CO-387

COMBINATION OF TECHNIQUES FOR THE SETUP OF THE BDT RHôNE, A HIGH ACCURACY ALTIMETRIC DATABASE FOR THE MITIGATION OF FLOOD EVENTS.

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1. BACKGROUND AND OBJECTIVES

The river Rhône flows from the Alps down to the Mediterranean sea across Switzerland and France. In France, the surroundings of the river gather many stakes in a small area (the floodplain of the river represents an area of 3000 sq. km, and the French course of the river is 512 km long): a highly populated area (500 000 inhabitants), a major axe of transport of Europe with high speed railways and motorways that link Germany and Northern France to Southern France and the Iberic peninsula, nuclear power plants, etc…The land use planning is therefore of key importance.

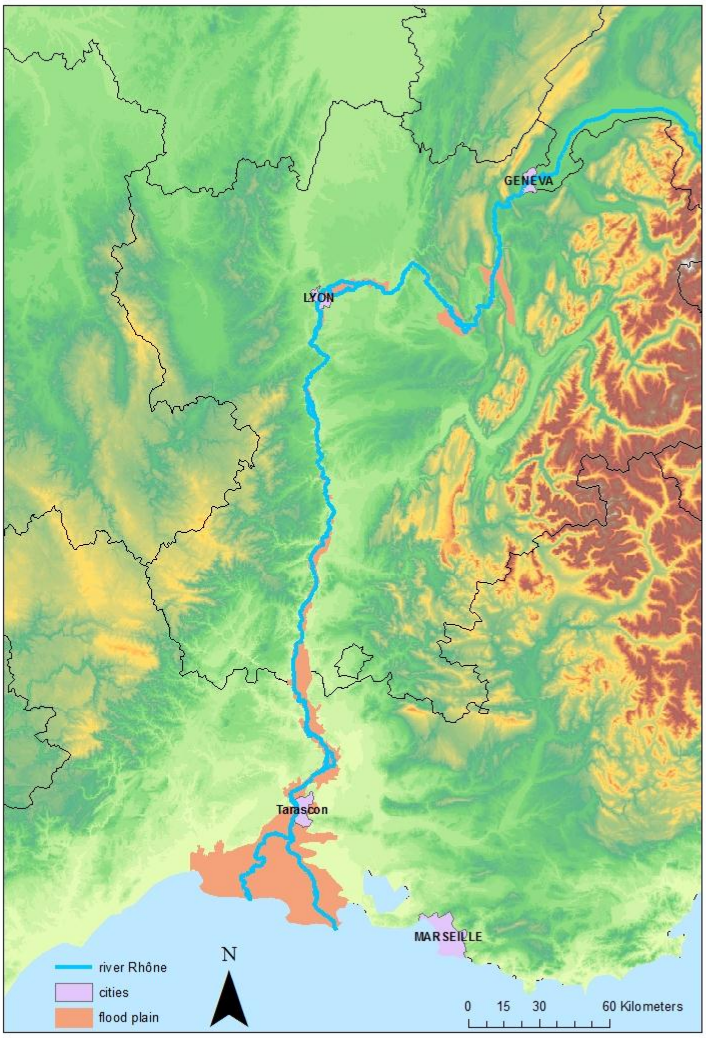


Figure 1: The French course of the river Rhône

The latest major floods of the river in 2002 and 2003 which caused several losses of lives and billions of euros of damages yet evidenced the importance of one common approach for land use planning the entire river long, as opposed to several isolated actions which might cause greater damages downstream. A land use masterplan was therefore set up: the “Plan Rhône”. It was approved by Prime Minister in 2004 and was 1.5 billion euros funded.

Within this framework, the setup of a high accuracy (20 cm in general, and up to 10 cm) altimetric database including a topographic database and a Digital Terrain Model (or DTM) was advocated. A partnership was set between the Institut Géographique National –the national mapping agency of France-, representatives of the state, the Compagnie Nationale du Rhône (in charge of the monitoring of most dykes on the river) and local authorities (Conseil Régional Provence Alpes Côte d'Azur, Conseil Régional Rhône-Alpes).

It was the first time that such an accurate database would be setup over such a wide area in France. This article explains how IGN tackled the issue of making a 20 cm accurate database over 3000 square kilometers. It first details the setup of the data specifications and the reasons that led to the choice of different techniques according to the data specifications. It then explains what problems surfaced when confronting the choices to their implementation, and which actions were decided to ensure that the database would meet the specifications, the dead-line and the funds dedicated to the project.

2. APPROACH AND METHODS

2.1 AREA OF SURVEY

In France, the floodplain of the river can be roughly decomposed in three parts:

- From the swiss border down to south of Lyon is the High valley of the Rhône. The relief is relatively stiff upstream and lies downstream into a larger plain.

- The Medium valley of the Rhône is situated between south of Lyon and roughly near the city of Tarascon. The flood plain is very small there, as the river flows between stiff mountains chains.

- The downstream 30 km: the "Rhône outlet" (also known as the Camargue"). This is an extremely flat area (for example, the city of Tarascon lies at around 10 meters above mean sea level). 50% (1500 sq. km) of the global area of the major bed lies in this plain. The Rhône outlet is twice as much filled with small pits and embankments than the upstream valley. As this area composes half of the global area to survey, this difference must absolutely be taken into account so as to schedule the work properly and meet the dead-lines.

Moreover, two international airports are located in or nearby the area of survey: the airport of Lyon Saint-Exupéry and the airport of Geneva-Quintrin.

2.2 SPECIFICATIONS OF THE DATABASE

The work started with the setup of the capture specifications of the database. The capture specifications should reach the appropriate level of detail, and mix the users' requirements with what was possible to do with the funds dedicated to the project.

The database aimed at filling both requirements of the flood modelers and of land use planners.

Several use cases were identified. Some of them are detailed here below:

- Flood modeling: this requires, among other datasets, a DTM (as accurate as possible). 20cm altimetric accuracy and 2m sample are deemed as being relevant. First order dykes (those which face the river) are required with 10 cm accuracy. Bathymetric data are also required.

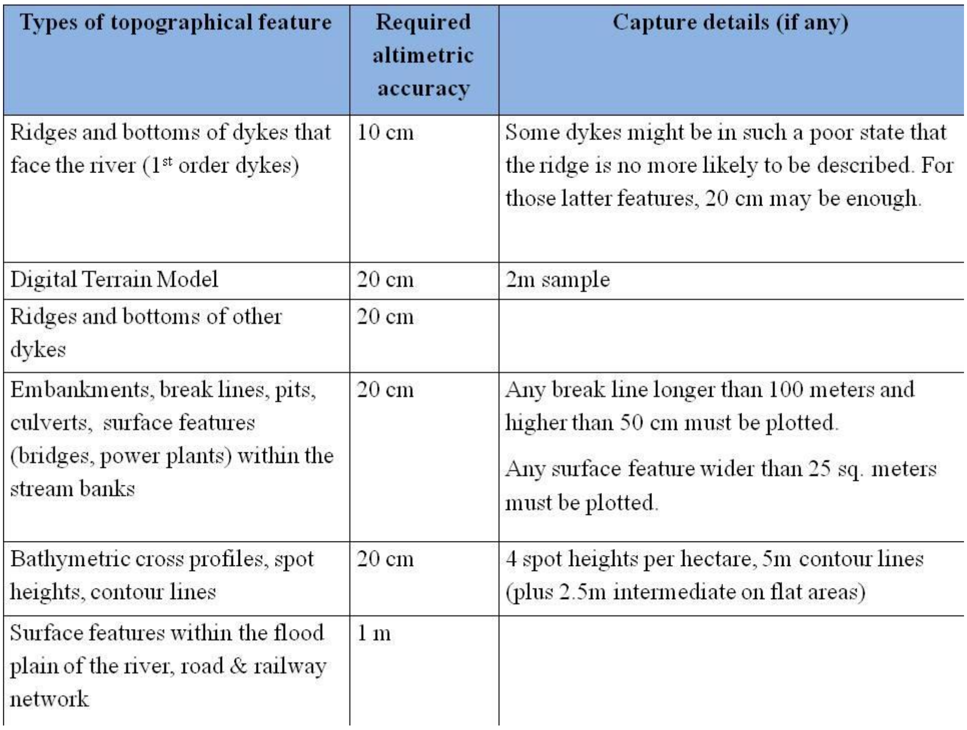
- Local investigation on ground configuration: this requires any piece of information that enables to determine how water can flow on a specific area. The location of any break line, of any culvert, pit, or building is therefore required, in addition to a DTM.

- Flood prevention plans: the setup of those flood risk prevention plans is legally required. Those plans are then released for public debate. Showing a flood simulation with existing buildings has a great impact on people's mind. Integrating 3D buildings in the major bed of the river is also relevant.

As a consequence, it was decided to include in the database a digital terrain model plus a set of topographical features, so as to combine a continuous representation of the altimetry with a topographical representation of the surroundings of the river.

The topographical dataset must moreover meet thematic requirements: the representation of the ridges and bottoms of each dyke is necessary, as well as the representation of river banks, for example. In addition to this, generic topographical data (such as the road and railway network, the vegetated areas) should be added so as to provide a topographic background to this thematic database.

Different levels of accuracy are required depending on the relevance of the topographical feature in terms of flood prevention and flood mitigation. The table herebelow details the altimetric accuracy required according to the feature types:



Types of topographical feature	Required altimetric accuracy	Capture details (if any)
Ridges and bottoms of dykes that face the river (1st order dykes)	10 cm	Some dykes might be in such a poor state that the ridge is no more likely to be described. For those latter features, 20 cm may be enough.
Digital Terrain Model	20 cm	2m sample
Ridges and bottoms of other dykes	20 cm	
Embankments, break lines, pits, culverts, surface features (bridges, power plants) within the stream banks	20 cm	Any break line longer than 100 meters and higher than 50 cm must be plotted. Any surface feature wider than 25 sq. meters must be plotted.
Bathymetric cross profiles, spot heights, contour lines	20 cm	4 spot heights per hectare, 5m contour lines (plus 2.5m intermediate on flat areas)
Surface features within the flood plain of the river, road & railway network	1 m	

Figure 2: Table representing the accuracy specifications decided along to the features that should populate the BDT Rhône

Several techniques may therefore be used to meet those specifications.

2.3 DETAIL OF THE PRODUCTION PROCESS

2.3.1 FIELD SURVEY AND DATA INTEGRATION FOR 10 CM ACCURATE TOPOGRAPHIC DATA AND BATHYMETRIC PROFILES

The 10cm acquisition of the ridges and bottom of 1st order dykes has early been solved due to the partnership that monitors the project: 75% of the surveys were already done by the Compagnie Nationale du Rhône –company in charge of the management of the Rhône facilities and installations- and were integrated in the database. Other surveys on dykes had also already been locally carried out: by the SYMADREM on the Rhône outlet, by the Syndicat mixte du Vidourle, and also by the Syndicat Mixte pour la gestion et la protection de la Camargue Gardoise, which are involved on the project partnership.

It was decided to make ground survey (such as GPS and tacheometer, when required by the configuration of the field) for the remaining features. This method was the best value for money, for following reasons:

- The Lidar data could not accurately describe the dykes, owing both to the point density (2 / sq meter) and to the altimetric accuracy of the Lidar(15 cm in theory).

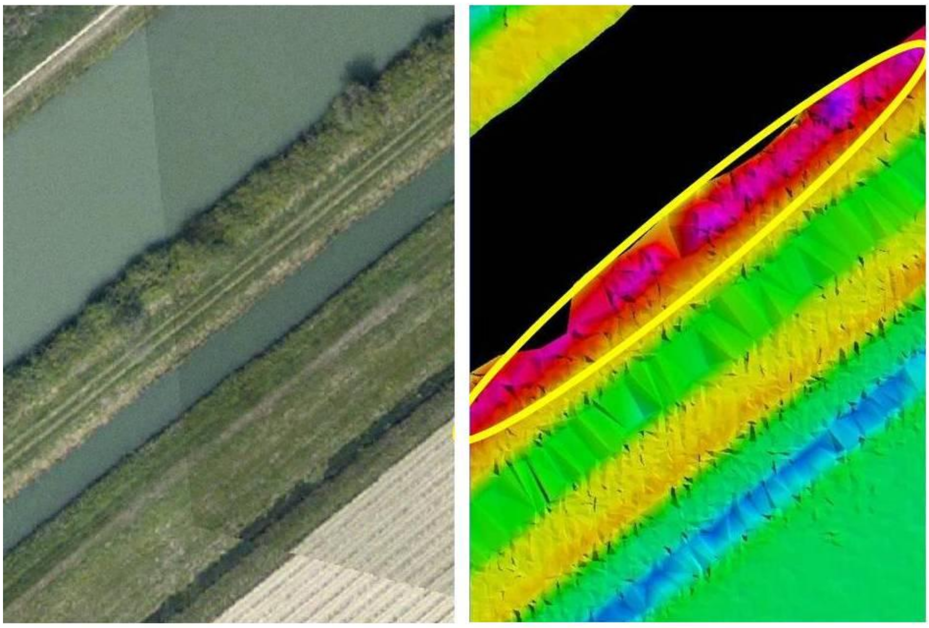


Figure 3: the ridge of the dyke is not entirely covered with Lidar echoes. This engenders local errors on the DTM after interpolation.

- Performing several flight surveys low enough to reach the 10 cm accuracy after stereoplotting specifically for these features would be far too expensive. The features at stake are scattered all over the area of survey, and are not gathered in a specific area. Making several surveys over the same area is not possible, due to the fact that it would be too expensive.
- To another extent, some ridges of dykes were covered with a dense vegetation of bushes: on those areas, the stereoplotting could not reach the naked soil.
- Ground control points should anyway be surveyed all over the flood plain of the Rhône. It was therefore easier to ask surveyors to perform the survey of 1st order dykes in the same time as ground control point surveys.

In the same way, 95 % of the bathymetric data already existed, and have been released for free by partners, such as the Compagnie Nationale du Rhône, the SYMADREM, the Voies Navigables de France, and the Syndicat mixte du Vidourle. 15km out of the 512 km remained to be surveyed. This has been done with a bathymetric sensor.

All those data have been integrated in the database using “Extract, Transport, Load” (ETL) system such as FME® software suite and ESRI ArcGIS® softwares.

2.3.2 LIDAR AND APPLANIX CAMERA FOR DTM AND 20 CM ACCURATE TOPOGRAPHIC DATA

Internal studies concluded that the use of the Lidar was the safest technique to meet the 20 cm accuracy target. Lidar Optech 3100 AE system is used. It is equipped with an Applanix DSS322 60mm focal digital camera with a Bayer 5436 * 4092 matrix sensor.

The Lidar pulse density is set to 2 pulses / sq. meter and the plane surveys the area flying 1300 meters above the ground. The Lidar point cloud is first geo-referenced using GPS and IMU data and system calibration parameters. Altimetric and planimetric accuracy is then improved using the TerraSolid software. This software both enables to assess the altimetric difference between overlaying stripes of data, and also enables to recompute the calibration parameters (by minimizing the differences between the stripes).

The choice that remained to be done was therefore about the camera to use to plot the topographical features. With the Lidar flight parameters previously set, the ground pixel size of the images taken by the Applanix DSS322 would be 18 cm, the forward overlap would be 60 % and the sidelap would be 50 %.

These values are compatible with an aerial triangulation of 20 cm altimetric accuracy, and therefore are compatible to a 20 cm accurate stereoplotting (as it is assumed that with this focal length, the relative accuracy of the stereoplotting is more or less 1 pixel).

This compatibility is a key aspect of the choice. The aerial survey all over the flood plain was actually quite complicated to set, due to the curved flood plain ground configuration. Moreover, specific authorizations were requested to the French and Swiss national civil air authorities to fly at low altitude in the near of international airports. By the time of the survey (from January to June), the weather was also relatively bad. Taking these aspects into account, making only one aerial survey with the camera and the Lidar airborne instead of two (if another camera had been chosen) released on major constraint on the dead-line of the project. Hence the Applanix DSS322 that is integrated in the Lidar system framework was chosen for the stereoplotting.

The Applanix could also benefit from the inertial measurement unit (IMU) system provided with the Lidar, so as to make a first rough aerial triangulation (with a relative accuracy of 1 pixel, and an absolute accuracy of 2 or 3 pixels) on the images. This helped during the tie points measurement and point filtering processes. Preliminary tests have ensured that the geometric accuracy obtained was consistent with the expected specifications.

2.3.3 IGN’S BDTOPO® FOR 1M ACCURATE DATA

The case of the acquisition of 1m accurate topographical features has not required technical investigation, in so far as those feature are already available in the BDTOPO®, the topographical database produced all over France by the Institut Geographique National. All of those latter features populate the database.

2.4 QUALITY CONTROLS

Several actions were undertaken so as to ensure that the quality was obtained. As the project gathers several datasets from different data producers, different techniques, several blocks of production, the quality controls were steadily carried out.

2.4.1 GROUND CONTROLS/ ABSOLUTE CONTROLS

Ground controls were performed all over the area of survey. GPS techniques were used on the ground control points so as to guarantee the quality of the aerial triangulations. Moreover, the absolute altimetric quality of the Lidar point cloud was assessed by comparing it with sets of ground points measured on football fields and tennis courts. Those latter places were chosen as the soil was almost naked, and the surface was supposed to be locally flat: no uncertainty due to the elimination of the vegetation could be at stake there. The Lidar point cloud was also compared to the control points. The coherence between both datasets was confirmed, as we measured that the root mean square of the altimetric differences was around 13 centimeters, with no significant bias. The theoretic accuracy of the Lidar system of 15 cm was here confirmed by those ground controls.

2.4.2 CROSS STRIPS IN THE FLIGHT PLANS

Several cross strips were added to the flight plans. Those strips aimed at controlling that the quality of the Lidar system would not derivate along with the duration of the flight. Adding cross strips enables to have two different Lidar measures on the area during the same flight, but surveyed later in the flight. Cross strips also help maintain the altimetric accuracy of the aerial triangulation.

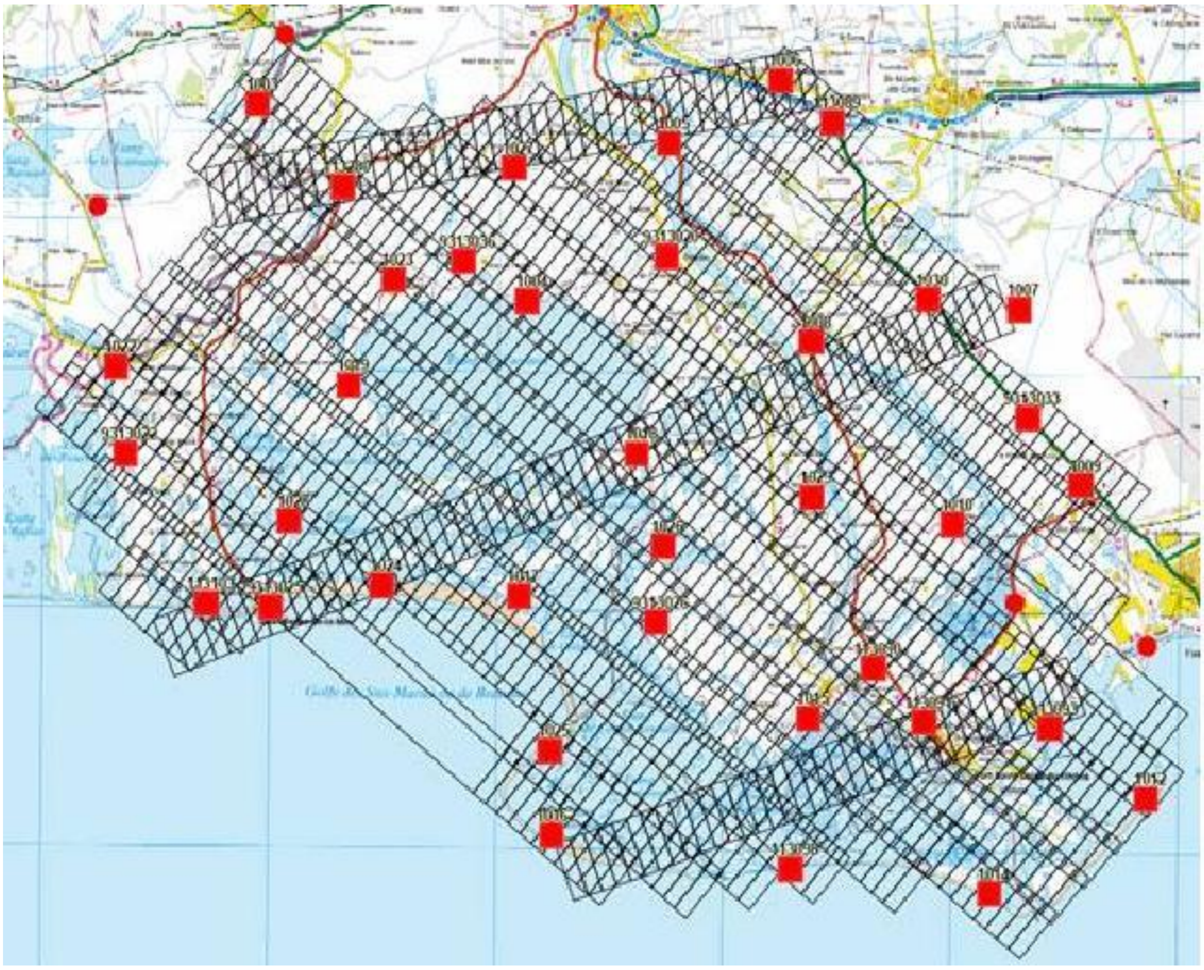


Figure 4: flight plan on the Rhône outlet including cross strips (the square dots represent the control points)

2.4.3 USE OF LIDAR SPOTS TO CONTROL AERIAL TRIANGULATION

On some areas, some ground control points prepared prior to the aerial survey had disappeared between their installation and the flight. This caused a lack of control or check points for the aerial triangulation. On specific areas, Lidar spots were used to control the coherence between the lidar data and the aerial triangulation. This was possible due to the coherence between the altimetric accuracy that the aerial triangulation was targeted to reach and the absolute accuracy of Lidar spots. These controls were performed on each block.

2.4.4 COHERENCE BETWEEN NEIGHBORING BLOCKS

The aerial triangulation was controlled for each block, but controls on the relative coherence of aerial triangulation made on neighboring blocks were carried out. The 21 blocks were slightly overlapping with each other. Stereopreparation was designed so as to have some control points on each overlap, so as to have them measured on both blocks. As a consequence, the relative coherence of the blocks could be validated.

2.4.5 GROUND CONTROLS AFTER STEREOPLOTTING

The accuracy of the stereoplotting depended to the quality of the aerial triangulation, which was already assessed with the ground control points.

Sampled controls were also performed so as to assess the exhaustivity obtained after stereoplotting on one hand, the global accuracy of stereoplotted features (the bottom of a pit for example) on the other hand. Unlike the aerial triangulation controls, those latter controls were made only at the testing phase of the project on sampled areas.

Surveyors were asked to perform an exhaustive survey of any topographic feature that should be plotted according to the specifications after the same area had been finished with stereoplotting. Their results of ground surveys were then compared to the plotted features, and the level of exhaustivity could then be assessed as being coherent with the specifications.

2.4.6 COHERENCE CONTROLS BETWEEN IGN DATA AND EXTERNAL DATA

As the BDT Rhône gathers different datasets from multiple origins, it was a key aspect to ensure that each dataset match with the others.

The coherence between data provided by partners and IGN data was assured by visualizing the external data over the triangulated images before the stereoplotting started on a block. IGN plotted first the ridges of the 1st order dykes, as they were the most accurately surveyed features, and compared the result to the external data. This control could reveal either that the aerial triangulation had a problem that the control points had not revealed or more likely that the external data processing had had a problem (which itself could originate either from the quality of the raw data that were provided by the partners or that the transformation processes had had problem, such as reprojection problems).

3. RESULTS

3.1 PRODUCTION STEPS

The global project was decomposed in two steps:

- A testing phase, during which IGN compared techniques and finally set the production process previously detailed. This phase occurred during 2007 and July 2008. They were carried out over 2 different areas, the Donzere-Mondragon Valley, and the North of Arles. Those two areas (which compose a global area of 660 km2) were chosen because they were good samples of the different landscapes that compose the Rhône flood plain.
- The rest of the production, which occurred from January 2009 and July 2010, on the remaining area. The aerial surveys were initially scheduled between January 2009 and June 2009.

The remaining area was divided into 21 different overlapping blocks (and the stereopreparation was planned accordingly). This was due to the complexity and curved area of survey.

On each block, the following process was implemented:

1. Ground controls: preparation and measurements of the control points
2. Aerial survey, with Lidar and Applanix camera airborne
3. Aerial triangulation and Lidar raw data analysis. Those tasks were done at the same time by different teams.
4. External data integration
5. Stereoplotting of the topographical features
6. Field completion, 1st order dykes surveys, and Lidar data processing to make the DTM. Those steps were done at the same time by different teams.
7. Extraction of contour lines and spot heights from the DTM

Once all the area was carried out, IGN finalized the database (specific format extraction, setup of the identifiers).

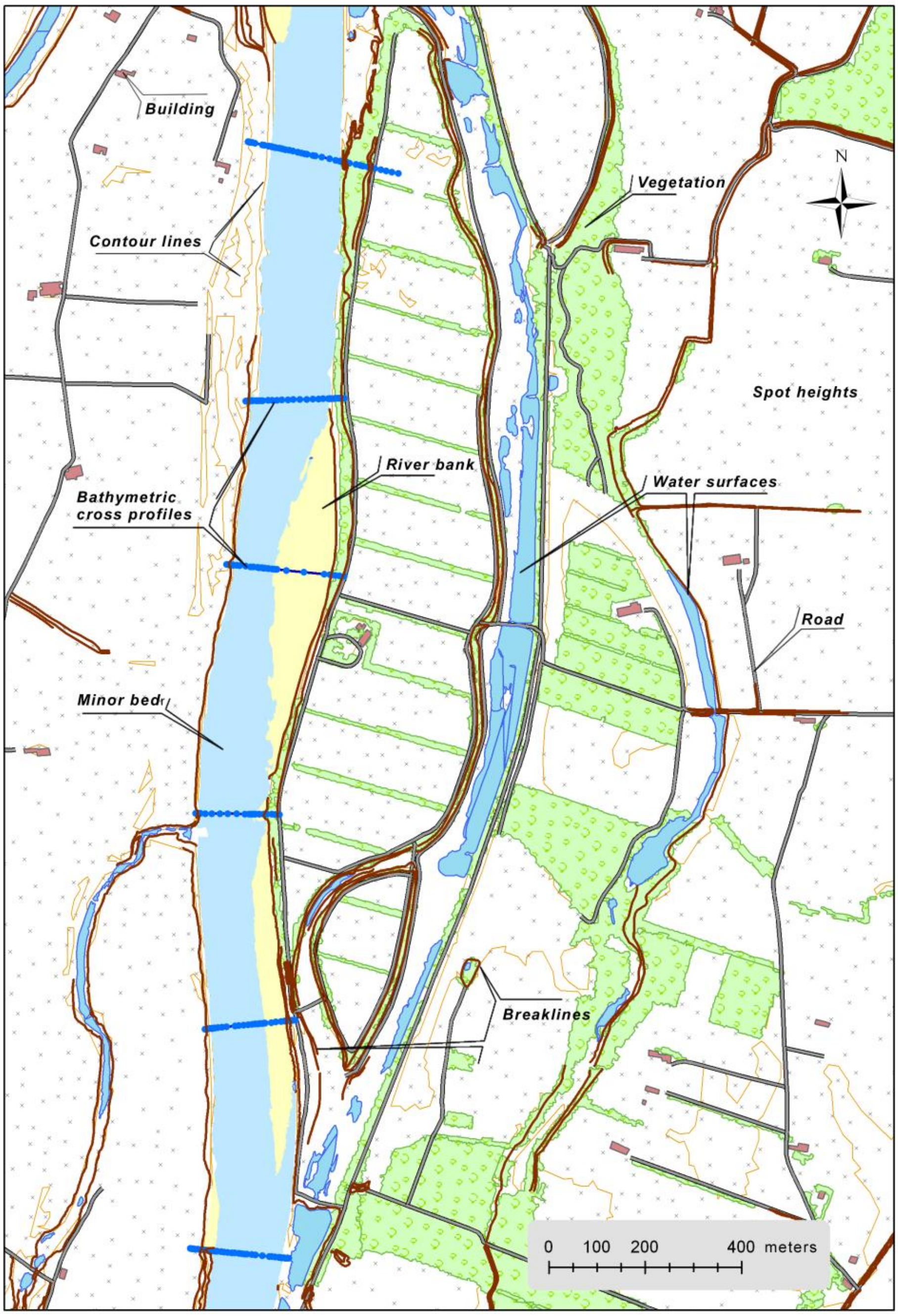


Figure 5: sample of the topographic database

3.2 REFINEMENT OF THE PRODUCTION PROCESS

The first feedbacks from the production line helped make several refinements due to a better understanding of the different possible interactions between Lidar production line and the stereoplotting production line.

3.2.1 INTEGRATION OF THE PLOTTED BREAK LINES INTO THE LIDAR PROCESS

Even though the Lidar system reached the 20 cm accuracy target, it still had its own problems. 2 of them were highlighted as being potentially harmful for the quality of the project (as the quality is defined by the respect of the specifications with the meeting of the dead-line within the budget initially designed).

- As the Lidar system provides point clouds reflected by the soil that are uniformly distributed, break lines may not be entirely properly described in the point cloud, as they might not be entirely covered with Lidar echoes. The quality of the DTM is at stake.

- Even if the Lidar system theoretically provides several echoes for one single pulse in case of vegetation above soil, it can be difficult –or time consuming- to help the system extract only the echoes that correspond to the soil when vegetation is dense (and remove those reflected by the vegetation above). The production rates (and therefore the budget balance and the respect of the dead-line) are at stake. This was particularly the case in Camargue, which is an area full of small pits, in which the vegetation grows easily.

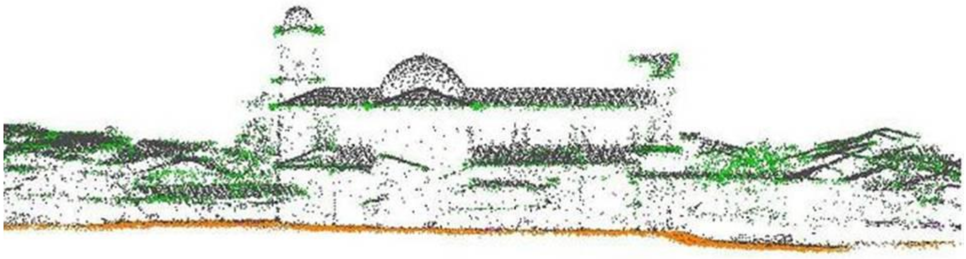


Figure 6: Profile view of the Lidar spots on the church of Beaucaire. Several echoes are reflected for one single pulse, depending on the presence of buildings or vegetation above the ground.

Processing like this meant that the two tasks (stereoplotting and DTM production) had to be done successively on the same area, and not in parallel (as it could have been done if we decide not to use the stereoplotting into the DTM production process), which could have resulted in a loss of time.

This drawback actually did not surface. Due to the complicated display of flood plain, several aerial surveys (21) were made to cover all the area. As a consequence, all the raw data had not been acquired at the same time, but had been acquired along with the progress of the aerial surveys. The DTM production unit was therefore able to work on a particular area upon which the stereoplotting production line had already completed, while the stereoplotting production unit worked on the next area that was surveyed.

3.2.2 USE OF A VEXCEL CAMERA OVER THE CAMARGUE

Radiometric problems were detected on the pictures taken over the Camargue: around 30 % of the images had strong saturations of white, which made stereoplotting impossible. Another photo survey was decided over Camargue, and took place in autumn 2009. By that time, the Lidar system was not available (IGN had to fill other commitments on Lidar survey), hence IGN could not use the Applanix camera either.

It was therefore decided to perform the survey with a Vexcel UltraCAM XP 11310*17310 matrix camera. The images were corrected from distorsion effects. The focal length was set to 100.5 mm and the ground pixel size was set to 15 cm. The 20 cm accuracy was easily reached all over the area.

This event postponed the dead-line of the project to July 2010 (the dead-line was initially set to beginning of 2009).

4. CONCLUSIONS / FUTURE PLANS

The main challenges of the project were to combine different techniques (aerial photogrammetry, Lidar, topometry, bathymetry…) to produce the data, to choose the most appropriate one for each type of data, to ensure their coherence within the specifications, and of course to cope with the shape and great geographic extent of the area of survey.

This raised both technical, organisational and management issues especially as to how to handle the different production lines and their interactions.

Field survey is the appropriate technique for the survey of 1st order dykes with 10cm accuracy.

Stereoplotting was made on images taken by Applanix camera taken in the meantime as Lidar survey on all the area, except on the Camargue, where another flight survey with Vexcel camera had to be carried out.

The Lidar –after integration of plotted features- is used to compute the DTM, the spot heights and the contour lines.

The features from IGN BD TOPO® for the backgrounding topographical features with metric accuracy suit the requirements.

The BDT Rhône is now on the shelf, and is made available to any public authority of the area which wishes to use this data for land use management, and flood modeling. Roughly 25000 images have been triangulated, and 250 000 features have been plotted. The overall time that people have spent on the project rises to 20 000 hours of work.

Moreover, this study helped IGN to set the specifications of the altimetric master map of France: the RGE Alti®. Combining DTMs with different levels of accuracy depending on their location will be broadened to the entire French territory: Lidar will be used for stake areas, such as river beds and shores, which require 20 cm altimetric accuracy. Other DTMs with less accuracy required will be produced with correlation and radar will be used.

5. BIBLIOGRAPHY

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