EAU |
| 1987 | 25,93 | 25 | 1,037114145 | 788 400 000 | 817 660 792 | 29 260 792 | AUGMENTATION DU NIVEAU D'EAU |
| 1989 | 26,26 | 25 | 1,050458833 | 788 400 000 | 828 181 744 | 39 781 744 | AUGMENTATION DU NIVEAU D'EAU |
| 1990 | 26,79 | 25 | 1,071452573 | 788 400 000 | 844 733 209 | 56 333 209 | AUGMENTATION DU NIVEAU D'EAU |
| 1991 | 26,92 | 25 | 1,076689964 | 788 400 000 | 848 862 368 | 60 462 368 | AUGMENTATION DU NIVEAU D'EAU |
| 1992 | 26,94 | 25 | 1,077632258 | 788 400 000 | 849 605 272 | 61 205 272 | AUGMENTATION DU NIVEAU D'EAU |
| 1993 | 26,79 | 25 | 1,071731959 | 788 400 000 | 844 953 476 | 56 553 476 | AUGMENTATION DU NIVEAU D'EAU |
| 1994 | 25,83 | 25 | 1,033100717 | 788 400 000 | 814 496 605 | 26 096 605 | AUGMENTATION DU NIVEAU D'EAU |
| 1997 | 25,38 | 25 | 1,015196359 | 788 400 000 | 800 380 810 | 11 980 810 | AUGMENTATION DU NIVEAU D'EAU |
| **2016** | **20,60** | **25** | **0,824146289** | **788 400 000** | **649 756 934** | **- 138 643 066** | **BAISSE DU NIVEAU D'EAU** |
| **2017** | **20,58** | **25** | **0,823040179** | **788 400 000** | **648 884 877** | **- 139 515 123** | **BAISSE DU NIVEAU D'EAU** |

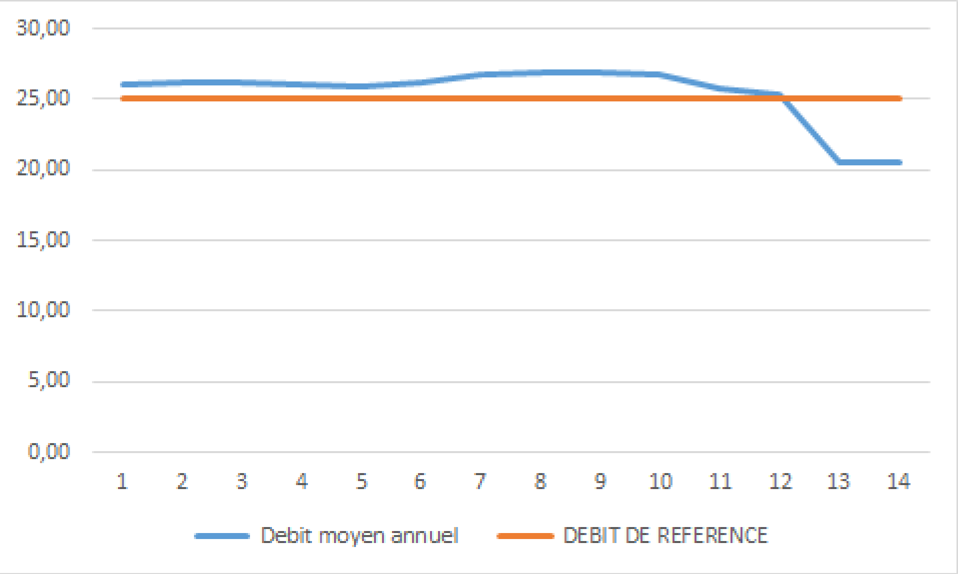



*Figure I*
Comparison reference flow and estimated annual average flow on the Djiri River.
Data source : Hydrology Laboratory, IRSEN.

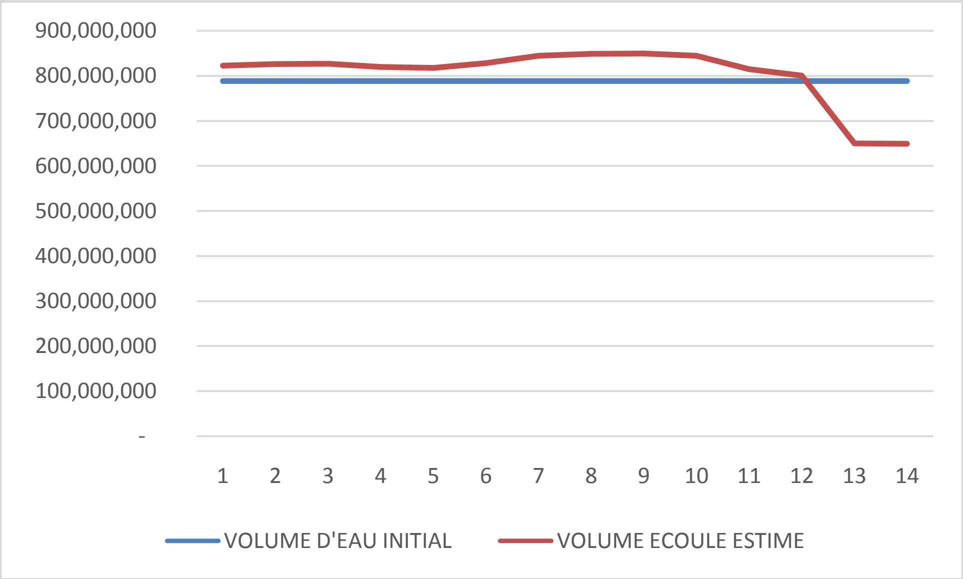



*Figure II*
Comparison reference volume and estimated annual average volume on the Djiri River.
Data source : Hydrology Laboratory, IRSEN.

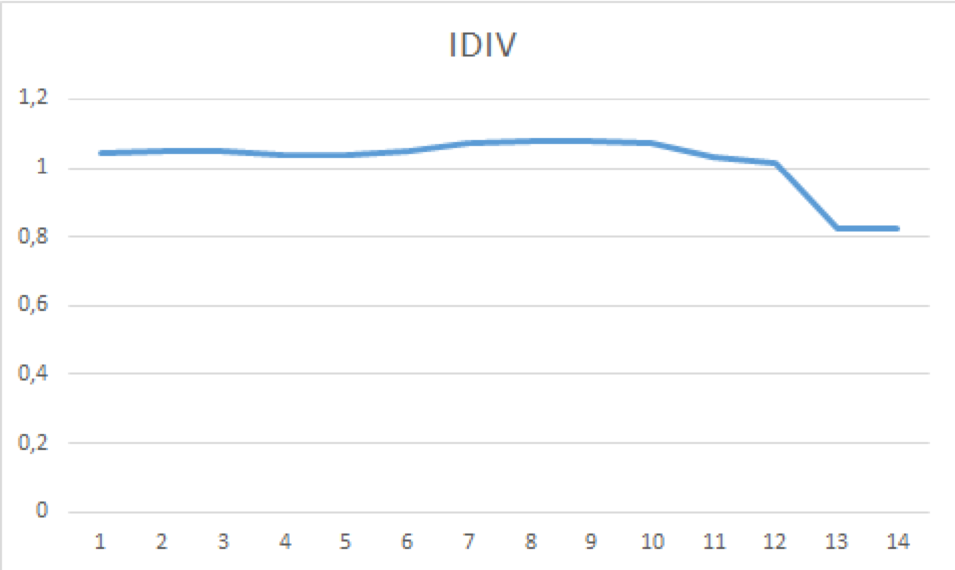



*Figure III*
Trend in the divergence index per year on the Djiri River
**Data source : Hydrology Laboratory, IRSEN.**

**Comment :**

Table 1 shows the estimated monthly average debits as a result of measurements taken at the Djiri station ; Figure 1 and Figure 2 shows that from 1983 to 1997 the divergence index is strictly higher than the unit and from 2016 to 2017 this index is strictly lower than the unit.

Table 2
*Monitoring the estimated monthly average flow on the Djiri River*

| MOIS | Janvier | Février | Mars | Avril | Mai | Juin | Juillet | Août | Septembre | Octobre | Novembre | Decembre | MOYENNE | DRF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1983 | 23,85 | 26,19 | 26,78 | 26,02 | 26,12 | 25,23 | 26,46 | 26,06 | 26,04 | 26,19 | 27,25 | 26,87 | 26,09 | 25 |
| 1984 | 26,66 | 26,22 | 26,62 | 26,86 | 26,12 | 26,03 | 25,89 | 25,90 | 25,90 | 25,86 | 26,23 | 26,01 | 26,19 | 25 |
| 1985 | 26,07 | 26,03 | 25,94 | 26,81 | 27,30 | 26,30 | 26,09 | 25,80 | 25,78 | 26,17 | 26,15 | 26,13 | 26,21 | 25 |
| 1986 | 26,11 | 26,15 | 26,09 | 26,21 | 26,32 | 25,83 | 25,71 | 25,54 | 25,74 | 25,90 | 26,01 | 26,33 | 25,99 | 25 |
| 1987 | 25,99 | 25,84 | 26,05 | 26,43 | 25,99 | 25,95 | 25,95 | 25,62 | 25,56 | 25,45 | 26,05 | 26,25 | 25,93 | 25 |
| 1989 | 26,47 | 26,29 | 26,33 | 26,39 | 26,29 | 25,63 | 25,92 | 25,84 | 25,90 | 26,39 | 26,79 | 26,90 | 26,26 | 25 |
| 1990 | 26,68 | 26,87 | 26,57 | 26,80 | 27,09 | 27,00 | 26,46 | 26,35 | 26,32 | 26,73 | 27,10 | 27,47 | 26,79 | 25 |
| 1991 | 27,13 | 28,23 | 26,36 | 26,65 | 27,28 | 26,72 | 26,56 | 26,46 | 26,43 | 26,54 | 27,47 | 27,18 | 26,92 | 25 |
| 1992 | 27,61 | 27,48 | 27,42 | 27,53 | 27,21 | 27,01 | 26,65 | 26,03 | 26,06 | 26,48 | 26,77 | 27,05 | 26,94 | 25 |
| 1993 | 26,84 | 26,95 | 27,25 | 27,23 | 27,14 | 26,77 | 26,85 | 26,47 | 26,33 | 26,40 | 26,54 | 26,74 | 26,79 | 25 |
| 1994 | 26,14 | 26,59 | 25,65 | 26,35 | 25,33 | 24,35 | 26,20 | 26,05 | 25,84 | 25,66 | 25,44 | 26,34 | 25,83 | 25 |
| 1997 | 25,50 | 25,44 | 25,68 | 25,81 | 25,34 | 24,99 | 24,89 | 24,85 | 24,82 | 25,27 | 25,95 | 26,02 | 25,38 | 25 |
| 2016 | 20,54 | 20,90 | 20,63 | 20,57 | 20,56 | 20,60 | 20,56 | 20,58 | 20,58 | 20,56 | 20,59 | 20,57 | 20,60 | 25 |
| 2017 | 20,56 | 20,59 | 20,56 | 20,60 | 20,57 | 20,57 | 20,58 | 20,56 | 20,59 | 20,57 | 20,56 | 20,60 | 20,58 | 25 |

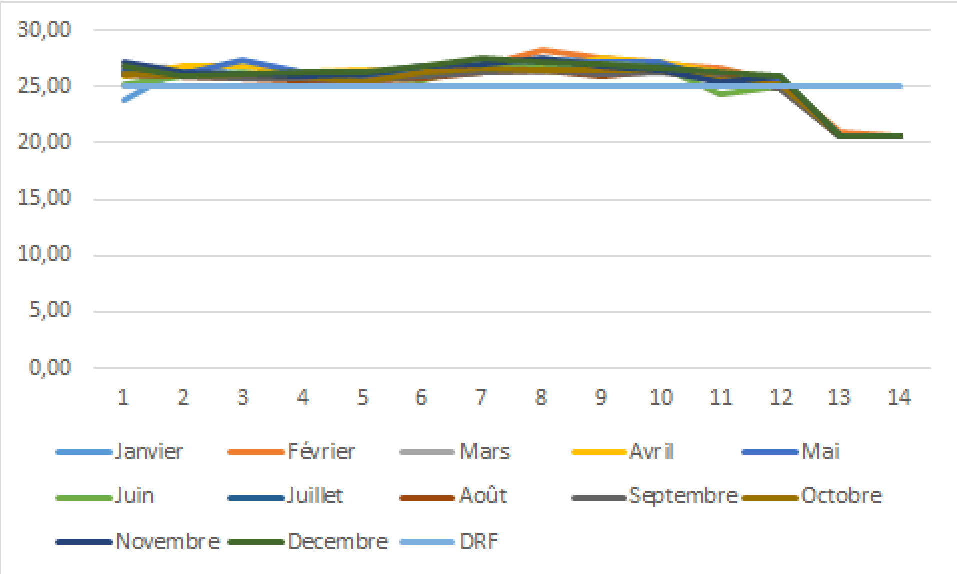



*Figure IV*
Monitoring the estimated monthly average flow on the Djiri River

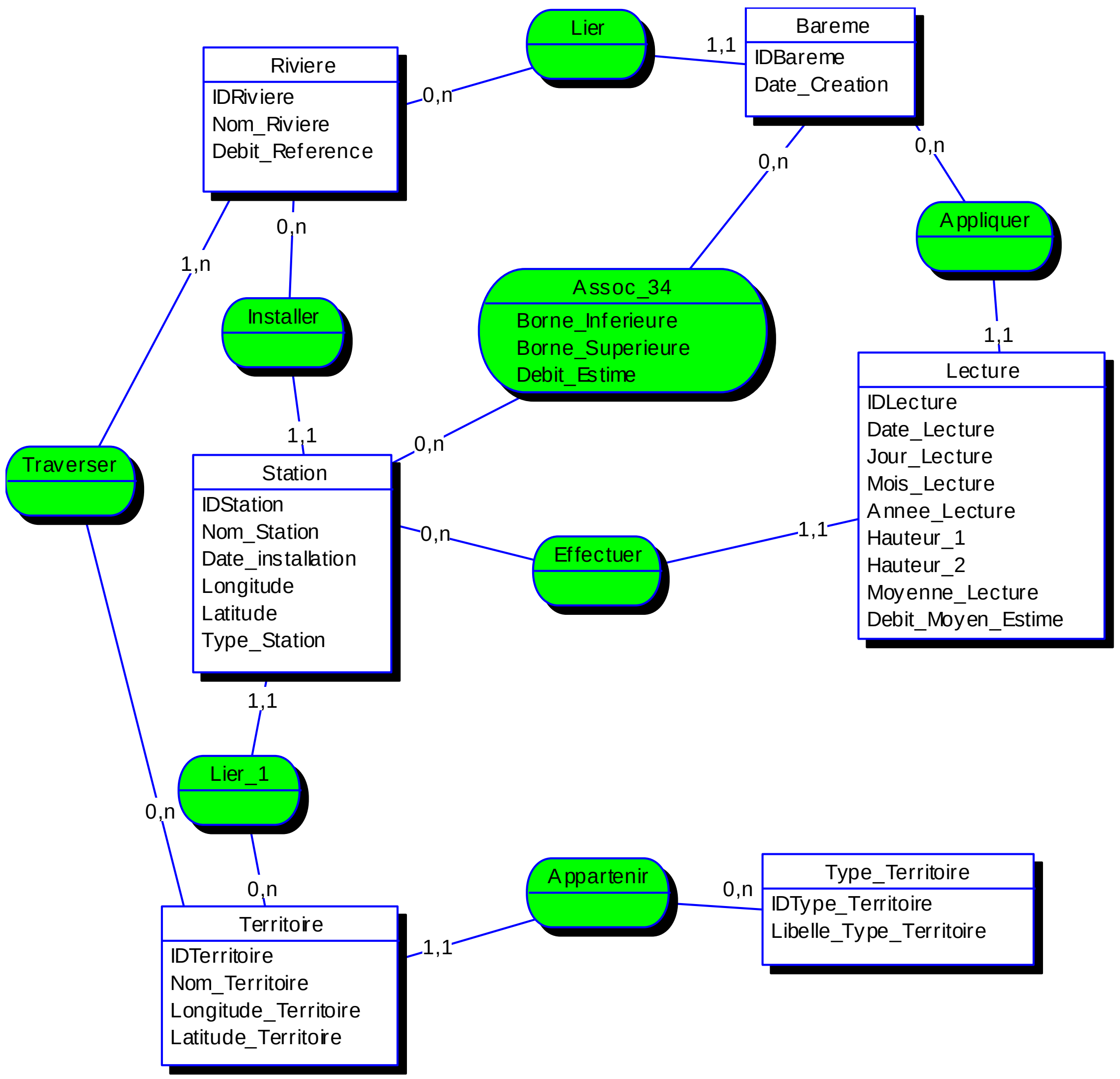
**Comment**

Table 2 and Figure 4 highlight the distribution of the estimated monthly average flow over the river Djiri.it stands out from this evidence that trends are below the reference rate in 2016 with an estimated average flow of 20.60 $m^s$/s and in 2017 with u n estimated average throughput of 20.58 $m^s$/s.

**Modeling the station management information system**

- **Conceptual Data Model**

The conceptual model of the data conceptually describes the semantics of the information system therefore highlights the repository of the information. This model is designed by application of the entity-association formalism of MERISE (Hubert Tardieu,1978) and in the context of our work describes the process of monitoring the flows of water ecosystems (Riviere, river, sea etc...).
The conceptual data model for tracking water ecosystem flows is as follows :




**Comment**

This modelling allows the structure of the database to be constructed by applying the rules for the transition from conceptual data modeling to logical data modeling.

- **Script for creating the DATABASE under SQL SERVER**

```
/* ============================================================ */
/*   Nom de la base :  MCD DEBIT                               */
/*   Nom de SGBD :  Sybase AS Anywhere 6                       */
/*   Date de création :  22/09/2019  14:49                     */
/* ============================================================ */

/* ============================================================ */
/*   Table : RIVIERE                                            */
/* ============================================================ */
create table RIVIERE
(
   IDRIVIERE              long varchar          not null,
   NOM_RIVIERE            long varchar  ,
   DEBIT_REFERENCE        float  ,
primary key (IDRIVIERE)
);

/* ============================================================ */
/*   Table : LECTURE                                            */
```

```
/* ============================================================== */
create table LECTURE
(
   IDLECTURE               numeric              not null,
   IDSTATION               long varchar         not null,
   IDBAREME                long varchar         not null,
   DATE_LECTURE            integer  ,
   JOUR_LECTURE            long varchar  ,
   MOIS_LECTURE            long varchar  ,
   ANNEE_LECTURE           long varchar  ,
   HAUTEUR_1               integer  ,
   HAUTEUR_2               integer  ,
   MOYENNE_LECTURE         float  ,
   DEBIT_MOYEN_ESTIME      float  ,
primary key (IDLECTURE)
);

/* ============================================================== */
/*   Table : STATION                                              */
/* ============================================================== */
create table STATION
(
   IDSTATION               long varchar         not null,
   IDRIVIERE               long varchar         not null,
   IDTERRITOIRE            long varchar         not null,
   NOM_STATION             long varchar  ,
   DATE_INSTALLATION       date                          ,
   LONGITUDE               decimal  ,
   LATITUDE                decimal  ,
   TYPE_STATION            long varchar  ,
primary key (IDSTATION)
);

/* ============================================================== */
/*   Table : BAREME                                               */
/* ============================================================== */
create table BAREME
(
   IDBAREME                long varchar         not null,
   IDRIVIERE               long varchar         not null,
   DATE_CREATION           date                          ,
primary key (IDBAREME)
);

/* ============================================================== */
/*   Table : TERRITOIRE                                           */
/* ============================================================== */
create table TERRITOIRE
(
   IDTERRITOIRE            long varchar         not null,
   IDTYPE_TERRITOIRE       long varchar         not null,
   NOM_TERRITOIRE          long varchar  ,
   LONGITUDE_TERRITOIRE    decimal  ,
   LATITUDE_TERRITOIRE     decimal  ,
primary key (IDTERRITOIRE)
);

/* ============================================================== */
/*   Table : TYPE_TERRITOIRE                                      */
```

```
/* ============================================================ */
create table TYPE_TERRITOIRE
(
   IDTYPE_TERRITOIRE       long varchar         not null,
   LIBELLE_TYPE_TERRITOIRE  longvarchar                  ,
primary key (IDTYPE_TERRITOIRE)
);

/* ============================================================ */
/*   Table : VALIDER_POUR                                     */
/* ============================================================ */
create table VALIDER_POUR
(
   IDSTATION               long varchar         not null,
   IDBAREME                long varchar         not null,
   BORNE_INFERIEURE        decimal  ,
   BORNE_SUPERIEURE        decimal  ,
   DEBIT_ESTIME            decimal  ,
primary key (IDSTATION, IDBAREME)
);

/* ============================================================ */
/*   Table : TRAVERSER                                        */
/* ============================================================ */
create table TRAVERSER
(
   IDTERRITOIRE            long varchar         not null,
   IDRIVIERE               long varchar         not null,
primary key (IDTERRITOIRE, IDRIVIERE)
);

alter table LECTURE
addforeign key FK_LECTURE_EFFECTUER_STATION (IDSTATION)
references STATION (IDSTATION) on update restrict on deleterestrict;

alter table LECTURE
addforeign key FK_LECTURE_APPLIQUER_BAREME (IDBAREME)
references BAREME (IDBAREME) on update restrict on deleterestrict;

alter table STATION
addforeign key FK_STATION_INSTALLER_RIVIERE (IDRIVIERE)
references RIVIERE (IDRIVIERE) on update restrict on deleterestrict;

alter table STATION
addforeign key FK_STATION_LIER_1_TERRITOI (IDTERRITOIRE)
references TERRITOIRE (IDTERRITOIRE) on update restrict on deleterestrict;

alter table BAREME
addforeign key FK_BAREME_LIER_RIVIERE (IDRIVIERE)
references RIVIERE (IDRIVIERE) on update restrict on deleterestrict;

alter table TERRITOIRE
addforeign key FK_TERRITOI_APPARTENI_TYPE_TER (IDTYPE_TERRITOIRE)
references TYPE_TERRITOIRE (IDTYPE_TERRITOIRE) on update restrict on deleterestrict;

alter table VALIDER_POUR
addforeign key FK_VALIDER__LIEN_35_STATION (IDSTATION)
references STATION (IDSTATION) on update restrict on deleterestrict;
```

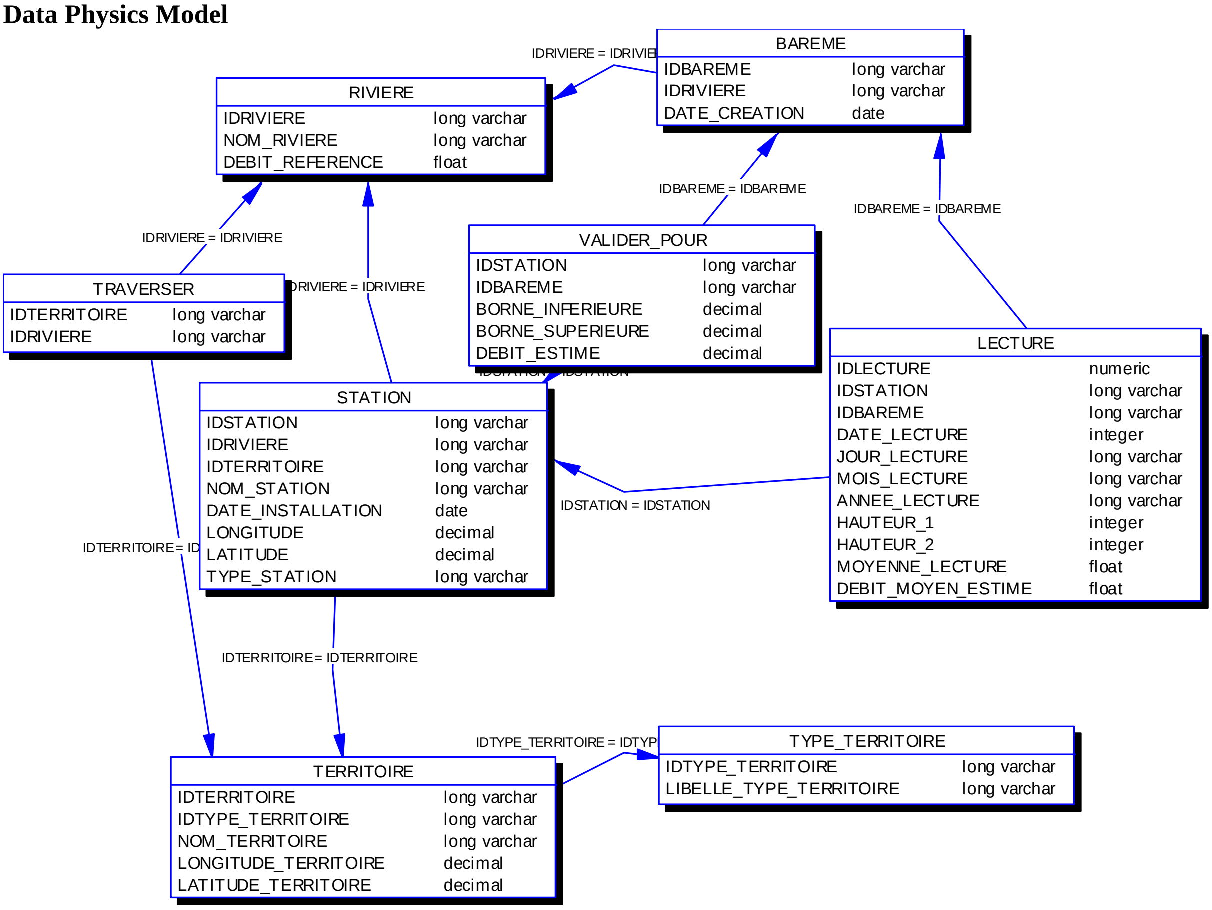
alter table VALIDER_POUR
addforeign key FK_VALIDER__LIEN_36_BAREME (IDBAREME)
references BAREME (IDBAREME) on update restrict on deleterestrict;
alter table TRAVERSER
addforeign key FK_TRAVERSE_LIEN_87_TERRITOI (IDTERRITOIRE)
references TERRITOIRE (IDTERRITOIRE) on update restrict on deleterestrict;

alter table TRAVERSER
addforeign key FK_TRAVERSE_LIEN_88_RIVIERE (IDRIVIERE)
references RIVIERE (IDRIVIERE) on update restrict on deleterestrict;

**Comment**

This script represents the code for creating the hydrometric station management data structure from the SQL SERVER relational database manager ; The database created from this script allows the creation of the application interface to facilitate the operationalization of the process of valuing hydrological data relating to hydrometric stations installed on rivers.

- **Data Physics Model**



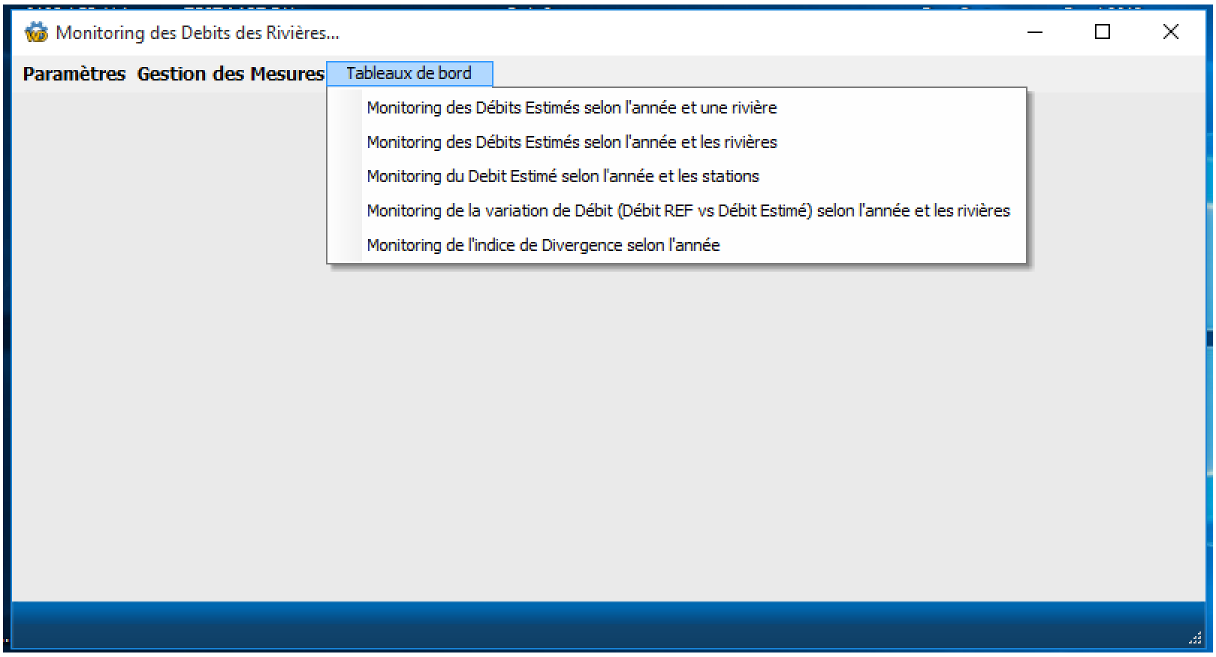

**Source : Concepteur Roch Corneille NGOUBOU.**

**Comment**

The physical model is the representation of the information system as it will be implemented. It consists of a set of tables that will host the data.

**Application Tool**

- **Main Application Menu:**
-




**Comment**

This view shows the features of the short-term implemented river flow tracking tool.
This tool takes into account:
-The setting of the information system : all tables containing the database's basic or initialization data ;
-Measurement Management : implementation of the entry and registration form of daily measurements taken at each hydrometric station ;
-Monitoring river flows.

**Application of script 1**

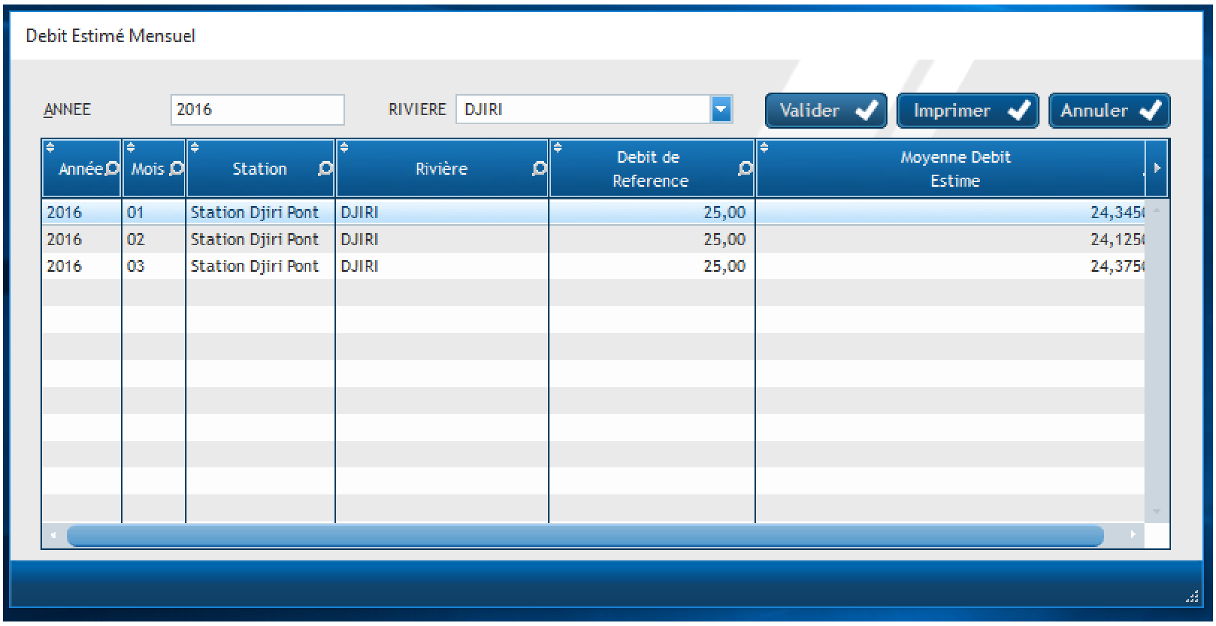
The implementation of script 1 allows you to see the data below:


This view illustrates both the monthly trends in estimated flow and gives the different values of the flow divergence index. These results show that the estimated flow divergence index is strictly lower than the unit for the first three months of 2016 shown.

- **Application of script 2**

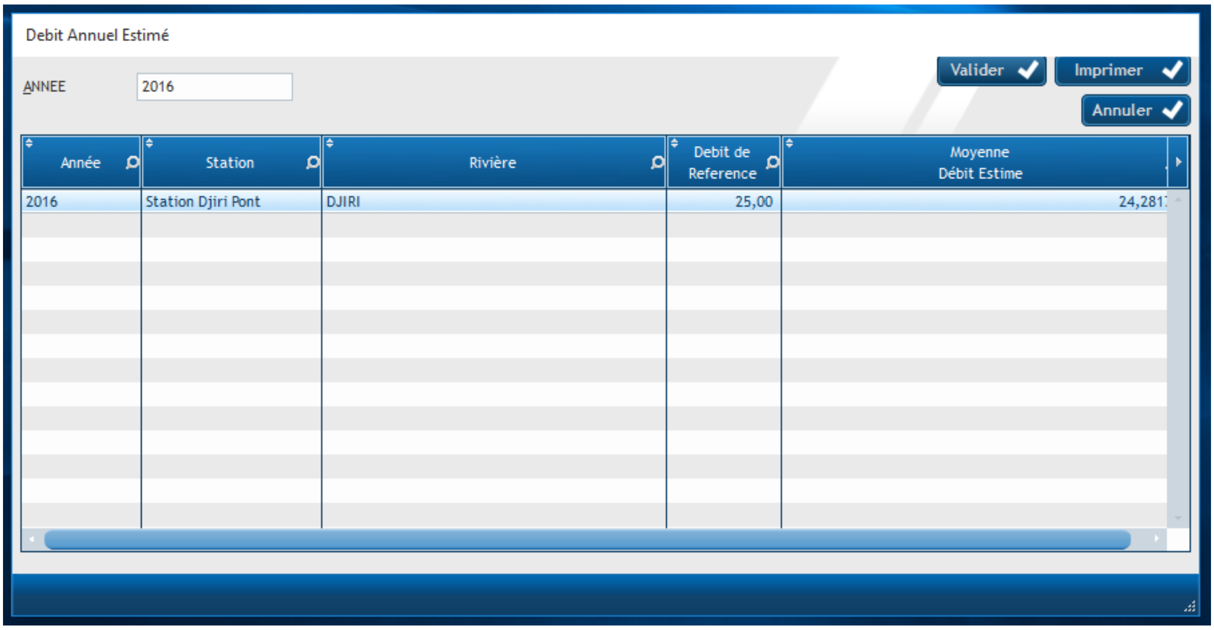
The implementation of Script 2 allows you to have the view of the data below from the test data in order to simultaneously track trends on the estimated monthly average throughput.

**-Consultation form for estimated monthly flows by year and river**




- **Application of script 3**

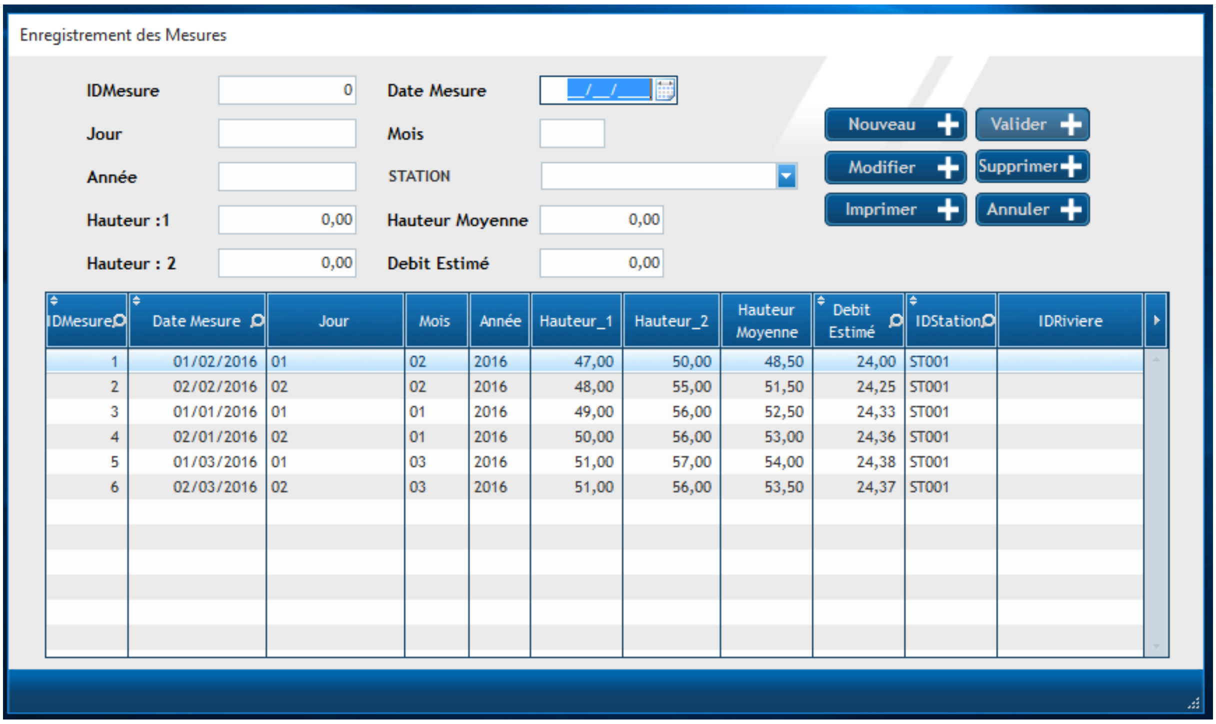
The implementation of Script 3 allows you to have the view of the data below from the test data in order to simultaneously track trends in the estimated annual average throughput.



- **Application of script 4**


The application of Script 4 provided a view of the average volume of water lost in 2016 from test data.

**Form for the seizure and recording of water heights recorded at hydrometric stations.**



This form allows the daily entry and recording of measurements taken at the level of each station. The forms of this application that we have not entered in this manuscript such as Station, River, Scale and Line setting or initializing the database.

**Discussion**

The application of the various algorithms registered in I.3.2 allowed us to obtain the results illustrated at 4.1:
Data on throughputs recorded since 1983 (IRSEN) ;
Indexes of divergence in estimated monthly or annual debit ;
Design and implementation of an information system to monitor river flows.

These results show and according to data received from the Research Institute for Exact and Natural Sciences on the Djiri River show that from 1983 to 1997 the average index of divergence is strictly higher than the unit but in 2016 and 2017 this index is lower strictly to the unit thus reflecting a decrease in water and thus a decrease in the flow of the Djiri River. The application tool developed will make a significant point in enhancing hydrometric data and monitoring our water ecosystems. Today and at the local level, no similar tools have been implemented and the development optics of this tool is that of preventing possible flooding in the event of an overflowing volume of water (increase in flows) or either a significant decrease in water volumes resulting in significant decreases in river flows and likely to cause river loss. In the long term, this information system will evolve towards the construction of a river monitoring portal, rivers in Congo-Brazzaville giving rise to the creation of an observatory to monitor the water levels of water ecosystems.

**Conclusion**

This research has made it possible to formally conceptualize the process of monitoring the flows of water ecosystems in the Republic of Congo from the description made by the various actors active in the operationality of this process and to build the operational indicators needed for this monitoring. From around the world similar tools have been put into implementation project such as Hydro3 (General Directorate of Risk Prevention,2013) in the French Republic which should be operational since 2014. In Congo Brazzaville and to date, no similar tool exists, the tool built will greatly contribute to the storage and archiving of data in the database and to the realization and analysis of hydrometric data enabling prevention, detection of hydrological situations.

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