EUROPEAN COOPERATION
IN SCIENCE AND TECHNOLOGY

COST is supportrd by the
EU Framework Programme
Horizon 2020

Sub-Urban

TU1206-WG1-009

Nantes

TU1206 COST Sub-Urban WG1 Report

F. Rodriguez, C. Le Guern, B. Béchet, Y. Gouriten

COST is supportrd by the
EU Framework Programme
Horizon 2020

TU1206 COST Sub-Urban Report
TU1206-WG1-009

Published March 2017

Authors: Fabrice Rodriguez (1,3), Cécile Le Guern (2,3), Béatrice Béchet (1,3),
Yves Gouriten (4)

1) IFSTTAR- GERS/Laboratoire Eau et Environnement, Bouguenais
2) BRGM, Direction Régionale des Pays de la Loire, Nantes
3) IRSTV, Nantes
4) Nantes Métropole

Editor: Ola M. Sæther (NGU)
Editor and layout : Guri V. Ganerød (NGU)

COST is supportrd by the
EU Framework Programme
Horizon 2020

Acknowledgements
This report is based upon work from COST Action TU1206 Sub-Urban, supported by COST (European Cooperation in Science and Technology). Sub-Urban is a European network to improve understanding and the use of the ground beneath our cities (www.sub-urban.eu)

Contents

Summary

Nantes is the France’s sixth largest city. The conurbation (Nantes Métropole) comprises 600,000 inhabitants, and should reach the 700,000 mark by 2030. The Loire River, and the closeness of the Atlantic coast played a key role in the city's history and development. In the past, the economy was driven by the city's shipyards and maritime industry. Today, the city's industry and economy have undergone profound transformations that have provided an opportunity to redevelop large urban areas, especially in former industrial sites like in the Ile de Nantes, while protecting the fragile eco-systems of the Loire estuary.

The urban planning is controlled by several guidelines. Nantes Métropole’s Climate Plan provides a means of combating global warming. The development of low-energy transport and buildings is an essential component of Nantes' commitment, along with a preservation of the living environment of the conurbation, characterised by a proportion of 60% of natural and agricultural areas and 250 kilometres of rivers and streams. The city development is additionally highly related to the urban soil management and makes it necessary to develop new research actions. Four case studies point out the need for subsurface characterisation (top layer, subsoils) and the relationship between soil pollution and hydrology/geology : management of metallic soil pollution in urban allotment gardens, impact of sustainable urban rainwater management, environmental impact of a municipal waste landfill site, excavated materials management according to geochemical properties. The overall research perspectives of this urban soil in Nantes are the development of novel field characterization approaches to improve the cost and time consuming phase of decontaminating soils.

1 – Introduction and city description

Situated on the Loire River, close to the Atlantic coast (Figure 1), Nantes is a green city of western France with a temperate and oceanic climate. It is France’s sixth largest city. The conurbation (Nantes Métropole) comprises 600,000 inhabitants, a number which should reach the 700,000 mark by 2030. The city of Nantes is the capital city of the Pays de la Loire Region, and the Préfecture of the Loire-Atlantique Department. In 2004, Time Magazine named Nantes ‘the most liveable city in Europe’ and in 2013 it held the title of European Green Capital[1]. The Loire River (the longest river in France) played a key role in the city's history and development. In the past, the economy was driven by the city's shipyards and maritime industry. Today, the city's industry and economy have undergone profound, sometimes difficult transformations that have provided an opportunity to redevelop large urban areas, while protecting the fragile eco-systems of the Loire estuary.

Embracing the legacy of the past and adapting it to the requirements of the future is also one of Nantes trademarks. Former industrial sites have been rehabilitated and turned into residential areas based on a sustainable city philosophy centred on building low-energy housing with green spaces and leisure facilities to house the growing population. On the Île de Nantes, urban territory located between two Loire river “arms”, a major sustainable urban planning project is currently underway. This "eco-district" will comprise housing, gardens, leisure facilities, shops and workshops. The Île de Nantes reflects Nantes' innovative and creative take on sustainable urban development. The scheme draws on cutting-edge approaches in terms of construction, public transport, recycling and renewable-energy technologies.

Nantes Métropole’s Climate Plan provides a means of combating global warming. The development of low-energy transport (Table 1) and buildings is an essential component of Nantes' commitment. Natural and agricultural areas account for 60% of the Nantes conurbation, which also boasts a lot of rivers and open streams. The city wants to preserve this living environment and promote balanced and sustainable development across the region. Controlled urban growth and the preservation of natural spaces are strategic objectives. Simultaneously and due to the population growth, Nantes has to develop its housing offer. This urban development is constrained because urban sprawl has to be limited.

1 http://ec.europa.eu/environment/europeangreencapital/winning-cities/2013-nantes/

Table 1 – Statistical data for Nantes Metropole & Nantes

	Size (km²)	Inhabitants [2]	Density (hab/km²)	Percentage of car trip / public transportation [3]	Housing [2]
City of Nantes	65.2	299 682	4415	57%	164 534
Nantes Metropole	523.4	619 172	1112	15%*	298 687

*** Public transportation length : 42 km tramway & 60 bus lines

Figure 1 - 24 municipalities composing Nantes Metropole. DIG Nantes Metropole

[2] Source AURAN 2012, AURAN 2013

[3] Sources : Insee, SOeS, Inrets - enquête nationale transports et déplacements 2007-2008

2 - Geological and physical geographical setting

Located at the confluence of the Loire, the Erdre and the Sèvre, just 55 kilometres from the Atlantic coast, Nantes boasts 250 kilometres of rivers and streams. The Nantes metropolitan area has a gentler morphology with an altitude varying from 0 to 80 m. This area encompasses two plateaus located on each side of the Loire river, which are notched by small valleys. The main rivers supplying water to the Loire river are the Sevre nantaise, the Erdre, the Chézine, the Cens, which are very important for the life quality of Nantes, with 53 kilometres of walking trails on river banks. This blue grid is however a fragile environment and has to be preserved. Wetlands are distributed in the whole metropolitan area (about 9500 ha), especially along the Loire river and near the Grand Lieu lake, which is the largest natural plain lake in France.

The geological setting is linked to the Armorican Massif. Rocks are structured along the South Armorican shear zone which crosses the metropolitan area from west to south-west (Figure 2). The bedrock is mainly composed of old plutonic and metamorphic rocks (granite, gneiss mica schists, and other) on which sedimentary rocks are deposited (including sand, loam and loess from late Tertiary and Quaternary times). Alluvial deposits are located on the Loire river Valley and other river valleys.. The city is also marked by anthropogenic deposits and artificial ground brought back in the city centre to fill some rivers arms and to expand the Ile de Nantes surface (located in the middle of the Loire River).

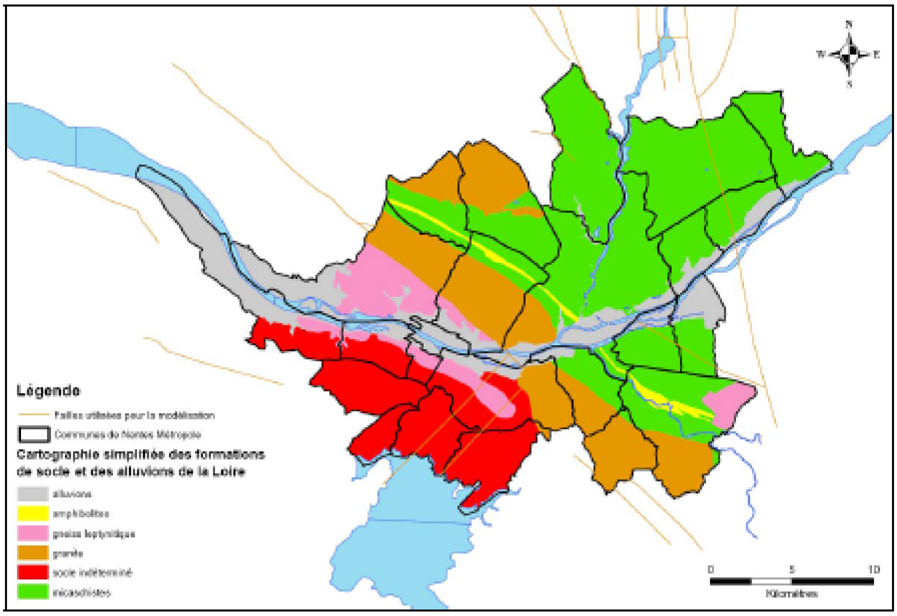


Figure 2 - Schematic geological map (BRGM, Conil et al, 2009)

Given the geological context, two types of aquifers can be found: bedrock aquifers and sedimentary aquifers. In magmatic and metamorphic formations, water can preferentially flow within cracked rocks (altered granite or mica schists) and be stored above in the weathered zones. The Loire river alluvial deposits contain an important sedimentary aquifer (supplying Nantes drinking water). In a large part of the Nantes metropolitan area, the groundwater level is within 5 meters below the soil surface (Figure 3).

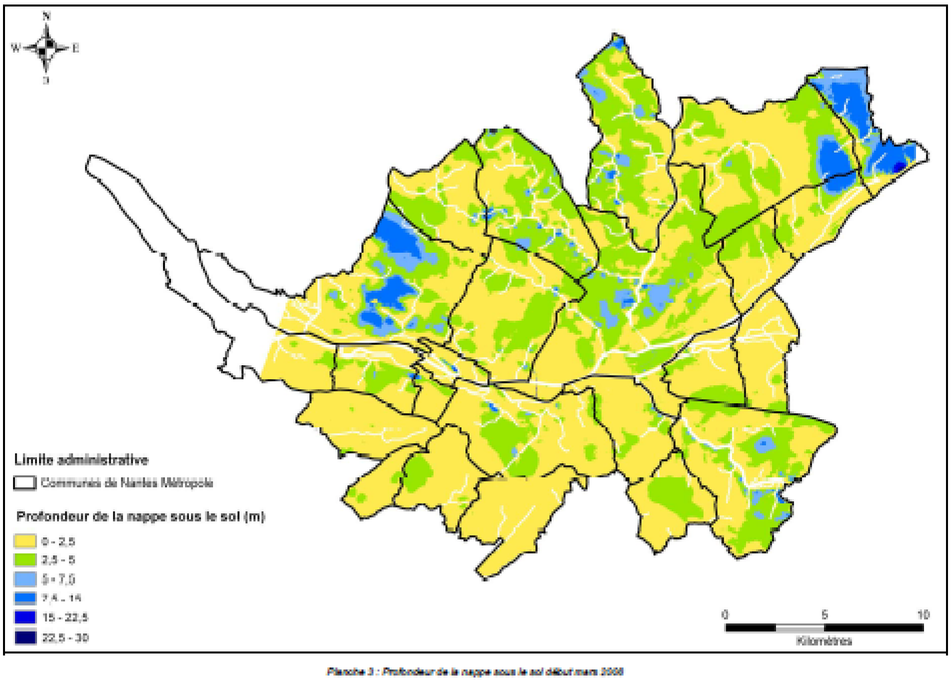


Figure 3 – Groundwater levels in the Nantes metropolitan area in March, 2008 (BRGM, Conil et al., 2009)

The area of Nantes is a moderately active seismic region, characterized by numerous minor earthquakes located in the whole Massif Armorican region, but with small intensities. The area is classified as a moderate seismic risk zone (soil acceleration estimated to be between 1 to 1.6 m/s²) according to the french zoning map[4] .

The interactions between geology and buildings are characterized by the following specific features:

- Land subsidence may occur in the city center where old buildings may be damaged, due to soil moisture variations/soil compaction.

- Due to the important urban pressure along the Loire river, where soils are composed of old or more recent alluvial deposits, buildings are constructed with pile foundation.

- The groundwater levels being quite high in the whole city (see Figure 3), buried constructions as car parks often make it necessary to drain and pump groundwater. The

4 http://www.planseisme.fr/Zonage-sismique-de-la-France.html

future management of this soil water, possibly contaminated by human activity, has to be taken into account.

The utilization of the geothermal resources is possible in Nantes, but is, at the present, not common. The mapping of a, in generally, very low energy geothermal potential showed that the main favourable areas for geothermal vertical probes in Nantes were located in the bedrock zones with gneiss and granites, and that this potential would be highly variable in alluvial deposits zones (Wuilleumier et al, 2009).

3 - Urban planning and management

Since 1 January 2001, Nantes Métropole has been acting in the interests of 590,000 inhabitants of 24 municipalities in the Nantes urban area. In creating Nantes Métropole, these 24 municipalities (See Figure 1) joined forces for greater solidarity between their residents and for development that would respect natural balances. The authorities of the institution Nantes Métropole encompass: urban planning, transportation, environment and energy, water and sewerage, sanitation, waste, street network, public spaces, housing, economic development, higher education and research, employment, Europe and international attractiveness. The City of Nantes is the biggest city of Nantes Métropole and it has specific complementary authorities such as public green spaces management.

The city of Nantes has been built in relation with water. Already well-known for its harbour, Nantes was firstly a trade place, and became a capital of shipbuilding, until a diversification to industrial activities occurred. The relation with water has influenced the morphological evolution of the city. Due to numerous islands and the presence of canals, it was called the "west Venecia". The Loire river embankments (quai de la Fosse and quartier Feydeau) made up the main historical elements of the city. This landscape changed drastically in the middle of the 20th century with two main events: the filling of the rivers and the Second World War bombing. The transformation of the hydrographical network of the city began in 1926 and lasted more than twenty-five years: the main river arms located in the city centre were filled and replaced with streets for cars. Rebuilding after the Second World War reorganized the city with boulevards devoted to cars. The relation with water tends to disappear slowly during the sixties, and the city set up large town planning projects similar to the current tendency at that time: urban sprawl and residential neighbourhood around the city centre. With the closure of the shipyards in the late 1980s, Nantes faced a difficult social climate tinged with disappointment and despondency. Believing culture to be essential to social cohesion, Nantes made it the central and crosscutting focus of all its plans, by highlighting industrial and port heritage. Moreover, during the lasts thirty years, the tramway introduction, the public space and big buildings ensemble transformation lead the city to favour public transportation, pedestrian and bicycle paths and urban landscape, and a special attention is paid on green spaces and river walk paths: each inhabitant lives less than three hundred meters from a green space.

The main objective of the city in terms of urban planning today is focused on the urban sprawl limitation, which imposes to “think” of the urban projects in places where the city already exists. The soil depth dimension is not really taken into account within planning, but the main interactions encountered between urban planning and the subsurface take place in the following topics:

(i) Due to the important need of build the city “in the city”, a lot of former industrial sites or previous official or unauthorized rubbish tips are renovated in order to create new housing, business or cultural buildings. However, attention has to be paid on the soil quality on these sites, and the digging soils management is a crucial point for the municipality. Environmental legislative aspects are considered through the statutory instruments dealing with contaminated sites and soils management (Ministère de l’Environnement, 2007)

(ii) The archaeology studies in Nantes are devoted to the historical knowledge improvement of the medieval architecture, the antique city, more recent funeral zones or the river. The city of Nantes recently created a service dedicated to the preventive actions in archaeology in urban planning, which consists of diagnostic and dig operations before urban planning operations.

(iii) The maintenance and rehabilitation of buried networks is of high interest for the municipality. The knowledge of the networks distribution within the subsoil is a real challenge for urban planners and public services: Nantes has a very active policy on heat networks development and the proximity of this network with water supply network may be a problem; the identification of heat or water leaks is another issue, along with the question linked to the duration of life of these buried networks, in relation to specific geological and soil type conditions. The urban planning may be classified as “balanced” in Nantes, in the way that it is established through a private and public partnership. The current regulation device in France is the PLU (Plan Local d’Urbanisme), which is used to define the building rights within each municipality. The urban planning is then constrained by this regulation, and the private developer may propose building innovations within the PLU. In Nantes, about 40% of the new housing is carried out within public operations, for example through ZAC (Zone d’aménagement concerté), which are public planning tools currently used in French cities to develop new urban projects.

4 - Full case description

The main research topics investigated by the research teams of the IRSTV[5] involved in urban soils study and characterization are: the urban pollution of soils, the impact of anthropogenic activities on groundwater, the evaluation of rainwater management strategies influence on soils and the role of the soil-sewer interactions on the water budget. The case description for the city of Nantes will emphasize the impact of urban pollution on the quality of soil and subsoils. Actually, many sources of inorganic and organic pollution have been documented in urban environments, mainly traffic pollution (due to emissions of vehicles and erosion of infrastructures), industrial activities (atmospheric pollution, industrial waste storage/burial), and landfills of municipal waste. Although most studies deal with anthropogenic origins, inorganic substances may also have a geogenic origin. Indeed, rocks can be subjected to metalliferrous mineralisation, conducting to abnormally high concentrations. Therefore, as soils are derived from underlying rocks, they may exhibit metal or metalloid anomalies too, due to the geochemical background. These substances may affect the quality of soils and may pose a real risk to health.

Risk research on polluted sites is an important tool for policy-makers and supervisors that have to ensure surface and groundwater quality. The soil quality of urban areas may have an important impact on future urban planning scenarios. The impact could be very important, at first from an economical point of view in case of remediation or when soil pollution induces long standby time of brownfields. The last topic of main concern in urban planning that should be mentioned is the management of sediments and excavated soils.

4.1 - Management of metallic soil pollution in urban allotment gardens of Nantes

The emerging concept of sustainable city encourages the expansion of allotment urban gardens. However, gardens may have been developed on areas where soil quality was not considered in urban planning. Attentive to the potential health risks associated with consumption of vegetables growing on contaminated soils, the city of Nantes has launched a program to assess the soil quality of its 24 collective gardens (one thousand plots) towards organic contaminants and trace elements and joined the French national research program JASSUR (ANR) on urban allotment gardens (2013-2016). The specific research objectives of the scientific teams involved in this project in Nantes are : i) characterisation of soils (global

5 Institut de Recherche en Sciences et Techniques de la Ville (*Research Institute for Sciences and Technology in Urban Areas)*

parameters and contamination) (Figure 4a); ii) origin of contamination (geogenic vs anthropogenic); iii) mapping of trace metals contents in soils; iv) evaluation of translocation from soils to vegetables; v) biophytoremediation processes development (Figure 4b); vi) advising local authorities for making-decisions and soil management. Such a methodology has been currently developed for 5 specific allotment gardens.


a)


b)

Figure 4 – a) Soil sampling and metallic concentrations measurements by portable X-ray fluorescence spectrometry; b) phytoremediation experimentation (June 2013).

4.2 - Sustainable urban rainwater management

BMP (Best management Practices, or SUDS as Sustainable Urban Drainage Systems) devices (trenches, swales, porous pavements, retention and infiltration facilities, biofilters, etc.) are widely used in urban stormwater management to provide protection from flooding, recharge of aquifers and improvement of downstream waters quality (Figure 5).

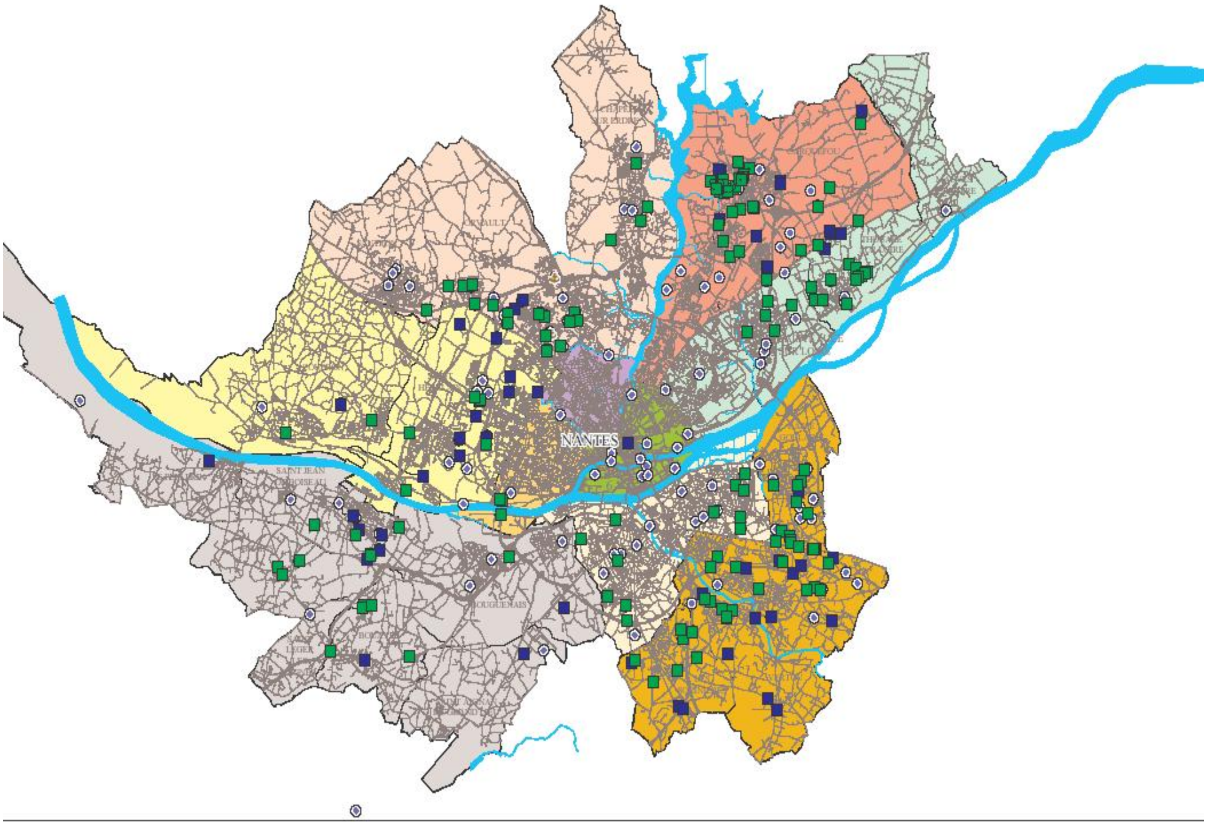


Figure 5 – Distribution of BMP devices over the Nantes Métropole area (blue point : wet basins; green point : dry basins)

Retention and infiltration basins are actually supposed to accumulate large amount of sediments over time and trap pollutants such as trace metals, nutrients and PAHs. If the pollutant removal mainly associated with sediments seems to be a good way to improve the quality of downstream waters collected by networks and discharged to water courses, some drawbacks have to be taken into account such as environmental risks, including a risk of degradation of the groundwater quality due to pollutant transfer, decrease of infiltration capacity and sediment settling. As the maintenance strategy is commonly to clean out of the basins, it is also a challenge for local municipalities to manage a significant quantity of potentially highly polluted sediments. Although various studies from both estimates and surveys differs in the assessment of amounts of sediment produced by road and motorway networks, a rough extrapolation for the entire French territory provides an estimation of about 5 million tons per year of sediments that have to be managed. In this context, sediment characterization represents a key issue for local authorities in terms of environmental issues, maintenance strategies for retention infiltration basins and treatment and valorization techniques of sediments (Figure 6).

a) b)

Figure 6 – a) retention-infiltration basin of the Cheviré bridge; b) water sampling at the entrance of the basin

The pollution of the sediments and underneath soils is readily linked to the quality of the runoff waters. A large experimentation developed at the watershed scale in Nantes (ONEVU hydrology observatory) aims at establishing the balance of the water and pollution fluxes to define pollutant sources (Ruban et al., 2007; Lamprea and Ruban, 2011). Another focus to assess BMP development concerns infiltration of water and transfer of pollutants in soils that could be strongly influenced by surface hydrology and local geology (Rodriguez et al., 2007). The impact of developing a systematic use of infiltration in rainwater strategies on the soil water distribution and on groundwater levels will nevertheless require further studies (Le Delliou et al., 2009).

4.3 - Environmental impact of a municipal waste landfill site (Prairie de Mauves, Nantes)

Observations of the transfer of pollutants in soils from a former landfill of the city of Nantes have been carried out since 2009. This site is particularly interesting because it contains a mixture of pollutants linked to the presence of household and industrial wastes associated with rubble. In addition, it presents vertical and horizontal heterogeneities of both anthropogenic and natural origin. The site is indeed located in an urban zone in the alluvial valley of the Loire River next to basement rocks (Figure 7).

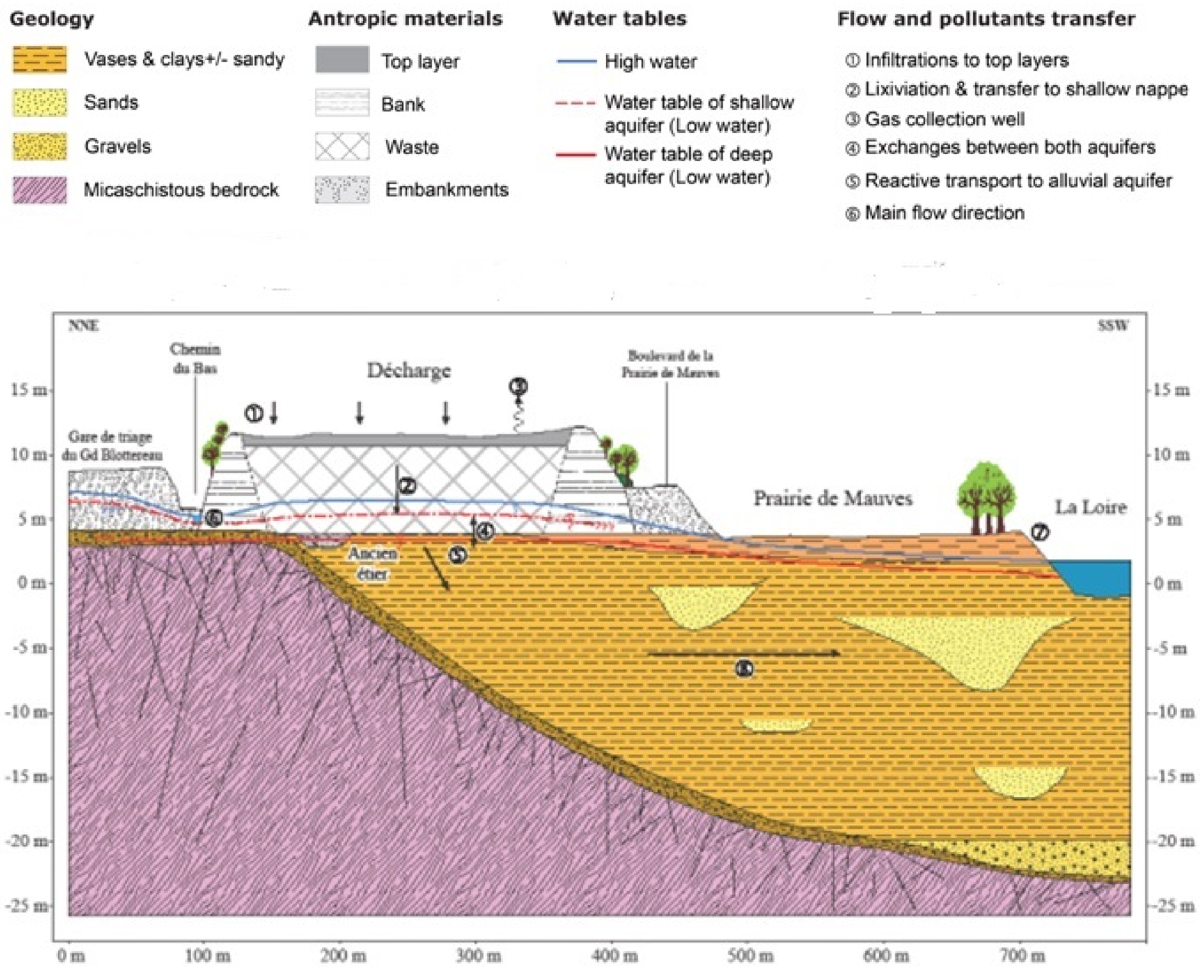


Figure 7 – Conceptual scheme of water levels and transfer of pollutants (Prairie de Mauves, Nantes) - (Lotram et al, 2011)

The methods of observation include the physico-chemical monitoring of groundwater quality and level, and investigations of soils and subsoils. A network of wells located on and around the landfill is equipped with pressure sensors and multi-parameter probes for groundwater level (including conductivity and temperature) registration. In addition, regular field campaigns allow water sampling for physico-chemical analyses of more than 80 parameters. Some campaigns are dedicated to emerging pollutants (residues of medicinal products). The investigations on solids include excavation of materials with a shovel, core sampling and upper soil collection with a hand-held helicoidal auger.

Groundwater conductivity (from 4000 µS.cm^{-1} in the landfill to 1700 µS.cm^{-1} close to the bank, 400 µs.cm^{-1} in the river) points out that the leachate plume reaches the Loire River (Figure 8). Trace element analyses stress high concentrations of heavy metals (As, Ni, Pb, Cr, Cu, Zn) in the waste (up to 800 mg.kg^{-1}). Only As and Ni show high concentrations immediately downstream of the landfill. Their concentrations are back to the background level in the wells near the Loire River. The concentrations of PAHs are lower in the downstream groundwater (mean value 0.2 µg.L^{-1}) than in the leachates (mean value 5.5 µg.L^{-}

^{1}) and in the waste (up to 19 $mg.kg^{-1}$). Most soluble PAHs such as naphthalene, phenanthrene, fluorene, acenaphtene and 2-methylnaphtalene were measured in the groundwater immediately downstream the landfill with mean concentrations from 0.01 to 0.1 $\mu g.L^{-1}$.

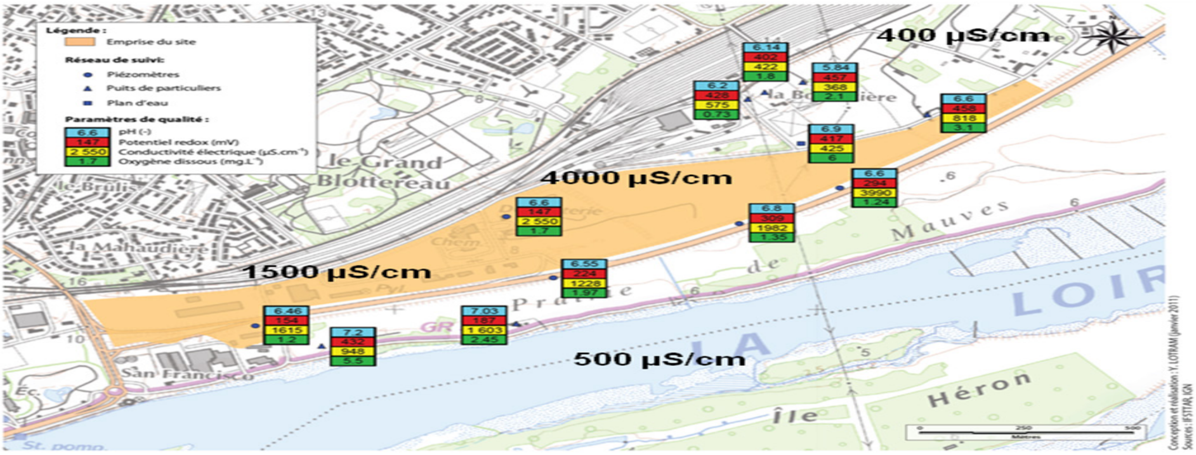


Figure 8 – Physico-chemical parameters of groundwaters (Prairie de Mauves, Nantes)

These results highlight that natural attenuation processes contribute to protect the alluvial groundwater from heavy metals and partly from PAH contamination. The investigations on soils and subsoils indicate that these processes probably include i) cationic exchange onto smectites of green sandy clays underneath the landfill and ii) co-precipitation with ferrous oxides. Besides the scientific contributions, these observations also allowed making operational proposals to the local authorities owning the landfill.

4.4 - Subsoil characterization and modelling to anticipate excavated materials management according to geochemical properties

The Ile de Nantes is a 337 ha wide district in the city center. It includes presently 18 000 inhabitants, 10 000 housing units and 16 000 jobs[6] (Samoa, 2016). Formerly made up of a group of small islands located on the Loire River, it was gradually infilled to accommodate various activities, including industrial ones. It is characterized by relatively deep bedrock (mica schist, 15 to 20 meters depth) and a stack of alluvial deposits. These natural layers are covered on almost the whole area by filling and raising made grounds from various origins, implemented gradually during the history of the neighborhood (Le Guern et al., 2016a). Recently, the closure of major industries and the growth of the city forced the developers to re-densify the district. The 30 years long redevelopment urban project (2000-2030) will led to a built environment surface of 1 million m², including 7 000 additional housing units, 300 000 m² of economic activities and 150 000 m² of urban facilities[6].

Large quantities of excavated materials (more than 100 000 t/y between 2015 and 2025) are expected. Part of these might be impacted by contaminations due in particular to former industrial activities, but also to anthropogenic deposits. The current management practice that consists in transporting the excavated materials to a landfill is neither economically nor environmentally satisfying. To allow the developer to anticipate and improve the management of these excavated materials, their quality and quantities were assessed. A major difficulty lies in the presence of anthropogenic deposits that present important geochemical heterogeneities.

To reach this objective, a 3D urban subsurface model was built using a typology of made grounds defined according to their intrinsic pollution potential (Figure 9). Geochemical baselines were also determined taking into account the contrasts of geochemical quality of the various types of made grounds and of the natural geological deposits. An important set of borehole data (mainly from pollution diagnosis and geotechnical studies) is valorized in this frame.

An Urban Industrial History was carried out in addition. It consists in mapping potential sources of pollutants of soils linked to former industrial activities (Figure 10). It corresponds to a synthesis of numerous archived data.

The knowledge on urban subsoil, including its chemical quality, helps anticipating and improving excavated materials management in this redevelopment area. It is also a way to adjust the redevelopment project, by adapting soil use to subsoil quality.

---

6 Samoa (2016) Ile de Nantes –Make the city differently. http://www.iledenantes.com/en/

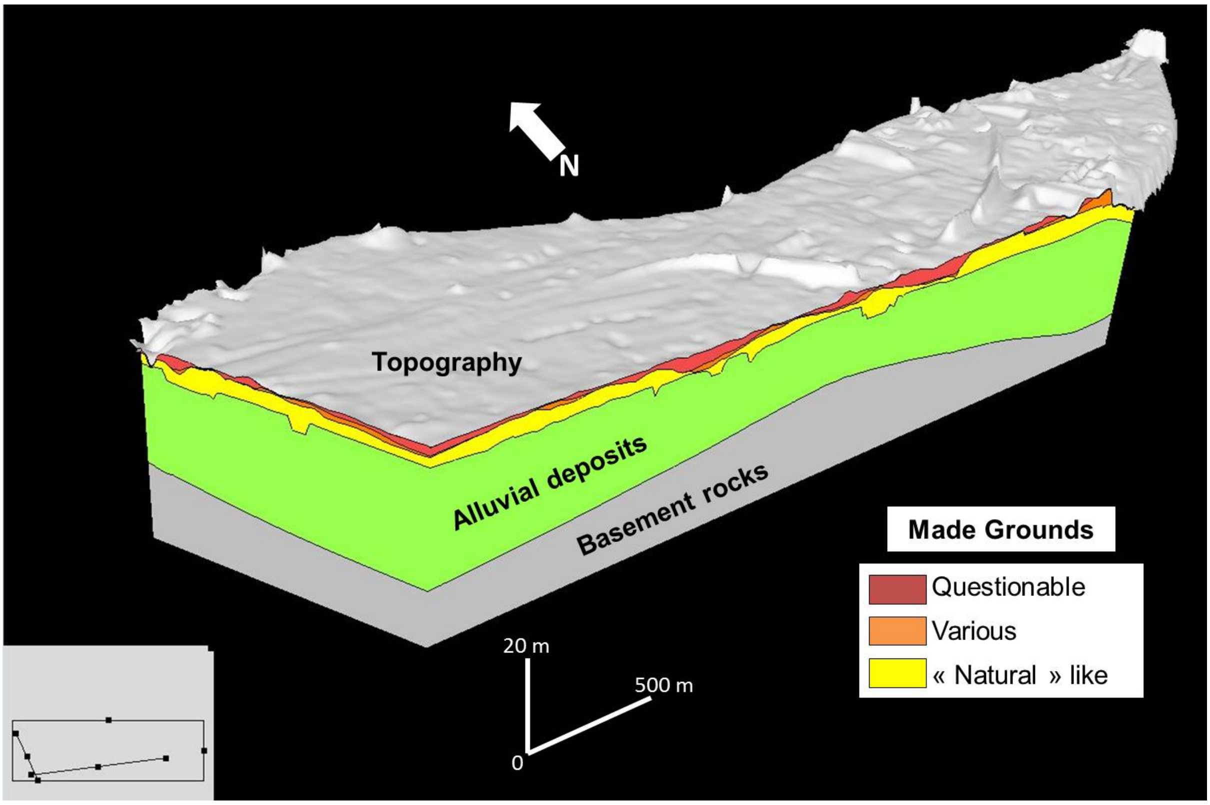


Figure 9 – 3D model integrating several classes of made grounds defined according to their intrinsic potential of contamination (from high for questionable made grounds to low for the natural-like present on the island) – Ile de Nantes, France (Le Guern et al, 2016a, b)

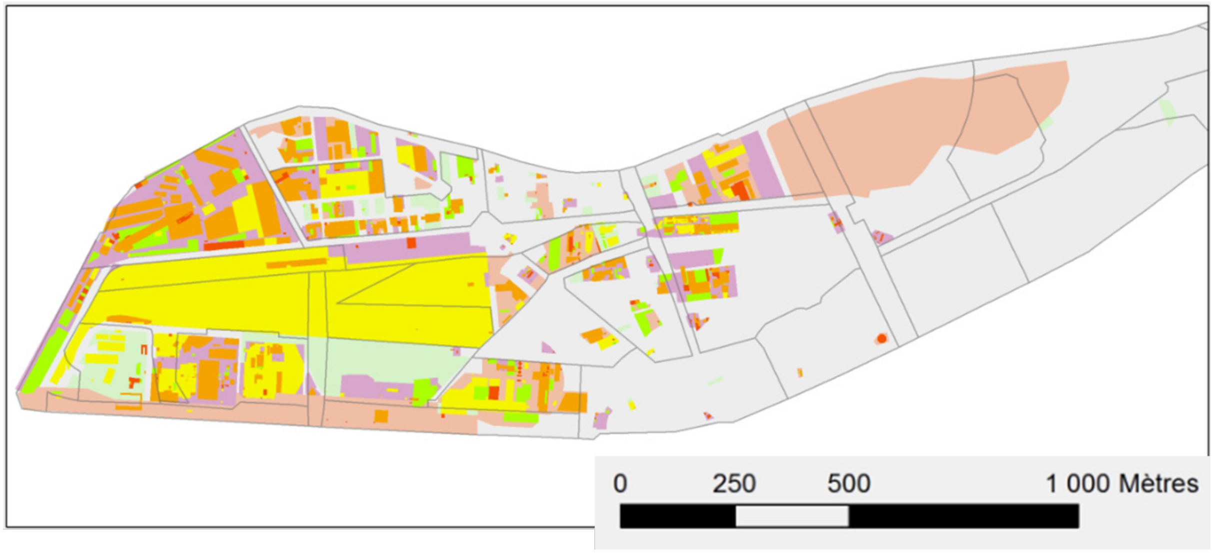


Figure 10 – Indicator of potential historical contamination of subsoils by lead linked to former industrial and service activities (from very low to absent in green to very high in purple) – Ile de Nantes, France (Le Guern et al, 2016b)

5 - Conclusion

These four case studies point out the need for subsurface characterisation (top layer, subsoils) and the relationship between soil pollution and hydrology/geology. The overall research perspectives of this urban soil in Nantes are the development of novel field characterization approaches to improve the cost and time consuming phase of decontaminating soil. Developments of in situ management of soil pollution are also in progress to decrease consumption of unpolluted soils, and expand land use in spite of the soil being contaminated (e.g phytoremediation techniques).

References

Conil, P., Rouxel, E., Toutain, J., Wuilleumier, A., Bourgine, B., Baudouin, V., Jégou, J-P (2009) Profondeur des eaux souterraines sur le territoire de Nantes Métropole/ Depth of groundwater on the territory of Nantes Métropole (France), Final Report BRGM/RP-56938-FR, 61 p.

Lamprea, K., Ruban, V., (2011). Characterization of atmospheric deposition and runoff water in a small suburban catchment. *Environmental Technology* **32**(10), DOI: 10.1080/09593330.2010.528045

Le Delliou, A. L., Rodriguez, F., & Andrieu, H. (2009). Modélisation intégrée des flux d'eau dans la ville-impacts des réseaux d'assainissement sur les écoulements souterrains. *La Houille Blanche*, (5), 152-158.

Le Guern, C., Baudouin, V., Sauvaget, B., Delayre, M., Conil, P. (2016a) A typology of anthropogenic deposits as a tool for modelling urban subsoil geochemistry: example of the Ile de Nantes (France). *Journal of Soil and Sediments*. DOI 10.1007_s11368-016-1594-z

Le Guern, C., Baudouin, V., E. Bridier, E., Cottineau, C., Delayre, M., Desse-Engrand, F., Grellier, M., Ménoury, A., Milano, E., Mouny, A., Pollett, S., Sauvaget, B., Bâlon, P. with the collaboration of P. Conil and L. Rouvreau (2016b) Développement d'une méthodologie de gestion des terres excavées issues de l'aménagement de l'Ile de Nantes - Phase 1 : Caractérisation des sols et recensement des sources de pollution potentielles // Development of a methodology to manage excavated soils generated by the redevelopment of Nantes Island – Phase 1: Characterisation of urban (sub)soils and inventory of potential contamination sources. BRGM Final Report RP-66013-FR (in French).

Lotram, Y., Le Guern, C., Béchet, B., Lassabatère, L., Andrieu, H., (2011). Transfert de polluants depuis une ancienne décharge urbaine-Apports de la caractérisation physico-chimique des déchets. *Techniques Sciences Méthodes*, (10), pp.62-71.

Rodriguez, F., Morena, F., Andrieu, H., Raimbault, G. (2007), Introduction of innovative stormwater techniques within a distributed hydrological model and the influence on the urban catchment behaviour, *Water Practice and Technology* 2 (2) doi10.2166/wpt.2007.0048

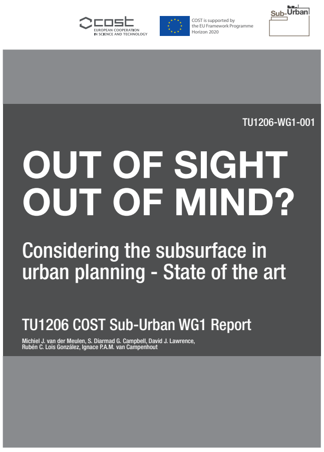
Ruban, V., Rodriguez, F., Rosant, J-M., Larrarte, F., Joannis, C., Mestayer, P., Andrieu, H., (2007). Hydrologic and energetic experimental survey of a small urban watershed, *NOVATECH*, Lyon.

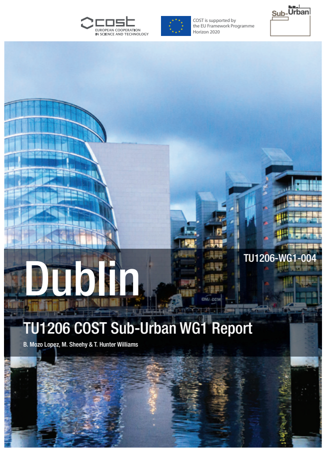
Wuilleumier A., Monnot P., Conil P., Prognon F., Lacquement F., Bourgine B., Baudouin V. (2009) Evaluation du potentiel géothermique très basse énergie sur le territoire de Nantes Métropole/Evaluation of the very low energy geothermal potential on the territory of Nantes Métropole (France), Final Report BRGM/RP-56333-FR, 251 p.

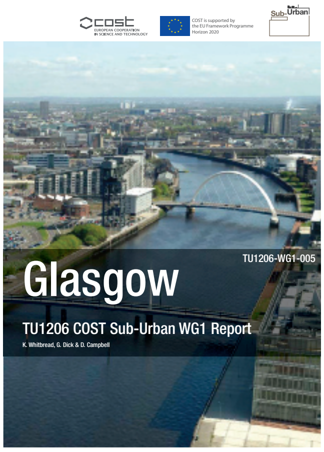
EUROPEAN COOPERATION
IN SCIENCE AND TECHNOLOGY

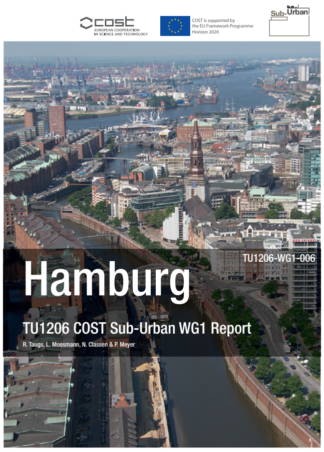
COST is supported by
the EU Framework Programme
Horizon 2020

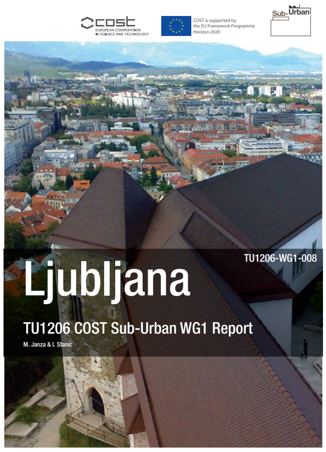
Sub-Urban

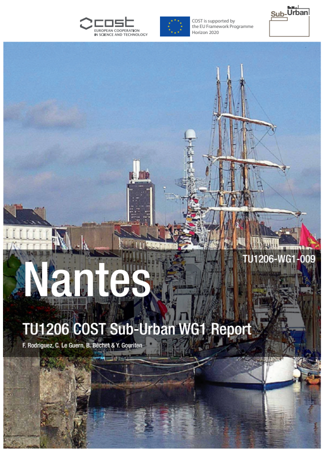


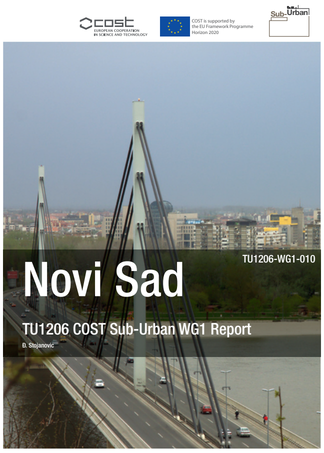


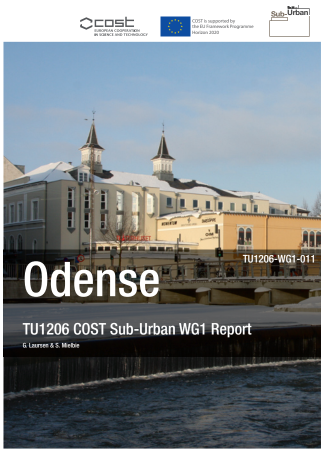












www.sub-urban.eu
www.cost.eu