# Chapter 78
# Influence of Topography Resolution and Quality on Modeling Hydrological Processes in Paillon River Basin in the South of France

**Paguedame I. Game, Philippe Audra, and Philippe Gourbesville**

**Abstract** Grid size and elevation resolution have a strong influence on runoff modeling results in areas with high elevation gradient. In medium-size catchments with narrow and steep streamlines, runoff generation is fast. The catchment of interest, Paillon, is in the south eastern region of France and covers an area of 250 km$^2$. Previous studies have highlighted the risks of flood hazards in the area. In this study, the assessment evaluates the challenges in meeting the simulation objectives with high resolution meshes. The model is based on DHI MIKE-SHE modeling system to build the basis for the development of a decision support system for the catchment of study. Simulation results show that an effective cleaning of the DEM allowed to suppress unrealistic accumulation of water within the catchment. In addition, DEM resolution affects computation time, which is highly correlated with the number of grid cells in the modelling domain, and with a good polynomial interpolation fitting curve. In Paillon catchment, the correlation coefficient is 0.999 between DEM resolution and computation time, but slightly lower between DEM resolution and computation time. The 20 m resolution DEM was selected as appropriate for the area of study. Some tests and validations revealed the capabilities of the model to reproduce runoff observed in the catchment. More testing and validation are needed to assess the performance of the models before integrating it to a real time forecasting system.

**Keywords** Mike SHE · Model · DEM resolution

P. I. Game (✉) · P. Audra
Polytech'Lab, Université Côte d'Azur, 930 Route des Colles, 06410 Biot, France
e-mail: paguedame.game@univ-cotedazur.fr

P. Audra
e-mail: Philippe.AUDRA@univ-cotedazur.fr

P. Gourbesville
Polytech Lab, Université Côte d'Azur, Sophia Antipolis, France
e-mail: philippe.gourbesville@univ-cotedazur.fr

China Institute of Water Resources and Hydropower Research, Beijing, China

 
P. Gourbesville and G. Caignaert (eds.), *Advances in Hydroinformatics*, Springer Water,
https://doi.org/10.1007/978-981-19-1600-7_78

## 78.1 Introduction

In south-eastern part of France, particularly in the Department of Alpes Maritimes, rainfall events generating flooding and damage to infrastructure are common. To cope with these disasters, several management approaches are implemented in communities that are facing flood events, including monitoring network, real-time decision-support systems, hydrological modeling systems, etc. [1, 2]. In addition, future climate projections seem to encourage decisions makers to assess and improve the tools used to manage these disasters. In fact, in a recent report, DRIAS 2020 [3], it is noted that climate change and its consequences such as extreme rainfall events are accelerating around the globe and France is not preserved from these adverse effects.

Deterministic hydrological models play an important role in providing decision makers with the basic information needed to understand hydrological processes in a catchment and in planning the management of extreme rainfall events. In order to build these models, it is useful to consider the objectives of the modelling project, the characteristic of the study area, and data availability. For physically-based models like Mike-SHE, topography and spatial discretization have important impacts, not only on model performance, but also on how the model can be used for decision making, especially on real-time management of extreme events [1, 4, 5]. Mike-SHE can simulate surface and groundwater flow, and their exchanges, with its functionalities such as ET (evapotranspiration), OL (overland flow), UZ (unsaturated zone), SZ (saturated zone), and allows coupling with Mike 11 (1D hydrodynamic Model). Many applications of the tools can be found in the literature. For example, Aquavar project [1], is based on Mike-SHE modules to reproduce surface runoff and surface–groundwater exchanges in the Var catchment [6, 7]. The interface of Mike SHE, which allows coupling with Mike 11, is suitable for modelling hydraulic structures and different hydraulic processes [8].

A review of the historical events and characteristics of the region where the study area is located highlights complex hydrological process in a steepy and mountainous region. In the Paillon catchment, which is the area of interest of this study, the downstream part is densely urbanized, but the upstream part is mountainous with large parts of natural or semi-natural densely vegetated areas. The region is characterised by low flows in summer and high flows in fall and spring, with sometimes extreme rainfall events and catastrophic flooding. The climate is characterized by wet and mild winters, hot and dry summers, with high variability in hydrological sediment transport processes [9]. In the area of interest, flood events are impressive not only they occur suddenly but also by their degree of violence [10]. Recorded information about flood events date back as far as 1240. In 1940 for example, an extreme rainfall event generated an estimated 1500 $m^3/s$ at the outlet and destroyed several infrastructures. The most recent extreme event, in October 2000 reminded the communities of the high sensitivity of the area to flood hazard. The Paillons catchment located in the south-eastern region of France covers an area of 250 $km^2$ in Alpes-Maritimes Department (06). Its main branch flows through the center of Nice

City, the 5th largest in France. The downstream part of the catchment is highly artificialized with some kilometers of river network covered with infrastructures (built mostly between 1868 and 1972), in contrast with the relatively preserved valleys at the upstream part. In 1983, a roadway tunnel (Le Tunnel Rive gauche du Paillon or TRGP) along with a flood warning system was built to protect people and infrastructure in Nice. With a growing population of about 170,300 inhabitants, the catchment is characterized by alternating severe low flows and sudden and strong high flows. Strong erosion processes drain out to the sea coarse materials (pebbles) which form the beaches of Nice. Socio-economic development in the area has increased the use of water resources for industrial activities and drinking supply. The geology is made of sedimentary rocks (mainly marls and limestones) that range from the Upper Triassic to the Quaternary with alpine deformations (folds, faults, overthrusts). Deep groundwater represents an important source of drinking water supply and shallow groundwater is mainly used for irrigation and industry in the region. Interaction between groundwater and surface waters is important in the catchment and part of the deep groundwater resources leaks out to the sea [10, 11]. Therefore, changes in hydrology of the catchment would significantly affect the sustainability of the area. A better understanding of these hydrological processes is necessary to optimize the management of water resources and to reduce the impact of flood hazards [11–15].

In this context, with the overall objective of building a decision support tool for the Paillon catchment, the aim of this study is to:

- Build hydrological models of the Paillon catchment
- Select an appropriate DEM resolution
- Use and evaluate appropriate data and parameters (land use, soil, etc.)
- Include a river network with a 1D hydrodynamic model
- And conduct some tests and validations for the hydrological models.

## 78.2 Study Area and Methods

To assess the hydrological processes in the Paillon river basin, a Mike SHE model coupled with a 1D hydrodynamic model Mike 11 is built, based on data available. With this model, the initial approach includes selecting a DEM resolution, cleaning it, and testing, using different grid resolutions on computation time and runoff results.

### *78.2.1 Study Area*

The study area is located on the east side of the Var river, covering around 246 $km^2$ and subdivided into 5 sub-catchments (Contes, L'Escarène, Nice, Banquière and Laghet), with L'Escarène being the largest sub-catchment (Fig. 78.1).

The topography varies between 0 and 1495 m, with the highest elevation in Paillon de Contes sub-catchment. With an average slope of 23.2° and a maximum slope of

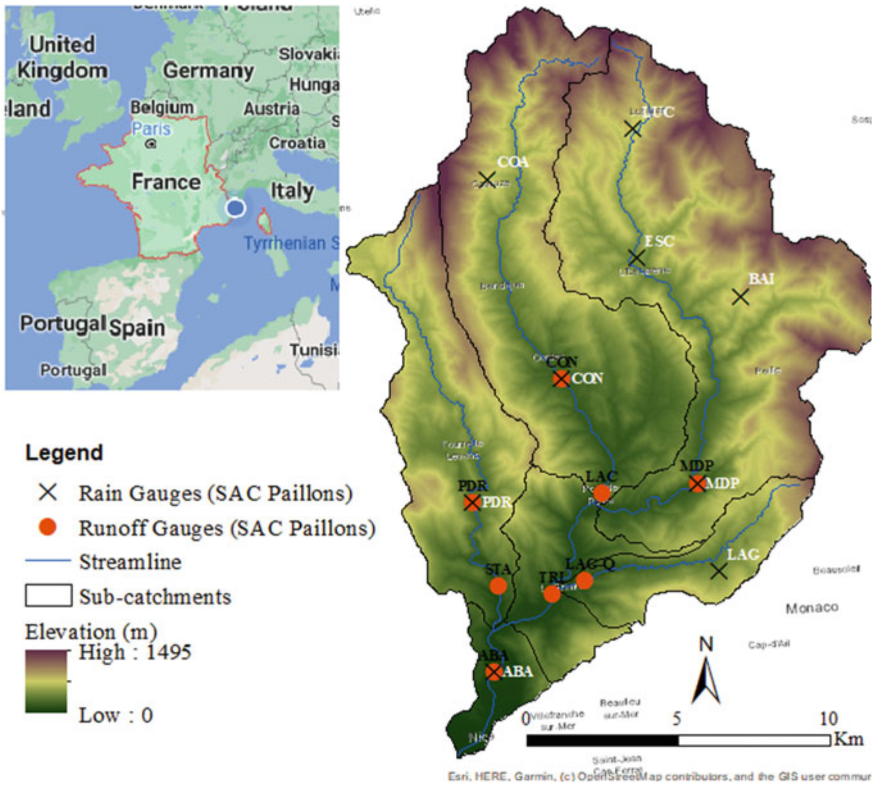



**Fig. 78.1** Topography, main rivers, rain and runoff stations (from SAC: Système d'Annonce des Crues) of the Paillon catchment

85.9°, this catchment has a total Longest flow path of 36.46 km. Five main river branches drain runoff waters to the sea at the outlet in the city of Nice. The most downstream branch, Paillon de Nice (11 km), receives waters from the other 4 branches (Paillon de l'Escarène (23 km), Paillon de Contes (19 km), La Banquière (17 km), and Le Laghet (10.5 km)). As indicated in Table 78.1, on the last few kilometers downstream, the river flows into tunnels up to the sea, due to infrastructures topping the river. Paillon catchment is characterized by narrow cross-sections upstream and the presence of dikes and other obstacles along the streamlines.

Different land uses are present in the catchment, especially in the downstream part (Fig. 78.2). The lower reach is highly urbanized. There are 4 categories (levels 1–4) of landuse classifications from the European Agriculture Centre (EAC), with level 4 being the most detailed one. In Fig. 78.2, level 4 is shown but with a grid resolution of 100 m × 100 m. However, finer resolution (50 cm × 50 cm) data from Metropole Nice Cote d'Azur (MNCA) is available and is used for further modelling assessments.

**Table 78.1** Characteristics of Paillon river basin (NGF is the General levelling of France)

| Parameters | Le Paillon de Contes | Le Paillon de l'Escarène | Le Paillon du Laghet | La Banquière | Le Paillon de Nice | All |
|---|---|---|---|---|---|---|
| Area ($km^2$) | 71 | 94 | 16 | 41 | 24 | 246 |
| Area (%) | 29 | 38 | 6 | 17 | 10 | 100 |
| Longest flow path (km) | 22 | 24.5 | 11.37 | 20.1 | 11.96 | 36.46 |
| Elevation range (m) | 106–1495.59 | 106–1426 | 68–1147 | 41–1373 | 0–794 | 0–1495.59 |
| Maximum slope (°) | 83.94 | 83.66 | 85.92 | 84.33 | 84.12 | 85.92 |
| Average slope (°) | 23.72 | 25.17 | 21.04 | 23.22 | 17.99 | 23.20 |
| Slope standard deviation (σ) | 19.88 | 20.21 | 18.96 | 19.33 | 18.94 | 10.6 |
| Outlet (m NGF) | Pont de Peille 100 m NGF | Pont de Peille 100 mNGF | Pont de la Trinité 70 m NGF | Pont Jumeaux 40 m NGF | Palais des expositions 16 m NGF | Palais des expositions 16 m NGF |
| Characteristics | 2 tributaries<br>– la Garde<br>– la Vernéa | 5 important tributaries | Covered on the last 900 m downstream | Narrow cross sections upstream Presence of dikes | Completely artificialized (dikes, infrastructures) Covered on the last 3 km | |

### *78.2.2 DEM Selection and Cleaning*

The objectives of the project motivates a choice of an appropriate DEM resolution, which should be as fine as possible and induce a computing time that is acceptable for real-time decision making on flood events. From the initial DEM of 1 m resolution (NCA, 2019), five DEMs were created by aggregation with resolutions 40, 30, 20, 10 and 5 m. Each resolution is used to build a model and run simulations for several hours of event and check how long it takes to get the results on a Desktop computer 16.0 G0 RAM, 64 bits, Intel ® Core™ i7-4790 CPU @ 3.60 GHz and 500 GB of memory. Models with Mike SHE and with Mike SHE coupled with Mike 11 are used.

A 40 m DEM resolution has 155,460 cells in the catchment area and 277,318 cells in the rectangular extent of the model domain, i.e. about 56% of the total number of cells in the rectangular extent are in within the catchment. The number of cells for the other DEM resolutions is presented as a ratio to that of the 40 m resolution DEM. In absolute numbers, in the rectangular extent, they are 492,650 cells for 30 m DEM, 1,104,020 cells for 20 m DEM, 4,433,850 cells for 10 m DEM, and 17,735,400 cells for the 5 m DEM. Cleaning the DEM, to allow water to move out of the catchment and

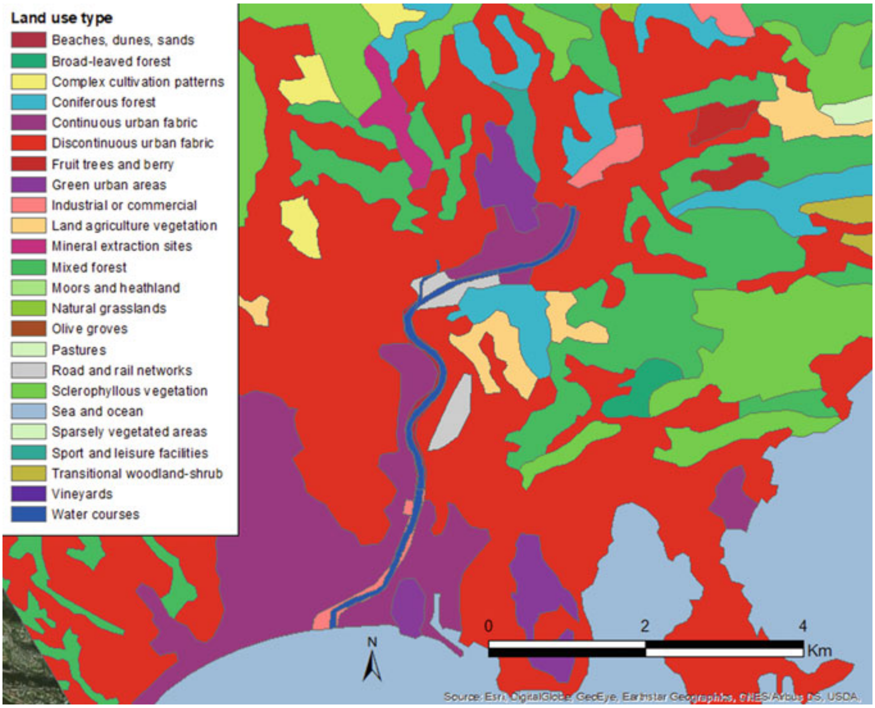



**Fig. 78.2** Land use types at lower part of the Paillon catchment (*Data Source* EAC 2006)

avoid unrealistic accumulation of water in the modelling domain, GIS pre-processing is required. To achieved this in an efficient way, it is possible to use results from a hydrological simulation, by running the simulation for a long period of time to make sure that most of the water is moved out of the catchment. Any remaining water is a results of obstacles in topography. Those could be realistic (lakes and other water bodies) or not (sinks, holes, obstacles). However, to make sure unrealistic obstacles do not impact on runoff estimation, it is better to remove them. One way is to use overland flow water depth at the last time step, and merge it with the DEM, to create a new one. Repeat the process several times, to remove most of the shallow sinks. There may be sinks that are deep (100 m deep for example) and generate high or low water accumulation. Identify those who generate high accumulation of water, estimate the difference in elevation with the neighboring cells, divide that difference by the accumulated water depth at that cell, and get a ratio N. With Mosiac to new raster, add the overland flow layer N times and add the DEM. A new DEM is create by selecting sum as operation and clicking on Ok. Sum up the rasters to create a new DEM. Then the simulations can be repeated with the new DEM. The results will be free of accumulation of water at the location of interest and an overall decrease in maximum accumulated water depth. New locations with some accumulation may appear due to the raster grid overlay inaccuracies that shifts some cells slightly when combining rasters.

### *78.2.3 Data and Model Set Up*

Steps and data needed to build hydrological models, select and cleaning DEMs, and test and validate models include, for each grid cell: target resolution (from 40 to 1 m), land use, Strickler coefficient for surface runoff, vegetation classes for evapotranspiration, potential evapotranspiration, soil depths for infiltration (Richards' equation), and soil classes for unsaturated zone. In addition, a stream network for 1D hydrodynamic model is useful when coupled with the hydrological model to move water downstream in a reduced computation time. Observation data are needed for validation. They include rainfall, water depth, and discharges data. Table 78.3 presents a summary of the different data and sources needed. SAC (System d'Annonce des Crues) Paillon is a flood monitoring system of the Paillon catchment.

In Fig. 78.3, the initial model is set up with Overland (OL) functionality with finite different method [6], the grid resolution, and the topography. Land use is expressed as Strickler coefficients for OL and Vegetation parameters for evapotranspiration. Rivers and Lakes is used as a functionality to represent the stream network as a 1D

**Table 78.3** Data for model assessment for the Paillons catchment

| Data type | Sources | Description |
|---|---|---|
| DTM (Department des Alpes maritimes) | Métropole Nice Côte d'Azur | 1 m × 1 m |
| Land use | European Agriculture Center and Métropole Nice Côte d'Azur | From EAC recorded in 2006 (100 m × 100 m resolution) and from NCA recorded in 2014 (50 cm × 50 cm resolution)<br>Vegetation database from DHI 2012 |
| vegetation | | |
| Soil | European soil data center | Recorded in 2009 (500 m × 500 m resolution maps of USDA soil texture, sand, clay and silt percentages) |
| Rainfall | SAC Paillon | 9 stations with 6 mn time step record |
| Air temperature | Météo-France | 9 stations with 6 mn time step record |
| Reference evapotranspiration | Météo-France | SAFRAN data (8000 m × 8000 m resolution) |
| Runoff | SAC Paillon (NCA) | 8 stations with 6 m, time step record |

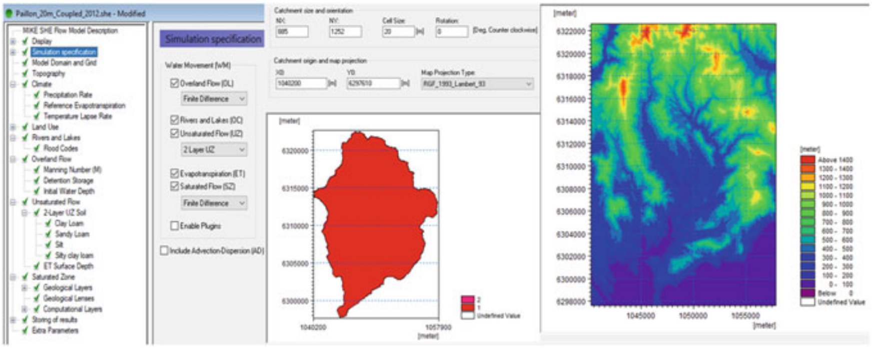



**Fig. 78.3** Model set up with selected functionalities, grid sizes and elevation data

hydrodynamic model. In the model, exchanges with groundwater are not considered, therefore the initial soil depth used allows to account for exchanges with the unsaturated zone based on 2 Layer UZ module.

From a 50 cm × 50 cm resolution landuse data, showing details such as spaces for parking uses, beaches, sports facilities, or different types of vegetation, 6 classes (agriculture, artificial, Forests, Grassland, Open space, and water bodies), are created as initial hypothesis of land use distribution for the hydrological model assessment. If necessary, more classes will be made to assess the sensitivity of the models to land use parameters. In Fig. 78.4, a Google map and the selected land use map are presented. The land use data and classes are from NCA 2014. In the model, land use is represented by Strickler (or Manning's M) coefficients (in $m^{(1/3)}/s$) as shown in Fig. 78.5. As initial values, coefficients are assigned, 25 for Artificial areas, Forests 4, Open space and grasslands 10, and water bodies 1.

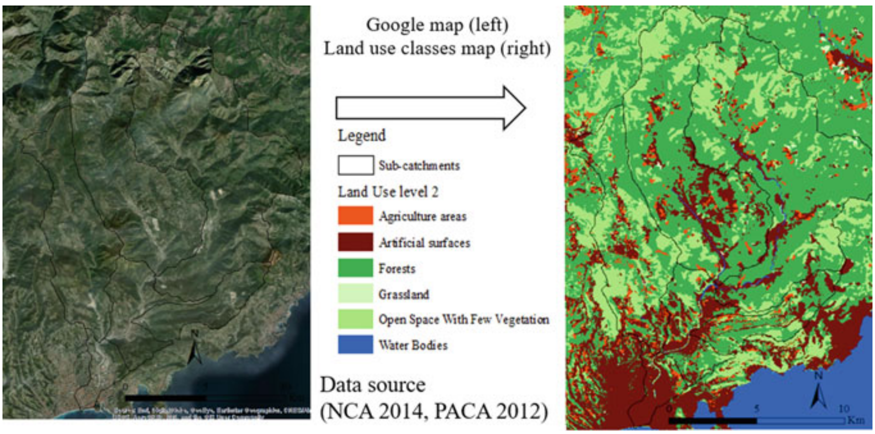



**Fig. 78.4** Identification of land uses (classification obtained from NCA 2014)

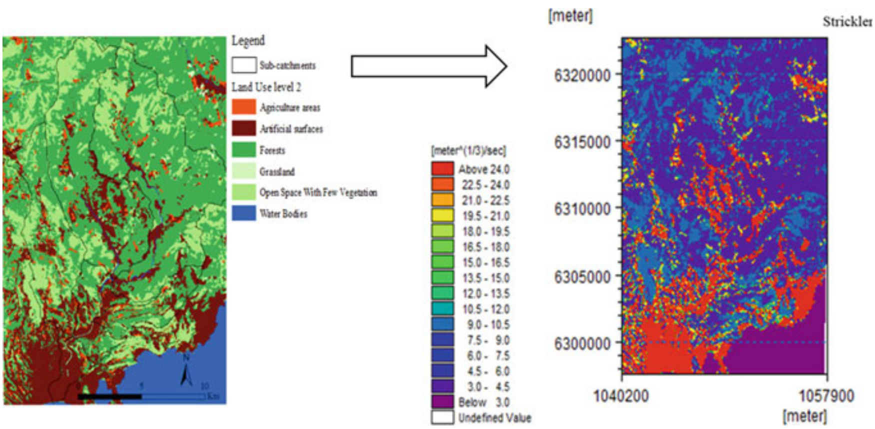
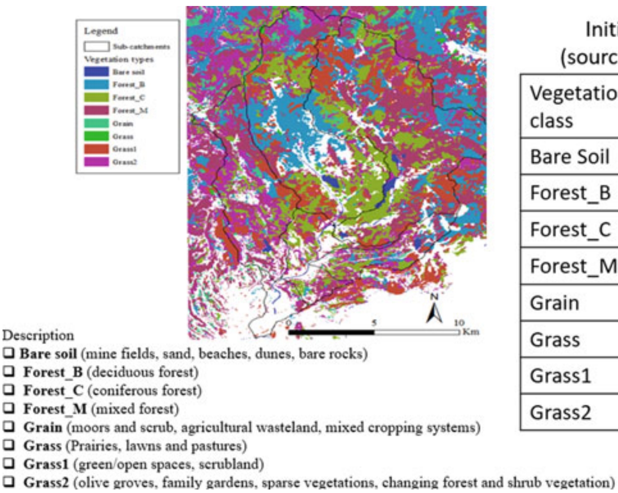



**Fig. 78.5** Strickler coefficients for land use classes

Vegetation parameters, as displayed, for evapotranspiration are also assigned based on vegetation from land use data (Fig. 78.6). Eight classes are defined as Bare soil (mine fields, sand, beaches, dunes, bare rocks), Forest_B (deciduous forest), Forest_C (coniferous forest), Forest_M (mixed forest), Grain (moors and scrub, agricultural wasteland, mixed cropping systems), Grass (prairies, lawns and pastures), Grass1 (green/open spaces, scrubland), and Grass2 (olive groves, family gardens, sparse vegetations, changing forest and shrub vegetation). With initial parameters retrieved from DHI_2012.ETV data base, the eight classes are sufficient to account for differences in Leaf Area Index (LAI), Root and Kc parameters of each type




Initial parameters
(source DHI_2012.ETV)

| Vegetation class | LAI | Root (mm) | Kc |
|---|---|---|---|
| Bare Soil | 0.8 | 100 | 1.2 |
| Forest_B | 7 | 800 | 1 |
| Forest_C | 5 | 800 | 1 |
| Forest_M | 6 | 800 | 1 |
| Grain | 1.5 | 200 | 1 |
| Grass | 1.1 | 300 | 1 |
| Grass1 | 1 | 300 | 1 |
| Grass2 | 1 | 300 | 1 |

**Fig. 78.6** Vegetation parameters for evapotranspiration

of vegetation, which may vary monthly, daily, or yearly. Deciduous forest has the highest LAI while bare soil has the lowest.

To account for interactions between the surface and the unsaturated zone, initial soil depths are required. These depths correspond to different slope ranges. Initially, depth per slope is attributed as follow (using similar principle as in AquaVar project [1]): −3 m for 0 to 10°, −1.5 m for 10 to 40°, −0.75 m for 40 to 50°, and 0 for 50 to 90° (Fig. 78.7).

In addition to soil depths, soils properties are required. From the European Soil Center (ESC) data at 500 m × 500 m resolution, two major classes compose the soil texture in the catchment, silty clay loam and silt. Two other types, clay loam and sandy loam, can be found (Fig. 78.8). Some key parameters that are evaluated

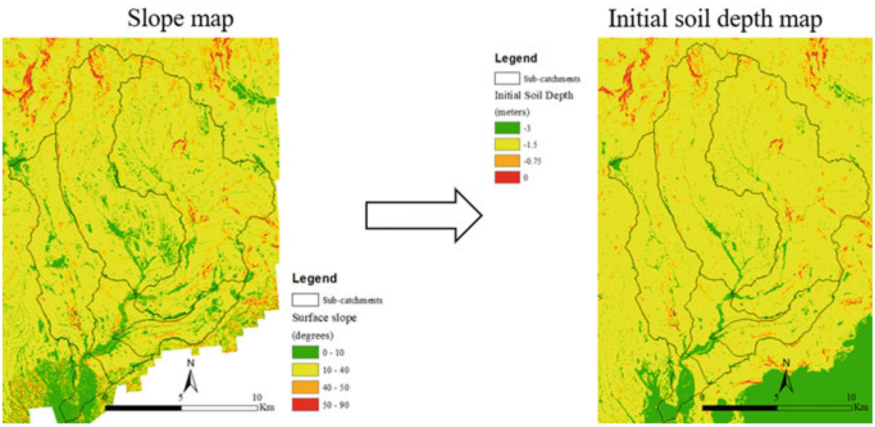
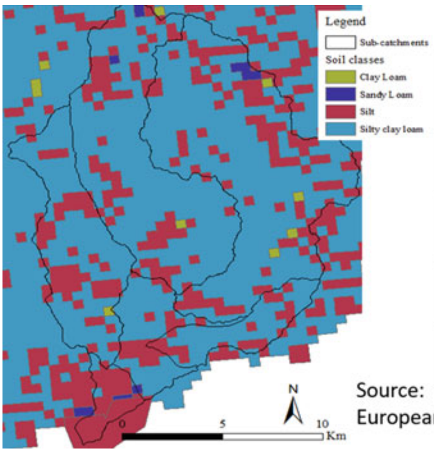



**Fig. 78.7** Initial soil depths for infiltration




Initial soil properties

| Initial Parameters | Clay Loam | Sandy Loam | Silt | Silty Clay Loam |
|---|---|---|---|---|
| Water content at saturation (-) | 0.5 | 0.38 | 0.5 | 0.5 |
| Water content at field capacity (-) | 0.31 | 0.32 | 0.32 | 0.33 |
| Water content at wilting point (-) | 0.21 | 0.08 | 0.22 | 0.2 |
| Saturated hydraulic conductivity (m/s) | 1.7e-6 | 8e-6 | 8.9e-6 | 9e-6 |

Source:
European Soil Center (500 m x 500 m resolution)

**Fig. 78.8** Soil classes map for 2-layer UZ soil properties

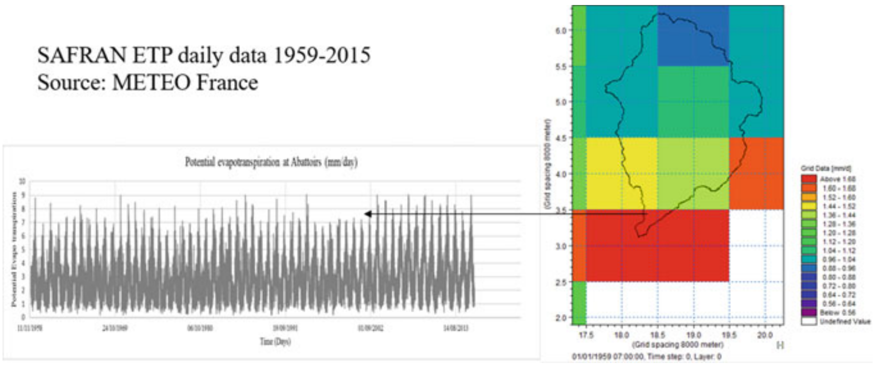



**Fig. 78.9** Potential evapotranspiration

in the modelling process include water content at saturation, water content at field capacity, water content at wilting point, and saturated hydraulic conductivity.

SAFRAN daily Evapotranspiration data from 1959 to 2015, obtained from Meteo France, is also used in the hydrological model (Fig. 78.9). It has a resolution of 8000 m × 8000 m and serves as reference data in the model.

As mentioned previously, a 1D HD model is integrated in the modelling system. From a 1 m resolution DEM, stream network for the catchment is defined and grouped into classes by length (Fig. 78.10). Branches longer than 4 km are used to define the river network in Mike 11 (1D model). This network is made of 25 branches and 2894 cross-sections. The interval between cross-sections is 50 m. Hydrodynamic module is set on unsteady simulation mode with global bed resistance of 20 $m^{(1/3)}$/s, and boundary conditions at outlet to 0 m water depth. Upstream inflow (depending on

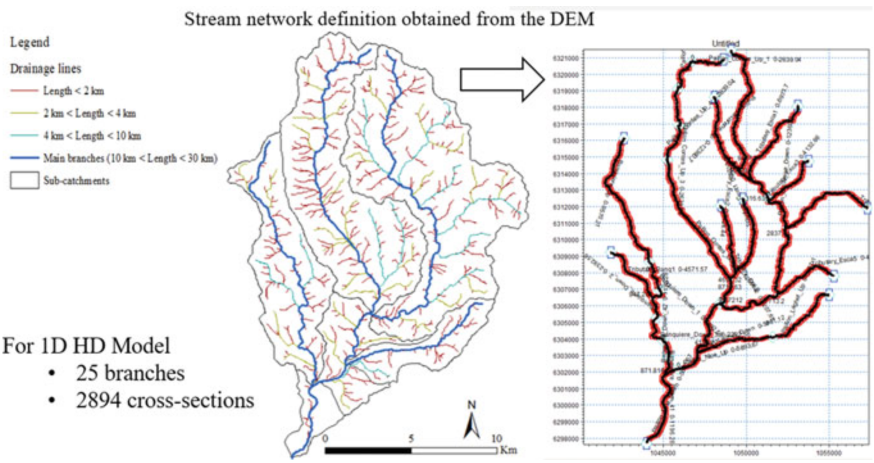



**Fig. 78.10** Stream network for 1D HD model

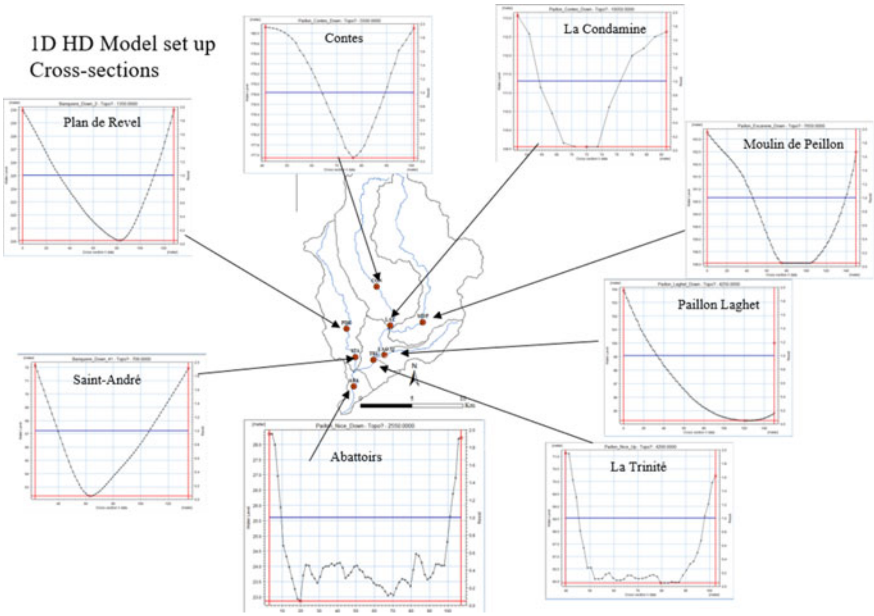



**Fig. 78.11** Runoff gauges and initial cross-sections of the Paillon catchment extracted from DEM

observations) is attributed to each stream as base flow. Some of the cross-sections, at the locations of runoff gauging stations of a local flood monitoring network, are shown in Fig. 78.11. At this stage, field measurements were not available to validate cross-sections, but this operation will be undertaken later to improve the modelling system.

A hydrological model needs rainfall information to generate runoff in the catchment. In Paillon, 9 rainfall stations record data at 6 mn time step for several years. At this time, data for 2011–2014 are used. It is reported from Meteo France that the maximum observed rainfall depth, in the department of Alpes-Maritimes, where Paillon catchment is located, is 22 mm (or 220 mm/h) in 2015. In Fig. 78.12, the rainfall data are below that extreme value. Further analysis will be conducted to assess rainfall information and to compare it with data from Meteo France stations in the catchment. There are different ways to use rainfall data in the hydrological model, either as uniform, or discrete (station-based or semi-distributed), or fully distributed. Many interpolation methods are reported in the literature, and a recent study in the nearby Var catchment (Aquavar Project [1]) shows that inverse distance weighting power 2 method is sufficient to accurately represent rainfall distribution. In the Paillon catchment, the same interpolation is used at the initial stage of the modelling process, before to assess the impact of different interpolation methods on simulated runoff results. Figure 78.13 shows an example of interpolating a rainfall event data from station-based to distributed 2D map.

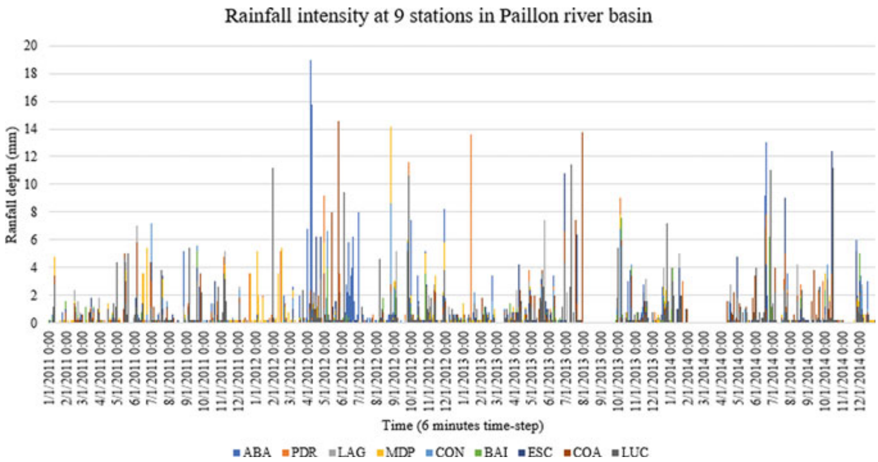



Fig. 78.12 Precipitation data for hydrological model

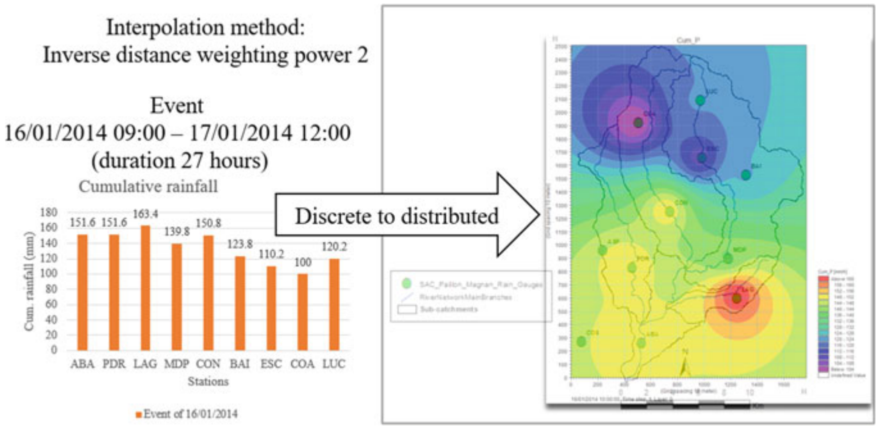



Fig. 78.13 Interpolation of precipitation data

Last but not least, observed runoff data are needed for validation. The purpose of building the Paillon hydrological models is to integrate it to a decision support system for flood forecasting and flood management. Past records are important in testing the response of the model to real events. From the Paillon flood monitoring system, water depths and discharge data are available for several years. From 2011 to 2014 (Fig. 78.14), some rainfall events generated important increase in water that, but no flood was observed. Interestingly, it is also important to test the behavior of the model for low intensity rainfall events. It is observed that for a base flow of 0.2 m of water depth, in 2012 some events generated up to 1.5 m of water depth at Abattoirs gauging station, near the outlet of the catchment. In 2014, from a base flow of 0.58 m, water depth increased up to 2 m during an event. With this available

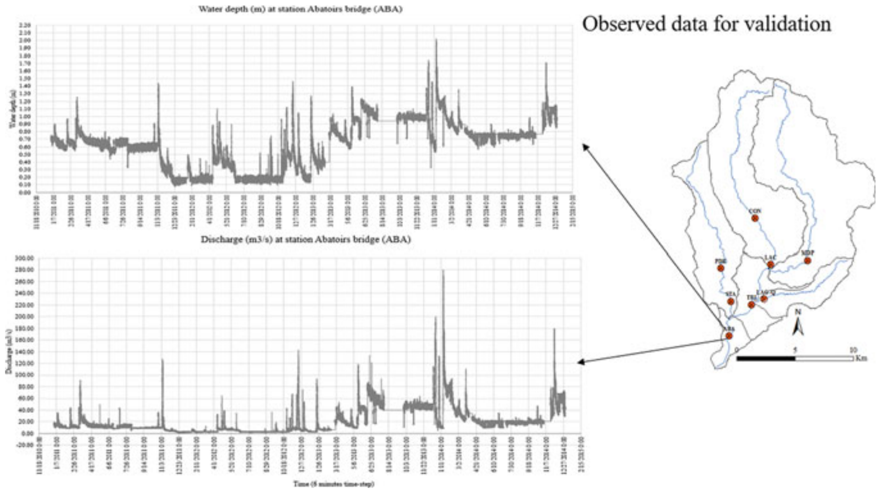



**Fig. 78.14** Observed runoff data used for validation at 8 local gauging stations from 2011 to 2014 (*Data Source* NCA)

data, some testing and validation is conducted, and results are presented in the next sections.

## 78.3 Results and Discussions

### *78.3.1 Selected DEM for Initial Testing and Validation of Hydrological Models*

A rainfall event from 16/01/2014 09:00 to 17/01/2014 12:00 (about 27 h) was used for simulations with Mike SHE. A subset of 13 h of that period is used for Mike SHE coupled with Mike 11 simulations. In Mike SHE, water is moved from one cell to the other, coupling with Mike 11, reduced the amount of time it takes to move water out of the catchment.

Results show that, for the event that last 27 h, it takes more than 18 days to produce simulation outputs with a 10 m grid resolution, 3 days for a 20 m grid, 5.5 h for a 30 m grid and 4 h for a 40 m grid. Meanwhile, for the event of 13 h of duration and Mike SHE coupled with Mike 11, it takes respectively 61 h, 1 h, 20 mn and 7 mn of computation time to generate outputs for 1, 20, 30 and 40 m grids. The difference between coupling Mike SHE with Mike 11 and running Mike SHE alone was expected, because the 1 D HD model reduces the number of cells that should have participated in moving water out of the catchment.

However, for real time decision making, it is necessary to choose a model that can forecast a 24 h event in few hours or minutes to allow decisions makers to plan the response to the specific event. From the outcomes of the simulations, the 20 m resolution is appropriate for the studied area. In addition, coupling Mike SHE with Mike 11 is important to reduce overall computation time. The 40 and 30 m grid may be useful for some specific applications where the requirements for detailed maps is not necessary. For the 10 m grid or finer, it may be possible to build and validate a model on it if higher computation power is available.

In Fig. 78.15, computation time is highly correlated to number of grid cells and a good trendline shows a polynomial interpolation (Poly.) can explain the changes

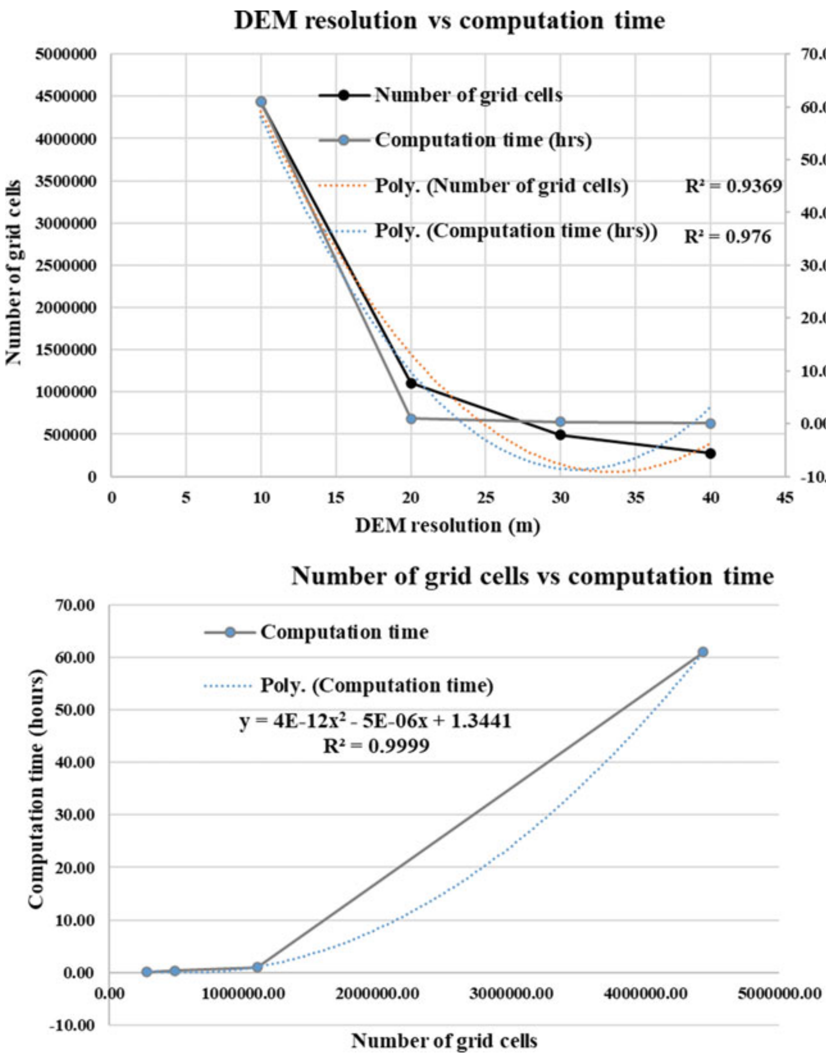



**Fig. 78.15** Effect of DEM and number of grid cells on computation time

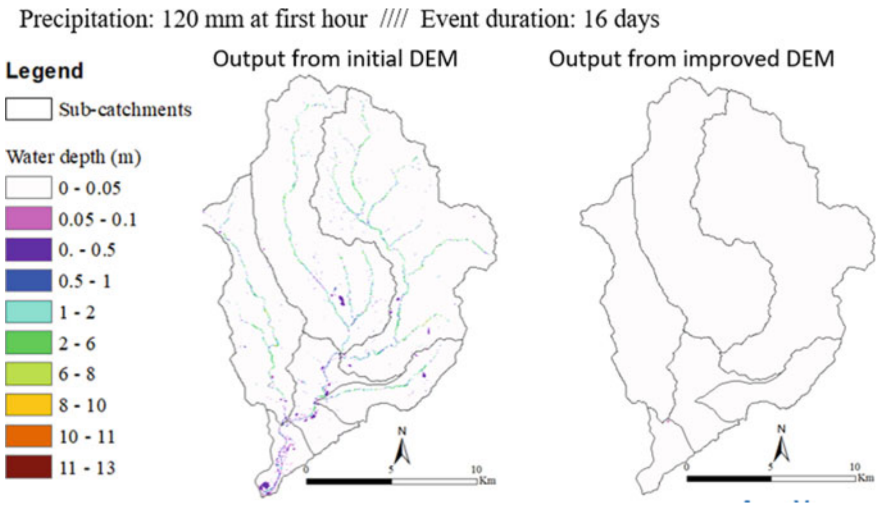



**Fig. 78.16** From initial DEM to improved DEM for overland water flow

in computing time against the number of grid cells in the model rectangular extent. The coefficient of correlation $R^2$ is 0.999 between computation time and number of grid cells. This coefficient is slightly lower between number of grid cells and DEM resolution (0.9369) and between computing time and DEM resolution (0.976).

### *78.3.2 Improved DEM for Overland Flow in the Catchment*

In Fig. 78.16, results of improving the DEM for water movement is effective. The initial DEM shows at the last time step of a 16-days of event duration and with 120 mm of rainfall in the first hour of those 16 days, that in the initial DEM, a lot of water is blocked, either in the streams or in other locations within the catchment. Accumulated water at some locations exceeds 6 m. The preprocessing method is ArcGIS was effective in cleaning the DEM by removing almost totally unrealistic accumulation of water.

### *78.3.3 Testing and Validation of Hydrological Models*

The results of the simulations show that the models are able to capture the runoff observed within the catchment. In Fig. 78.17, results show that the model is able to capture the runoff hydrograph. Only two events in the same month are shown here, but more testing on longer periods of rainfall data is needed to fully assess the models.

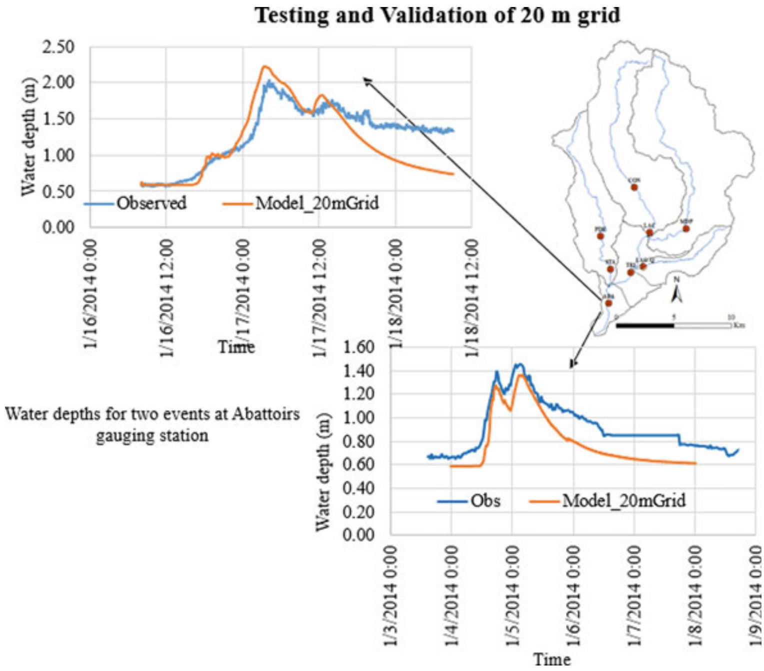



**Fig. 78.17** Testing and validation of 20 m grid and DEM resolution at Abattoirs Gauging station

## 78.4 Conclusions

The analysis of 4 different resolutions (40, 30, 20, and 10 m) DEMs resulted in selecting 20 m resolution as appropriate for elevation data in the hydrological model. Other resolutions are either too coarse or require computation time that is not suitable for real decision support systems built on common office Desktop computing power. However, depending on project objectives, any resolution can be used. Preprocessing of the selected resolution led to improve the DEM for overland water flow by suppressing unrealistic accumulation of water within the catchment. Initial DEM generated high accumulation of water, up do 13 m at some location. Using GIS tools and Mike SHE overland water depth outputs, the sinks and obstacles were removed.

Testing and validations of the models show some promising results. Assumptions made about the different input data and parameters seem to be efficient in capturing hydrological processes in the catchment. However, more data and testing are needed to calibrate the model and to simulate long periods of runoff flow. When enough sensitivity analysis and validation are completed, the model can be integrated into a decision support system. In addition, rainfall and runoff data will be fully assess statistically and different data interpolation methods will be used to evaluate their influence on modeling results.

**Acknowledgements** This report is part of an ongoing PhD project funded by public services, specifically Régie Eaux d'Azur and Métropole Nice Cote d'Azur. Therefore, it is time to acknowledge their availability and support in this journey. The progress made so far and resulted in writing this report was possible thanks to the help of my colleagues and supervisors. Masoud Ghulami, Mingyan Wang and Hezouwe Amaou Talle are always available to share insights on data processing, modeling, and the overall objectives of the project.

## References

1. Ma Q (2018) Deterministic hydrological modelling for real time decision support systems: application to the Var catchment, France, Other. UniversitéCôted'Azur. NNT:2018AZUR4015. tel-01815956, Nice
2. Zavattero E (2019) Integration of surface water modeling in a decision support system: application to the Lower Var Valley, France, Risques. UniversitéCôted'Azur. English. NNT:2019AZUR4004 . tel-02442008, Nice
3. Soubeyroux J-M, Bernus S, Corre L, Drouin A, Dubuisson B, Etchevers P, Gouget V, Josse P, Kerdoncuff M, Samacoits R, Tocquer F (2020) Les nouvelles projections climatiques de référence DRIAS 2020 pour la métropole, Météo-France, France
4. Vázquez RF, Feyen L, Feyen J, Refsgaard JC (2002) Effect of grid size on effective parameters and model performance of the MIKE-SHE code. Hydrol Process 16:355–372
5. DHI (1998) In MIKE-SHE v.5.3 user guide and technical reference manual. Danish Hydraulic Institute: Denmark; 50
6. DHI (2007) Mike she user manual volume 2: reference guide DHI software 2007. DHI Water & Environment (DHI)
7. Waseem M, Kachholz F, Tränckner J (2020) Suitability of a coupled hydrologic and hydraulic model to simulate surface water and groundwater hydrology in a typical North-Eastern Germany Lowland Catchment. Appl Sci 10(1281):4
8. Sloan PG, Moore ID (1984) Modeling surface and subsurface storm flow on steeply-sloping forested watersheds. Water Resour Res 20:1815–1822
9. Chapuis M, Elabas AA, Souriguére K, Compagnon F, Mayen V, Terrier B (2018) Quantification of the morphodynamics and ecological functionality of a Mediterranean river. In: E3S web conference, 40 (2018) 02042
10. De Saint-Seine J (1995) Monographie hydrologique et hydraulique du Paillon de Nice en vue de la gestion du risque inondation. Thèse de doctorat I.N.P.G
11. Syndicat intercommunal des Paillons (2016) Etude de restauration de la continuité écologique des Paillons. Phase 2: diagnostic des obstacles. Rapport 80386 version D. Syndicat intercommunal des Paillons, Nice
12. Emily A, Tennevin G (2009) La source karstique de Sainte-Thècle. Evolution des débits annuels depuis 1940 (Peillon, Alpes-Maritimes). Ann. Mus. Hist. Nat., vol. 2, no. XXIV fasc., pp 1–14
13. Durozoy G, Gouvernet C (1965) Les reservoirs aquiferes entre Nic et Menton. Alluvions du Paillon. Massifs calcaires Jurassiques. DSGR65.A69, Marseille
14. Syndicat Intercommunal des Paillons (2014) LA PRESENTATION DU BASSIN VERSANT. SIP, Nice
15. Martin B (1999) Pland de Prévention des Risques Naturels Prévisibles d'inondation du Paillon. Rapport de Présentation. COMMUNE DE NICE, Nice