

TOWARDS AN INTEGRATED MANAGEMENT OF URBAN DRAINAGE AND DEVELOPMENT: Methodological approach, data model and information system

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ABSTRACT

In this paper, we focus on the modelling and the management of information useful for the main protagonists in the urbanization process (architects, town-planners, civil engineers and build masters) in order to achieve a more global stormwater management strategy. To achieve this, we have to take into account much more efficiently the interaction between the city and its hydrological environment, and to consider the sustainable development of the cities. Our working approach was to define the «Urban Hydrological System», characteristic of an integrated management of urban drainage and development (existing and/or evolving). Its modelling allows us to much better define the Water-City interaction and to gather in the same data model the information of urban planning and drainage management. Then, the integrated management processes, at planning and project levels, have been defined. In order to monitor them, a supporting Information System (IS) has been specified. It is organised as a framework composed of a Geographical Information System (GIS) and modules dedicated to acquisition, organisation, processing and production of useful information. To illustrate our proposal and thus show its value and interest, we present a use scenario of the IS for the support of an urban development project.

Key-words : Stormwater drainage – Town planning – Integrated management – Systemic Analysis – Data modelling – Geographical Information Systems – Sustainable development.

1. INTRODUCTION: STORMWATER MANAGEMENT IN URBAN AREAS

1.1. Integrated approach and stormwater management

The efficiency and the durability of a stormwater management strategy, as well as the system associated with it, supposes a balanced solution regarding social, environmental and economical aspects. Early in the 90's, the Action 21 program of the United Nations proposed a new and more global management approach, which integrates environment and development topics with town planning, ground use and environmental facilities management (CNUED, 1992). Afterward, the so-called «integrated» approach appeared in the urban stormwater management field. This approach is the result of reflections to complete the answer brought by the environmental approach and its best management practices (runoff limitation), thus by risk management.

As a very recent approach, it has not been deeply formalized and its setup is still at an experimental stage. Nevertheless, current scientific understanding allow us to bring out four complementary principles of action :

- the continuous hydraulic management, based on the analogy with a river behaviour by defining a minor system for common flows and a major system for exceptional flows (Wisner, 1983) (O' Loughling, 1987) ;
- the town planning regulation rewriting, in order to encourage an urbanization which take into account stormwater management in a preventive way (Piel, 1996) ;
- the multidisciplinary which supposes a decompartmentalization of technical sectors and traditional working methods (Norotte et al., 1998) ;
- raising the awareness of stakeholders and citizens, which aims at developing a new urban water culture by rethinking its place in the city (Olivry, 1989).

1.2. Integrated management strategy setup

A stormwater management strategy said to be “integrated” implies a simultaneous elaboration of urban planning and main drainage system design on one hand, development projects and their drainage structures on the other hand. Then, we have to consider levels of service defined according to thresholds. These thresholds correspond to return periods of rain events and are to be defined in agreement with the local authorities. This strategy also supposes that stormwater networks are disconnected from sewer networks every time it is possible and that priority is given to local (plot) scale management, using the so-called “alternative” drainage techniques (best management practices).

This strategy has therefore considerable consequences on master plans design, relations between developers and technicians, and also on citizens’ involvement in the infrastructures management. Its setup implies a real cooperation between all the protagonists, especially within the local authorities services where information sharing and cooperative approaches collide even frequently with the compartmentalization of managing services (town planning, sewage and drainage, public road and green areas). Thus, it is necessary for them to get the means and tools to build new strategies. This requires to built up specific working approaches.

Finally, integrated stormwater management in urban areas appears to be less a technical issue than a question of methodologies and tools based on control, operation and sharing of urban information, which facilitate the multidisciplinary approaches that are more complex to setup (Joos, 2006). Our work and propositions are based on this observation.

2. OBJECTIVES AND APPROACH

The main objective of our work is to propose a methodology and tools for “integrated” urban stormwater management, based on :

- the modelling of the water-city interaction representative system ;
- an Information System (IS) to capitalize (acquire, organize and store) and operate the urban information useful for it;
- management processes associated with information streams facilitating the cooperation ;
- tools to operate information and support the key management processes.

To reach our objectives, we adopted a four-step work plan :

- step 1 focused on the study of the “town planning - urban drainage” interaction with regards to stormwater management. It allowed us to model the characteristic system of this interaction ;
- step 2 consisted in formalizing the IS immaterial component, the Conceptual Data Model (CDM) that meet the need of organized information related to the system modelled in step 1 ;
- step 3 focused on the human component of the IS (protagonists and activities) to define processes which operate the proposed CDM and produce useful information for activities ;
- step 4 allowed us to experiment and validate our approach on tangible cases.

In this paper, we only present some key elements of our work and a “realistic” use scenario of the IS during the operational management activities (capitalization, assessment, synthesis and transmission of information) allowing to illustrate the interest of our proposal. We mention successively the integrated management protagonists and activities, the Urban Hydrological System (UHS), the way the support IS works and a scenario for the support of a development project.

Thus, the complete modelling of the UHS, the structure of the corresponding CDM and its use for data elaboration during the planning management activities (prospectings, diagnoses, simulations) will not be presented here.

Nevertheless, the results below allow to illustrate the “information loop” which characterized the integrated management.

3. RESULTS

3.1. Integrated management protagonists and activities

The inadequate consideration of constraints regarding stormwater management during the planning process is a limiting factor for integrated management. The absence of a “globalized” and “long term” complementary approach can be explained by a **lack of knowledge and information about the stormwater management system in its environment**. To remedy this, a **new protagonist (or skill)** has to come into play, **the urban hydrologist, in charge of the planning level** (Fig. 1).

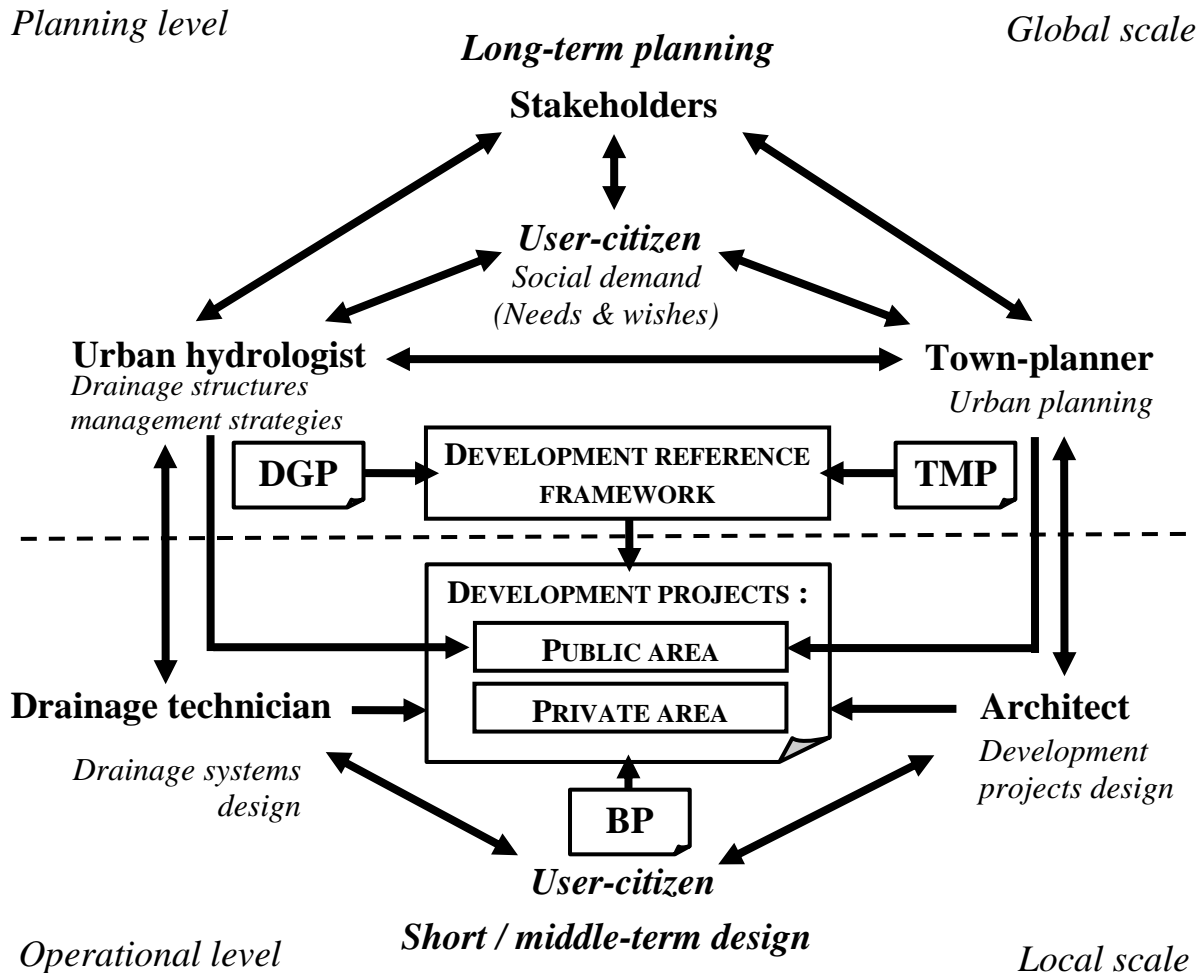


Figure 1 : Integrated management activities organisation.

At **planning level**, management activities concern **long-term planning** that requires a **global scale approach**. The protagonists define a **reference framework** for urban development in the planning documents : Drainage Guiding Plan (DGP) and Town Master Plan (TMP).

At **operational level**, management activities concern **short/middle-term development projects design** that requires a **local scale approach respecting the reference framework** of the planning level. To achieve this, a Building Permit (BP) is filled out by the master builder (citizen with/without architect or builder) and then investigated by legal authorities representatives (mainly drainage and town planning technicians).

Our first analysis helped us to confirm a real **need** for these various protagonists, in term of **methodologies and tools based on urban information controlling, operating and sharing as well as on decision-making process**, aiming at coordinating all their activities.

3.2. The Urban Hydrological System

The Water-City interaction being complex and hard to study, it was a priori necessary for us to define a “Conceptual framework” allowing to materialize it (Fig. 2) :

- the **Hydrological System** (HS) can be seen from various scales : from a global (earth) to a local one, whose characteristic boundary is the **Drainage Area** (DA), a conceptualized and localized representation of this system from the hydrologist’s point of view ;
- the **Urban System** (US) is the city’s conceptualized representation, from the town planner’s point of view. It is defined by city limits and organized by human being to support his activity. It can be therefore described in term of **Activity Area** (AA) where interact all the city protagonists;
- the **Hydrological Urban System** (HUS) is the conceptualized representation of the city settled on a drainage area. As this settlement modify its functioning, we have defined it as the product of two “parents” systems from which it inherits the main components, while acquiring its own characteristics. Thus, the **Urban Drainage Area** (UDA) materialize the interaction between the “AA” and “DA” sub-systems on a given area, and **constitute a common workspace** for all the protagonists. So, an HUS consists of a set of UDA describing the city as an “artificial” sub-system of a “natural” DA, the functioning of which it modifies.

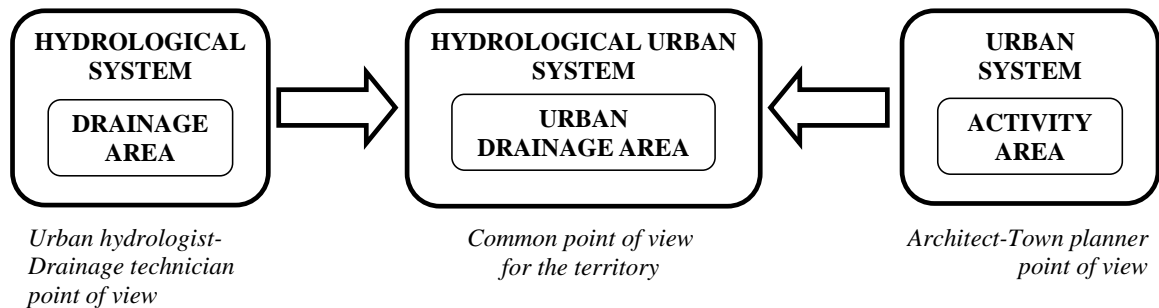


Figure 2 : Conceptual framework : Hydrological Urban System.

3.3. The support Information System

Town and country planning is a continuous process (Fig. 3) which requires to capitalize on the structural (describing its state and organization) and functional (describing its way of evolving) information. This information is organized in an Urban DataBase (UDB) used by a Geographical Information System (GIS) linked to specific application softwares.

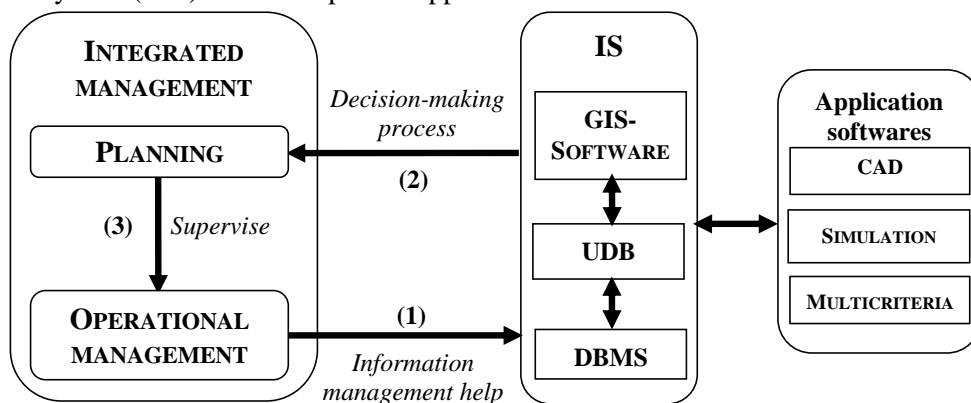


Figure 3 : Information System’s usage regarding integrated management.

Within the information loops of integrated management, the IS is used as follows :

- (1) Operational management, implemented through specific procedures (i.e. Building Permit Investigation), allows to create data (rather structural) which supply the UDB ;
- (2) GIS synthesis capabilities and application softwares allow to operate these raw data in order to produce new one (rather functional), useful for decision-making process at planning level ;
- (3) Produced synthesis help to define a global framework used to supervise operational management.

The continuous progress of these steps is similar to what we call in a systemic approach a **continuous feedback loop which helps to regulate a process** : output data act on input data, allowing the system to adapt itself to its evolving environment. In our case, this process is the soil usage modification engendered by urbanization, **the proposed IS allowing to ensure this loop**. Such a management approach can thus be called an “integrated” management of urban drainage and development.

3.4. Use scenario of the IS for operational management

The development project organize in the urban space a set of superstructures (buildings, plot laying out) and infrastructures such as the drainage system. At operational level, the management activity consists of providing some information, “upstream” to a development project on one hand, and acquiring some specific information, “downstream” to it during the building permit investigation which conclude the project design on the other hand. Development project support is thus a necessity to make sure that urban drainage and town planning integrated management is applied at an operational level. The proposed scenario deliberately focus on the smallest project unit, the plot; It could be applied at a wider scale (housing development, industrial area).

“Upstream” to the project, the drainage technician **fix local constraints regarding stormwater management** (outlets, maximum outflow) which are to be used for the design of the plot drainage system. The plot is likened to an “elementary” drainage area of the UHS.

Supplied at a near 1/10000th scale, the **“project global situation plan”** (Fig. 4a) represents the project plot in its Urban Drainage Area (UDA or BVU). These can be automatically delimited using our GIS Framework (another case study we do not present in this paper). The synthesis process consists of selecting the plot in the GIS and using the spatial query *“select the UDA which intersects the selected plot”* in order to get the legal maximum outflow rate which have been defined at planning level and stored in the IS. From this first selection, we proceed the same way to select the objects (branches and sections) of the associated drainage networks as well as their outlets. The rest of the process is a cartographic job of the design constraints (network components, outlets, limited outflow and outgoing volume,...).

Supplied at a range of scale between 1/1000th and 1/500th (master plan of a building permit), the **“project local situation plan”** (Fig. 4b) is a bigger scale version of the global plan, centred on the plot. It shows new elements which were not visible at a smaller scale. Data to exploit are :

- (I.) **The plot stream lines**, obtain from an « hydrologically compatible » Digital Earth Model (build in another case study) by selecting the mesh related to the plot.
- (II.) **The design rain event** (return period, duration and average intensity) which is to be used to design the devices of the plot drainage system.
- (III.) **The localization and the classification of the potential outlets** of the project ; The spatial query *“select the network sections located within a radius of X m”* allows to identify the superficial or underground outlets and to get their attributes (invert elevation for example).
- (IV.) **The outflowing limitation of the plot** ; A simple attribute query on the «plot» and « urban drainage area» objects can do this :
 - a. **Infiltration capability**; A soil permeability value that is not quantitative but rather qualitative (bad or satisfactory) to guide the designer.
 - b. **Maximum outflow to the public network** ; Calculated from the legal maximum outflow rate of the UDA where is situated the plot, multiplied by its total surface.
 - c. **Maximum outgoing volume** ; Calculated by multiplying the maximum outflow (previously obtained) by the duration of the design rain event.

These plans and the information they provide define the hydrological frame of the project which must be taken into account during the design. Using automated reporting functions of the database management system, an accompanying document entitled **“Stormwater section”** is edited (Fig. 5b).

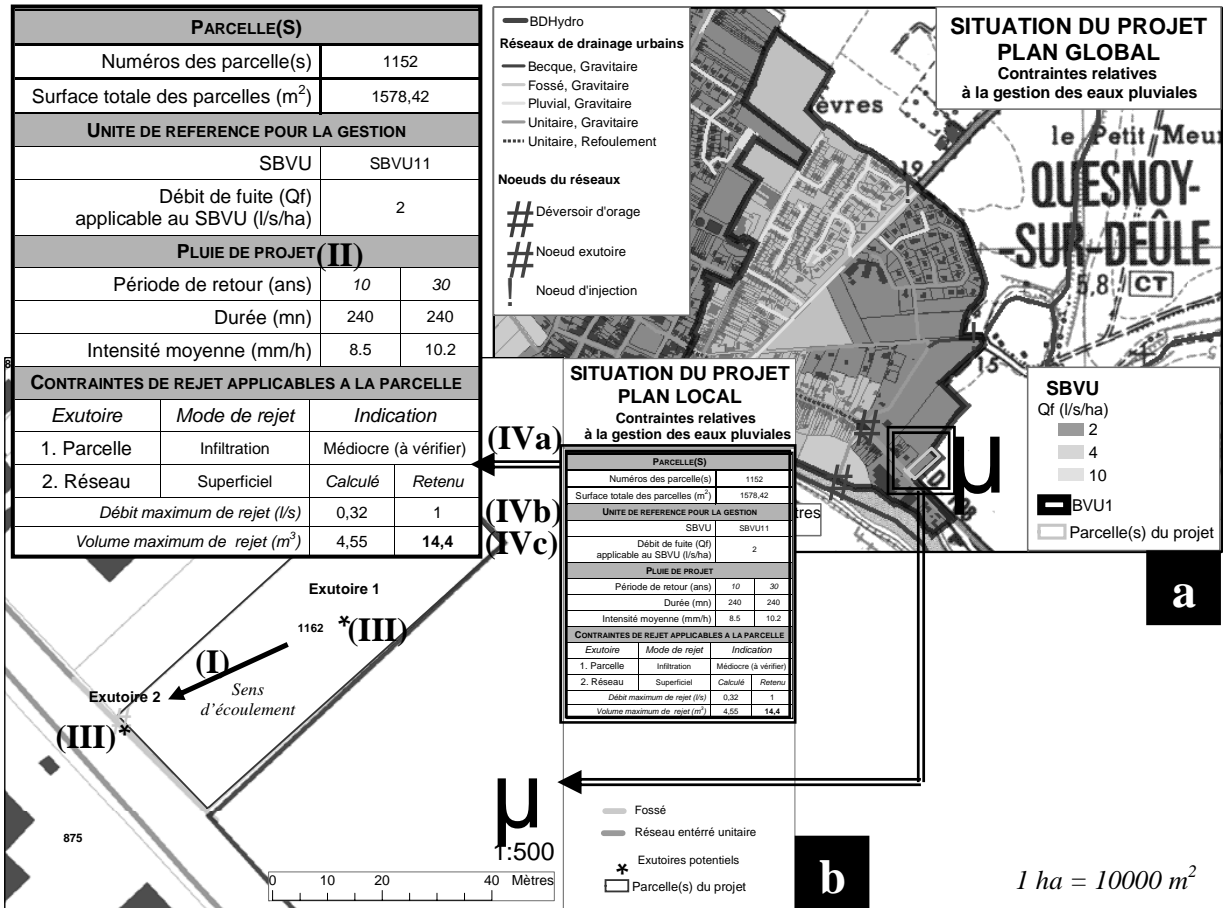


Figure 4. Project situation plans with information provide «upstream» to a development project.

It provides general data about the plot (identification, localization, classification, owner’s name and total surface) and summarizes the data about the plot’s drainage system that is represented on plans. The part entitled “Description of plot surfaces” is intended to be completed by the master builder along with the master plan (Fig. 5a) supplied in the Building Permit Investigation (BPI). Consequently, the master plan must be drawn by numbering each of the surfaces. To help filling this document used downstream to the project during the BPI, a classification list of “constructed” and “not constructed” urban surfaces is supplied. Integrated into our information system, these surfaces are associated with an average runoff coefficient for rain events from 1 to 100 years return period.

“Downstream” to the project, the main activity consists in **checking that the stormwater constraints were respected during the design**, and by the way acquiring stormwater management specific information useful for the planning activities. This is to say :

- Calculate plot imperviousness and global runoff coefficients using the « Stormwater section »,
- Calculate a minimum stormwater volume to be managed on the plot according to the fixed maximum outgoing volume,
- Check that these constraints were respected by comparing these volumes to those exposed in the drainage project.

To achieve this, the **available data** are :

- The **project master plan** (Fig. 5a) where are represented and numbered all the plot’s surfaces, and the « **Stormwater section** » (Fig. 5b) where they are summarized in a table (type, number, material, area), and classified in « constructed / not constructed » surfaces,
- A **calculation note of the plot stormwater management system**.

Having been checked on the master plan, **data filled on the plot surfaces table of the “Stormwater section”** are then input in the database using an input form (Fig. 5c) created under

the DataBase Management System (DBMS) Access®. Then, a **first query** in the DBMS allows to select all the constructed surfaces and calculate the corresponding total area (A_C), which is then divided by the total area of the plot (A), in order to **obtain its imperviousness coefficient** ($C = A_C / A$). A **second request** in the surface list table is used to determine for each of them, the average runoff coefficient for the design's rain event of a t return period, and then to **calculate the average runoff coefficient of the plot** by making a level-headedness of the small areas by the total area of the plot.

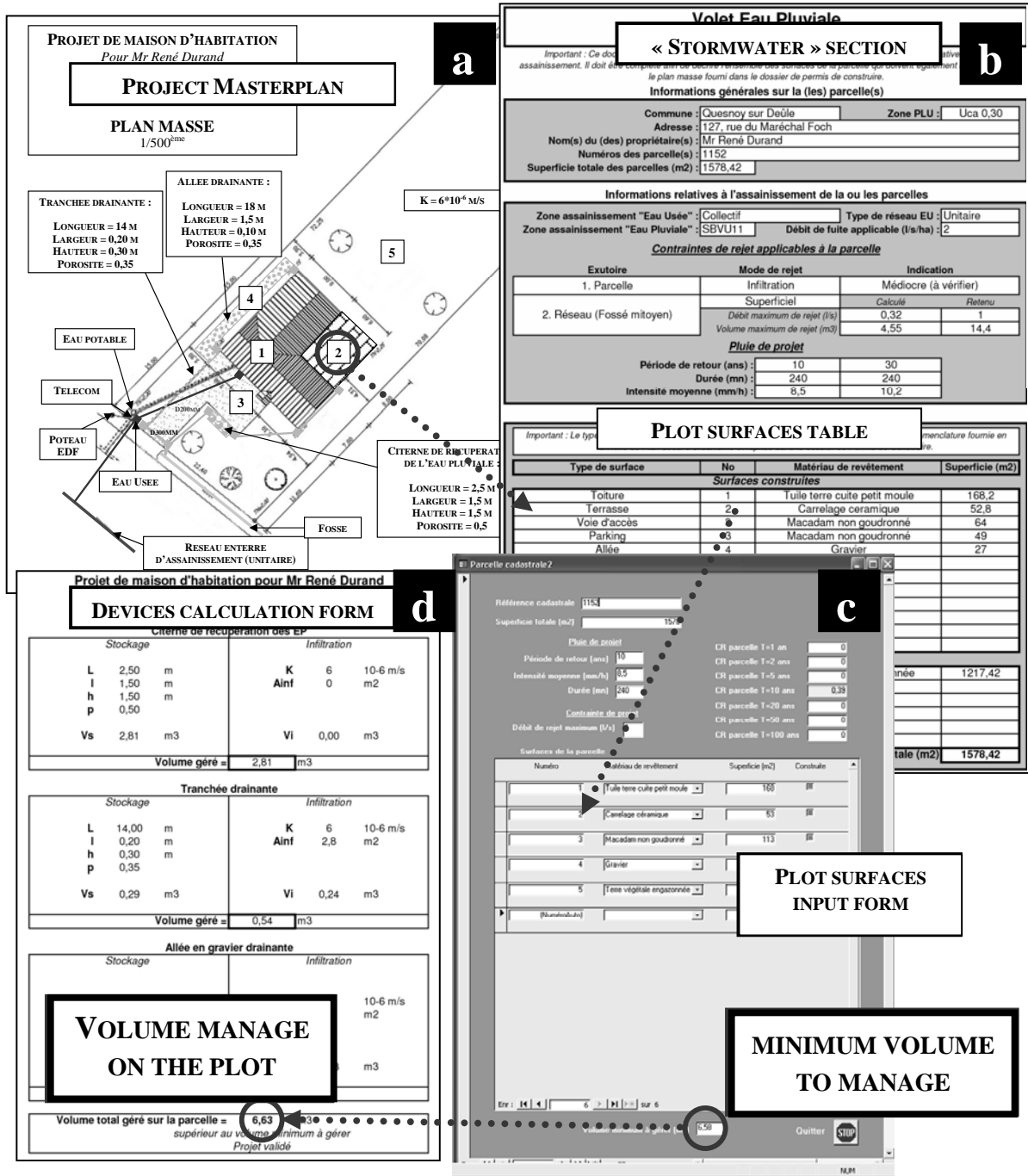


Figure 5. Plan, table and forms used during the building permit investigation.

A balance (ingoing runoff volume minus maximum outgoing volume permitted) allows finally to calculate a **minimum stormwater volume to be managed on the plot**. This volume is the reference for checking the stormwater management devices proposed by the petitioner during the BPI. Using a specific input form (Fig. 5d), every device is roughly modelled to estimate its storage capacity, its infiltration capacity and finally the volume it manages. If all the devices globally manages a water volume bigger than the minimum volume to be managed, the project is validated.

4. DISCUSSION AND FUTUR DEVELOPMENTS

The use scenario of the IS proposed in this paper illustrates the operational management activities by showing how the information produced at the planning level (Zone and legal maximum outflow) is operated and transmitted “upstream” to the project before the design process : the project’s situation plans fix the hydrological and urban framework; the “Stormwater” section is used to acquire the information coming from the design process and to prepare the project’s support “downstream”. Information produced “downstream” to the project (imperviousness and runoff coefficients, outgoing and stored volumes) and integrated in the IS is used for studies at planning level, what allows to complete the integrated management information loop. This experiment showed us the interest and the feasibility of an IS for the development projects support, and so contribute to stormwater integrated management in urban zones. According to us, the proposed IS is a really useful tool for the town planning and urban drainage managing services of a local authority.

We have not described in detail the Conceptual Data Model which is the core of our IS ; Its framework has been designed so that automated delimitation of the Hydrological Urban System is possible at different scales (Macro, Meso and Micro); Linked with many application softwares, this functionality of the IS is fundamental for every planning activities based on simulation and diagnosis. Focusing on the development of these activities support, our ongoing works come up against a lack of information about the pre-existing urbanization which could not be acquired during the project. Nevertheless, to acquire the missing information, it is possible to do some additional analysis using orthographic photos (geolocalized aerial photos rectified for digitalization) whose current precision (1 pixel for 10cm) allows to study very exactly the urban surfaces. Finally, the global efficiency of our IS could only be assessed in middle / long term, as it has been thoroughly used inside the managing services of a local authority.

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