Assessing the benefits of groundwater protection

A Case study in the Rhine district, France

Author Jean-Daniel Rinaudo

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Contact information AquaMoney Partners

Institute for Environmental Studies (IVM),
Vrije Universiteit Amsterdam
De Boelelaan 1087, 1081 HV Amsterdam
THE NETHERLANDS

Institute for International and European
Environmental Policy (Ecologic)
Pfalzburger Strasse 43/44, D - 10717 Berlin
GERMANY

Department of Systems Ecology and Sustainability
University of Bucharest (UNIBUC)
Spl. Independentei 91-95,
Postal Code: 050095 Sector 5, Bucharest
ROMANIA

Norwegian University of Life Sciences (UMB)
Department of Economics and Resource Management
P.O. Box 5003, N-1432 Aas
NORWAY

Institute for Water and Environmental Engineering,
Universidad Politecnica de Valencia (UPVLC)
Camino de Vera s/n, 46022 - Valencia
SPAIN

Bureau de Recherches Géologiques et Minières (BRGM)
Direction de la Recherche
3, Av. Claude-Guillemin
BP 36009 45060 Orléans, cedex 2
FRANCE

University of the Aegean (AEGEAN)
Faculty of Environment
University Hill 81 100 Mytilini
GREECE

Research Institute for Soil Science and Agricultural
Chemistry (RISSAC),
Hungarian Academy of Sciences
Herman O. street 15. 1022 Budapest
HUNGARY

School of Environmental Sciences
University of East Anglia (UEA)
Norwich NR4 7TJ
UNITED KINGDOM

Center for Environmental Policy (AAPC)
A. Juozapaviciaus 6/2, Vilnius LT-09310
LITHUANIA

Flemish Institute for Technological Research (VITO)
Boeretang 200, B-2400 Mol
BELGIUM

Department of Agricultural Economics and Engineering
(DEIAGRA)
Faculty of Agriculture
University of Bologna,
Viale Fanin, 50, 40127 Bologna
ITALY

Norwegian Institute for Water Research (NIVA)
Brekkeveien 19, 0411 Oslo
NORWAY

Royal Veterinary and Agricultural University (RVAU)
Food and Resource Economics Institute
Rolighedsvej 25, 1958 Frederiksberg C
DENMARK

Institute for Advanced Studies Carinthia (IHSK)
Domgasse 3, 9020 Klagenfurt
AUSTRIA

Corvinus University of Budapest (CUB)
Fovám tér 8., 1093 Budapest
HUNGARY

European Commission
DG Research
Unit I.2 - 'Environmental Technologies and
Pollution Prevention'

Colophone

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Content

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Summary

- This report presents the results of a valuation study conducted as part of AQUAMONEY in the Rhine basin district. The study focuses on specific problems related to economic valuation of groundwater protection benefits. It particularly focuses on a problem of groundwater over-exploitation.

- The area selected to conduct the case study is located in Eastern France, in the Lorraine region and in the Moselle and Sarre river basin sub-district. It corresponds to the area where the Lower Triassic Sandstone (LTS) confined aquifer shows signs of overexploitation. It covers approximately one third of the Vosges District (*département* des Vosges) and half of the Meurthe et Moselle districts.

- The study was conducted using the contingent valuation method. The baseline (reference) scenario was constructed using the results of groundwater simulation model. A policy scenario was then constructed, based on policy orientations which are currently being defined by a group of local stakeholders. The questionnaire was designed to test three hypotheses: (1) WTP is negatively influenced by the time lag between the date of payment and the date at which benefits actually occur; (2) the presence of substitute resource (for production of drinking water) has a negative influence on WTP; and (3) respondents level of information prior to the survey has a positive influence on WTP.

- The CV was implemented using a mail survey. Six thousand questionnaires were sent to a sample representative of the diversity of water supply sources. Approximately 10% of the questionnaires were returned (646 usable questionnaires).

- The results of the survey show that households are poorly informed about groundwater and its problems. While 61% of the respondents have never heard about the aquifer or about the depletion problem, only 6% considered themselves as well informed about groundwater and the depletion issue.

- However, in spite of this poor information level, two third (67%) of the respondents (430) accept to contribute financially to the implementation of the policy scenario; 206 refuse to contribute (32%); less than 1% have no opinion (5); and 6 do not answer this question. The main motivation for paying is related to future use. 64% of the respondents agree with the sentence “I accept to pay because this groundwater is what my grand children will drink in 40 years”. This motivation is quoted as the main reason for paying by 36% of the respondents.

- The average WTP is 39,5 € per year and per household if true zeros are included, it is equal to 45°€/y/h if true zeros are not included.

- An econometric analysis is then performed to identify the factors explaining WTP. Several models are estimated, using Ordinary Least Square regressions or Tobit regression (including true zeros). The main significant variables are the following: income; the perception of drinking water price (expensive or not); the credibility of

the reference scenario; the level of concern for future generations; the adoption of water saving practices; and an indicator of warm glow effect.

- The statistical analysis also confirms that time matters. WTP is influenced by the time lag between the date of first payment and the date at which the benefit will take place. In particular, the OLS best reduced model shows that WTP is higher (at 95% confidence level) for respondents living in the area where the benefit will take place before 2015 (variable BEFORE_2015). This result allows splitting the sample according to this variable for conducting separate regressions with two sub-samples.

- Respondents' level of information on groundwater has a significant impact on WTP (95% confidence level). Surprisingly, this impact is negative (both in the models using the full sample and the "before 2015 sample"), meaning respondents who discover the problem during the survey are willing to pay more than those who had heard about the problem before reading the questionnaire. This suggests that the information provided in the questionnaire may have a WTP enhancing effect. Similar findings were reported by Venkatachalam (2000) who found that additional information provided about the drinking water quality to the respondents, who possessed different levels of information about the water quality, can significantly influence the WTP values.

- Variables describing direct use of groundwater are not statistically significant.

- The presence of substitute resources has been found to influence stated willingness to pay in the sub-sample where respondents will benefit from the improvement before 2015. In the other sub-sample (benefits occurring in the longer term, up to 2050) the substitute variable is not significant. This may reflect households' belief that, by the time the problem really takes place (2015 to 2050), the authorities will have time to construct the pipelines required to import water from another place, water being generally abundant in the region. This would be less credible in the area where the problem may take place in the short term, explaining the different result found in the other sub-sample.

- The report also presents recommendations and best practices concerning the use of CV method for valuing the benefits of groundwater protection. It provides recommendations on how groundwater management issues can be presented to a lay public. These recommendations are based not only on the results of the CV survey but also on a social survey (72 detailed face to face interviews).

- We also report on our interaction with stakeholders during this project. Based on our experience, we recommend
    - to verify very early in the design of the case study how the WTP question can be perceived by local stakeholders and to make sure that the study will not negatively interfere with political or policy making processes;
    - to involve local stakeholders in the design of the questionnaire; this can reduce the risk of interference but also improve the quality of the questionnaire, as local experts may identify information likely to generate protest answers;

- to insist, when presenting the survey, on the information other that related to the WTP question which can be obtained; and to highlight that this information can help policy makers and politicians to design a communication strategy, an information and awareness raising campaign; also insist on the fact that telling to their constituencies that 65% of the respondents are in favour of the policy and are willing to pay will legitimate their political action.

1 Introduction

This report presents the results of the case study conducted in the Upper Rhine river basin district (France) as part of AQUAMONEY workpackage 4. The main objective of WP4 is to test the guidelines developed for assessing WFD resource and environmental costs and benefits of water services across ten representative European river basins. The present case study focuses on the Contingent Valuation section of the Guidelines. It also focuses on specifics aspects related to groundwater valuation, as all other case studies of Aquamoney focus on surface water.

One of the key issues investigated in this case study is the ability of lay persons to understand groundwater related issues – and consequently the relevance of CV method for assessing the benefits of groundwater protection. To answer this question, a preliminary social survey was conducted, using detailed semi-structured face to face interviews. The results of this survey were used to design a contingent valuation questionnaire adapted to the average public information level on groundwater. Based on this experience, some recommendations are proposed in the concluding section of this report.

Several theoretical assumptions have also been tested in the case study. In particular, we looked at the potential impact on WTP of (i) substitute water resources; (ii) of prior information on groundwater; and (iii) of level of current use of groundwater.

This report is organised as follows. Section 2 presents the case study area and the groundwater management issues. Section 3 presents the scientific objectives of the case study. It is followed (section 4) by a description of the survey set-up (questionnaire, sampling procedure, etc). Results of the survey are presented in section 5 (descriptive statistics) and section 6 (statistical analysis). Section 7 presents the main conclusion of the case study and section 8 proposes best practice recommendations.

2. Description of the case study

2.1 Location of the case study area

The area selected to conduct the case study is located in Eastern France, in the Lorraine region and in the Moselle and Sarre river basin sub-district. It corresponds to the area where the Lower Triassic Sandstone (LTS) confined aquifer shows signs of overexploitation. It covers approximately one third of the Vosges District (*département* des Vosges) and half of the Meurthe et Moselle district (Figure 1. The aquifer recharge area (unconfined LTS aquifer), identified as a different water body by RBD authorities, is excluded from the case study.

The study area includes a small industrial area, located around Nancy (over 100 000 inhabitants) and Lunéville (20 000 inhabitants). The rest of the area is mainly rural, with many settlements having less than a thousand inhabitants.

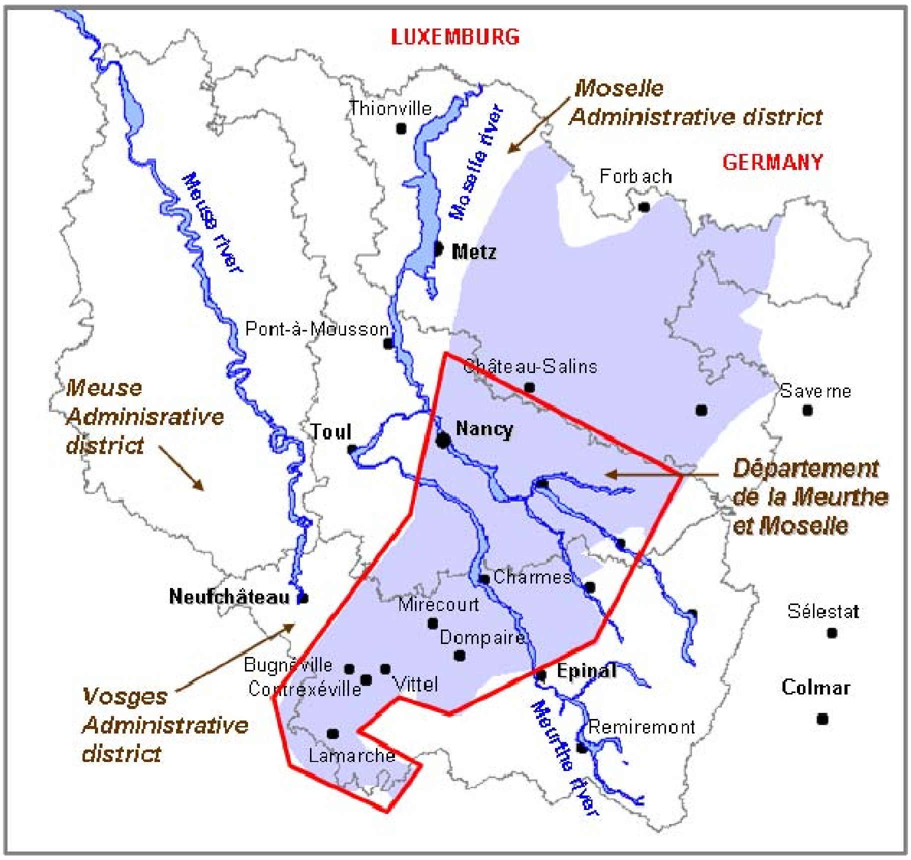

Figure 1: Location of the Lower Triassic Sandstone confined aquifer of Lorraine (in grey) and area covered by the study (red). Alluvial aquifers along rivers are shown in blue.

2.2 Aquifer characteristics and water uses

The Lower Triassic Sandstone aquifer is a strategic resource at the regional level. Water is contained in a 30 to 90 meters thick layer of sandstone (compacted sand) which extends over more than one third of the region. This rock layer shows on the surface in the Vosges Mountains where rainfalls infiltrate (see Figure 6). The reservoir plunges deeply under the surface to the North-West. It is approximately 800 meters deep below the city of Nancy.

Water flows very slowly in this underground reservoir: it will take 5000 years for a drop infiltrating in the Vosges mountain to reach the Luneville or Mirecourt, where it is approximately 300 meters bellow the surface. Thanks to this long trip underground, water is filtered and it is characterised by a very good chemical and biological quality. Moreover, being protected by several hundreds of meters of rock and impermeable clay layers, it is protected against any pollution coming from the surface.

In *Vosges* and *Meurthe et Moselle* districts, the water supply of more than 100,000 inhabitants and many industrial activities depend on this resource[1]. In some municipalities, this aquifer is the only water resource. In other municipalities, more superficial aquifers or even surface water resources are used in conjunction with the LTS aquifer. This aquifer however represent a resource that can be used all other the regional territory in case of major pollution of more superficial resources.

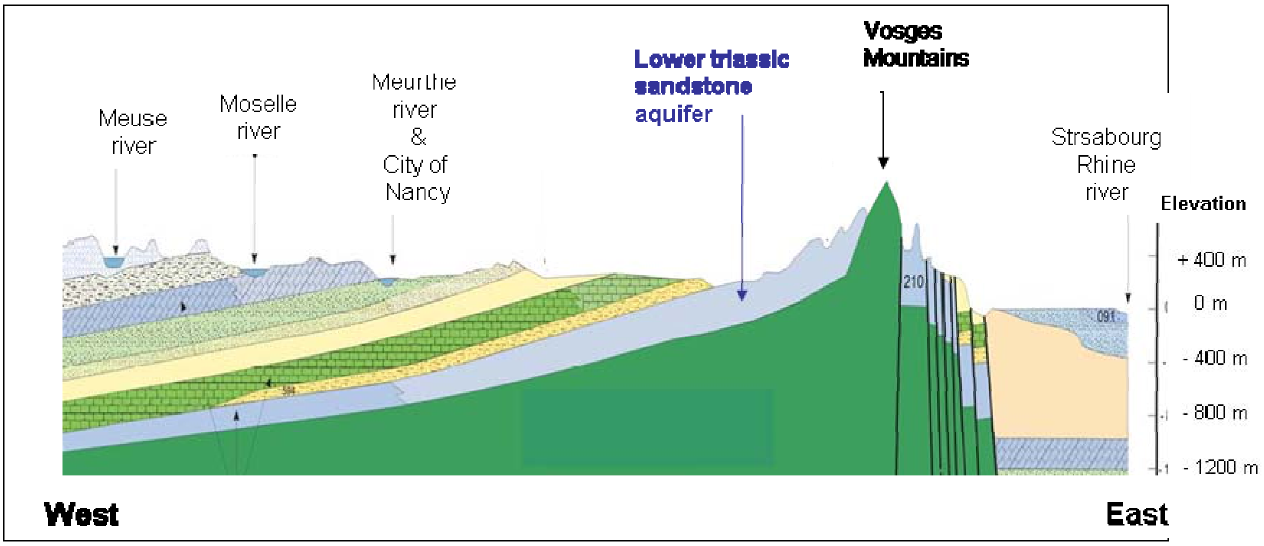

Figure 2: East-West geological cross section of the Lorraine region. The Lower Triassic Sandstone aquifer is shown in blue. Adapted from AERM 2002.

2.3 Main water management and policy issues in the context of the WFD

Abstraction for drinking water supply has significantly increased between 1965 and 1980. Many municipalities, which where getting water from superficial springs or shallow aquifers, have been financially encouraged by the Health Department to abandon their resources considered as vulnerable to pollution and to drill deep

[1] *Water abstracted from this aquifer is mainly used for drinking water purposes (approximately 80%), the remaining 20% being used by agri-food industry and bottling water industry.*

boreholes in the lower Triassic sandstone aquifer. Figure 3 illustrates this trend for the Vosges administrative district.

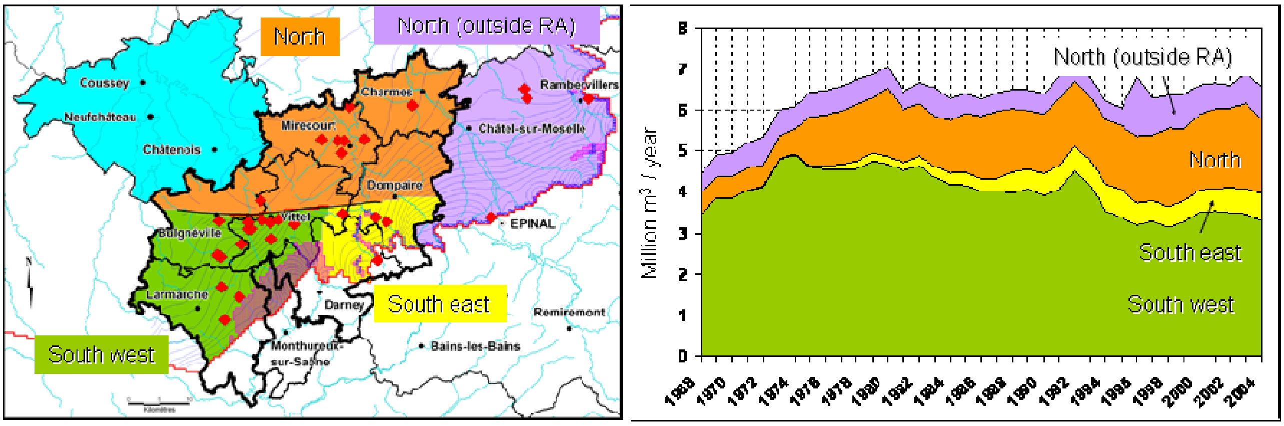

Figure 3: Historical evolution of groundwater abstraction (LTS aquifer) in the Vosges administrative district between 1968 and 2004. Adapted from Vaute., 2004; Vaulte et alii. 2007.

This trend has led to a decline of groundwater levels all over the aquifer. The difference in water levels observed between 1968 and 2000 is around 15 meters on average, with spatial variations as depicted on Figure 4 bellow.

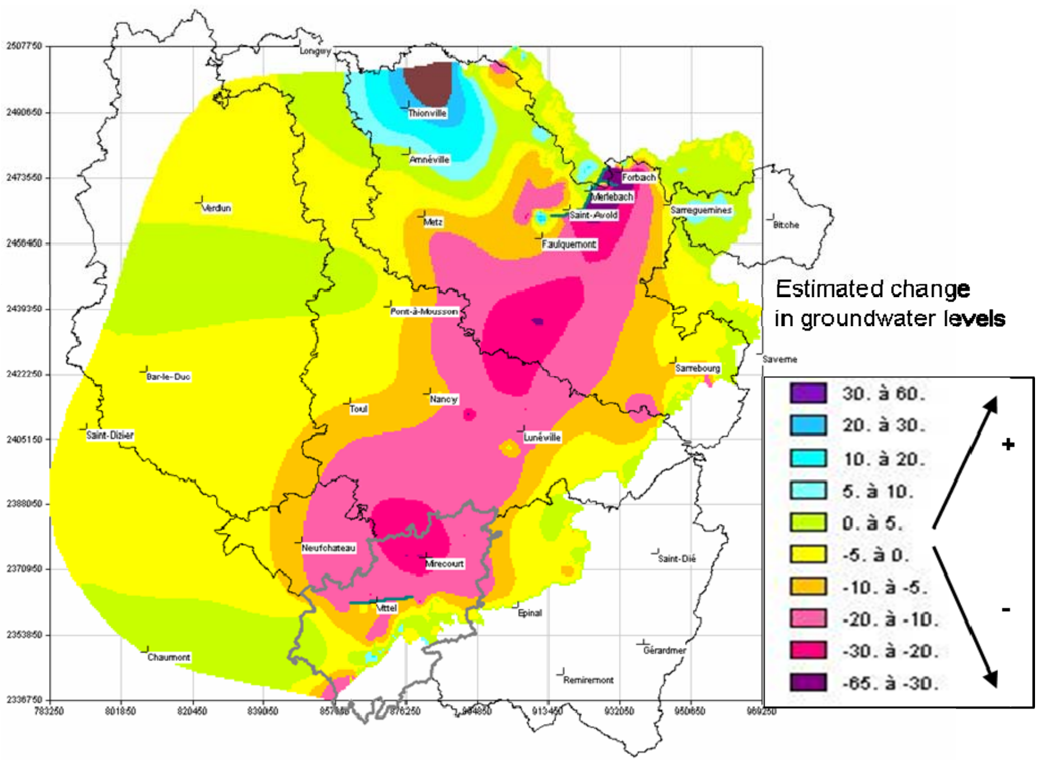

Figure 4: Estimated groundwater level decline between 1968 and 2000. Source : Vaute et alii, 2007.

A hydrodynamic model has been developed by Brgm (Vaute, 2004, Vaute et alii, 2007) to simulate future evolution of groundwater levels. Simulation results show that water levels would continue to decrease if the current rate of pumping is maintained (Figure 5). In the long term, water level would continue to go down, in particular in the South of the study area where drinking water wells could dry up in certain areas. However, the population will only be affected in the long run (between 40 and 100 years).

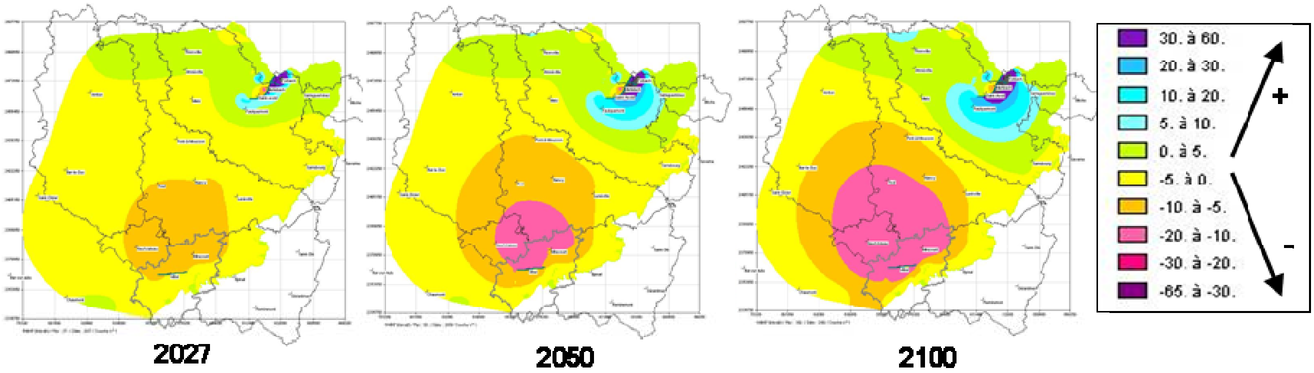

Figure 5: Simulated evolution of water level between 2004 and 2100 (adapted from Vaute et alii, 2007).

The resource overexploitation described above is a relatively slow phenomenon. Since no significant deterioration is expected to take place by 2015, the LTS aquifer has not been classified as a water body at risk of not achieving good quantitative status.

Government agencies and regional territorial bodies are however aware of the possible long term consequences of this slow aquifer deterioration. They clearly acknowledge the need to reduce pumping rates in this aquifer in order to reduce imbalance between abstraction and recharge.

Different technical solutions are envisaged to reduce quantitative pressures exerted on the resource: to substitute existing deep wells with alternative water resources (springs, superficial aquifers) where possible; to conduct massive rehabilitation of drinking water distribution pipes to reduce water losses; to promote rain water recovery by households; subsidise the installation of water saving devices in private and public buildings, etc.

2.4 Stakeholder demand for economic analysis

Government agencies in charge of water resources management in the Vosges administrative district are currently promoting the establishment of a stakeholder platform which would be in charge of defining a groundwater management strategy. This plateform, called Local Water Commission (Commission Locale de l'Eau) would comprise 40 to 50 representatives of government agencies, elected politicians, water users (agriculture, drinking water, industries) and nature protection NGOs. Its mandate would be to elaborate a medium term water management plan called SAGE (Schéma d'Aménagement et de Gestion des Eaux).

In this context, government agencies in charge of promoting this participatory process have expressed a clear interest for the Aquamoney survey. They expected that the answers to the questionnaire would demonstrate the interest of the population for this issue. And that this would legitimate their action. At the same time, they feared that the willingness to pay would worry elected politicians who could consider as politically risky to initiate the debate by asking people to pay.

Due to this ambivalent perception of the survey, the questionnaire had to be constructed with the input of stakeholders and its final validation validated by them. This was a rather long process which partly explains the additional delay needed to finalise this case study.

3. Case study objectives

The main objective of the French Rhine case study was **to test the AquaMoney guidelines** for assessing the environmental benefits of groundwater protection, as all other case studies focus on surface water bodies only. The present case study complements the results of the EU FP6 research project BRIDGE where 5 groundwater valuation case studies were conducted in 2005 and 2006.

The present study was also designed **to test three hypotheses**: (1) WTP is negatively influenced by the time lag between the date of payment and the date at which benefits actually occur; (2) the presence of substitute resource (for production of drinking water) has a negative influence on WTP; and (3) respondents level of information prior to the survey has a positive influence on WTP.

3.1 Time lag between the date of payment and the date at which the benefits will take place

Stated WTP reflect both present and future use values as well as non use values (existence and bequest).

Theoretically, non use values should not be affected by the time lag between the date of payment and the date where the benefits of groundwater restoration actually occur.

On the contrary, use value should be a function of the number of years (noted N) each respondent will benefit from the environmental improvement associated with the action scenario. N is itself a function of:

- Perceived life expectancy of the respondent at the time of survey (noted L_{exp}) where L_{exp} = 83 –age for women and L_{exp} = 77 – age for men (zero if negative);
- The time lag between the date of payment and the date when the benefits occur (noted T_{lag}); this time lag defers from one location to another within the case study area;
- The perceived probability that the respondents will continue living in the case study area (if he has to move out of the area, he will not benefit from the environmental improvement); this probability is noted P_{mov}.

The test will consist in estimating the influence of variables L_{exp}, T_{lag} and P_{mov} on the decision to participate (accept or refuse to pay) and on the stated WTP amount. If these variables are not significant, we could conclude that the non use value, which should not be sensitive to these three variables, represent a large share of the total value.

3.2 Impact of substitute resources

Groundwater use value is theoretically higher in locations where groundwater represents the sole source of drinking water than where different substitute resources exist.

We would therefore expect WTP to be negatively correlated to a variable depicting the availability of substitute resources S_r, where :

S_r = 0 if the Lower Triassic Sandstone (LTS) aquifer is the sole source of drinking water supply (no rivers accessible at a reasonable distance, superficial shallow aquifers polluted by agriculture)

S_r = 1 if the LTS aquifer is used together with another resource (either a different aquifer or a river); in most of these cases, the LTS aquifer represents a security resource which can be used in case of pollution affecting the other resource;

S_r = 2 if the LTS is the sole source of drinking water supply

3.3 Impact of initial level of information

Groundwater is a complex and invisible resource which can be perceived – and thus valued – very differently by households, depending on their level of information.

In our survey, we provide the same level of information to respondents, through a detailed description of the aquifer characteristics, of its uses, of the services it provides to the society, of the management problem and of the benefits expected from the policy scenario. All respondents are supposed to have the same information when answering the WTP question.

However, there may be great differences in the level of **appropriation** of this complex information by respondents. Respondent who discover the aquifer under study when reading the questionnaire are in a situation of **preferences construction**, whereas those with prior knowledge of the resource and benefits expected from its restoration are in a situation of established preferences.

We therefore want to test if a significant difference is observed between respondents with prior information and others. If there is no difference, we can assume that non informed households have been able to assimilate the technical information provided to them and that their stated WTP is as robust as for informed households. In the opposite case, we could fear that stated WTP is not robust and could change with time, or with the supply of additional information.

4. Set up of the survey

4.1 Preliminary social survey

A preliminary social survey was conducted in May and June 2008 in view of characterising the perception of groundwater by lay public. A total of 72 semi-structured face to face interviews were conducted in the streets of two main cities of the area (Nancy and Metz) and in small rural villages of their periphery.

The interviews were guided by a semi-open questionnaire comprising three main parts.

- In the first part, respondents are asked to describe what the term groundwater means to them. The objective was to capture the lay vision of the reservoir in itself, its geographic extension and to assess if respondents are able to locate groundwater resources on a map. It was also to assess the level of understanding of the water cycle underground, a specific attention being paid to the understanding of exchanges between ground and surface water.
- In the second part, respondents are asked to list the reasons why groundwater is useful to society; the objective if to identify which services provided by groundwater to the society are perceived by respondents. These services include “filtration of water”, “protection against pollution”, “storage and insurance against drought” and “recharge of superficial ecosystems such as rivers and wetlands”. The interview goes on with a discussion of factors representing a threat for groundwater and of the need to protect these natural resources.
- The third part comprises 5 close ended questions and questions related to the socio-economic profile of the respondents.

The main results of this social survey were the following (for more details, see Rinaudo, 2008):

- The public knows very little about ground water bodies, defined as the geological reservoirs and the water they contain; laymen can hardly locate water resources on a map and find very difficult to explain how and why water moves underground.
- The dominant representation of groundwater is that of an underground lake or river, as can be seen in some spectacular caves (karstic aquifers); very few respondents are aware of the characteristics of other aquifers, alluvial or sedimentary in particular.
- Although almost all respondents understand that groundwater is not static but part of the water cycle, only 40% of the respondents have a complete vision of this cycle and spontaneously mention the existence of exchanges between surface and groundwater bodies.
- The fact that groundwater is filtered during its infiltration, ensuring a better quality, is quoted by over 30% of the respondents. Above 40% also recognise the fact that groundwater are protected against pollution by the different soil and geological layers above them.

- Most respondents are aware that groundwater is intensively used for the production of drinking water (83%), for agriculture (51%) and for industrial uses (13%). Approximately 75% of the respondents express a clear preference for drinking treated groundwater rather than purified surface water.
- The key role played by groundwater in sustaining aquatic life in rivers and wetlands is acknowledged by 35%, which is considered as a relatively high figure.
- 35% of the population see groundwater bodies as water reserves which could be useful in case of drought (19%) or in case of pollution of surface water bodies 13%).

These results were used to design the CV questionnaire. Implications in terms of best practice recommendations are also derived and presented in section 6 of this report.

4.2 Questionnaire design

The questionnaire, consisting of 8 A4 colour printed pages, was sent to households by surface mail, together with an introduction letter presenting the project objectives. The questionnaire in itself comprises five main sections:

❖ **Section 1: presentation of the aquifer**

The presentation of the aquifer focuses on 3 key information we absolutely want respondents to understand: (1) water is contained in a layer of rock, where water infiltrates and circulate; (2) since water moves very slow in the aquifer, the water we pump in drinking water wells is several thousand years old; given that it is protected from recent pollution sources by hundreds of meters of rocks, it can be considered as pristine; (3) the aquifer is a resource of regional importance, supplying more than 100,000 inhabitants and many industries. A map and the following 3 dimensional diagram are used to illustrate the text.

This informative part is followed by a series of knowledge and perception questions related to: (i) prior knowledge of the aquifer; (ii) prior knowledge of the origin of drinking water supply; (iii) perception of future evolution of water demand in the coming 40 years; (iv) perception of climate change and its impact in the region.

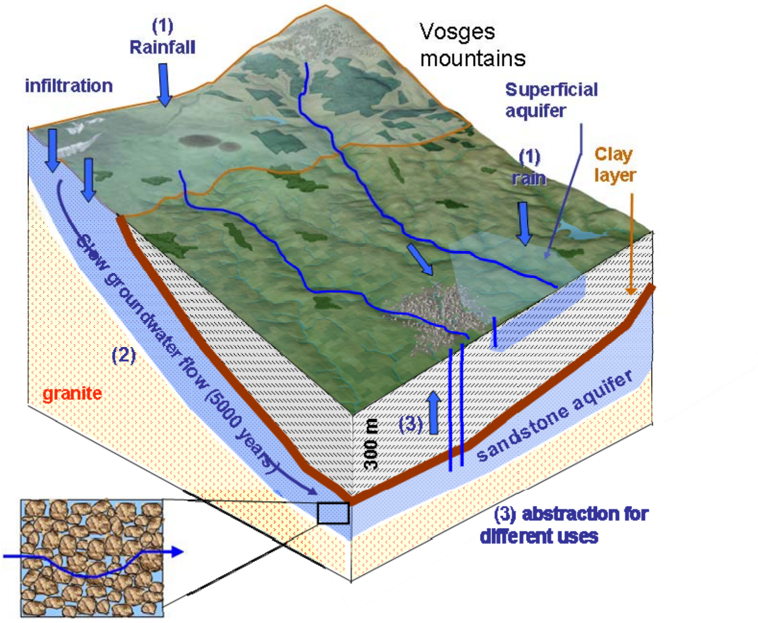

Figure 6: Simplified representation of the Lower Triassic Sandstone aquifer (diagram used in the CV survey).

Households are then informed of the origin of drinking water they receive at their tap, with a table as shown bellow:

Département de la Meurthe et Moselle (54)			
Barbonville	■	Remenoville	■
Charmois	■	Remereville	○
Diarville	○	Saint-Nicolas-de-Port	▲
Dombasle-sur-Meurthe	▲	Seichamps	○
Einvaux	■	Tantonville	○
Haussonville	■	Varangeville	▲
Herimenil	▲	Villacourt	■
Laloeuf	○	Virecourt	○
Lamath	■	Xirocourt	○
Lunéville	■		

Département des Vosges (88)					
Auzinvilliers	▲	Dompaire	○	Monthureux-le-sec	■
Bulgneville	▲	Evaux et Menil	▲	Nomexy	○
Charmes	○	Floremont	▲	Oelleville	■
Châtel-sur-Moselle	○	Gircourt les Vieville	▲	Poussay	▲
Chatenois	■	Gironcourt sur Vraine	■	Rainville	■
Contrexeville	▲	Hagecourt	▲	Remoncourt	■
Crainvilliers	▲	Houecourt	○	Rouvres en Xaintois	▲
Dombrot sur Vair	▲	Mandres sur Vair	▲	Suriauville	▲
Domjulien	▲	Mattaincourt	▲	Ubexy	▲
		Mirecourt	▲	Vittel	▲

The water you receive at your tap is pumped:

▲ In the lower triassic sandstone aquifer only

■ in the LTS aquifer for one part, and in rivers and other aquifers for another part

○ only from rivers and other resources, and not from the LTS aquifer

Figure 7: Table showing where tap water comes from in the municipalities selected for case study (used in the questionnaire).

❖ Part 2: the over-exploitation problem

The historical decline of water table as well as the anticipate evolution is presented to respondents who are informed that this will lead to the drying up of certain water wells. The area likely be affected are depicted on a map which also show at which date the problems are likely to occur (see Figure 8).

This description is followed by a 2 of questions related to (i) prior information of the respondents of the problem described above; and (ii) the credibility of the description of future evolution of the problem.

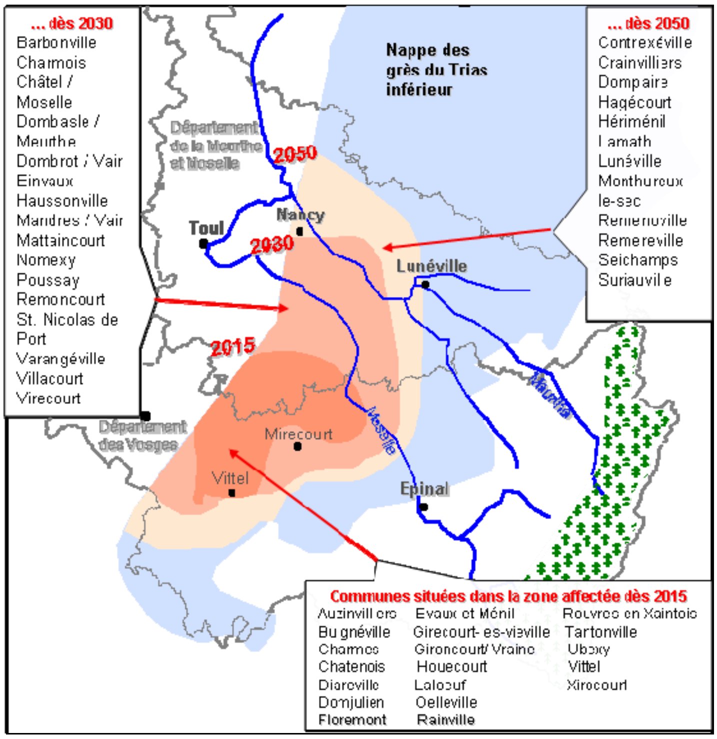

Figure 8: Map depicting the area likely to be affected by the decline of water tables at three different dates.

❖ **Part 3: policy scenario**

The third section concentrates on the description of the policy scenario and the WTP questions. The description of the scenario is the following (translation of the text in French):

> *"To stop the decline of water levels, pumping rates have to be reduced. Although water users are already making significant efforts, groundwater abstraction still has to be reduced by 15%.*
>
> ***Experiences conducted elsewhere in France have demonstrated that this objective can be achieved.***
>
> *Domestic consumption can be reduced if households invest in water saving devices (double button flushes, tap pressure reductors, rain water harvesting systems…). Public water utilities can intensify the repair of distribution pipes to reduce leakages and reduce volumes used for watering parks. Also, industries and farmers are able to optimise their production tools in order to reduce water consumption.*
>
> ***A collective action is needed***
>
> *Changing water use behaviour and practice can not be left to voluntary initiative. To make sure that environmentally*

> *responsible behaviour becomes the rule, and that all actors make real efforts, a collective action is needed. Some actions will have to become compulsory while others will be financially supported. The exact nature of actions will be determined by representative of government agencies, users and elected politicians.*
>
> ***… for the benefit of future users***
>
> *For cities having access to an alternative water supply, this collective action will guarantee the existence of the safety water reserve which can be used in case of river pollution or of severe drought. For cities which entirely depend on this resource, this action will avoid constructing costly pipelines to import water from far away. In both cases, future generation will still have at their disposal and right under their feet, this resource of pristine quality, well protected against all sources of pollution".*

Respondents are then asked if they find the scenario realistic. The WTP question follows, using the water bill as a payment vehicle and a payment card. Two follow up questions ask the respondent to specify their motivations for paying (identification of warm glow effect) or refusing to pay (identification of protest).

❖ **Part 4: respondent's water use**

Respondents are then asked a set of question related to their use of water: access to a private well, type of water used for drinking (tap or bottled), water saving practices, knowledge of the water bill, knowledge of the volume used per year at home, perception of the price of water, experience with water use restriction in case of drought.

❖ **Part 5: socio-economic characteristics**

Classical questions follow related to socio-economic characteristics follow: gender, age, employment, education, number of persons in the household, number of children and grand children, income. Respondents are also asked to say if they expect moving out of the case study area in the future, as we predict this could influence their non use value. Two follow up questions on the perception of the questionnaire come at the end of the questionnaire.

4.3 Test of the questionnaire

The questionnaire was tested in three cities of the case study area: Lunéville, Mirecourt and Vittel. A total of 50 face to face interviews were conducted over three days by Brgm researchers to test the formulation of the questions, the suitability of the graphs and maps used, and to identify the information contained in the text which could increase the rate of protest.

4.4 Sampling procedure and response rate

A total number of 6000 household addresses were selected as shown on Table 1 bellow. The sample was stratified according to the source of water supply used to deliver tap water and according to the date at which the benefits will take place if the policy scenario takes place.

Date of impact of water table depletion	Only LTS aquifer	LTS aquifer and alternative resource	Alternative resource only	total
2015	906	1454	584	2944
2030	426	150	872	1448
2050	588	450	570	1608
All dates	1920	2054	2026	6000

Table 1: Distribution of the sample of households (6000).

5. Valuation results: descriptive statistics

5.1 Respondent characteristics and sample representativeness

5.1.1 Socio-economic and demographic characteristics

The main demographic characteristics of the sample are the following:

- 69% of the respondents are men, only 31% are women;
- Respondents are aged 55 years on average. People under 40 years old are under-presented (depicted by see range A in the figure bellow) while people aged between 60 and 80 are over-represented (range B in figure bellow).
- Households are composed of 2,6 persons on average; single person households represent 15% of the sample, 2 persons households 45%, 3 and 4 person households 30%.
- More than 80% of the respondents are part of a family household with children.

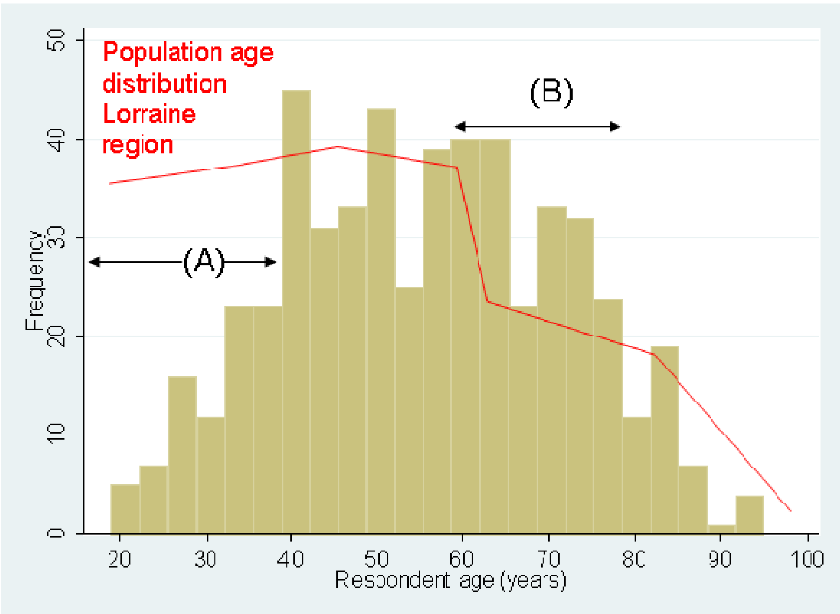

Figure 9: Population age distribution (N=465)

If we assume that life expectancy is 77 years for men an 83 years for women (French average values), we can calculate the percentage of the population who will still be alive at the three different dates when the benefit will occur (Figure 10). If we now compare, for each respondent, the date of anticipated end of life with the date at which the benefits of GW protection are expected to take place in the area where the respondent live, we can calculate an indicator which takes the value 1 if the respondent will have a chance to benefit from GW improvement, 0 otherwise. This variable is expected to have a negative impact on WTP.

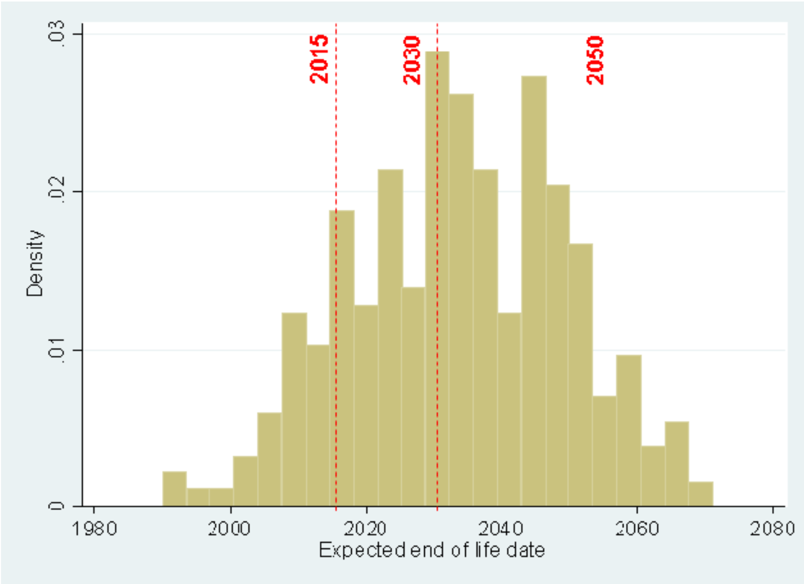

Figure 10: Expected end of life date (N=465)

Retired people are over-estimated and unemployed workers are under-represented. The low presence of student is not surprising as there are no universities in this rural area. The average income is 2630 €/month per household.

Members of nature and environment protection organisations are also over-represented (9,7%).

	Workers	Retired	Unemployed workers	Student	Other
%	54%	39%	3%	1%	3%
Number	306	224	17	3	15

Table 2: Employment status (N=565)

	no diploma	elementary schol	technical short studies	Intermediary level	A level (high school)	higher studies
Number	32	65	100	98	115	199
%	5%	11%	16%	16%	19%	33%

Table 3: Education level of respondents (N=609)

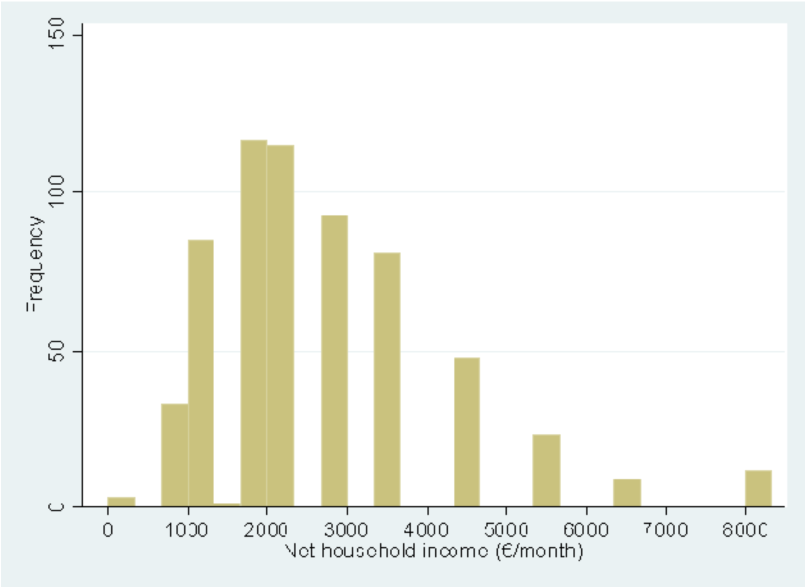

Figure 11: Income distribution (N=620)

5.1.2 Water use characteristics

Direct water use:

- 17% of the respondents (92) directly use water which they access to via a private well or a spring (N=553); water is mainly used outdoors (watering garden, washing cars) by 75% of these respondents, while only 25% use it indoors.
- Concerning drinking water, 52% of the respondents declare that they mainly drink tap water; 41% declare drinking mainly bottled water or water from another source (thermal spring) while 7% are equally relying on tap water and bottled / spring water.
- Almost all respondents declare making efforts to reduce their water consumption; a description of the efforts they actually do shows that: 94% declare not leaving taps open unnecessarily; 89% taking showers instead of baths; 58% having installed double volume toilet flushes; 46% collect rain water from their roof; 46% have purchased low water consumption washing machines; 32% reuse water after washing vegetables; 15% have installed pressure reducers on their taps.
- The motivations explaining why they make some efforts to reduce water use are the following : reduce the water bill (49%), never waste anything by principle (43%), for environmental concern (25%).
- Concerning the water bill, 91% of the respondents declare that they directly pay their water bill; this suggests that home owners are over-represented in the sample. 84% of these people declare knowing the amount of their water bill;

Indirect use

- 63% of the respondents declare that they often or very often walk along rivers or lakes; 18% declare that they often or very often fish; 6% declare that they often or very often swim in rivers and lakes; 3% declare practicing canoe, often or very often.

- An aggregate variable is created, taking the value 1 if respondent declares practicing often or very often one of the above activities; 68% of respondents are in this situation.

5.2 Public perception of water resources and management problems

5.2.1 Level of information

Many respondents are discovering the existence of the resource and its management problems as they fill the questionnaire. :

- Knowledge of source of drinking water supply: 50% of the respondents said they knew where the drinking water they receive at their tap is coming from; this percentage is independent from the type of resource actually used (groundwater, surface water or a combination)
- Knowledge of the aquifer: whereas 45% of the respondents were not informed of the existence of the aquifer before reading the questionnaire, 41% said they already heard about and 14% consider that they were well informed.
- Knowledge of the overexploitation problem: more than half of the respondents (54%) had never heard about the groundwater problem before reading the questionnaire; 39% declare that they little heard about it and only 6% declare that they were well informed.

An aggregate information variable is constructed, taking the value (0) if the respondent did not know the aquifer or did not know about its depletion; (1) if the respondent heard about the aquifer and heard about its depletion problem; (2) if the respondent considers that he was well informed about the aquifer and well informed about the depletion problem before reading the questionnaire. The analysis of this variable shows that, while 61% of the respondents have never heard about the aquifer or about the depletion problem, only 6% considered themselves as well informed about groundwater and the depletion issue.

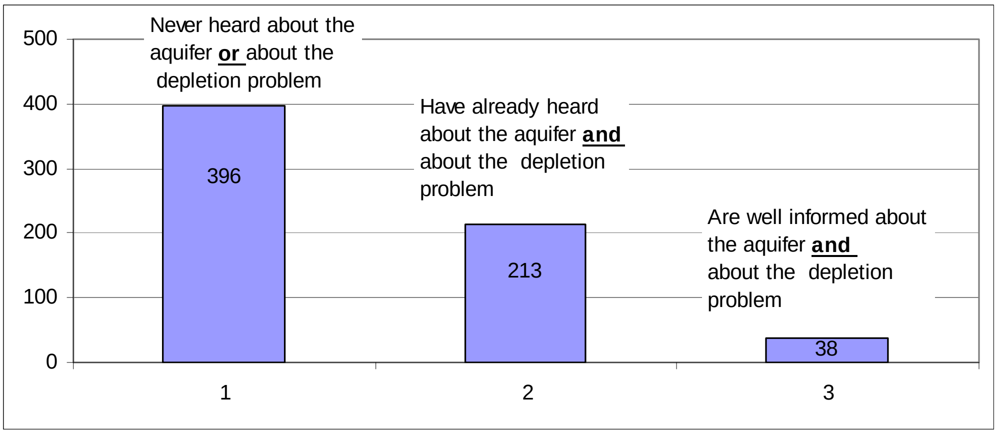

Figure 12: Level of information (knowledge of the aquifer and its depletion problem; N=647)

5.2.2 Perception of the groundwater depletion problem

The baseline scenario is considered as quite / very realistic by 58% / 24 % of the respondents. While 12% do not have an opinion, 6% consider it as unrealistic. Respondents who do not believe in the baseline scenario support their judgment with the following statements:

- They do not understand how groundwater levels can go down in a region where it is raining so often; they actually do not understand that groundwater recharge is very low as compared to rainfall.
- They think that drinking water demand will remain stable in the coming 40 years (approximately 21% of the total sample) or even decrease (18% of the total sample).
- They do not believe that the situation can change so quickly, contest the validity of the mathematical model or simply do not believe in scientist predictions

More than 77% of the respondents consider that climate change will affect their region (11% think there will be no impact, 12% have no opinion on this issue). Increase in winter rainfall is considered as a possible impact of climate change by 47%. Close to 62% consider that CC will lead to more frequent drought with a decline in river discharges and water tables.

Climate change impact is expected to take place in the very short term: 42% of the respondents think that climate change can already be observed, 35% think climate change impact will be observed in 20 years, 18% in 40 years and only 5% in more than 40 years (N=406).

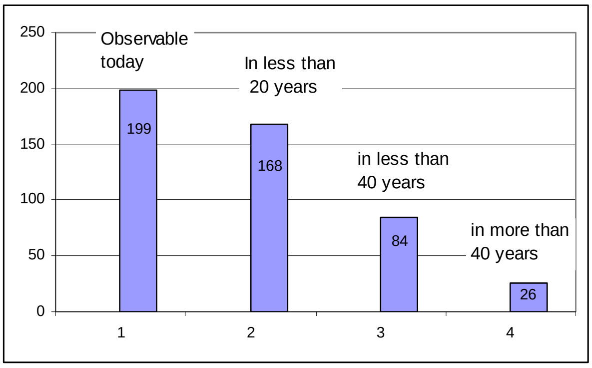

Figure 13: Perception of when climate change will impact the region (in number of respondents).

5.2.3 Perception of the proposed policy scenario

Restoring groundwater quantitative equilibrium is considered as a quite / very realistic objective by 66% / 20%of the respondents. While 7% have no opinion, achieving this objective is not considered as realistic by 7% of the respondents who support their opinion with the following arguments:

- Households will not feel concerned by this problem; also, they will not be motivated to reduce their water consumption as this would imply a renouncement to a certain level of well being; on the contrary, they feel that water demand is increasing, as shown by the increasing number of swimming pools in gardens; the only solution to make people change behaviour is to increase drastically the price of water.
- Not all local politicians will support and actually implement this action plan, which is therefore not credible.
- There will not be sufficient public financial resources made available for implementing the programme of measures described.
- It will be very difficult to compel farmers and industries to reduce groundwater abstraction; the efforts made by households will be offset by increase in pumping by farmers and industries.

5.2.4 Willingness to pay for the policy scenario

Two third (67%) of the respondents (430) accept to contribute financially to the implementation of the policy scenario; 206 refuse to contribute (32%); less than 1% have no opinion (5); and 6 do not answer this question.

The main motivation for paying is related to future use. 64% of the respondents agree with the sentence “I accept to pay because this groundwater is what my grand children will drink in 40 years”. This motivation is quoted as the main reason for paying by 36% of the respondents.

A high number of respondents agree with the statement “I am ready to pay for this aquifer as I would do for any other aquifer in France” – a question inserted in the questionnaire to detect warm glow effects. However, only 56 persons quote this reason as main motivation, and only 36 quote it as unique motivation. The impact of this motivation will be analysed in the multivariate analysis.

Respondents motivation for paying (N=364)	**Motivation quoted (*)**	**as main motivation (**)**
This groundwater is what my grand children will drink in 40 years	274 (64%)	153
I prefer to pay now for groundwater than later to bring water from far away	190 (44%)	55
I accept to pay because I use this aquifer	186 (43%)	58
I am willing to pay for this aquifer for any other one in France	188 (44%)	56
Depleting this aquifer would represent an handicap for the local economy	139 (32%)	26

Figure 14: Motivations for paying. N =430 for (*); N=292 for (**)

Motivation for protesting are carefully analysed, using the answer to close ended questions (see Table 4) and looking at the hand written answers to the open ended question.

Respondents motivation for refusing to pay (N=184)	**Motivation quoted (*)**	**as main motivation**
My income level does not allow me to pay	58 (28%)	49
I would accept to pay but not through an increase of the water bill	22 (11%)	14
I don't feel personally concerned by the depletion of this aquifer	17 (8%)	12
I don't think that the overexploitation of this aquifer is a priority issue	5 (2%)	3
Other reasons (protest)	33 (16%)	26

Table 4: Motivations quoted by respondents refusing to pay (N=206 for (*). N=104 for (**)

The question related to motivation for refusing has only been answered by half of the respondents refusing to pay (104 over 206). When no motivation is provided (92 observations), we systematically consider refusal as protest.

Half of the respondents give only one reason for refusing; they are classified as protesters or true zero depending on the motivation quoted. And 8% give between 2 and 4 reasons; they are classified as protesters or true zero depending on the motivation they rank in first position. Overall, the estimated rate of protest is equal to 23.4%.

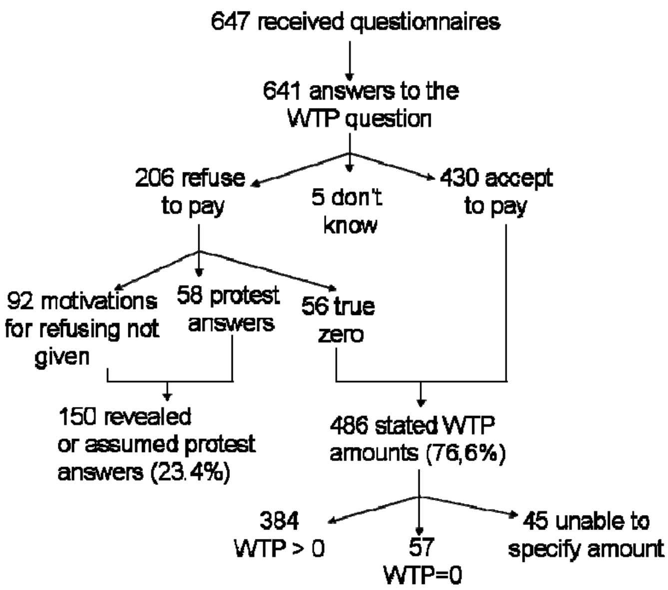

Figure 15: Proportion of protest answers.

The analysis of the comments written on the questionnaires enables to understand the reasons underlying protest answers. The main reasons quoted are the following:

- The main cause of protest is related to the payment vehicle (increase in water bill). The price of water is considered as already too high as compared to the cost of the water delivery service. Some people suggest that part of the revenue from water sales should be used to cover the cost of the proposed programme of measures, even if this means reducing the profit of private water companies. A lack of trust of the transparency related to the use of the money collected is also clearly expressed.

- Some respondents consider that economic users (farmers and industrialist) should pay, as they are pumping larger volumes than households[2]. They do not consider themselves as responsible for the problem and expect that those who have generated it pay to fix it.
- The same attitude is found with households who consider that they already make a lot of efforts to reduce their water consumption; they also consider that other households, who use a lot more water than they do, should pay – not them.
- Other respondents consider that the protection of water resources is a matter of public health and this is typically the responsibility of the State.

5.3 Estimated economic values for water resource management

5.3.1 WTP values

The average WTP is 39,5 € per year and per household if true zeros are included, it is equal to 45°€/y/h if true zeros are not included. The distribution of WTP values is depicted bellow.

Given the shape of the density function of lo(WTP), the dependent variable selected for regressions is log(WTP).

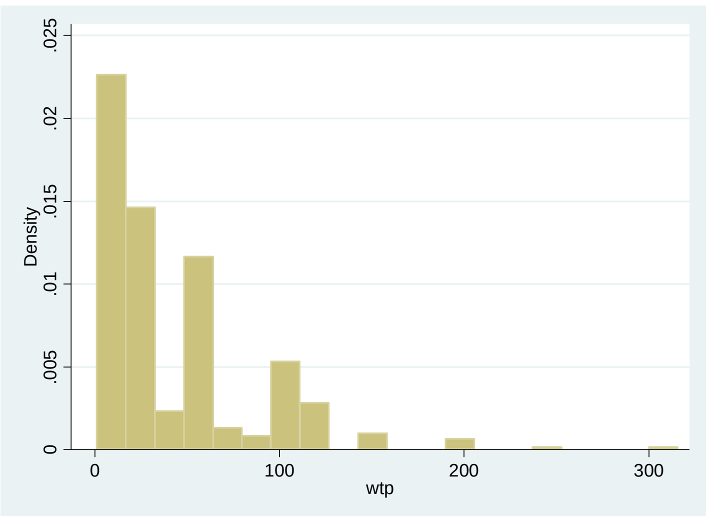

Figure 16: Distribution of positive WTP amounts (N= 322, average=41)

[2] *The public perception is not confirmed by facts :the volume of water pumped for producing drinking water is 6 times higher than*

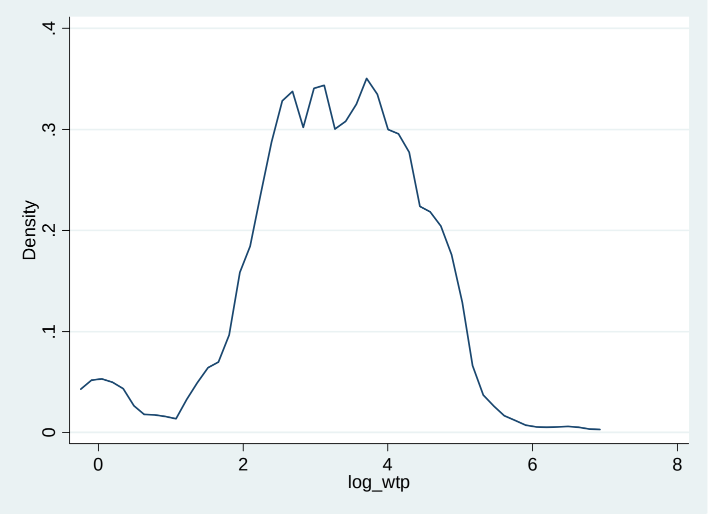

Figure 17: Distribution of positive log WTP.

6. Factors explaining economic values for water resource management

6.1 Conceptual model

Variations in stated individual willingness to pay fro groundwater protection can theoretically be explained by five main factors:

- the intensity of direct **groundwater use**, in particular as a source of drinking water;
- respondent's concern with **future use**, in particular for future generations;
- perception and **awareness of the groundwater problem**;
- **date** at which the benefit will take place;
- **socio-economic characteristics** of the household;

6.1.1 Intensity of direct groundwater use

Intensity of individual groundwater use depends on:

- the origin of drinking water which respondent receives at the tap; depending on the location, drinking water may come from the LTS Aquifer solely; it may also come from this aquifer and from other surface water resources (blend); or it may solely come from surface water resources; a variable labelled **TAP_GWAT** is created, taking the value 1 if groundwater is used; this variable is expected to have a positive impact on WTP; another variable **TAP_SUB** is created, taking the value 1 if, in the respondent's municipality, drinking water supply depends not only on groundwater but also on a substitute resource; this variable is expected to have a negative impact;
- whether respondents drinks tap water or bottled water; a variable **DRINK_WAT** is created, taking the value 1 if respondent declares mainly drinking tap water; this variable is expected to have a positive impact on WTP;
- whether respondents has a direct access to groundwater in his garden, through a well, borehole or even just a spring; a variable **WELL** is created to depict if respondents have a direct access to groundwater; this variable is also expected to have a positive impact on WTP;

6.1.2 Respondent's concern with future generations;

Given that the benefit of the programme will only take place in the medium to long term, WTP will necessarily reflect respondents' level of concern for future generation.

- This concern can directly be characterised from the questionnaire, as respondents where asked to tell the reasons why they accept to pay, one of the reasons being "This groundwater is what my children and grand children will drink in 40 years time"; a variable **FUTGEN** is created, taking the value 1 when this reason is quoted as a motivation for paying.
- Concern with future generation may also depend on whether respondent have children and/or grand children; we expect grand parents to be more concerned

with future generations than others; one additional variable is created (**G_PARENT**), with an expected positive impact.

- It may also depend on whether respondents expect to move out of the area or not; respondents who do not expect to move out of the land where they live are expected to have higher WTP; a variable **SEDENTARITY** is created, taking the value 1 for respondent declaring that they are not likely to move out of the district in future years;

6.1.3 Perception and awareness of (ground) water management issues and problems

Given that all respondents are not familiar with groundwater, we expect that WTP may vary depending on:

- Level of knowledge of groundwater itself and the awareness of the overexploitation problem; a composite information and awareness variable (**INFO**) is created, taking the value 1 if respondent consider her/himself as well informed about the aquifer overexploitation problem and the source of drinking water in his municipality, 0 otherwise.
- Perception of factors likely to reinforce the overexploitation problem in the future, like climate change leading to more frequent drought (variable **DROUGHT**) or increase of water demand in the region (variable **DEMAND**); also, respondents believing that climate change can already be observed today (variable **CC_OBS**) are likely to feel more concerned by the groundwater overexploitation problem than others, with a positive impact on WTP.
- Perceived credibility of the reference (no action) scenario (variable **CRED_REF**) and the perceived credibility of the policy scenario (**CRED_POL**).

We also expect that respondents are more aware of water scarcity problem if:

- They make efforts to reduce their water consumption (two variables). The first variable **WAT_SAVE_ENV** takes the value 1 if respondents declare making significant water saving effort and doing so for environmental concern. A similar variable WAT_SAVE_FIN is created, taking the value 1 if respondents declare making water saving efforts to reduce their water bill; it is expected that respondents who are already saving water to reduce their bill will be less prone to contribute than others, as they already contribute to the effort;
- They have already experienced water use restrictions (lawn watering and car washing prohibited during dry summers); a variable **RESTRICT** is created, taking the value 1 if respondent declares having already experienced.
- One member of their household work in a sector concerned by groundwater (agriculture, bottling water industry, food and beverage industry, spa industry, etc. (variable **WORK_WAT**)
- They are frequently practicing a leisure activity related to water such as fishing, canoeing, swimming or walking along rivers and lakes (**LEISURE**).

6.1.4 Date at which the benefit will take place

As explained above, the benefits of the scenario will take place at different dates, depending on the location. Approximately 200 respondents will benefit from the improvement in the short term (2015) 200 in the medium term (2030) and 200 in the long term. The following variables are created:

- **BEFORE2015** takes the value 1 if the benefits are expected to take place before 2015, 0 otherwise. We expect that this variable will have a positive impact;
- The perception of the date at which the benefit will take place also depends on the age of the respondent; to take this factor into account, we construct a variable **SEE_BENEF** which takes the value 1 if the respondent can expect to benefit from the improvement in his / her lifetime. This variable is calculated taking into account an average life expectancy of 77 years for men and 83 years for women.
- Another similar variable **BENEF_15Y** is constructed to characterise the duration of the period P during which respondent may benefit from the improvement; this period is calculated for each respondent taking into consideration his/her age and the date at which groundwater improvement will take place. The variable BENEF_15Y variable takes the value 1 if this duration is greater than 15 years, 0 otherwise.

6.1.5 Socio-economic characteristics of the household

- Income is expected to be a main variable explaining WTP amounts (**INCOME**);
- Educational level is also expected to have a positive impact, given that the representation of groundwater and the conceptualisation of the benefits associated to its protection may be remain difficult for less educated people than for those with higher education. A continuous variable **EDUCATION** is created.

6.1.6 Other variables

The impact of the following variables is also tested:

- **WARMGLOW**: this variable takes the value 1 if respondents have agreed with the following statement: "I am willing to pay for this aquifer as I would be willing to pay for any other aquifer in France", which reflects a warm glow attitude. This variable is expected to have a positive sign.
- **ENV_NGO**: this variable takes the value 1 if respondent is a member of a nature or environment protection NGO, 0 otherwise. This variable is expected to have a positive sign.
- Perception of water price and water bill are also expected to have an impact on WTP; we would expect respondents considering that drinking water is relatively cheap have a higher willingness to pay than those considering that water is expensive (**PERC_PRICE**); also, we would also expect a positive correlation between the amount of the water (variable **WATER_BILL**) bill and WTP (although the effect of this factor remains quite uncertain).

The following table presents a list of the variables selected:

Variable short name	Description	Expect. impact
TAP_GWAT	1 if tap water supplied at respondent's tap is produced with groundwater (solely groundwater or groundwater blend with surface water)	+
TAP_NO_SUB	1 if, in the respondent's municipality, drinking water supply depends only on groundwater, 0 if a substitute resource exists	+
DRINK_TAP	1 if respondent declares mainly drinking tap water, 0 if he mainly drinks bottled water (or water from a spring)	+
WELL	1 if the respondent has a direct access to groundwater through a well, a borehole or a spring located in his garden	+
FUT_GEN	1 if the following sentence is quoted as a motivation for paying : "This groundwater is what my children and grand children will drink in 40 years time"	+
G_PARENT	1 if the respondent has grand children, 0 othervise	+
SEDENTARITY	1 if the respondent thinks he/she will most probably remain in the same region for the rest of his life	+
INFO	1 if the respondent considers himself as well informed about the groundwater overexploitation problem and the origin of his tap water	+
DROUGHT	1 if the respondent thinks that climate change will increase the frequency and intensity of droughts	+
DEMAND	1 if the respondent believes that drinking water demand will increase in the future	+
CC_OBS	1 if respondent believes that CC will impact his region AND thinks that climate change can already be observed, 0 if he does not believe there will be an impact OR thinks it will only be observed in the coming decades	+
CRED_REF	1 if the respondents finds the reference scenario not credible, 0 otherwise (no opinion or quite / very credible)	-
CRED_POL	1 if the respondent finds the policy scenario is not credible, 0 otherwise (no opinion or quite / very credible)	-
WAT_SAV_ENV	1 if respondents make significant efforts to reduce their water consumption (install pressure reducing devices on taps, reuse water, harvest rainwater) and declares doing so for environmental concerns	+ ?
WAT_SAV_FIN	1 if respondents make significant efforts to reduce their water consumption (install pressure reducing devices on taps, reuse water, harvest rainwater) and declares doing so for financial reasons (reducing the amount of the water bill).	+ ?
RESTRICT	1 if respondents have already experienced water use restrictions	+
WORK_WAT	1 if one member of the household works in a sector concerned with groundwater (agriculture, food & beverage industry, spa, mineral water)	+
LEISURE	1 if the respondent practices often or very often at least one activity related to water, including fishing, canoeing, swimming or walking along rivers and lakes	+
BEFORE2015	1 if the respondent lives in a municipality where the benefits will take place in the very short term (before 2015)	+
BENEF_15Y	1 if the respondent can expect to be benefit from groundwater improvement for more than 15 years in the locality where he/she lives.	+
INCOME	Yearly net income of the household	+
EDUCATION	Education level (continuous variable)	+
WARM_GLOW	1 if respondents have agreed with the following statement: "I am willing to pay for this aquifer as I would be willing to pay for any other aquifer in France", which reflects a desire of warm glow and possibly non-economic motivations for paying.	+
ENV_NGO	1 if member of a nature / environment protection NGO	+
PERC_PRICE	1 if perceives water as expensive	-
WATER_BILL	Amount of the water bill in €/year/household	-

Table 5: Description of explanatory variables.

6.2 Regression results

6.2.1 Ordinary least square regression (full sample)

A series of OLS regressions were carried out to identify the factors explaining variations in stated WTP. An extended model was first estimated including 25 variables suspected to have a significant impact on WTP (see global model in table bellow). Several reduced model were then tested with an ascending approach (variables added one by one). The best reduced model, which includes10 significant variables is also presented in table bellow. The dependent variable is log(WTP).

Variables	Extended model			Best reduced model		
	Coef,	**t**	**P>t**	**Coef,**	**t**	**P>t**
TAP_GWAT	0,134	0,680	0,498			
TAP_NO_SUB	-0,154	-0,810	0,419			
DRINK_TAP	-0,050	-0,350	0,724			
WELL	-0,175	-0,930	0,355			
INFO	**-0,299**	**-1,930**	**0,054**	**-0,238**	**-2,000**	**0,046**
BEFORE2015	0,177	1,030	0,305	**0,248**	**2,140**	**0,033**
BENEF_15Y	0,008	0,050	0,962			
INCOME	**0,000**	**3,870**	**0,000**	**0,000**	**6,970**	**0,000**
FUTGEN	**0,493**	**3,110**	**0,002**	**0,584**	**4,700**	**0,000**
CRED_REF	**-0,834**	**-1,790**	**0,074**	**-0,832**	**-2,560**	**0,011**
CRED_POL	-0,134	-0,390	0,695			
WARM_GLOW	**0,747**	**2,480**	**0,014**	**0,759**	**3,430**	**0,001**
WAT_PRICE	**-0,602**	**-4,060**	**0,000**	**-0,446**	**-3,950**	**0,000**
WAT_SAV_FIN	**-0,292**	**-1,820**	**0,071**	**-0,290**	**-2,400**	**0,017**
WAT_SAV_ENV	**0,358**	**2,000**	**0,047**			
RESTRI	-0,034	-0,230	0,817			
LEISURE	-0,222	-1,540	0,125	**-0,261**	**-2,260**	**0,024**
G_PARENT	0,102	0,670	0,501			
SEDENTARITY	-0,052	-0,290	0,770			
DROUGHT	-0,065	-0,450	0,650			
DEMAND	-0,055	-0,390	0,696			
CC_OBS	-0,063	-0,430	0,667			
WORK_WAT	0,001	0,000	0,998			
EDUCATION	0,049	0,870	0,383			
ENV_NGO	-0,138	-0,670	0,502			
WAT_BILL	0,000	0,970	0,332			
CONST	2,672	7,260	0,000	2,556	13,880	0,000
Nb of obs	265			354		
F	F(26, 238)			F(9, 344)		
Prob > F	0,0000			0,0000		
R²	0,3241			0,2976		
Adjusted R²	0,2503			0,2792		

Table 6: Results of the OLS regression (WTP >0, N=354). Dependent variable = log(WTP)

6.2.2 Tobit model (full sample)

Other models were then estimated using a Tobit regression, which allows using the zero bids. Only true zeros were included in the analysis (protests are excluded). The dependent variable is log (WTP+1). The results of the estimations confirm the findings of the OLS regressions, they are discussed into more details in the following section.

Variables	Extended model			Best reduced model		
	Coef,	**t**	**P>t**	**Coef,**	**t**	**P>t**
TAP_GWAT	-0,278	-1,300	0,196			
TAP_NO_SUB	0,225	1,090	0,276			
DRINK_TAP	-0,113	-0,730	0,468			
WELL	-0,106	-0,500	0,614			
INFO	-0,218	-1,270	0,206			
BEFORE2015	0,071	0,370	0,712			
BENEF_15Y	0,145	0,760	0,450	**0,227**	**1,740**	**0,083**
INCOME	**0,000**	**3,150**	**0,002**	**0,000**	**4,800**	**0,000**
FUTGEN	**1,380**	**8,230**	**0,000**	**1,440**	**10,560**	**0,000**
CRED_REF	**-0,800**	**-1,660**	**0,098**	**-0,974**	**-2,460**	**0,014**
CRED_POL	-0,136	-0,370	0,714			
WARM_GLOW	**1,495**	**4,350**	**0,000**	**1,485**	**5,660**	**0,000**
WAT_PRICE	**-0,731**	**-4,520**	**0,000**	**-0,660**	**-5,180**	**0,000**
WAT_SAV_FIN	-0,034	-0,190	0,849			
WAT_SAV_ENV	**0,504**	**2,430**	**0,016**	**0,385**	**2,240**	**0,026**
RESTRI	-0,103	-0,630	0,527			
LEISURE	-0,075	-0,470	0,638			
G_PARENT	0,239	1,420	0,157			
SEDENTARITY	-0,195	-0,980	0,330			
DROUGHT	0,079	0,500	0,619			
DEMAND	-0,086	-0,550	0,581			
CC_OBS	-0,178	-1,090	0,276			
WORK_WAT	-0,090	-0,400	0,687			
EDUCATION	**0,180**	**2,970**	**0,003**	**0,153**	**3,350**	**0,001**
ENV_NGO	-0,002	-0,010	0,994			
WAT_BILL	0,000	0,710	0,478			
CONST	1,448	3,620	0,000	0,986	5,060	0,000
Uncensored obs	265			347		
Left censored obs	31			45		
Log likelyhood	-466,6			-613,4		
LR chi2	LR chi2 (26) = 161,1			LR chi2 (9) = 215		
Prob > chi2	0,000			0,000		
Pseudo R^2	0,147			0,149		

Table 7: Results of the Tobit regression (WTP >0, N=354). Dependent variable = log (WTP+1)

6.2.3 Predicted versus observed values (full sample)

The OLS regression model and the Tobit model both under-estimates WTP (see Table 8). The difference is mainly due to the fact that models do not reproduce high WTP values. All predicted values are lower than 200 € whereas certain respondents have stated WTP up to 800 € per year.

Model	Nb. of observations	Observed WTP	Predicted mean WTP	Maximum (observed / predicted)
OLS regression – reduced model	354	46 €	31,7 €	800 / 164
OLS regression – extended model	230	50,5 €	34,6 €	800 / 156
Tobit reduced model	392	41,2 €	28 €	800 /173
Tobit extended model	286	45,2 €	30,5 €	800 / 188

Table 8: Predicted versus observed WTP values.

6.2.4 Analysis of WTP of respondents benefiting of the improvement in the short term (before 2015)

Since the variable BEFORE_2015 is significant in the OLS model, we repeated the econometric analysis with a sub-sample consisting in all households located in the area where the benefits are expected to take place in the short term (2015). The model is estimated with an OLS regression (excluding true zeros) and with a Tobit (including true zeros).

The results obtained are similar to those found with the full sample, with one key exception: the substitute variable is found to be significant, with the expected positive sign (WTP is higher if no substitute is available). Respondents living in municipalities where groundwater is the sole resource for drinking water (no substitute) have a higher WTP than respondents living in municipalities where rivers or other aquifers can be used as a substitute.

Variable	Coef,	t	P>t
TAP_NO_SUB	**0,348**	**2,070**	**0,041**
INCOME	0,000	2,950	0,004
FUTGEN	0,404	2,330	0,022
CRED_REF	-1,048	-2,820	0,006
WAT_PRICE	-0,668	-3,810	0,000
WAT_SAV_FIN	-0,455	-2,390	0,019
INFO	-0,348	-1,910	0,058
CONSTANT	3,028	12,170	0,000
Nb of obs	112,000	R^2	0,3959
F (7,104)	9,740	Adjusted R^2	0,3553
Prob > F	0,000		
Predicted WTP Average 35,4 € Max 156 €		Observed WTP Average 45 € Max 250 €	

Table 9: Results of the best reduced OLS model with constraint BEFORE_2015 = 1. Dependent variable = log(WTP)

Variables	Coef.	t	P>t
TAP_NO_SUB	**0,461**	**2,200**	**0,030**
INCOME	0,000	2,110	0,037
FUTGEN	1,351	6,260	0,000
CRED_REF	-0,998	-2,180	0,032
WAT_PRICE	-0,823	-3,860	0,000
DEMAND	-0,548	-2,690	0,008
CC_OBS	-0,506	-2,310	0,023
EDUCATION	0,189	2,490	0,014
CONSTANT	1,770	4,640	0,000
Uncensored obs	113	Prob > chi2	0.0000
Left censored obs	13,000	Pseudo R2	0.1750
LR chi2(8)	79,74	Log likelihood	-187.94494

Table 10: Results of the best reduced Tobit model with constraint BEFORE_2015 = 1. Dependent variable = log(WTP)

6.2.5 Analysis of WTP of respondents benefiting from GW improvement in the long term (between 2015 and 2050)

The same analysis is repeated for respondents who will benefit from groundwater improvement after 2015. Significant variables do not really change, except the substitute variable which is no longer significant.

Variables	Coef.	t	P>t
INCOME	0,000	6,940	0,000
FUTGEN	0,476	3,480	0,001
CRED_POL	-0,998	-3,110	0,002
WAT_PRICE	-0,304	-2,190	0,029
WAT_SAV_ENV	0,342	1,930	0,055
WAT_SAV_FIN	-0,317	-2,160	0,032
CONSTANT	2,245	12,190	0,000
Nb of obs of obs	251	R^2	0,2788
F(6, 244)	15,72	Adjusted R^2	0,2611
Prob > F	0,0000		

Table 11: Results of the best reduced OLS model with constraint AFTER_2015 = 1. Dependent variable = log(WTP)

The results of the Tobit model show that the use of groundwater has a negative impact, in this subsample. This result runs against theoretical prediction as we would expect users to attribute to groundwater a greater economic value than non users. The result probably reflects a questionnaire artefact, namely that, in this subsample, users are mainly located in a few large cities which are close to the limit of the area concerned by the problem (Lunéville, Dombasles, St Nicolas de Port et Varangéville). By looking at the map presented in the questionnaire, respondents living in these cities may have had the impression that they were not concerned by the problem – this explaining a lower WTP.

	Coef,	t	P>t
TAP_GWAT	**-0,352**	**-2,020**	**0,044**
INCOME	0,000	4,060	0,000
FUTGEN	1,300	7,630	0,000
EDUCATION	0,167	2,880	0,004
WAT_PRICE	-0,581	-3,490	0,001
WAT_SAV_ENV	0,571	2,530	0,012
CONSTANT	1,218	4,530	0,000
Uncensored obs	243	LR chi2(6)	125.86
censored obs	34	Prob > chi2	0.0000
Log likelihood =	-452.50877	Pseudo R2	0.1221

Table 12: Results of the best reduced Tobit model with constraint AFTER_2015 = 1. Dependent variable = log(WTP)

7. Case study conclusions

7.1 Main significant independent variables

Five variables are found to be significant in all models estimated using OLS regression or Tobit regression. They are equally significant in extended (global) models as in reduced models. These variables are the following.

Income is significant at more than 99% in all models; the coefficient has the expected positive sign.

Perception of water price is also significant in all models, with a confidence rate of more than 99%; households who consider that drinking water is an expensive good are on average willing to pay less than others.

Warm glow effect indicator is an independent variable significant with a 99% confidence in all models; let's remind here that this variable takes the value 1 if respondents assert that they would have agree to pay for protecting any other aquifer in France. Respondents who tick this answer in the questionnaire reveal that they derive moral satisfaction or a warm glow from the act of giving per se (Kahneman and Knetsch,1992), in addition to the utility attached to the protection of LTS aquifer. Said differently, their motivation for paying is not only economic but also possibly driven by the desire for a "warm glow". This variable has a positive impact on WTP, as predicted by the theory and shown in many other studies.

Credibility of the reference scenario is also significant in all models (with a confidence level higher than 95%), with the expected sign. Some respondents are not convinced that the problems described in the reference scenario will take place and they pay significantly less than others. As mentioned previously, some respondents do not believe that the aquifer is overexploited given the significance of the yearly rainfall in the area.

Concern for future generation is significant in all models at more than 99% confidence level, with the positive negative impact. Respondents who declare that their main motivation for paying is to preserve groundwater for future generations have a higher WTP than others. For these respondents, higher WTP may reflect a feeling of personal responsibility for contributing to the protection of groundwater for future generations.

The adoption of water saving practices is a significant variable in almost all models, with a sin depending on the motivations underlying water saving practices. Respondents who declare making water saving to reduce their water bill (financial concern) have a lower WTP (negative impact of the variable WAT_SAVE_FIN). Symmetrically, respondents who declare making water saving to protect the environment (environmental concern) have a higher WTP (positive impact of the variable WAT_SAVE_ENV).

7.2 Impact of the time factor

As expected, WTP is influenced by the time lag between the date of first payment and the date at which the benefit will take place.

The OLS best reduced model shows that WTP is higher (at 95% confidence level) for respondents living in the area where the benefit will take place before 2015 (variable BEFORE_2015).

The Tobit model shows that WTP is higher for respondents who expect to benefit from groundwater improvement for a period of 15 years or more. The duration of this period is calculated as follows: $D = (2008 + L_{exp} - Age) - D_{imp}$, where L_{exp} is the average life expectancy in the region, Age is respondent's age and D_{imp} is the date at which the improvement will take place (2015, 2030 or 2050).

Following this result, we could split the full sample into two sub-sample: respondents who will benefit from GW improvement before 2015 and others who will benefit from the improvement between 2015 and 2050.

7.3 Initial information level and judgement of the problem

Respondents' level of information on groundwater has a significant impact on WTP (95% confidence level). Surprisingly, this impact is negative (both in the models using the full sample and the "before 2015 sample"), meaning respondents who discover the problem during the survey are willing to pay more than those who had heard about the problem before reading the questionnaire. This suggests that the information provided in the questionnaire may have a WTP enhancing effect. Similar findings were reported by Venkatachalam (2000) who found that additional information provided about the drinking water quality to the respondents, who possessed different levels of information about the water quality, can significantly influence the WTP values.

Unexpectedly, there are no apparent links between WTP and the perception of factors likely to exacerbate the groundwater problem in the future. For instance, there is no significant difference between respondents who believe that the frequency of drought will increase in the future, a change which could exacerbate the groundwater depletion problem. Similarly, there is no difference between respondents who consider that the consequences of climate change can already be observed and those who think that they will only be visible in the longer run. Also, respondents who think that the total water demand will increase in the future (reinforcing imbalance between natural recharge and human use of groundwater) are not willing to pay more than others.

7.4 Water use

Variables describing direct use of groundwater are not statistically significant. For instance, the ownership of a private well of a spring (WELL) is not significant; this may suggest that respondent make a difference between shallow aquifers which they may access to through a well or a spring in their garden and the deep aquifer under study.

More surprisingly, there is no difference between WTP of respondents whose tap water supply depends on groundwater and others (variable TAP_GWAT). This finding can't be explained by an information problem, as all respondents were told in the questionnaire where their drinking water comes from. However, this may suggest that WTP mainly reflect an option value than a real value, and possibly non economic motivations such as altruism for instance. This is corroborated by the fact that the concern for future generation is a significant variable (see above).

7.5 Presence of substitute

Information about related environmental goods that may be substitutes has been found to influence stated willingness to pay. For instance, Whitehead and Blomquist (1990) showed that if substitutes are not presented, then the stated WTP becomes an overstated one.

In the case of groundwater, the value of a specific aquifer theoretically depends on the existence of substitute resources (rivers, lakes or other aquifers). The existence of substitute resource was provided to respondents in the questionnaire. It was therefore expected that respondents' WTP would reflect the presence or absence of substitute to groundwater in their locality. The results obtained differ between the full sample and subsamples :

- Concerning the subsample who will benefit from GW improvement before 2015, the substitute variable is significant (confidence level higher than 95%). This variable (TAP_NO_SUB) takes the value 1 if drinking water supply is partly or totally dependent of an alternative resource (river or shallow alluvial aquifer).
- Concerning the full sample, as well as the subsample where the benefit take place after 2015, the substitute variable is not significant. This may reflect households' belief that, by the time the problem really takes place (2015 to 2050), the authorities will have time to construct the pipelines required to import water from another place, water being generally abundant in the region. This would be less credible in the area where the problem may take place in the short term, explaining the different result found in the other sub-sample.

8. Best practice recommendations

8.1 Recommendations concerning the design of the survey

8.1.1 Description of groundwater body under study

In the context of the WFD, groundwater valuation studies will often be conducted at the **water body level**, where a cost benefit analysis has to be performed. The social survey conducted in our case study shows that the public will rarely be familiar with the notion of groundwater body or aquifer. Groundwater is generally perceived as a whole, but not as an object well delimited in space.

Unlike rivers and lakes, underground water is invisible. Moreover, most households are not direct users of groundwater, most of them being supplied by a public collective drinking water network. As a result, a majority of respondents need to be informed in details about the aquifer or water body which is valued. In most cases, it is expected that they will have little knowledge about its geographical location, its physical characteristics, how water circulates in it, etc. Detailed information shall therefore be supplied (maps, 3D diagrams, etc.) to explain the notion of reservoir, water flow, etc. Face to face interviews conducted as part of the test of our questionnaire have clearly shown that respondents can easily understand 3D diagrams and maps.

The results of the survey also show that many respondents do not know where their tap water comes from. This implies that they did not know, prior to the survey, if they were groundwater users or not.

Due to this lack of information, respondents will often be in a situation of preference construction with a risk that the stated WTP be relatively unstable over time. This may not be true where respondents are direct users of groundwater (as it is the case in most US groundwater valuation studies).

8.1.2 Survey method

Supplying a large amount of technical information to respondents represents a challenge. If face to face interviews is used, interviews are likely to last very long; moreover, the risk of interviewer bias is quite high, as an answer-reply dialogue may take place, generating a situation of heterogeneous information level. Web survey and mail survey are considered as more appropriate to convey the necessary information. Response rate are however expected to be relatively low, as reading the questionnaire may take relatively long. In the French AquaMoney case study, the mail survey was chosen to conduct the CV survey (see bellow).

8.1.3 Payment vehicle

Water bill is generally used as payment vehicles in most groundwater CV studies. This vehicle was also considered as the most suitable by the respondents we interviewed during the pre-test of our questionnaire. However, the analysis of the answers shows that many protest answers are linked to the choice of the water bill as payment vehicle. This may be due to the fact that water prices have recently risen quite sharply in certain municipalities of the case study (Vittel, 6000 inhabitants for instance). The use of a local tax, levied to protect a resource considered as a natural heritage, could have been better accepted by the population.

8.1.4 Description of the benefits

The results of our social survey show that no all respondents are aware of the benefits associated to the protection of groundwater.

To make sure that stated WTP amounts are reflecting the true value of groundwater, the description of the benefits associated to the policy scenario should be very clear. The following benefits should in particular be described where they exist:

- Groundwater is better protected against all sources of pollution than surface water (rivers and lakes). Having access to clean groundwater resources therefore represents an insurance against extreme pollution events.
- Producing drinking water with groundwater is generally cheaper than purifying surface water; this is due to the ability of the soil and geological layers coverig the aquifer to filter and purify infiltrating water, playing the role of a costly infrastructure.
- Groundwater is often accessible in large quantities which can be used in drought periods to compensate for fluctuations of surface water supplies (buffer value). Groundwater plays the role of a costly surface water reservoir.
- Groundwater ensures river base flow in summer; during certain periods of time, water flowing in rivers is exclusively coming from aquifers; in such cases, protecting groundwater is avoiding the deterioration of associated river ecosystems.

As simply shown on Table 13 bellow, these benefits will differ from one type of aquifer to another:

	Insurance against drought	Filtration of surface water	Protection against pollution	Sustaining river base flow
Karst aquifer	moderate	low	low	moderate to high
Alluvial aquifer	low	high	low	moderate to high
Sedimentary non confined aquifer	variable	variable	variable	high
Sedimentary confined aquifer	high	high	high	low
Hard rock aquifer	low to moderate	low	low	moderate to high

Table 13: Intensity of groundwater protection benefits for different types of aquifers.

8.1.5 Sampling

The sample can be stratified to be representative of:

- Groundwater uses: respondents can be selected in municipalities where tap water is produced with groundwater only and in others where it comes from surface water only or a combination of both; the sample should also contain a number of private well owner representative of the overall population (in particular in areas where many dwelling solely depend on private well and are not connected to the mains).
- Intensity of the groundwater problem (depletion or contamination): respondents can be selected in areas characterised by different levels of problem intensity. Alternatively, they can be selected in areas where the problem will take place (or be solved) at different dates (short, medium and long term).

The representativeness of the sample for other characteristics is more difficult to control as we do not have at our disposal more than a list of addresses (and possibly telephone), and no information on age, income and other socio-economic characteristics. Random sampling is therefore considered as appropriate as questionnaires are sent to several thousands of households. A stratification could be done through controlling the average socio-economic characteristics of the population per municipalities, using national statistics (e.g. select 50% of household in municipalities with high average income and 50% in low average income).

8.2 Recommendations concerning the execution of a mail survey

8.2.1 Estimation of number of questionnaires to send out

Based on our limited experience in two French case studies, we find that response rate is relatively low. This response rate was 10% in the present case study and 13% in a previous groundwater CV survey in Alsace, France (2006).

This may be due to at least two factors:

- Firstly, groundwater is not a visible resource. Unlike rivers, lakes and wetlands, it does not contributes to the landscape and it is not directly supporting leisure activities (swimming, fishing, boating). As a result, people may feel less concerned by this resource than by surface water resource.
- Secondly, the questionnaires we sent out are relatively long (8 pages in the two case studies), they contain a lot of information to read and the time needed to fill them is approximately 20 minutes. This may be quite long for a number of poeple.

8.2.2 Incentive to increase response rate

The 10% response rate quoted above was obtained with the provision of an incentive. We informed respondents that we would offer a book to 100 respondents to be selected ramdomly among questionnaires returned at a certain date. Respondents willing to participate were asked to write down their address and to state which book they would prefer in a list of 5.

More than 70% of the respondents (405/560) accepted to give their address and selected a book in the list: this suggests that the provision of an incentive was really necessary.

8.2.3 Data entry

Optical reading is a cheap way of entering data. The cost is 1,5 to 2€ per questionnaire (8 pages). It requires that the questionnaire be printed by the company doing the data entry. Answers to open ended questions have to be entered and typed by the analyst.

8.3 Meeting stakeholders' demand

The choice of the case study area and the design of the CV survey have been conducted together with regional and local stakeholder in the French part of the Rhine basin. We summarize this process and its outcome hereafter.

8.3.1 Regional stakeholders

We first had discussions with stakeholders operating at the river basin district level in order to identify their needs in terms of economic valuation of environmental benefits. Stakeholders associated to the discussion were the Rhine Meuse Water Agency, the Environment Regional Government Agency and the regional Council.

The conclusions of this first round of discussion were the following:

- The Water Agency has initiated a programme of CV studies which mainly focus on surface water resources. These studies are directly conducted by staff of Agency, using mail surveys. Although additional studies are still needed to constitute sound basis for benefit transfer exercises, producing an additional surface water body CV survey was not considered as a priority.
- Instead, stakeholders expressed a real need for studies valuating the benefits of groundwater protection. Only one study, produced by Brgm as part of the Bridge project, currently exists. This study, which was carried out in the Upper Rhine valley aquifer (Alsace), can not be representative of all other groundwater problems.
- Many groundwater bodies are considered as at risk of not achieving good chemical status, mainly due to nitrates and pesticides, but also other chemical pollutions such as chlorinated solvents. Regional stakeholders found it interesting to assess the benefits of restoring good chemical quality for one of these aquifers, selecting a groundwater body quite with different geological characteristics than the Alsace aquifer.
- The case of the Lower Triasic Sandstone aquifer was also identified as a candidate for conducting AquaMoney case study. This aquifer was ultimately preferred by stakeholders because they felt that results could be very useful to raise awareness among local politicians of the necessity to implement a groundwater management plan. It was in particular expected that the results of the survey could legitimate the development

of this plan, which necessarily have a cost and generate new constraints for water users – hence political risks for local politicians.

8.3.2 Local stakeholders

Local stakeholders operating at the level of this aquifer were then contacted (government agencies and district council). They clearly supported the idea of a survey which was briefly presented to them.

The draft questionnaire was then elaborated and circulated. Surprisingly, it generated many comments and some anxiety among staff of government agencies and district council (*département*). It is only at this point of time that they realised that conducting a CV survey was no neutral action and could generate interferences with political processes and policy implementation. There was a general fear that the WTP question would be considered as a signal given by the government that the problem had to be solved by local people without financial support from the public authorities.

Concerns were particularly strong due to the choice of a postal survey as the number of persons contacted was quite high (as compared to face to face interviews) and the questionnaire could circulate quite widely. There were fears that questions like “who is behind this survey” would immediately arise. The choice of a face to ace survey would have been preferred.

8.3.3 Recommendations based on this experience

Based on this experience, we recommend:

- to verify very early in the design of the case study how the WTP question can be perceived by local stakeholders and to make sure that the study will not negatively interfere with political or policy making processes;
- to involve local stakeholders in the design of the questionnaire; this can reduce the risk of interference but also improve the quality of the questionnaire, as local experts may identify information likely to generate protest answers;
- to insist, when presenting the survey, on the information other that related to the WTP question which can be obtained; and to highlight that this information can help policy makers and politicians to design a communication strategy, an information and awareness raising campaign; also insist on the fact that telling to their constituencies that 65% of the respondents are in favour of the policy and are willing to pay will legitimate their political action.

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