Forest management and drinking water: Case studies and recommendations

A Thesis submitted

in partial Fulfilment of the Requirements of the Degree of
Master in forest Science (Mountain Forestry)

Responsible Supervisor: Eduard Hochbichler (Ao.Univ.Prof.Dipl-Ing.Dr.nat.techn)

September 2008

Institute of Silviculture
Department of Forest and Soil Sciences
University of Natural Resources and Applied life Sciences
Vienna

Catherine DECK

Abstract

This Master thesis report has been realised in the context of the Interreg project “Alpeau” between France and Switzerland. Alpeau aims to sustain the protective functions of forest towards drinking water resources and to establish amicable contracts between local authorities responsible for water supply and forest actors.

Cases all over the world where particular forest management has been implemented to protect drinking water resources have been inventoried. The forest management measures applied at these sites and the way they are implemented (land acquisition, regulation, contract) are studied. Broad forest management principles could be highlighted.

These rules are then transposed to French and Swiss sites of Alpeau project. Forest management recommendations are made and propositions of contracts establishment are suggested.

Acknowledgment

I would like to thank all the persons who have helped me during this Master thesis and contributed to the realisation of this report. And especially:

- My supervisor in Austria, **Eduard Hochbichler** (Ao.Univ.Prof.Dipl-Ing.Dr.nat.techn) from Vienna Boku University, for the help he brought to me ;
- My supervisor in France, **Claude Barthelon** (Water and risks coordinator in Rhône-Alpes region of ONF- French national forest agency), and **Olivier Ferry** (Director of the development service in Rhône-Alpes region of ONF - French national forest agency), for the support and the trust they gave me ;
- All the water and forest managers I contacted, in several countries, for their collaboration, the time they gave me and the interest they showed in my work ;
- The service of the ONF of Grenoble for their welcome ;
- My tutor in ENGREF (Ecole nationale du génie rural des eaux et forêts – French National Forest School), **Eric Lacombe,** who gave me precious advice to lead this study.

I sincerely appreciated to work on the links between forest management and drinking water quality and to include many different countries in my research area. This topic really interested me a lot and I wish I will be able to follow Alpeau evolutions and results within the next coming years.

This Master thesis work brought me a lot both professionally and personally.

Table of contents

List of figures

List of tables

List of acronyms

BMP : Best management practices
DNR : Department of Natural resources (Etats Unis)
DWSP : Division of Water Supply Protection (Boston)
ENGREF : Ecole nationale du génie rural, des eaux et des forêts (= National French School of Forestry)
FC : forêt communale (= city owned forest)
IWB : Industrielle Werke Basel
ONF : Office national des forêts (=French State Forest Agency)
PPE : Périmètre de protection éloignée (= remote protection zone)
PPI : Périmètre de protection immédiate (= immediate protection zone)
PPR : Périmètre de protection rapprochée (=inner protection zone)
SIEM : Syndicat intercommunal des eaux des Moises
SM3A : Syndicat mixte de l'aménagement de l'Arve et de ses abords
SWM : Satdt Werke München
TMWB : Tokyo Metropoplitan Waterworks Bureau
USDA: United States Department of Agriculture
WAC : Watershed Agricultural Council (New York)

1. Introduction

Having drinking water is the first necessity.

But, whatever their superficial or underground origins, human activities can degrade this resource.

In many places in the world, people noticed that underground water coming from forests has generally a better quality than water coming from agricultural or urban watersheds. Forest produces a cheap and good quality drinking water.

Some local cities try to develop this resource and to understand better the role of forests.

Water policies have created many tools to treat water and punctual pollution sources, but they have less developed support to activities that guarantee good water quality. The regulations to protect drinking water catchment points are necessary but not sufficient. In farm and forest lands, prescriptions are often not well defined, not well understood and not well applied.

Protection zones are not always coherent and prescriptions are fixed without any possibility of evolution. Local stakeholders wonder about the relevance of these constraints, all the more as, sometimes, the identification of forest owners is already a huge difficulty.

On a technical level, the protective functions of forests are recognised as essential by the scientific community but they are not taken into account in water policies.

An interreg project, called « Alpeau », is being elaborated between France and Switzerland. This partnership aims to consolidate and sustain the protective role of forest for drinking water resources. Its objective is to establish amicable contracts between local authorities responsible for water supply and forest actors.

Managers of this project proposed me to work to prepare the Alpeau project, during my master thesis which took place from February to August 2008, in Grenoble (France) at the French National Forest Agency (ONF).

The first objective of my thesis is to realise a prospective study of sites, in the world, that have adopted a particular forest management to protect their drinking water resources. This study concerns both technical forest measures but also modalities to implement them (land acquisition, regulation or contracts). The goal is to make a synthesis of scientific research publications about the interactions between forest and water quality and to learn international experiences in this field to define « good practices » and their associated modalities of implementation.

The second objective is to propose recommendations that can be applied in French and Swiss sites of Alpeau project or to give them ideas that could be implemented later in the scope of this interreg project.

2. Presentation of the Alpeau project and of the legal context

2.1 Presentation of the Alpeau project

The Alpeau project is an interreg program between France and Switzerland, which will start in November 2008.

The ONF is leading this project in France and the University of Neuchâtel is leading the project in Switzerland.

The main objective of the project is to show in order to sustain drinking water resources; it is possible to establish direct amicable contracts between local authorities responsible for water supply and forest owners or managers.

The creation of a common method in France and Switzerland to establish contracts between forest and water managers by the means of this project and to give tools to implement them, is a major innovation and the outcome of several long processes in this alpine region.

A panel of pilot sites has been chosen in France and Switzerland to represent the diversity of the region around Leman Lake, including the Alps and Jura mountains. In each site, both water and forest managers collaborate, which is rather innovative in such projects.

There are three sites in France, all situated in the Alps: Moises-Forchat (Haute Savoie), Arve watershed (Haute Savoie) and Chambéry (Savoie).

There are four sites in Switzerland, situated in the most western part: Côte (Vaud), Broye (Fribourg), Areuse gorges (Neuchâtel) and Lausanne.

Figure1 localises the sites in the Alps.

The Alpeau project will implement actions site by site, but also transversal actions for all sites. Among these transversal actions, a prospective study of sites that are already protecting drinking water with forests is programmed.

My thesis work is totally linked to this action.

2.2 Legal context: current legislation about drinking water protection zones in France and in Switzerland

2.2.1 Legislation in France

Drinking water in France comes from more than 36 000 public catchment points. Their type and number varies in function of regions.

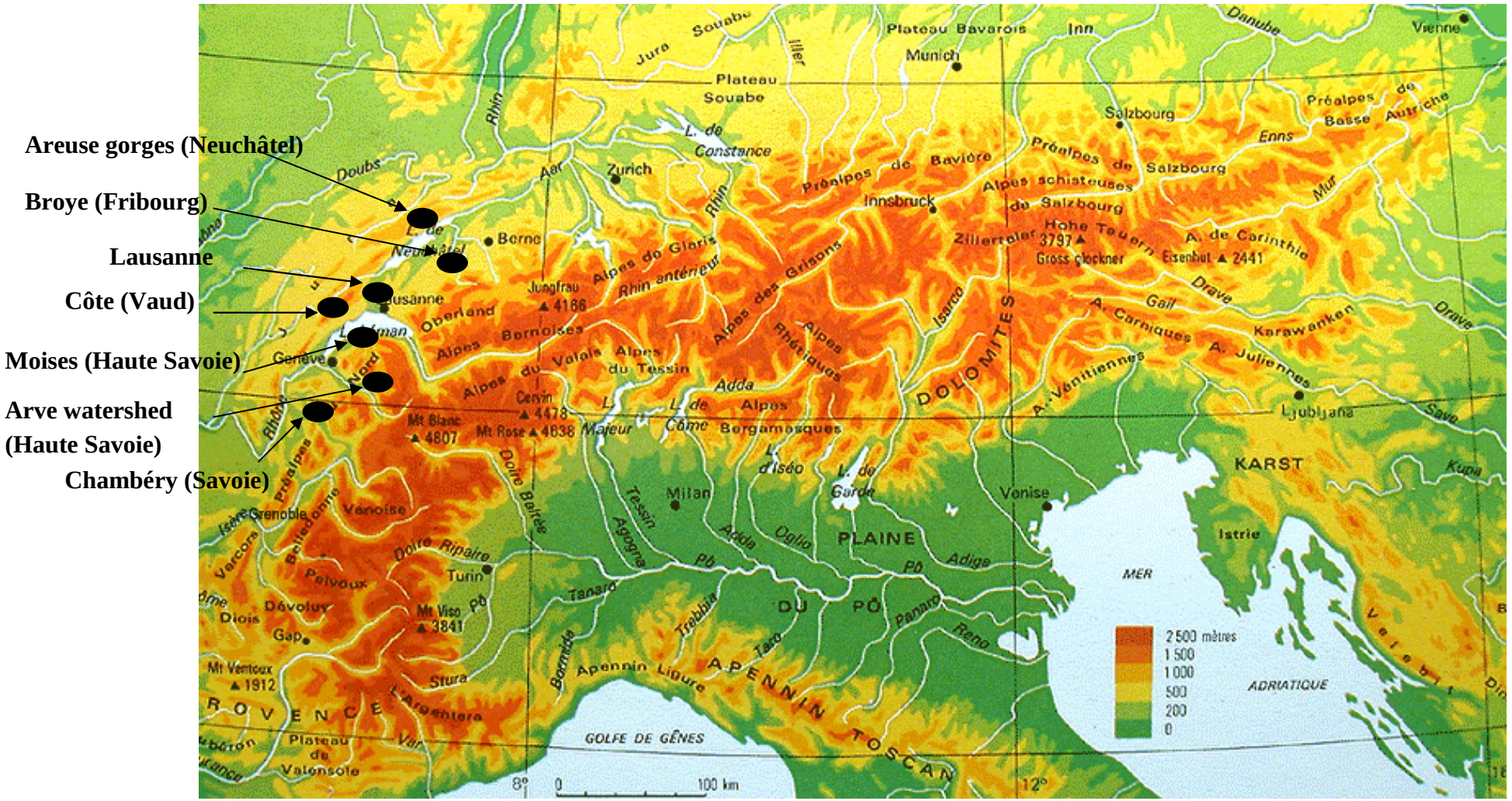
Whatever the catchment type (superficial or underground water), water quality is degraded because of human activities. Water catchment protection is therefore a high necessity.

Laws in 1964 and in 1992 made the protection of each catchment compulsory, with the determination of a protection zone.

But the procedure is long and only half of catchments (70 % of water volume) have a protection zone today.

The protection zones are defined around catchment points after a hydrological study and are validated by the State.

Figure 1: Localisation map of the Alpeau sites
Source of the map: www.alpimages.net/cartes/alpes.php.



Three protection perimeters are defined (figure 2):

- **Immediate protection zone** (« périmètre de protection immédiat » - **PPI**): first level of protection, compulsory. It aims to prevent from direct pollution in the water catchment. This area is usually bought by the water supplier and fenced. No activity is allowed inside, except those linked to the catchment maintenance (picture 1).

Picture 1: Typical PPI situated in forest, deforested and fenced (Masevaux, April 2008)

- **Inner protection zone** (« périmètre de protection rapproché » – **PPR**): this protection area is extended around and upstream the water catchment point. Its shape and area depend on the geologic and topographic context. It can go from 1 to more than 10 ha. It aims to prevent from underground water flow pollution. Human activities are restricted.
- **Remote protection zone** (« périmètre de protection éloigné » - **PPE**): this zone is not compulsory. Its area varies a lot in function of the situation. It corresponds to a restricted watershed. Human activities can be regulated.

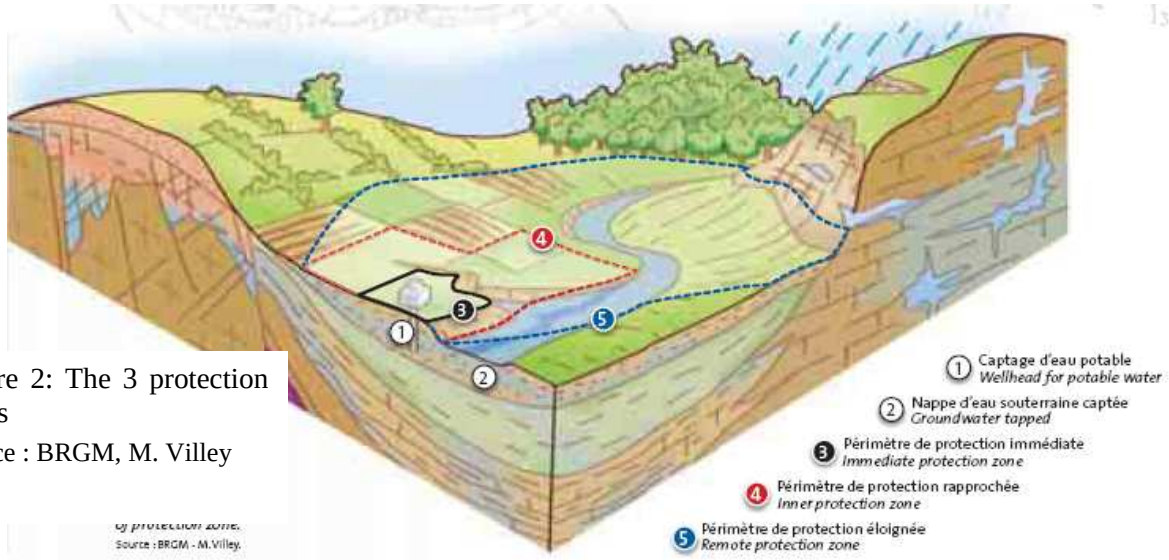


Figure 2: The 3 protection zones

Source : BRGM, M. Villey

2.2.2 Legislation in Switzerland

The Swiss legislation presents the same principles.

Three S zones of protection are defined.

- **Zone S1**: Immediate protection zone; it has to prevent from direct pollution; it has to be fenced (except in forest).
- **Zone S2**: Inner protection zone; it has to prevent from liquid pollution or pollutant input (like fuels).
- **Zone S3**: Remote protection zone; this is a buffer zone; it is a protection against dangerous activities or infrastructures.

In karstic environments, all sensitive zones of the watershed can be classified as S1 zones, which can be very huge areas.

The fundamental difference between France and Switzerland legislations is that, in Switzerland, the rules are the same for every catchment. They are defined by the Federal State. In France, the regulations are adapted to every catchment. They can differ a lot in function of the context but also be very incoherent.

3. Objectives of the thesis method

3.1 Presentation of the objectives

Two of the main actors of the Alpeau project in France at ONF, Claude Barthelon and Olivier Ferry, proposed to work in order to prepare this project.

As the thesis takes place before the official start of the project, the goal for me was to produce a first explorative study. The concrete objectives given were:

- Realise a case inventory where a particular forest management has been implemented towards drinking water protection purposes.
- Analyse these sites/cases to establish a typology of the different forest management methods that protect water resources, and identify the best ones.
- Give recommendations of forest management for two or three sites of the Alpeau project, according to the previous typology. The goal is also to create a dialog with the Alpeau partners of the site: local administration in charge of water resource, foresters…

The schedule initially expected to follow was:

- bibliographic study, taking contacts: 1 month;
- data collection, field trips: 3 months;
- analysis and final report writing: 2 months.

3.2 Presentation of the actual employed procedure

Different steps have been followed during the thesis work. Some of them have been slightly modified compared to this previous frame. The complete analysis of all the Alpeau sites (and not just two or three of them) took more time.

Scientific literature was first gathered to make a bibliographic study to know better the interactions between forest and drinking water.

Cases have been searched, all over the world, where forest is specifically managed to protect drinking water resources. This study concerned both the particular forest management measures and the type of action used to implement them (land acquisition, contracts with owners…). The data collected helped me to highlight general forest management and implementation principles.

The third step of the thesis work has been to study the main characteristics of the French and Swiss Alpeau sites. The ultimate goal was to give recommendations or to bring ideas that could be implemented during the Alpeau project.

Finally, as a last step, a critical discussion of the work has been made, to suggest potential improvements.

The structure of this report follows the same chronological articulation.

4. Methods and data collection

4.1 Scientific context

I first collected information to point out the main scientific results about the interactions between forest management and drinking water.

I tried to gather as much as possible literature about this topic and to find scientific papers from many different countries. I found scientific journals and publications in libraries, through the Internet, and by contacts I had with researchers.

The synthesis of this bibliographic study can be found in paragraph 5.1.

4.2 Case studies

4.2.1 Site inventory all over the world

One of the main objectives of my thesis is to inventory and to study cases all over the world where forest is specifically managed to protect drinking water resources.

Cases have been found on the Internet and in scientific reports that quoted some examples. When I had the information that one site had implemented particular forest management concept and measures to protect its watershed, I looked on websites, contacted managers, asked for information. Sometimes they knew about another similar site, and so on.

This step of my thesis work was pretty long and laborious, but very interesting. A wide majority of water or forest managers I contacted were very interested in my work and are waiting for the final results. They also pointed out that they were lacking of exchanges of experience between sites.

I mainly found sites in Europe and in North America (and one ine Japan). I could only gather sufficient information for these sites. I really regret I did not have enough time to search more in Asia, Africa, Oceania and South America. I found some interesting sites in these continents but I could not have, in time, any contact there that could tell me more about forest management.

My case studies is made of these 12 sites:

- in France: Vittel, St Etienne, Masevaux;
- in Germany: Munich, Hanover;
- in Switzerland: Basel, Winterthur;
- in Austria: Vienna;
- in the USA: Boston, New York, Baltimore;
- in Japan: Tokyo.

4.2.2 Procedure to identify the most important case studies

I compared the 12 sites with the first information I could collect for each of them (appendix 1), according to different criteria.

- <u>Presentation of the criteria</u>

The comparison criteria are:

- type of catchment: catchment of deep water or surface water, stream catchment;

- number of m^3 of "produced" water/day, with corresponding number of people supplied;
- area of the total watershed;
- area of the protected zone of the watershed;

Usually, only one information concerning the area is known (either the total area, or the area of the protected); the ultimate goal is to know both, if possible.

- percentage of forest cover over the watershed;
- type of action: land acquisition, contracts with owners, scientific research, public education, payment of environmental services;
- Peculiarities of forest management over the watershed: species composition, silvicultural treatment, restrictions of harvesting operations, regulation of the use of chemicals…

With the first information received, the sites have been graded for each of these criteria in order to rank them. The goal is to point out the most interesting ones to study in priority.

- Weight given to the criteria

It is difficult, as a first approach, to give more importance to one criterion than to another.

However, 2 criteria, the number of m^3 and the area of the watershed (either the total area, either the protected zone area), give more or less the same information about the size of the watershed. Therefore, in order not to give more importance to large sites and, as a consequence, bias the grading, these 2 criteria will be given a weight of 0,5 and all the other criteria a weight of 1. As a result, to this "global size criterion" will be attributed a weight of 1, like to the other criteria.

- Explanation of the grading

Each criterion has a grade out of 4. 1/4 is the lowest grade, 4/4 is the highest. The thresholds are subjectively fixed in order to have a balanced distribution of the grades among sites.

For each site, all the grades are summed up to give a global "grade of interest".

Below is following the explanation to grade the criteria:

- **Type of catchment**: the shallow catchments or catchments in karstic areas have a high grade, because they are very sensitive to forest management and pollution. Catchments of deep water receive a lower grade.
- **Number of m^3**: the more water, the higher grade.

1/4: Number of m^3 < 50, 000

2/4: Number of m^3 between 50, 00 and 200, 000

3/4: Number of m^3 between 200, 000 and 1 million

4/4: Number of m^3 > 1 million

- **Area of the watershed**: the larger area, the higher grade.

1/4: area < 10, 000 ha

2/4: are between 10, 000 and 50, 000 ha

3/4: area between 50, 000 and 100, 000 ha

4/4: area > 100, 000 ha

- **Area of the protected zone of the watershed**: the larger area, the higher grade.

1/4: area < 1, 500 ha

2/4: area between 1, 500 and 10, 000 ha

3/4: area between 10, 000 and 50, 000 ha

4/4: area > 50, 000 ha

As only one of these 2 area criteria is known, there is no bias left to calculate the final grade.

- **Percentage of forest cover**: the more forest, the higher grade.

1/4: percentage < 25 %

2/4: percentage between 25 and 50 %

3/4: percentage between 50 and 75 %

4/4: percentage > 75 %

- **Type of action**: the more a site has developed its types of action, the more it receives a high grade. Only land acquisition is graded 1/4. Land acquisition with contracts with farmers receives 2/4. Land acquisition with contracts with farmers and forest owners, and education receives 3/4 to 4/4.
- **Peculiarities of forest management**: the more is done to protect water resources, the higher the grade.

1/4: no particular protection measure

2/4: information/education of foresters, encouragement to have management plans

3/4: different measures about silvicultural treatment (irregular usually), species diversification, harvesting restrictions, restricted use of chemicals, education…

4/4: application of all these measures

- Results

Out of this ranking, the most interesting sites are Baltimore, Vienna, Boston, St Etienne (France), New York, Masevaux (France) and Munich. Therefore, these sites will be the first ones to be studied thoroughly.

- Discussion

Some critics can be formulated concerning the employed method:

- Some criteria are not filled (because of lack of information) and therefore the final grade these sites receive is not significant.
- Data is sometimes very uncertain for a few sites; as a consequence, the final grade is also very uncertain.
- The attribution of weights and thresholds for the grading is debatable.
- The case of the site of Basel is particularly penalised by this method, because it is very different from the other ones and therefore it does not fit to the criteria. This site will be therefore studied with attention, despite of its low final grade.

I thought of making a more rigorous analysis, like a multi-criteria analysis. But I abandoned this idea because of the too small sample (only 12 sites) and because the criteria did not fit to every site (case of Basel, for example). Therefore, a more complicated analysis would certainly not have showed more interesting results.

Here, my objective was only to highlight the main characteristics of the sites and point out the most interesting ones, to know which one study in detail would be in priority. I studied each of them afterwards anyways.

4.2.3 Construction of a questionnaire

This questionnaire is available in appendix 2.

Briefly, the main asked points are:

- **Presentation of the situation :** area of the total watershed, area of the protected area of the watershed, percentage of forest cover over the watershed, number of people relying on drinking water from this watershed, number of m^3, price of water;
- **Type of action :** scientific research, land acquisition, contracts with forest owners/farmers, regulations, information of the public, education … ;
- **Management implemented for the protection of drinking water :** *particularities of the forest management over all the watershed area (*tree species composition, silvicultural treatment, harvested volume per cut, regulation/restrictions for harvesting, use of chemical products/ pesticides…), *particularities of the forest management just around the water catchments points (above the water pipes), forest road network (*density, particular measures to prevent erosion processes or surface water streaming), *hunting and recreation management, pasture land or agricultural land management ;*
- **Forest situation :** *forest characteristics (*geologic situation, main types of soils, topographic situation, natural forest communities, actual situation), *forest management* (actual management, articulation between forest management plans and watershed management plan), *ownership* (percentage of public or private owners) ;
- **Relationships between the actors / stakeholders :** relationships with private forest owners, problems or conflicts, others actors/ stakeholders, relationships with research organisms ;
- **Costs :** estimation of the cost (or extra-cost) linked to drinking water objective in forest management, how it is financed ;
- **Evaluation of water quality and of the action plan :** monitoring before/after implementation of the watershed action plan, further water treatment, global evaluation of the action plan, improvements in the future ;
- **References.**

4.2.4 Data collection

I filled in this questionnaire firstly for the most interesting sites identified before, to give them more time.

The data came from management plans and other documents I could find on the Internet and from mail interviews I had with the managers.

For some sites, I could not get all the information I wanted because the managers could not or did not want to answer all my questions.

I also had the great opportunity to visit the sites in France (St Etienne, Vittel and Masevaux), Munich and Vienna. The direct interviews with the managers and field trips I could make there were very fruitful and rich for my study.

All the filled questionnaire forms are shown in appendix 3.

4.3 Application to Apleau sites

The second objective of my thesis is to use all the collected information to give recommendations to Alpeau sites.

The first step has been to collect data on French and Swiss Alpeau sites. I used for this a similar questionnaire to the one from the previous inventory (appendix 5: questionnaire for Alpeau sites).

The different asked points are:

- Presentation of the situation : type and number of catchment points, watershed area, protected zone area, estimation of forest cover, number of people supplied with water, number of m^3/day, price of water ;
- Actual water supply system : actors, water treatment, protection measures around catchment points, quantity and quality of water, encountered problems ;
- Actual situation of the forest : forest sites, management in public and private forest, ownership, forest road, hunting, tourism, pasture land ;
- Relationships between actors : between forest and water managers, with private owners, problems or conflicts, other relationships ;
- Expectations of Alpeau site managers: interest in this project, objectives…

To obtain this information, I went to each site to meet managers and see the situation. The descriptions of the Alpeau sites are in appendix 6.

5. Results

5.1 Scientific context: bibliographic synthesis of the interactions between forest and drinking water

5.1.1 The soil-plant-water system

5.1.1.1 Water fluxes and infiltration process

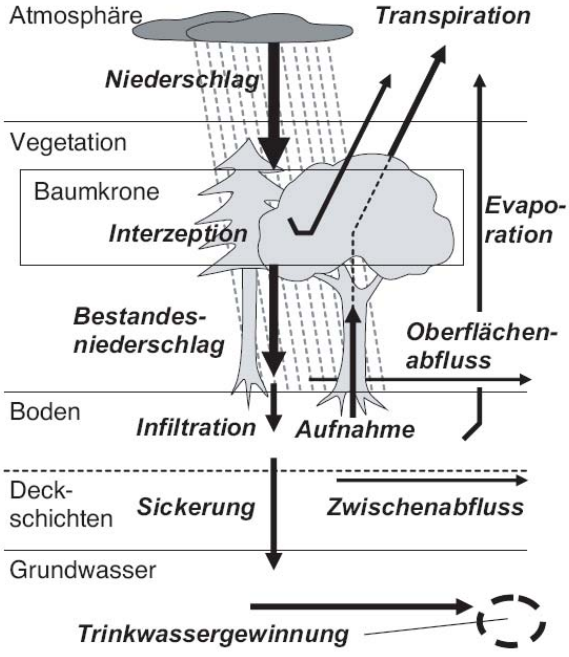
In forests, many water and substance fluxes influence the quantity and the quality of the water that infiltrates in the soil.

The main water fluxes going through the compartments of this system are described on figure 3. Vegetation (mostly leaves and needles from trees) intercept precipitation. Interception varies from 15 to 33 % for broadleaved trees, from 20 to more than 50 % for conifers (COMBE, 2005). The season also influences interception.

This water can then:

- Infiltrate in the soil as through fall or stem flow,
- or move back in the atmosphere by evaporation.

Water storage in the soil depends on the type of the soil (soil type, soil depth, porosity, etc.). The type of vegetation influences the water quantity which will be taken by the roots or directly evaporated in the atmosphere on the soil surface (interception, stem flow, shadow, litter layer). The part of water that is not stored in the soil, or not absorbed by the roots, infiltrates into the aquifer water through superficial soil layers.



Atmosphäre	atmosphere
Niederschlag	precipitation
Baumkrone	canopy
Interzeption	interception
Bestandesniederschlag	throughfall
Oberflächenabfluss	surface runoff
Boden	soil
Aufnahme	uptake
Deckschichten	superficial horizons
Sickerung	percolation
Zwischenabfluss	hypodermic flow
Grundwasser	water table
Trinkwassergewinnung	drinking water catchment

Figure 3: Water fluxes
Source: Hegg,C. et al.(2004). *Wald und Trinkwasser*. WSL

Water coming from several small watersheds infiltrates in the same aquifer water. The transport duration and mixing/transformation processes depend on the type and characteristics of the aquifer (unconsolidated materials, fault, karst).

Figure 4 represents the main substance fluxes determining components concentration in water. Snow and rain contain components from aerosols and gases (humid deposition). Dust and particles also accumulate on vegetation (dry deposition).

Leaves and needles act like a filter to catch these depositions, but the quantity of intercepted pollutants depend a lot on tree architecture (HEGG, 2004). Water that evaporates from leaves is pure, therefore the concentration of the deposited components increases in the water that remains on the tree and reaches the soil. This process is called the purification effect of tree crown (HEGG, 2004).

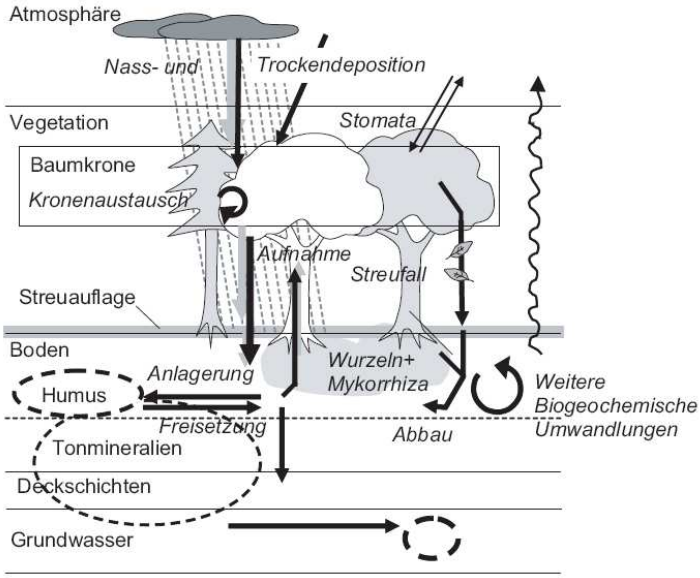


Figure 4: Substances fluxes
Source: Hegg,C. et al.(2004). *Wald und Trinkwasser*. WSL

Atmosphäre	atmosphere
Nass- und Trockendeposition	dry and humid deposition
Baumkrone	canopy
Kronenaustausch	exchanges between tree crowns
Aufnahme	uptake
Streufall	leave fall
Streuauflage	litter layer
Anlagerung	deposition
Freisetzung	releasing
Wurzeln+Mykorrhiza	roots and mychorriza
Abbau	decomposition
Weitere Biogeochemische Umwandlungen	other biogeochemical modifications
Tonmineralien	clay minerals
Deckschichten	superficial horizons
Grundwasser	water table

Forest soil also purifies water. In the underground water of a forest soil, substance concentrations are modified by different processes:

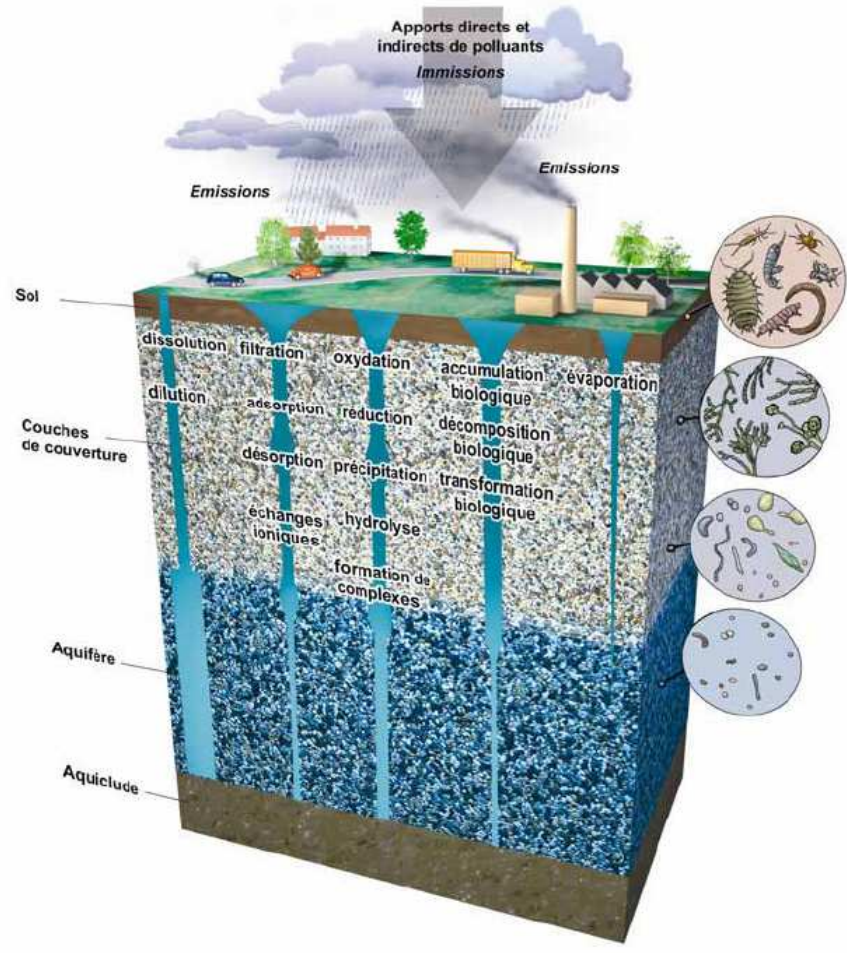
- deposition on humus and clay minerals (ions exchanges),
- uptake of substances by roots,
- fixation in biomass and other biogeochemical transformations.

These transformations are influenced by pH values and Oxygen quantity (redox reactions). Biogeochemical transformations can also solubilise solid substances present in the soil or biomass, this is the process called mobilisation (HEGG, 2004).

Auto-purification phenomena that occur in soils, mainly in horizons A and B, have a very important impact on water quality (fig. 5). Solid particles are filtered and dissolved particles are adsorbed or transformed by biochemical phenomena. Adsorption takes place mainly on clay, oxides and humic substances.

A big part of the pollutants present in infiltration water is retained and degraded in the superficial part of the soil. Auto-purification phenomena decrease in the non saturated zone of the soil. And in the saturated zone, dissolved substances are transported rather quickly on huge distances with

underground water; the decrease of the concentration of these pollutants is then mainly realised by dilution.



sol	soil
couches de couverture	superficial layers
aquifère	aquifer
aquiclude	impermeable rock
emissions	emissions
apports indirects de polluants	indirect input of pollutants
dissolution	dissolution
dilution	dilution
filtration	filtration
adsorption	adsorption
désorption	desorption
échanges ioniques	inonic exchanges
oxydation	oxydation
réduction	reduction
précipitation	precipitation
hydrolyse	hydrolyse
formation de complexes	complex formation
accumulation biologique	biologic accumulation
décomposition biologique	biologic degradation
transformation biologique	biologic transformation
évaporation	Evaporation

Figure 5: Elimination of pollutants in soil and underground. The column width variation corresponds to the relative efficiency of purification phenomena during water infiltration.
Source: Instructions pratiques pour la protection des eaux souterraines (2004). Office fédéral de l'environnement des forêts et du paysage, Berne

5.1.1.2 Factors determining the capacity of a soil to produce good water quality

Several factors have to be taken into account to determine underground water vulnerability for a particular soil.

The DRASTIC method is a well known method used by hydro geologists. Its main principles are described below (SANTE CANADA, 1997).

This method relies on three hypotheses:

- Potential pollution sources occur at the soil surface ;
- Potential pollutants go from the soil surface to the aquifer through infiltration ;
- The nature of potential pollutants is not taken into account.

The seven letters of « DRASTIC » represent the seven factors determining the vulnerability index. These factors are:

- D : depth of water table (5) ;
- R : recharge or infiltration (4);
- A : aquifer media (3) ;
- S : soil media (2) ;
- T : topography (1) ;
- I : impact of vadose zone (volume of soil from 1 meter depth to the water table) (5) ;
- C: conductivity (3).

A weight is associated to each factor (coefficient from 1 to 5 corresponding to the figure given into brackets after each factor just above). The most important factors are the water table depth and the impact of vadose zone, then infiltration, then aquifer media and conductivity, lastly soil media and topography.

A value from 1 to 10 is then attributed to each factor. The lowest value represents the lowest contamination vulnerability. All these values are then multiplied with their associated weight and finally summed up to give the global vulnerability value of a particular hydro geological unit.

The global trends to consider are:

- The deeper the water table, the less vulnerable the site is.
- The more annual infiltration, the more vulnerable the site is.
- Karstic aquifers are the most vulnerable, then sandstone. Metamorphic rocks are the less vulnerable.
- Shallow soils, gravels and sandy soils are very vulnerable. Loams have an average sensitivity. Clays are the less vulnerable.
- The steeper the terrain, the less vulnerable the site is.
- Karstic or basaltic vadose zones are very vulnerable. Then are the sandy vadose zones, sandstone and shale. The less vulnerable ones are made from clay.
- The higher conductivity, the more vulnerable the site is.

5.1.2 Forest roles on underground water

The following results are based on different bibliographic study, in particular from JENNI (2000).

5.1.2.1 Quantitative aspect

Infiltration is higher in forest soil than in any other soil.

Forest influences hydraulic conductivity and, as a result, infiltration capacity of the soil. Under a forest, soils present a very deep and efficient porosity, because of biologic activity and deep roots. In addition, the permanent vegetation cover in forest decreases the risk of crusts formation (due to erosion) and losses by runoff.

Forest soil and its litter layer allow better infiltration and create a high water storage capacity (DUFOUR, 2006). Absorption capacity can be enormous but depends on soil type (BENOIT, 1999). For all these authors, forest soils act like a sponge.

Vegetation limits runoff (COMBES et al., 1995) but favour infiltration.

Forest consumes more water than any other vegetal cover.

Forest intercepts a part from precipitations falling on the ground.

Evapotranspiration of deciduous trees is 20 % higher than coniferous trees (GODI, 2005). In spring transpiration is higher in coniferous stands, but later is higher in deciduous (GODI, 2005). Trees with their deep roots can also better use water stored in soil.

Forest soil structure also limits runoff losses.

5.1.2.2 Qualitative aspect

Forest is the best soil cover in watersheds.

There are very few pollutants inputs in forest ecosystems. Usually, carbon, phosphorus and nitrogen cycles are balanced and there are no or very few losses. Many studies show that nitrogen concentrations are lower in forest soils than in any other soils.

Water quality depends on forest type.

Nitrification is active in aerobic conditions and in soils rich in Ca^{2+}. Under tempered climate, in a deciduous forest, nitrogen absorption is almost equal to annual mineral nitrogen production in mull humus (DUCHAUFOUR, 1997) and there are few losses into underground water.

In acidic or less oxygenated soils (moder humus, coniferous forests), ammonification is the main process. Ammonia is adsorbed on clay and releases H^+ and Al^{3+} ions. As a consequence, the soil is acidified. Coniferous canopy catches more air pollutants, leaching is therefore higher. Moreover, in acidic soils, there is less buffer effect. Forests can therefore receive more nitrogen than they can use it. There is a risk of nitrogen saturation and that nitrogen infiltrates into underground water.

The situation is different in riparian forests where denitrification by micro-organisms plays a very important role (DUFOUR, 2006). Riparian forests could then store more nitrogen than they need it.

Passive and active protection of forests can now be distinguished.

By its presence, forest decreases or prevents from activities that could endanger water quality (no fertiliser or pesticides, no dangerous materials deposition). This is the passive protection of forest.

Active protection encompasses all processes where forest influences directly water quality and quantity. In forest, biochemical cycles are balanced, water infiltrates better, roots structure the soil and therefore water can be better in contact with humus or clay minerals. Forest soils really purify water. But this effect can be affected by air pollution and deposition on canopy.

5.1.3 Forest management influence

5.1.3.1 Influence of a forest cut

- In quantity

Many studies show that, after a forest cut, runoff increases and there is more superficial water flowing in the watershed. But there are few studies concerning underground water flows after a forest cut and results are contradictory (JENNI, 2006).

- In quality

The influence of a forest cut depends on the type of cut. Main cut types studied in the literature are clear cut, strip cut and single tree cut (JENNI, 2006).

Studies show that the presence of natural regeneration has a very huge impact on underground and superficial water quality. This means that the effects of a windstorm or a clear cut depend a lot on the forest site.

Harvesting wood modifies or stops natural biogeochemical cycles and some harvesting methods can increase temporary nutrients leaching. Because of this, no clear cut should be made in zones saturated in nitrogen. After a clear cut, sun radiation coming to the earth is more intense, temperature increases in organic horizons and therefore mineralisation and nitrification increase (DUFOUR, 2006).

Moreover, the increase of water that infiltrates into the soil after a clear cut increases nitrogen leaching during the first years.

This phenomenon has been recorded in many studies. WENGER (2002) found that this effect can happen after a 1 000 m² cut. Progressive cuts that maintain forest cover on the ground limit nitrogen migration in infiltration water. But the amount of nitrogen that is leached depends a lot on forest site and on the nitrogen saturation.

Regeneration decreases nitrogen leaching after a cut (JENNI, 2006). Therefore it is very important to have successful regeneration in forest areas.

Tree branches and cullwood also accumulate nitrogen (DISSMEYER, 2000). But their removal from forest has to be thoroughly examined because other very important nutriments are exported at the same time (Ca^{2+}, Mg^{2+}, etc.).

The area of forested land is also important regarding atmospheric deposition. Deposition decreases from forest border to the middle of the forest. Therefore, small dispersed forests accumulate more pollutants than a huge continuous forest (JENNI, 2006).

Studies in the USA have shown that accelerated nutriment leaching did not occur after heavy cutting, but did follow when herbicides sustained barren conditions after clearcutting. Sediment increases in in-streams exports are minor and short-lived and mostly from roads when best managment practices (BMP) are conscientiously employed (ADAMS et al.;2002).

Another study found that forest practices with the greatest potential for causing erosion and stream sedimentation are road construction, tractor skidding of logs and intensive site preparation (STEDNICK, 2000). Undisturbed forest watersheds usually have erosion rates around 0.57 ton/ha/year. Typical timber harvesting and road construction activities may increase rates to 0.11 until 0.57 ton/ha/year. More intensive site preparation treatments such as slash wondrowing, stump shearing, or roller chopping may increase soil erosion rates up to 11.4 ton/ha/year.

However, many different studies have shown very different results and therefore it is not possible to generalise any of them. Some show that cuts have a huge impact on nitrogen release, some do not show that.

Yet it is possible to summarize that:

Clear cuts induce a sudden and strong nitrogen increase in underground water.

Water quality remains acceptable, except excessive suspended matter loads because of logs extraction.

This influence is limited in the time.

5.1.3.2 Influence of tree species

Infiltration is higher under deciduous trees than under conifers.

In winter time, infiltration is much higher under deciduous trees than under conifers. During the vegetation period, infiltration is higher under young stands and is independent from tree species (JENNI, 2006).

There is less nitrogen losses under deciduous trees than under conifers.

On the one hand, nitrogen cycle is better balanced under deciduous trees:

- Soils are usually less acidic and biologic activity more efficient in deciduous litter ;
- Broadleaved trees have deeper roots and therefore catch more nitrogen.

On the other hand, the « acidic rain » effect is stronger in conifer stands:

- There is more nitrogen deposition on canopy and more nitrogen input in the soil: except alder and acacia trees that fix nitrogen, deciduous trees catch less atmospheric pollutants.
- Soils are more acidic and cannot buffer pollutants inputs. The water saturated zone is reached quicker by pollutants.

To end with, deciduous trees consume less water than conifers. For example, ROETHE et al. (2002) measured that annual percolation fluxes are 223 mm under spruce stands and 329 mm under beach trees in Bavaria. Therefore, for the same quantity of leached nitrogen, the concentration is higher under conifers.

5.1.3.3 Influence of tree age

There is less nitrogen losses under a young growing forest than under an old forest.

In a mature forest stand, nutrient uptake by roots is lowered. In addition, the « acidic rain » effect is more important in mature forest because the canopies are bigger and pollutant interception is higher.

Synthesis

Forest is definitely the best possible cover to protect drinking water catchment areas.

The forest stand age and composition, the type of soil and forest management influence significantly water quality.

In deciduous forests, the nitrogen cycle is well balanced and there are less nitrogen losses. These ecosystems can absorb huge nitrogen quantities. Even natural perturbations (wind throw, fire…) or clear cuts have little impact on underground water quality, except excessive suspended matter loads because of logs extraction.

Forest ecosystems that contain more nitrogen (acidic rain, pure coniferous stands) are more sensitive and forest management is therefore more important.

5.1.4 Basics for “Management concepts”: introduction of the Hydrotop model

The city of Vienna has developed with the University of Bodenkultur a new scientific model, the hydrotope concept.

Hydrotopes are defined as areas with (relatively) homogeneous hydrological conditions (GURTZ, 1999; ENGEL, 1996). All different forest communities act in a specific way on a forest-hydrological level, which is caused by the hydrological differences between the specific tree species. As a result of the different actuation of tree species on a forest-hydrological level, the hydrotope system was regarded as appropriate for the stratification task within the headwaters region (KOECK et al., 2007).

The natural forest community was regarded as the most important stratification category of the hydrotope model and was therefore selected as the uppermost stratification level. The uppermost stratification level is an orientation framework, which categorises the headwaters region by creating operational units. In addition, the natural forest community reflects other information layers of the hydrotope system, like soil type, bedrock type (geology) and elevation above sea level (relief parameters). The further advantage of the hydrotope model is that it is possible to define optimal and suboptimal states of each hydrotope.

This model is a management tool to define, in each forest site, which is the ideal stand to optimise the water protection functionality of the forest stands (KOECK et al., 2007a).

5.1.5 Paying forest for its services

5.1.5.1 Different evaluation techniques of forest amenities

Few functions and services offered by forest ecosystems are directly tangible. Their value depends on the social and economic context. They are complex goods that procure a different satisfaction in function of each individual. This satisfaction corresponds to the direct or indirect use of these goods, or to the simple existence of these goods.

The main methods to evaluate forest goods are given in the following table (table 1).

Source : CEMAGREF, Unité de recherche agriculture et forêts méditerranéennes (1992). Usages et fonctions multiples de la forêt méditerranéenne. Guide technique du forestier méditerranéen français, chapter 8

Function	**Main evaluation method**
Recreation Hunting Picking Pasture	Substitution method Marginal productivity method Opportunity cost method
Education Landscape Culture Hydro regulation Soil protection Purification Climate regulation	 Travelcost method Contingent method Hedonist prices method Avoided cost method
Symbolic Scientific Biodiversity	Contingent method Expected productivity method

Table 1: Economic evaluation functions of forest functions

5.1.5.2 Examples of environmental payments services in the world

Here are some examples of environmental payments services taken from IUCN (2006). Establishing payments for watershed services.

- **Sustainable water management in the Catskill and Delaware watersheds, USA**

The Catskill and Delaware watersheds provide New York City's 9 million residents with 90% of their drinking water supply. Historically, these watersheds have supplied high quality water, but in the 1980s concerns about pollution increased. In 1992, the City of New York decided to invest in protecting watersheds rather than new water filtration facilities, which would have cost US$ 6 to 8 billion to build and US$ 300 million annually to operate. The costs of investing in watersheds to maintain and restore natural filtration are much lower. Diverse mechanisms for investment in the watersheds are used. Investment of US$1 to 1.5 billion over 10 years was financed by a 9% tax increase on New York City water bills. In comparison, a new filtration plant would have required a two-fold increase in water bills.

Funds have been used to finance a US$ 60 million trust fund for environmentally sustainable projects in the Catskill watershed. The City has provided US$ 40 million in compensation to cover the additional costs of dairy farmers and foresters who adopted best management practices. Foresters who adopted improved forest management, such as low impact logging, received additional logging permits for new areas. Forest landowners with 20 ha of land or more that agree to commit to a 10-year forest management plan are entitled to an 80% reduction in local property tax. The City is also purchasing development rights for sensitive land near reservoirs, wetlands and rivers at market price. Farmers and forest landowners are able to enter into 10 to 15 year contracts with US Department of Agriculture to remove environmentally sensitive land from production.

- **Securing aquifers – a private sector payment scheme by Nestlé Waters in France**

Vittel (a subsidiary of Nestlé Waters) is the world's largest bottler of natural mineral water. Its most important water sources in France are in heavily-farmed watersheds. Runoff of nutrients and pesticides risked contaminating the aquifers on which the company's business depends. The company determined that purchasing farmland, reforesting sensitive infiltration zones, and financing farmers to build modern facilities and switch to organic farming was in fact more cost effective than building filtration plants. The cost advantages were so significant that participating farmers could be offered extremely profitable terms.

Stakeholders involved:

• *Buyers:* Vittel, a bottler of natural mineral water.

• *Sellers:* Farmers and landowners. In compensation for reduced use of fertilizer – and hence reduced profitability and higher perceived risk – farmers were given contracts by Vittel for up to 30 years.

• *Intermediaries:* The *government* facilitated the deal by providing a small amount of financial aid and a strong legal framework to ensure the enforceability of contracts.

Payment scheme type: Private sector payment scheme. Vittel purchased 1500 ha of farmland for US$ 9 million, paying more than the market price. Usufruct rights were then granted back to the farmers, giving them the legal right to use and derive profit from land owned by Vittel. Farmers receive US$ 230 per hectare annually to manage the land using sustainable practices that ensure high water quality standards.

- **Controlling nitrogen discharges – a cap-and-trade scheme in the USA**

The Clean Water Act in the USA limits the level of nutrients allowable in waterways. To comply with the Clean Water Act, states have developed strategies to keep nutrient discharges below the total maximum daily load allowed under the Act. The Connecticut Nitrogen Exchange Programme is a 'cap-and-trade' scheme for nitrogen discharges through which entities that discharge less than the nitrogen loads allowable (or 'capped') under the Act, can sell (or 'trade') their nitrogen discharge rights to those who exceed their allowances. This creates a financial incentive to diminish nitrogen discharges below allowable limits in order to profit from the sale of those discharge rights – while at the same time the scheme ensures an acceptable cap on total discharges.

- **Saving native salmon – a certification scheme in the Pacific Northwest of the USA**

A successful certification scheme was set up a decade ago to protect the habitat of the Pacific salmon, which is native to the Northwest of the United States. The scheme was established by 'Salmon-Safe', a non-profit organisation. Erosion and runoff from hillside vineyards and farms brought silt into streams, which had reduced the ability of native salmon to spawn and thrive. Salmon-Safe certifies farms and urban land in watersheds in the states of California, Oregon, Idaho and Washington that practice 'fish friendly' management. Salmon-Safe has now certified management of 20,000 hectares of land.

Stakeholders involved:

• *Buyers:* Consumers in the Pacific Northwest who choose "Salmon-Safe" products and pay a premium on top of the normal retail price to support land management that keeps rivers clean and safe for wild salmon.

• *Sellers:* Farmers and winegrowers.

• *Intermediaries:* Salmon-Safe, who oversees the certification scheme and supports the price premium through education and marketing campaigns.

Payment scheme type: Certification scheme. Participating farmers apply ecologically-sustainable agricultural practices that protect water quality in rivers and salmon habitats. These practices include tree planting on stream banks, growing cover crops to reduce runoff, and application of biological control methods for weeds and pests. The extra costs are paid out of the premium that participating growers receive for their products. Marketing of these products, including wine and foods, is assisted by public education and awareness campaigns by the Salmon-Safe organisation.

- **Protecting watersheds – a water protection fund in Quito, Ecuador**

The Water Protection Fund (FONAG) was created in 2000 in response to the pressing need for better management in the watershed that provides Quito's water supply. The fund was created by a local NGO, Fundacion Antisana, and The Nature Conservancy (TNC), after the Ministry of Environment commissioned the development of a management plan for two reserves in the upper watershed. It was designed to run for 80 years, to ensure long-term institutional and political legitimacy. In 2006, the fund's endowment was US$ 3.5 million, but was expected to grow to US$ 7.4 million by 2010.

Stakeholders Involved:

• *Buyers:* FONAG and its contributors.

• *Sellers:* Watershed managers and advocates. Those who undertake reforestation, surveillance of protected areas, sustainable management in agriculture, and development of ecotourism, training, communication and environmental education.

- **Management of watersheds by "Water agencies" in France: a environmental tax system**

France is divided into 6 different watersheds which are, each one, managed by a water agency. These agencies establish pluriannual programs to implement the European framework water directive and to protect water resources.

These agencies are financed by a tax taken on water bills paid by consumers calculated in function the volume they consume. For the next 6 years, these agencies will receive 11.6 billion Euros.

5.2 Case studies of sites where forests are managed to protect drinking water

5.2.1 General characteristics

Table 2 presents the types of action used for each site.

Table 3 gives the general characteristics of each site (type of water catchment, number of m^3/year, watershed area, percentage of forest cover in the watershed, price of water, water treatment).

Table 4 indicates forest management measures (forest site, actual forest situation, management objectives, method and means, particular measures nearby catchment points).

Site	Land acquisition		Contracts with farmers	Contracts with foresters
	past (before 1980)	current (after 1980)		
Basel	x			
Baltimore	x		x	x
Boston		x	x	x
Hanover	x			
Masevaux	x			
Munich	x	(x)	x	
New York		x	x	x
St Etienne	x	x		(x)
Tokyo	x		*No contract but strong awareness raising of the public*	
Vienna	x	(x)		
Vittel		x	(x)	
Winterthur	x		(x)	

Table 2: Summary of types of action used in each site

Site	Type of water catchment	Number of m^3/day	Watershed area in ha	Protected area in ha	% of forest	Price of water	Water treatment
Basel	water from the Rhine river is pumped and seeped into a forest to be filtered and pumped again when it arrives in the water table	75, 000		230	100	1.40 CHF/m^3 (supply and sanitation)	chlorination, degassing, coal treatment
Baltimore	catchments of rivers/streams (reservoir)	~ 2, 800, 000	11,5 000		?	?	chlorination and filtration
Boston	catchments of rivers/streams (reservoir)	600, 000		48 000	90	1 \$/ m^3 (supply and sanitation)	chlorination
Hanover	110 wells in water table	137, 000	30, 000		50	0.6 €/ m^3 (supply)	Chlorination and filtration when pipes maintenance
Masevaux	10 shallow catchments (3 to 4m) and wells in alluvial water table	700		1, 250	100	2.85 €/ m^3 (supply and sanitation)	Chlorination (and soon neutralisation)
Munich	catchment of surface streams, catchments of shallow water	411, 000		6, 000	~50	1.42 €/ m^3 (supply and sanitation)	none
New York	catchments of rivers/streams (reservoir)	5 millions	414, 100		75	?	?
St Etienne	shallow catchments (1.80 to 2m), filtering soil	29, 000	2, 500	1, 200	100	4.32 €/ m^3 (supply and sanitation)	Chlorination and UV
Tokyo	catchments of rivers/streams (reservoir)	4, 400, 000	48, 000		100	2 €/ m^3 (supply and sanitation)	chlorination and filtration
Vienna	almost all water comes from the catchment of 2 streams, karstic area, spring water	400, 000		60, 000	65	1.2 €/ m^3 (supply and sanitation)	chlorination
Vittel	deep wells, soil sensitive to pollution	Not comunicated	5, 000		11	Mineral water	none
Winterthur	water comes from alluvial water table	23, 000		1, 900	100	?	none

Table 3: Main characteristics about water supply in each site

Site	Forest site characteristics	Actual forest stands	Objectives	Methods	Other measures	Measures near catchment points
Basel	Rhine alluvium, plain, P= 788 mm/year et T= 11.3°C/year	Mixed deciduous forest, uneven-aged	Reached (corresponds to actual forest)	Different harvesting methods (chainsaw, harvester, tractor/skidder)	Biologic oils recommended	Deciduous trees, fence, manual forest work, no wood production
Baltimore	Well drained soils, elevation : 30 to 275 m, P= 1035 mm/year, T=12.8°C/year	Very diverse : deciduous forests and pine plantations	Diverse stands (in species, age and structure) and alluvial forests	Measures against game to favour regeneration and against invasive species, deciduous trees plantation, application and evaluation of BMP		Riparian zones restoration
Boston	Well drained soils, elevation : 161 to 421 m, not steep, P=1178 mm/year	Uneven-aged stands, mainly *Quercus rubra* and *Pinus strobus* (natural species)	Mixed species stands, uneven-aged	Regeneration by small openings, measures against invasive species	Particular measures for road log landings, biologic oils recommended	Limited harvest, opening < 0,2 ha, cut < 50 % of volume
Hanover	podzols and sandy gleys, plain, P=712 mm/y, T=9.9°C/y	Stands resulting from pine plantations	Mixed stand deciduous-conifer, continuous forest cover	Beech and red oak plantation	no pesticide	Fence around catchment points
Masevaux	Rich brown soils, elevation : 395 to 1190, steep, P= 1400 mm/y, T=8°C/an, 620 m alt → beech-fir forest	Beech/ beech-fir stands, continuous forest cover (long regeneration period), some stands recently destroyed by wind throw	High forest (but long regeneration period) of beach, fir and other species	Generalise cable yarding in protection zone	Exchange of GIS data between water and forest managers, biologic oils compulsory	No tree around catchment points
Munich	Deep and rich soils, not steep, elevation : 600 to 900m, P=1500 mm/y → beech-fir forest and deciduous trees in valleys	Stands resulting from spruce plantations	Mixed stand deciduous-conifer, continuous forest cover)	Harvest in winter (chainsaw : harvester, tractor), 50 to 100 m^3/ha removed per cut, 5 year rotation (to reduce volume)	Biologic oils, no pesticide, low pressure tyres	No tree around catchment points (superficial pipes)

Table 4-a: Forest management in each site

Site	Forest site characteristics	Actual forest stands	Objectives	Means	Other measures	Measures near catchment points
New York	Acidic soils, steep	Diverse deciduous stands, different ages	No management objective except keeping forests in the long term	No particular prescriptions	Management plans creation, development of BMP (erosion, river crossing, riparian zones), forest owners education	No access, adapted « soft » management
St Etienne	Deep brown soils, elevation : 800 to 1250 m, P=1000 mm/y → beech-fir	Fir forest, uneven-aged	Fir-beech forest, uneven-aged	Favour deciduous trees regeneration	Biologic oils, no pesticide	No tree around catchment points (superficial pipes), no fence, no machines crossing above pipes
Tokyo	Elevation from 500 to 21000 m, brown soils, T= 8.5 to 13.1°C, P= 1552 to 1684 mm	70% of « natural » forests (deciduous and conifers) and 30% of conifer plantations	Conserve « natural » forests, 44% of plantations have to become « natural » and 56% of plantations have to become a high forest	No management in « natural » forests and 44% plantation, forest cuts in 56% plantations	no pesticide, protection against game for regeneration	?
Vienna	karst, elevation : 470 to 2277 m, rendzine-leptosols and chromic cambisols, P=614 to 1071 mm/y et T=6.7 to 9.4°C /y	Stands resulting from spruce plantations and also natural mixed stands	Mixed forest defined by hydrotope model, uneven-aged	Deciduous tree regeneration under spruce by small openings, cable yarding	Biologic oils, no pesticide	Very soft management around dolines, best management practices to optimise the water protection functionality of the forest stands
Vittel	elevation : 330 to 450 m, not steep, P=923 mm/y, T=8.7°C/y	Deciduous stands (oak), mostly high forest	Uneven-aged forest stands, oak and other deciduous	Small openings, harvest very careful with soil (sometimes with horses)	no pesticide, machines with double tank wall	Very deep wells → no particular measures
Winterthur	?	63% of conifers, 37% of deciduous	Adapted species, uneven-aged forest	Riparian forest restoration, silviculture « close to nature »	Biologic oils	Riparian zones restoration

Table 4-b: Forest management in each site

5.2.2 Study of the different types of action

The methods to implement forest management measures are really diverse. Land acquisition and contracts with farmers or foresters are largely used.

5.2.2.1 Land acquisition

In Europe, land acquisition is the main tool and many cities have bought land in their watershed since the end of the 19th century, understanding the importance of this zone to protect drinking water. Today, some cities still buy, at the market price or higher, forest lands situated in the protection zones, or outside, to exchange them later.

In the USA, the issue of protecting water resources is more recent and cities usually do not own large forests. These towns try actively to buy land in their watershed, usually at the market price to voluntary forest owners. For example, New York City has bought 24, 000 ha of forest for 10 years, after having solicited the purchase of 144, 000 ha.

But for most cities, land acquisition is not enough and they also establish contracts with private owners.

5.2.2.2 Establishing contracts with farmers

On many sites forest and farmland are both present within watersheds or protection zones.
Farming activities are often a source of pollution (nitrates, pesticides) and therefore local authorities have established contracts with them, both in Europe and in the USA.

Munich case is well known.
Strong pollutions in nitrates and pesticides happened in the 80s and 90s. The city of Munich decided to implement an organic farming program with 3 organic associations (Bioland, Naturland and Demeter) within the protection zone. Farmers have to join one of these associations and respect organic farming rules. In exchange, they receive financial compensation from Munich city. Farmers receive around 500 €/ha/year when they accept this contract.
Today, more than 100 farmers have signed this contract. This represents 2, 300 ha (85% of farmers), of which 1, 800 ha are situated in the protection zone.
Thanks to these measures, today no nitrates can be found anymore in Munich water.

In Vittel (France), the situation is different.
Nestlé started since 1987 to buy land from farmers, because of problems of nitrate pollution in the 70s and 80s. The farm lands have then been rented for free to the farmers (tenant farming of 18 to 30 years) with rules to respect concerning water protection.
It is interesting to see the difference: Munich managed to establish contracts; Nestlé in Vittel had to acquire the land. Finding a simple explanation is not easy. The cultures of the two populations are different and the financial consequences were not the same.

In the USA, cities establish very easily contracts with farmers and foresters. But the aim is mainly to keep a farming or forest activity on the ground, and not to make owners adopt a particular management. These contracts are detailed in the next paragraphs.

5.2.2.3 Contracts with foresters

It is possible to find contracts with forest owners only in the USA. These contracts are based on interesting principles totally unknown in Europe.
For information, it is possible to cite a recent initiative in Soleure Canton (Switzerland) which aims to give financial compensation to the restrictions imposed by water protection laws in forest.

5.2.2.3.1 Rural land protection programs in the USA

Different programs have been implemented in the USA to protect sensitive rural lands (farmlands and forests). They are listed by an organism called American Farmland Trust and they are adapted State by State. Their implementation is very flexible and can be very different from one county to another. For example, in Maryland, the Rural Legacy Program implements these contracts.

- **Basic principle of the contracts : the concept of development rights**

These programs give an alternative to farmers and foresters to selling their land to developers by the possibility of selling only the development rights of their land and therefore to continue with their farming or forest activities.

The development rights are distinct from the residual farm /forest value. An owner can sell the developments rights of his/her land, but he/she remains the owner.

Concretely, owners keep the right to manage and harvest their forest/farm but they cannot build new infrastructures there (building, road…)

When they sell the developments rights, owners have to keep their land in the present state.

If it is forest land, they have to respect BMPs to limit erosion. If it is farm land, they have to follow a « nutrient management plan ».

These programs identify different sensitive zones that are very important to protect. They concern only lands that are situated in these sensitive zones.

To be eligible to sell the developments rights, the land must:

- be situated in a rural conservation zone ;
- have a minimum area of 20 ha ;
- have a soil conservation plan.

- **Conserve rural areas : some examples of programs**

- Transferable Development Rights (TDR)

Transfer of development rights programs allows landowners to transfer the right to develop one parcel of land to a different parcel of land. Generally established through local zoning ordinances, TDR programs can protect farmland by shifting development from agricultural areas to areas planned for growth. When the development rights are transferred from a piece of property, the land is typically restricted with a permanent agricultural conservation easement. Buying development rights generally allows landowners to build at a higher density than ordinarily permitted by the base zoning in designated receiving areas.

Two types of TDR exist: land developer can buy directly development rights to farmers/foresters, or the market can be indirect (local authorities buy development rights to farmers/foresters and they sell them after to land developers).

- Conservation easements purchase

Agricultural conservation easements are designed specifically to protect farmland. Landowners who sell easements retain the right to use their land for farming, ranching and other purposes that do not

interfere with or reduce agricultural viability. They continue to hold title to their properties and may restrict public access, sell, give or transfer their property, as they whish. Conservation easements limit land to specific uses and thus protect it from development. These voluntary legal agreements are created between private landowners (grantors) and qualified land trusts, conservation organizations or government agencies (grantees). Grantors can receive federal tax benefits as a result of donating easements. Grantees are responsible for monitoring the land and enforcing the terms of the easements.

- Instalment purchase agreement

An instalment purchase agreement (IPA) is an innovative payment plan offered by a handful of jurisdictions with Purchase of Agricultural Conservation Easement (PACE) programs. IPAs spread out payments so that landowners receive semi-annual, tax-exempt interest over a term of years (typically 20 to 30). The principal is due at the end of the contract term. Landowners also can sell or securitize IPA contracts at any point to realize the outstanding principal.

- Tax credit exchange : example of Colorado

Colorado has developed a program where land owners can sell their development rights as « conservation easements ». Land owners do not receive the money of the sale in one time, but as tax credits.

The credit can be used to pay the taxes in lieu of cash. If the credit is applied to the owner's own state income tax, the taxes will be reduced by the amount of the Credit.

If the credit exceeds the taxes owed, the credit can be carried forward and used over the next 20 years. After twenty years, any unused portion of the credit expires.

Case study: Facilitated credit transfer transaction

John Brown has a $230,000 Colorado Conservation Tax Credit that exceeds his taxes due. Rather than using the Credit over 20 years, he wishes transfer it and immediately receive cash that he can reinvest in his ranching operation. John is unable to find a buyer for the Credit, so he contacts a tax credit facilitator.

John's Credit is matched with a purchaser who needs the Credit to offset his or her Colorado state income tax. Credit prices are market driven, but purchasers have recently saved approximately 13% on their state income taxes.

Sellers like John have typically received approximately 82% of the value of his Credit. The remaining 5% of the value of the Credit funds the transaction costs of the facilitator (Conservation resource Center (2007): Tax credit exchange).

- **Change owners practices : example of the Florida panther protection**

Another original example deals with the protection of the Florida panther. This endemic animal was threatened of extinction, partly because of the degradation of its habitat. After many failures to convince farmers to change their practices to respect Florida panther habitat, an association suggested to farmers to gather and to define themselves which measures will make them change their practices.
Landowners created a program of restoration and conservation of the panther habitat, by using different types of contracts. Every farm land has to have a global management plan, approved by authorities. This plan defines which measures have to be taken in each land, according to the importance of the land ecological characteristics for the panther.
Three levels of action, corresponding to three levels of remuneration, have been set (table 5).

	Action	Corresponding remuneration
1	Land owners lease their non-agricultural development rights (they can go on with farming activities but they cannot build infrastructures).	Income and estate tax credit (during 25 year = duration of the lease)
2	Land owners lease their agricultural development rights if experts estimate that some farming activities are not compatible with habitat panther protection.	Agricultural development rights value determination - The difference between the value of land in its most restrictive agricultural use and the value of land sold on the open market fully permitted for the most intensive agricultural use allowable. Agricultural development rights compensation - the landowners would be compensated for the lease of agricultural development rights in the form of income and estate tax credits, cash or other non-cash methods, agreeable to by both parties.
3	Owners have to restore panther habitat if experts think it is necessary.	Landowners are compensated for the amount of money spent to restore the habitat

Table 5: Different levels of action and financial compensation to save Florida panther habitat

5.2.2.3.2 A contract experience in Switzerland

In Soleure canton, the research office Kaufmann tries to implement a system of remuneration to compensate for restrictions management imposed to forest owners in water protection zones.
Forest produces good quality water at a low price. But regulations forbid some activities in forested protection zones (no pesticides, precautions concerning fuels and lubricants, no intensive forest harvesting, restriction about circulation on forest roads, no nursery creation, no soil extraction). Forest owners have therefore to transport wood out of the forest very quickly. This can induce over costs because machines are not allowed to stay during the night in water protection zones.
The State does not have to compensate for these restrictions.

The research office had the idea to create, in association with private forest owners and the Soleure canton, a contract-form that could establish rules of remuneration between forest owners and local water managers. Both parts have to agree to sign this contract.
The price scale criteria for the compensation rely on several information linked to the forest site productivity, the slope of the terrain (consequences on harvesting costs), the accessibility (consequences on storing, transport), the ground obstruction (vegetation, rocks), the percentage of conifers, the distance until the limit of the protection zone (Amt für Umwelt, 2006).

The distribution of points in function of the criteria is explained in table 6.

Criteria	Points				
Productivity (m^3/ha)	> 12	10-11.9	8-9.9	6-7.9	< 6
	8	6	4	2	1
Slope	< 30 %	30-60 %	> 60 %		
	2	1	_		
Accessibility (ml/ha of forest roads)	> 100	70-100	<70		
	2	1	_		
Ground obstruction	low	average	high		
	2	1	_		
% of conifers	> 60 %	30- 60 %	< 30 %		
	6	4	2		
Distance to the limit	> 400 m	200- 400 m	< 200 m		
	8	4	2		

Table 6: Distribution of points between different criteria – Remuneration method of Kaufmann office
Source: Amt für Umwelt (2006). Merkblatt, Entschädigung von Grundwasserschutzzonen im Wald

The points given for each criterion are summed up. In function of the total number of points, a financial compensation rate is suggested (table 7). This remuneration differs in function of the protection zone (S2 or S3; S1 is not considered because the restrictions are too high and it is better for owners to sell their land).

Total of points	Remuneration in Swiss Francs by ha/year	
	Zone S2	**Zone S3**
25-28	130	70
21-24	110	60
17-20	90	50
13-16	70	40
9-12	50	25
5-8	30	10

Table 7: Remuneration rate corresponding to the total of points - Remuneration method of Kaufmann office
Source: Amt für Umwelt (2006). Merkblatt, Entschädigung von Grundwasserschutzzonen im Wald

In S2 zone (inner protection zone) 30 to 130 CHF/ha/year could be given to owners (20 to 80 €/ha/year).

Up to now, no contract based on the method has been signed between local authority and forest owners.

The research office points out that there are financial compensations for farmers but not for foresters, and this should change. They recommend to insist and to ask to water managers to give remuneration to foresters, ans this because it is not sure that forest will always produce pure water « for free » (KAUFMANN, 2008).

5.2.2.3.3 « Remunerate » public forest: examples of Saint-Etienne and Winterthur

In Saint-Etienne (France), the private company that delivers water has signed a contract (provision of service) with the French national forest agency (ONF) for 22, 000 €/year. In exchange, ONF has to do a regular surveillance of harvesting activities nearby water pipes and of recreation, program the maintenance work of the pipes (master building), deforest just above the water pipes. Other services can be done by ONF under punctual estimate.
This provision of service is not equivalent to a contract where ONF would be remunerated for its protective forest management (SABOT, 2008).

In Switzerland, the city of Winterthur manages and delivers water by communal services. In the water protection zone, wood harvesting is restricted by some precautions, which induces an over cost for forest communal services. Since 2002, these over costs are not attributed anymore to forest but to the product « protection of nature, landscape and water » (HAAGMANS, 2003).
A new step is made so that wood production does not take « for free » over costs from other forest services.

5.2.3 Analysis of forest management measures

5.2.3.1 Very strong similarities

There is rather a strong consensus about the forest management measures to apply to protect drinking water resources among the sites.

- **Continuous forest cover**

A wide majority of sites have adopted uneven-aged forest treatment (strip, group or single tree selection system), which guarantees continuous forest cover.

Managers insist on the importance to have multi-layered stands, both horizontally and vertically.

There are some differences concerning the forest cover density. Some managers recommend to have a quite dense cover, like in Munich or Vienna, some other prefer a clearer density, like in Vittel. But this is linked to the main species requirements. In Munich and Vienna, shadow tolerant species like beech or fir trees are favoured due to climatic restrictments and site conditions. In Vittel, it is mainly oak, which is a light demanding species.

To regenerate light demanding species, like larch, this plenter management is not possible. In Vienna, larch is therefore regenerated in strips in the « edges » of suitable parcels.Yet small gaps, which provide enough light and still are suitable for continuous cover forest management techniques (KOECK et al., 2007).

Light management remains one of the main challenges to find the right balance to regenerate all species adapted to forest site conditions.

- **Presence of deciduous trees**

When forest site conditions are suitable, managers favour deciduous trees or introduce them to have a mix with conifers.

Usually, managers try to have the most diverse species stands as possible.

This choice is related to scientific considerations: deciduous trees catch less pollutants and structure better the soil with their roots.

- **Dynamic and healthy vegetation**

The main goal of forest managers is to have stable, resilient, vigorous and site conditions adapted forest stands.

Stability in the time is the only way to guarantee continuous forest cover. And continuous forest cover is the key for good water quality. When a forest area is suddenly cleared, from natural or man activity origin, water quality is often affected. There are more suspended matter and bacteria.

This is why managers have chosen uneven-aged forest. They also try to have « natural » and adapted stands, with diverse species in order to resist better to wind throws and pests (LINDER, 2008).

Vienna and Munich apply a kind of precaution principle when they replace their spruce stands by more naturals species stands. These sites have no problem of water quality with spruce stands, but they fear that *Ips typographus* attack more and more forests and that the number of wind throws increases, particularly because of climate change. They do not want to take the risk to have suddenly huge forest area devastated. They want to minimize this risk to keep good water quality.

- **Careful forest harvesting**

Harvesting techniques have to be the most soft and soil-respectful possible: winter harvesting, cable yarding…

The level of precaution depends on soil vulnerability. If soils are not particularly sensitive, a traditional harvest is alright, with machines concentrated on skid roads, and by protecting the soil with cullwood.

It is important to underline that wood production is always possible. A forest with water protection objective is less profitable than a « normal » forest, but it is still productive. Production and protection are not contradictory, that is forest multi-functionality.

- **Pollution sources limitation**

In many sites, biologic oils are recommended or compulsory. Pesticides and chemicals treatments are forbidden.

These measures prevent from accidental pollution

- **Particular attention around sensitive points**

Around sensitive points (water catchment points, dolines or riparian forest), foresters adopt a very soft management.

The first step is to identify these areas and create vulnerability/sensitivity maps. Managers define then an adapted management in function of the degree of sensitivity. Usually, in very sensitive zones, machines are not allowed; forest work is realised manually and very softly.

5.2.3.2 And some disagreements

Some management aspects differ from one site to another.

- **Case of « Best Management Practises » in the USA**

The « best management practises » are a set of measures recommended by public forest services. They focus mainly on forest roads creation and maintenance and on river crossings (see appendix 4: Description of « Best Management Practises »).

These measures do not directly concern forest management.

New York forest administration recommends to forest owners to apply these measures and to have management plans, but there is no particular recommendation concerning the type of sivicultural management. Forest authorities consider that the essential is to a keep a certain forest cover, whatever management concepts and measures are applied there.

Erosion control and river protection are the key points to have a good water quality.

- **Case of Tokyo**

In Tokyo, the majority of forests is not managed. Managers think that the best management is to do nothing.

But this site is the only one.

- **Dead wood and cullwood: good or bad?**

In France, dead wood is seen as a problem, in particular in immediate protection zones. Managers fear that it brings too much organic matter and it is eliminated. In Masevaux (France), cullwood is even burnt in glens. On the opposite side, in Switzerland, it is forbidden to burn cullwood in water protection zones.

Other countries do not have this practise. In many place, dead wood is not a problem, even near catchment points. Dead wood means biologic activity and biodiversity, which is a guarantee of forest stability.

For example, in Vienna, a windthhrow recently devastated 20 ha of spruce plantation in a very sensitive zone for water protection. It was not possible to build a road to extract wood. The army helped foresters to debark 6, 000 m^3 of spruce to prevent from bark beetles attack. Logs have been let on the ground, to be naturally decomposed. No water quality problem has been detected by this excessive amount of dead wood.

- **Management near catchment points**

In France, immediate protection zones are usually cleared cut and fenced. Grass is cut regularly.

Again, France is rather isolated.

In Munich, a part of the forest stand just above water pipes is cleared, but not fenced. Superficial water pipes must not be blocked by a root. As soon as water pipes are deep enough, forest is not cleared anymore.

In Vienna, dolines are in some cases fenced, if cattle grazing poses a threat to water resources because of potential fecal contamination. In general they cannot be forested because of their specific site conditions (long lasting snowpack).

In America, the majority of drinking water comes from open air rivers. Therefore, riparian forest buffers are carefully conserved or restored.

Many managers believe that forest is the best protection around sensitive points, as long as roots do not degrade infrastructures.

All these considerations could lead French managers to change their practices in immediate protection zones.

- **Remark : case of private forest management**

When both public and private forests are present in a watershed, public forest management is usually more restrictive than in private forest. One can then wonder if these restrictive measures are really necessary. Forest managers think that they are, because the most sensitive areas are situated in public forest and they require a softer management and higher precautions.

5.2.4 Management recommendations

One of the objectives of my thesis is to give recommendations that should be applied to protect drinking water.

At the beginning of my thesis, I thought that it would be possible to build a typology of forest measures, in function of important site factors. But it has not been possible, because all the sites apply more or less the same forest management to protect their drinking water resources.

Therefore, I will recommend applying the same measures.

- Have a dynamic forest management to get stable, healthy and site suited species.
- Favour silvicultural treatments that guarantee a continuous forest cover: uneven-aged forest or even-aged forest with a long regeneration period.
- Favour species adapted to the site conditions and keep the widest tree species diversity possible (usually deciduous species), to mix with main tree species.
- Adapt harvesting methods in function of the site sensitivity (geology, soil type, topography…). The more sensitive the site, the more careful the harvest. Respect soils in any ways.
- Limit pollution sources: biologic oils, no chemicals, double tank wall machines.
- Do not build roads in sensitive zones, check that runoff water on roads is deviated from water catchment zones.
- Do not install game feeding places near sensitive points and prevent from game concentration there. Keep low enough populations to have sufficient regeneration.
- Do not develop touristic activities that can threat water protection, keep « soft » recreation levels.

The more sensitive the site, the more strict the application of these recommendations have to be.

These recommendations deal more with the qualitative aspect of water, than with the quantitative aspect. Water quantity is no problem for the studied sites, even if managers are conscious about the risk of seeing water quantity decreasing because of climate change.

It is very difficult to estimate if a particular silvicultural treatment applied to a particular species leads to more or less water consumption than another one, and therefore, has an impact on underground water quantity.

5.2.5 Conclusion about the types of action

All the sites have to face two necessities to protect drinking water resources: first the conservation of forest and then the application of adapted forest management.

In Europe, land acquisition has been the answer to these two challenges.

But if land acquisition has not been realised in the past, cities cannot buy today anymore huge forest areas (excepted sometimes immediate protection zones).

The new solution has been regulation. In many countries, regulations fix restriction to land uses situated in protection zones.

These restrictions do not lead to any compensation in forest, in spite of the over costs they imply.

In France, a recent decree allows farmers to receive compensation for the restrictions they have. But nothing is done for forests and regulation has reached its own limit.

Indeed, regulation guarantees forest occupation of soil, but it did not really manage to impose management restrictions, which led to today's problems.

In the USA, these two challenges have been solved in a different way. Authorities have developed contracts to conserve forest and, when it is necessary, to make land owners apply a different management.

This method is very different from the European one: gather owners and ask them which measures would work instead of imposing them tools that are not always efficient.

In Europe, authorities consider that forest multifunctionnality works « on its own ». But wood production does not always compensate for over costs linked to the others forest functions. In a sustainable development logic, these other functions should be remunerated to ensure that they will always be filled by the forest.

Land acquisition and regulation are not enough. Therefore news tools have to be developed. Contracts seem to be a satisfying alternative.

The contract diversity in the USA offers us huge perspectives. The application of the development rights principle, the remuneration as tax credits and the sale of tax credits between owners is not possible without an adaptation of our laws. Therefore, we could think of a possible adaptation.

But legislation is not the only obstacle for establishing contracts. Land owners, used to regulation, are not familiar with contracts.

Awareness raising, information and negotiation are preliminary steps to any contract process.

Propositions of such contract processes adapted to Alpeau sites are made in the next part of this report.

5.3 Application to Alpeau sites

5.3.1 Site analysis and diagnostic

The following table (table 8) presents the difficulties encountered at each site and the expectations of the managers. These sites, even if they are all different, have to face common challenges.

From the answers to the questionnaires I collected, I figured out these key points.

- In public forest, the silvicultural treatment is compatible with water protection. Forest stands are mixed, adapted to the site and managed so that they cover continuously the soil. The constraints are linked to harvesting methods that are very restrictive in protection zones.
- In France, in private forest, forest management can sometimes be a threat for water protection (clear cuts, barren soil as a resulet).
- In Switzerland, the problems are linked to the prohibition of chemical treatment of wood and of refuelling and parking of machines in S1 zones.

Sites	Problems cited by Alpeau partners	Expectations of Alpeau partners	Remarks
Areuse (Switzerland)	–	Lead scientific studies on the interactions between forest management and water quality	–
Arve (France)	Many water catchments, very divided ownership Some « dangerous » recreation activities Possible pollution from pastures	Know more about scientific studies on this topic Economic study to compare water production costs Think about changing prescriptions in PPI and PPR	The Alpeau partner is preparing a global water plan management
Broye (Switzerland)	Over costs linked to harvesting in protection zones Compensation not planned by law	Know more about scientific studies on this topic Create contracts to remunerate forest owners	Long thinking about creating contracts Precise Alpeau site not yet defined
Chambéry (France)	Sometimes difficult to apply law relative to water catchment protection	Know more about scientific studies on this topic Think about changing prescriptions in PPI and PPR Monitor water quality before, during and after a forest cut Create contracts to remunerate private or public forest owners	7 sites defined for Alpeau
Côte (Switzerland)	Over costs linked to harvesting in protection zones	Creation of a global project based on sustainable development, reorganize wood industry chain in the region	Long thinking about creating contracts
Lausanne (Switzerland)	Chemical wood treatment forbidden But small over costs	Promote water from forest Extend if possible the water catchment network in forest Monitor water quality of some sources	Precise Alpeau site not yet defined Tax on water → sustainable development fund
Moises (France)	Sometimes difficult to apply law relative to water catchment protection Some « dangerous » recreation activities Problems of bacteriologic pollution in water	Know more about scientific studies on this topic and on hydro geologic processes in this site Create contracts to remunerate private or public forest owners Think about changing prescriptions in PPI and PPR Manage forest belonging to the SIEM Secure and extend if possible the water catchment network in forest Economic study to compare water production costs	The Alpeau partner has the project to create a hydro geologic park

Table 8: Main problems and expectations of Alpeau sites managers

5.3.2 Suggestions

5.3.2.1 General suggestions

Some common suggestions can be made for several sites.

- **Know more about scientific research on the interactions between water and forest management**

Managers wish to know more about the interactions between forest management and water: which type of forest management can improve water quality and which forest practices can deteriorate this quality.

The aim is to define which rules are really important in respect to efficient drinking water protection.

The scientific review presented at the beginning of this report can be a starting point to answer this demand.

Experiments are planned on two sites, Chambéry and Neuchâtel (Areuse gorges). Forest cut are programmed near water catchment points and managers will monitor water quality during time. It will be interesting to see if forest cuts have or have not an impact on water quality, knowing that these two sites are in Karstic area, so rather sensitive (see 4.3.2, propositions for each site).

- **Develop exchanges between forest and water managers**

One of the main expectations of Alpeau partners is to multiply exchanges between forest and water managers. On many sites, foresters do not know anything about the water infrastructures and they are not told if water quality is suddenly degraded, so they cannot link it to an eventual forest operation. Water managers, on their side, complain about not knowing anything about what is done in forest near catchment points.

The Alpeau project has to give the opportunity to establish a partnership between these two « worlds ». Each partner has a lot to learn from each other and the results on water quality will only be better.

- **Think about changing prescriptions in PPI (or S1 zones)**

The majority of French managers wonder about the relevance of regulations in immediate protection zones (PPI). They are sometimes incoherent from one catchment to another and some practices are in opposition with scientific results.

With the study made in other countries, where prescriptions are different and where it does not lead to any problem, I would give the following suggestions.

- Forest is the best protection possible, much more than a meadow. If water pipes are situated in more than 2 meters depth in the soil, deforestation is useless (roots cannot go further). A deciduous or mixed uneven-aged forest is optimal.
- Soil should not be totally covered by cullwood, but foresters should not eliminate cullwood systematically.
- The obligation to fence PPI seems to be excessive. France is the only country to do that. Some cities, like Saint Etienne have managed to be dispensed of this obligation, and no problem ever happened there. The materialization of PPI with milestones, like it was done in Switzerland, seems to be very relevant, because foresters locate the protection zones very easily.
- In France, machines circulation is normally forbidden in PPI, which can be excessive for some cases. In Switzerland, circulation is tolerated in S1 zones.
- Drinking water protection is not incompatible with "adequate and adapted" forest activities (see 3.2.2.3, Management recommendations). However wood harvesting has to be more respectful,

which means cutting trees when the soil is the less sensitive, concentrating machines on skid roads situated far from water pipes, using biologic oils, not refueling in PPI, not parking machines in PPI, not using any chemical treatment. Clearcuts of course should be forbidden within drinking water protection areas.

- Prescriptions have to be adapted to each situation, in function of the catchment vulnerability.
- In France, in public forests, an agreement could be passed between water managers and the ONF, so that ONF foresters, when they make their regular surveillance round in forest, check also water catchment surroundings.

The major constraints in Switzerland come from the prohibition of treating wood and parking machines in protected zones. The treatment problem will be discussed later.

Concerning machines parking, the thing is that, in Karstic areas, S1 and S2 zones can be really huge and it is difficult to ask to a forest worker to make several kilometers at the end of day to park his machine outside of the protection zone.

However, managers do not all agree on law interpretation. For some of them, the prohibition of parking machines does not concern forest activities. A precision of this regulation is therefore necessary and in some cases, a compromise with authorities could be accepted if machines have a double fuel wall.

This recommendation could also be applied in France.

Lausanne city has adopted the following prescriptions in the protection zones. They are cautious but they remain realistic and allow forest management (table 9).

Activities or infrastructures	Zone S3 ~ PPE	Zone S2 ~ PPR	Zone S1 ~ PPI
Deposition of non-treated wood	o	o	x
Deposition of treated wood	x	x	x
Use of chemical sanitary products, herbicides, products for wood conservation, fertilisers	x	x	x
Burning of branches	x	x	x
Use of mineral oil and fuel (chainsaw…)	x	x	x
Use of mineral lubricants (machines…)	o	o	x
Refuelling of machines	o	o	x
Parking of machines	o	o	x
Clear cutting	x	x	x
Not intensive forest harvesting	o	o	o

Legend: o = allowed, x = forbidden

Table 9: Recommendations of Lausanne forest service in protection zones

Source: FODOVI (Service des forêts, domaines et vignobles de Lausanne). - *Zones de protection des eaux, restrictions et contraintes*

Two pictures (picture 2 and picture 3)taken in Switzerland illustrate the previous recommendations in S1 zones (~PPI).

Picture 2: S1 zone in Lausanne (June 2008)

Picture 3: S1 zone in Mont-Gibloux (June 2008)

Tha application of forest management concept or measure in a PPI can, in some cases, induce an ownership problem. Indeed PPI are usually bought by water managers. If this water manager owns also the forest around the PPI, like in public forest, having forest management measures within PPI does not provoke problems. The cases of Masevaux or Saint Etienne, where city services and ONF collaborate, are examples to follow.

But if the PPR belongs to a private owner and the PPI is too small or does not have any access road to be separately harvested, a contract should be established with the forest owner of the PPR. It could be possible to remunerate a passing right on the PPR so that managers can make harvest operations on the PPI.

But usually, water managers already dispose access to do the maintenance of the water catchment infrastructures in the PPI.

- **Inform forest owners**

Accidents happened in protection zones (in PPR mainly), and forest owners should be better informed. They have to know where these zones are and which prescriptions or restrictions have to be respected.

For that, meetings with forest owners should be organised by water managers. They should be explained, very simply, how infrastructures are, how water catchments work, how forest management influences water quality and what are the prescriptions to respect. It is really very important to explain them why they are asked to do so. Local forest owners will be all the more receptive as they themselves drink water from these catchments.

The example of Areuse gorges (Switzerland) is very interesting. Water quality was more and more degraded because of agricultural pollution. Farmers were not paying any attention to recommendation letters they were receiving from water managers. Therefore, water managers organised a meeting with farmers to make them visit the infrastructures, and explain where the water they were drinking was coming from. They then debated all together on farming practices that can affect water quality. Since then, farmers respect these small but necessary restrictions, without asking any compensation. And never any pollution accident happened again.

Meet, explain, discuss, motivate and give sense of responsibility can be the key for the solution of the problem.

- **Indemnify private owners**

Legislation in France allows the establishment of amicable contracts between forest and water managers. The objective of Alpeau is to create such contracts and not to create a legal framework where forest owners could be systematically indemnified, like it is done with farmers. The advantage of an amicable contract is that it does not only compensate for restrictions but it gives value to a real ecological service.

In Switzerland, the context is more difficult because the law says that forest owners have to apply a management that guarantees water protection. This is the problem pointed out by the research office in Soleure: few local authorities are ready to pay for something that is due to them.

An adaptation of law in Switzerland is therefore necessary and Alpeau could act as a lobby to raise awareness about the importance of this topic and to propose contract frames.

Concerning the method to evaluate and define indemnification rates, the principle suggested by the research office Kaufmann in Soleure could be adapted and applied (see 3.2.3.3.2). Economic studies could also help.

The process implemented in Florida, to gather owners and ask them to imagine which measures will make them change practices, gives a sense of responsibility and is motivating.

The creation of a fund to give indirectly money to owners that apply a protective forest management is also possible (see next paragraph).

In France, cities could, like in Saint Etienne, pass contracts with ONF to remunerate harvesting over costs and surveillance.

In both countries, over costs, when they take place in a public forest owned by a city, could be attributed to the water budget, and not to the forest budget.

- **Create a sustainable development fund**

The city of Lausanne has been very innovative with the creation of a fund for sustainable development.

A tax of 2 cents CHF is taken on each consumed m^3 of water, as well as a tax on gas and electricity and also on industrial city services benefits. For information, this fund receives each year around 3 million CHF (~1, 800, 000 €). With this money, Lausanne develops several actions:

- Use and promotion of wood (« un arbre-un enfant », sawmill, bus shelter, pedagogic hut, parking, promotion of deciduous trees …),
- Research and studies,
- Public relations, communication, information,
- Support to associations,
- Education (sport, obesity prevention, waste recycling…)
- Other isolated realisations (children council, subsidy for gas vehicles, bio ethanol for public services, batrachians « roads »…).

For information, this fund finances a part of Alpeau project.

This example could be adopted in the case of other sites.

A part of the money collected could be used to remunerate foresters for their protective management.

- **Inform public**

Local population and tourists should be informed about the protective function of forests: explain to give a sense of responsibility and respect.

Two French sites underlined the risk of « dangerous » recreation activities, like motor circulation in forests, to become more frequent.

Some information is already available, but not enough. Other actions could be implemented to educate the public about the protection role of forests and the rules to respect:

- Diffuse in local media: newspaper, radio, tourism office, city hall…
- Create pedagogic trails in forest.
- Install informative notice boards in forest.
- Organise school field trips in forest.
- Organise field trips in forest for tourists and make them discover the functions of forests and how water catchments work. « Green tourism » develops more and more, people are more and more preoccupied by ecological problems. Therefore, this type of field visits would certainly be a success. Tourist offices could promote them and forest or water managers could organise, during school holidays, some visits in forest. The majority of French people do not know where the water they drink comes from. They would be very interested and happy to know that a part of the water is protected « naturally » by forests. These visits could be financed by public participation and by water services.
- Increase awareness of local inhabitants by annual celebrations. The city of Lausanne has created, for example, a celebration called « un arbre-un enfant », which means « a tree-a child ». Once a year, all the parents that have got a baby during the previous year are invited to plant a tree in forest.

If all these measures are not enough to control recreation activities, water managers could pass a contract with public services responsible for forest surveillance, like it is done in Saint Etienne where the city has passed a 2, 000 €/year contract with the ONF to increase surveillance against motorized circulation in forest.

- **Give up treating woods in Switzerland: reorganize wood industry chain?**

One of the major constraints for water protection in Switzerland is linked to the forbidding of log treatment to prevent bark beetles spreading. Sawmills do not have log storing places and therefore foresters took the habit to let logs in forest and be progressively absorbed by sawmills. Now foresters treat systematically conifers.

These practices are very difficult to change today. Even if the number of logs treated has decreased, a percentage of wood remains treated.

In Vaud canton, during the two last years, foresters have worked in constant flow with sawmills and no log has been treated. But this was possible only because the market was favourable during this period.

The idea of managers is to re-organise the entire wood industry chain. Local sawmills should be helped to create log landing places.

The Alpeau project can be the opportunity to give a frame and legitimacy to this discussion.

- **Promote a local use of wood and communicate intensively**

Shorten wood supply circuits is also a challenge.

Cities could use directly the wood from their forests and promote it. Build benches or bus stop shelters made of wood from « forests which protect water » would certainly have a very positive feedback from local inhabitants. Lausanne city has already implemented such actions and this is an example to follow. In Vienna, Christmas market huts are made of wood from Viennese forests and inhabitants are aware of the protective management applied there.

Alpeau has to intensify communication about wood produced in these forests. The public has become very sensitive to « forest stores Carbon »; it would also adhere to « forest protects water ». Cities would by the same way acquire an innovative « green » image, based on environmental services remuneration.

The creation of a common certification for Alpeau sites could also be a possibility. A certification could promote locally « the forest which protects water » and help to remunerate partly forest owners for their protective management. The certification would be innovative because it recognises a function, and not a provenance, like the example of « Salmon safe » in the USA (see 2.2.4.2). But creating a label is very long and difficult to implement, it is beyond Alpeau missions.

5.3.2.2 Specific propositions for each site

- **Site of Areuse gorges (Switzerland)**

This site situated within a karstic area does not have the objective to establish any contract. The aim of Neuchâtel University is to conduct scientific experiments to learn more and evaluate the impact of forest management on underground water quality.

The studies planned by François Zwahlen, the director of the hydrology centre of Neuchâtel University, are:

- Study data collected since more than 40 years on water quality to try to link it with past forest operations, in function of soil vulnerability ;
- Study thoroughly some experimental sites to measure physic-chemical water quality in function of forest type and management.

- **Site of Arve (France)**

No precise water catchment area has been chosen for the moment. It is planned to realise an inventory and a typology of all the water catchments of the Arve watershed during the Alpeau project. Particular actions could then be implemented in 2-3 of the most interesting/representative ones.

Potentially, 250 to 300 water catchment points are concerned, of which more than half are in forest. Forest ownership is mostly private and much divided.

If Alpeau partners want to establish minimal rules of forest management to implement on every water catchment areas, some suggestions can be given.

Firstly, managers should be sure that all private owners know that their forest is situated within a protection zone and that they are aware of what it implies.

Regulation constraints could be adapted to each water catchment in function of forest activities and protection stake. A GIS program could help to determine the most vulnerable catchments. Constraints would then be higher (restrictions on harvesting methods). For low vulnerability catchments, tolerance towards forest activities could be larger.

If the SM3A (Alpeau partner) or local authorities directly concerned wishes to go further, it would be possible to establish contracts with owners if they accept to adopt another forest management, like the one applied by the ONF (see paragraph on the Moises site).

In any case, information of owners and public should be abundant. Water managers should tell forest managers which type of water catchment is in their forest and where water pipes are to prevent from accidents.

Lastly, forest surveillance should be strengthened.

For information, the sites of Arve and Moises plan to conduct economic studies to compare the cost of the different water supply types.

A first study has to compare the production costs of drinking water between pumping in water table (electricity, treatment…) and collecting water from forest (treatment, cost of forest management…). The ultimate goal is to evaluate the financial saving provided by forest water supply.

The second study, which concerns forest water catchments, has to estimate the production costs of water in function of forest management:

- Cost associated to a « preventive » forest management (technical cost of a different siliviculture, information/education cost, control cost),

- Cost associated to a « curative » management (no measure to manage watershed forest, but measures to purify water and to face probable accidents).

- **Site of Broye (Switzerland)**

If the Mont-Gibloux forest is chosen to be the precise Alpeau site of the Broye region, some improvements can be proposed there. This forest is public but owned by 5 different cities.

If the same city owns the catchment point and the forest around, over cost linked to the protective forest management could be attributed to the water budget of the city.

If the water catchment belongs to another city, the city that benefits from water could indemnify the city that owns the forest for the restrictions in forest management.

The main constraints are the prohibition of wood treatment and accessibility in S1 zones.

Concerning the chemical treatment, the cities could agree to extract from forest in priority logs situated in protected zones. A log landing place could be created in a not sensitive zone. And in case that wood treatment could not be avoided, special equipments could receive polluted water runoff from the treatment place.

Concerning the accessibility of S1 zone, a hydro geological study could confirm or infirm the forbidding to build a road to access in S1 zone. Winter harvest, when soil is frozen, could be allowed. Cable yarding could also be an alternative. Machines with double fuel wall could be allowed.

- **Site of Chambéry (France)**

Seven water catchments are planned to be studied, four of them are already fixed.

- The PPR of the catchment called « Dhuy » is situated in a zone recently devastated by bark beetles. Forest stands are in regeneration. The constraints are therefore almost inexistent for foresters. Concerning the PPI, managers could try to modify the regulation adopted there, not to deforest it.
- The PPR of « Pierre Rouge » catchment is situated in public forest, treated in coppice and standards. This silvicultural treatment has not been very detailed in scientific research and therefore it would be very interesting to plan a coppice cut and to monitor its influence on water quality.

- The PPR of « Fontaine Froide » catchment is also located in public forest. A selection cut is planned during the coming years in one of the parcel of the PPR. Here again, water quality could be monitored before, during and after the cut.

  Another water catchment is situated very near from « Fontaine Froide », site conditions are the same for these two catchments. A selection cut has also to be done in the PPR. A cut could be made in the PPR of each catchment, but the intensity could be different, to see if this has a different impact on the water quality from each catchment.
- The determination of protection zones of the « Fontaine Noire » catchment has not been done yet. Managers wish not to deforest on the future PPI, which is for the moment covered by a mature spruce plantation. The solution could be to regenerate this spruce stand, by little openings, and to favour beech trees and firs (corresponding to the « natural » forest site).

  The water from this catchment has a low quality (lot of suspended matter and bacteria, linked to pasture land above, and too much Iron in water). Therefore, water is ultra-filtered. All these problems could hide a possible positive effect from forest and as a consequence, monitoring efforts should not be concentrated there.

  However, several private forests are present on the PPR and an owner association could be created there (see paragraph of the Moises site).

- **Site of Côte (Switzerland)**

The cities of Gland and Aubonne that are chosen to be the precise working sites of Alpeau, do not own forests that protect their water resources but they feel very concerned by sustainable development.

Gland is very motivated to give value to water coming from forest streams. These streams come, for the majority, from forest in Karstic area, which belong to other cities. Gland could sign a contract with these cities that have management restrictions to compensate for the over costs they undergo.

Aubonne owns 450 ha of forest down in the plain, but they do not directly protect the water resources. Aubonne water comes from an artesian resurgence and it is therefore impossible to define any protection zone around

These two cities could join to form a global project based on sustainable development and valuate a regional use of wood, by re-organising the wood industry chain, shortening wood use distances and informing public.

To finance this program, a sustainable development fund, like in Lausanne, could be created.

This project could also allocate land for soil transformation firms. Indeed, land is very expensive in this region and an owner/manager cannot buy land to build a sawmill for example. So if the city sells him a piece of land cheaper, he will be able to create a sawmill, logs will be extracted more easily and quickly from forests and they will not be treated.

The Alpeau project could give an impulse to this program.

- **Site of Lausanne (Switzerland)**

No precise water catchment has been designated yet.

Constraint compensation is not really a problem for the managers of Lausanne forest. They wish, with Alpeau, to promote water yielded from forested watersheds.

Managers consider also the possibility to extend the water catchment network in forest.

The Alpeau project could give the opportunity to monitor more precisely the water quality from some catchments. Forest cuts could be realised near them, like in Chambéry.

- **Site of Moises (France)**

The department of Haute Savoie is characterised by a very strong forest ownership division and the parcels are very small (3, 000 m² in average). When owners manage their forest, which are mainly spruce plantations, they clear cut them. Normally, in protection zone PPR, clear cut superior to

5, 000 m² are not allowed. But forest cooperatives manage to group owners that have contiguous parcels, each one smaller than 5, 000 m², but realise on each one clear cut. Therefore, the cumulated area clear cutted can reach several hectares, which represents a real danger for water protection. In addition, they usually, in order to clear the soil after, gather cullwood on strips, and plant spruce between, although natural vegetation works perfectly (natural seedlings come into artificial plantation).

These practices should change.

After a meeting with the president of the Haute Savoie forest owner association, it was concluded that it would be possible to create an owner grouping around the Moises catchment points.

The Alpeau partner on this site, the SIEM (Alpeau partner), which is the joint association that supplies water, could sign contracts with forest owners of this grouping. Forest owners will receive money from the SIEM to be compensated of changing forest practices and remunerated for the protective management they have.

The ideal forest stands would be mix species stands, with an adequate proportion of broadleaved tree species, treated in the selection system; but this ideal will be difficult to apply.

The SIEM could then propose to owners to harvest their spruce stands by small openings (tree group or strip) and extend the regeneration period to 10-20 years (instead of clear cutting all the trees at once). Spruce trees would be cut around gaps where natural regeneration is already present, and deciduous tree seedlings could be kept also. The ONF already adopted this management since more than 10 years to progressively replace spruce plantations. Forest owners could « copy » this management (picture 4).

The grouping of several contiguous parcels would make the harvest operations profitable, even if only a small percentage of volume is harvested in each parcel.

This new type of sivicultural management requires less forest work but more knowledge and control. It requires also more surveillance during harvest operations to make sure that the remaining trees are not injured and that soil is respected.

Picture 4: forest management applied by ONF in Arraches public forest (Haute Savoie), a selection cut of large diameter trees has just been done in the spruce stand (July 2008).

Information and education of forest owners will be very important. Information meetings on the impact of forest management on water quality will have to be organised.

The SIEM should also apply this management on the forest lands it recently acquired. Demonstration forests, to teach owners which trees to mark to be harvested, could be created in these parcels.

This forest management could be controlled by the SIEM, the forest owner association or the ONF within a convention frame.

The remuneration given by the contract would constitute a strong incentive to join the forest grouping and adopt new silviculture. The SIEM would, on its side, secure water resources and acquire a « sustainable development » image to the eyes of the public and local authorities.

The SIEM would like to establish this frame of contracts with all the forest owners situated in the future hydro geological park they are planning to create, which means all the parcels situated around the catchment points, in or out protection zones. The level of management restrictions (and therefore the level of remuneration) asked in the contract could be adapted to the sensitivity of each parcel towards water protection.

6. Critical analysis of the study

6.1 Discussion of the method

- **Limits of the study**

The research of information about sites, throughout the whole world, that have implemented a particular forest management to protect drinking water resources could be improved and extended. A more exhaustive inventory has not been made because of lack of time. Sites known too late could not be studied. And information about sites studied here remains sometimes incomplete.

The sample constitutes only of sites from Western Europe, the United States and Japan. The study would have been richer with sites from South America, Asia, Africa or Oceania.

The study of Alpeau sites is also limited. It was not possible to collect information collected for all the sites. Some Alpeau sites have not chosen their precise research water catchment for the project. Therefore, a lot of information is lacking to be able to improve or give more appropriate recommendations.

However, all Alpeau sites have been visited and managers met, as well as in Saint-Etienne, Vittel, Masevaux, Vienna and Munich. These visits and the direct exchanges with managers have brought a lot to my study.

The lack of juridic knowledge about the legal possibilities to establish contracts in France and in Switzerland is regrettable. Once again, time was too short to acquire competence in this field.

- **Debatable points**

The grading method to compare sites lacks of scientific validity: too much subjectivity to choose criteria, to fix thresholds and to evaluate each site. But the goal of this classification was only to determine which sites were to be studied in priority to give them more time, but all the sites have been studied anyway.

The realisation of a multi-criteria analysis has been considered; but the too small sample would not have given interesting results.

The data collection has been made from Internet web pages, mail exchanges and field visits. But, for some sites, the contact person did not speak English well enough to go into details or could not answer all my questions.

- **Possible improvements**

The knowledge of juridic and legal contexts about the regulation in each country about the protection of water catchment is lacking, therefore I would include questions about this topic in the questionnaire.

- **Outcome of the work**

The objectives of this thesis have been reached:

- The international case studies have been realised; management recommendations have been formulated, according to the experience of the sites studied and to the scientific synthesis made about the interactions between drinking water and forest. Main types of forest management implementation have been identified (land acquisition and contracts).
- The Alpeau sites have all been studied. General and specific recommendations have been suggested to be implemented during the Alpeau project. This work has also created a contact with and between Alpeau partners.

6.2 Discussion of results

Many sites in the world have understood that forest plays a very important role to protect water and have implemented particular forest management concept. Forest alone is not enough; an adapted management has to be conducted.

- **Forest management and scientific research**

It has not been possible to determine keys factors leading to one type of forest management or to another one. Almost all sites apply the same forest management. This observation is explained by the fact that managers, in each site, referred to scientific literature to define their management rules. As a consequence, they all apply the same principles, all on their side.

Most of the managers recognized ignoring if any other site, where forest protects water, exists. They have been reassured to learn that in other sites, the same management rules were applied and they said they were interested in exchanging experience with forest managers from other countries on this topic.

Forest practices can be compared to the precaution principle. As managers do not know exactly which harvest operations or silvicultural treatment can have a negative influence on water quality, they prefer not to take risk and be careful.

Scientific studies always bring news answers, despite of the results that are sometimes contradictory.

It is interesting to develop studies where effects of forest cuts on water quality are monitored during time. Such experiments are planned on Chambéry and Areuse gorges.

Two aspects are lacking in scientific research:

- Define a scale of importance of forest management in function of site conditions (for example, it seems to be more important to have a soft forest management on a very sensitive soil, than on a less sensitive soil). The keys factors (soil, geology, topography…) could be determined and the importance of forest management quantified.
- Determine if a particular forest stand (species composition, silvicultural treatment…) allows higher or lower quantity of water infiltration into the soil.

Concerning management rules near water catchments, this study shows how France is isolated with the practise to deforest PPI. In other countries, forest is considered to be the best protection. The Alpeau project could lobby to change these prescriptions.

- **Land acquisition, regulation and contracts**

Regulation is the main tool used in France and Switzerland, and there are still problems of water catchments protection.

Europe begins to think of establishing contracts with foresters.

Signing contracts with foresters both indemnifies constraints they have and valuates ecological functions of forest.

The logic of contracts is not well introduced in our minds. It is not easy to establish a contract system with owners who have always been used to regulation without compensation.

Legislation in Switzerland is a major issue. It will be difficult to create new tools without changing it. Law recognises constraints for farmers and gives access to financial compensation. One of the challenges of Alpeau will be to promote forest functions and to propose contracts to make these functions sustainable.

Some initiatives can be adapted to create new contracts: sustainable development fund, system of indemnification with points (Swiss research office), contracts between water and forest services…

A working group could see how American contracts may be adapted in Europe: development rights principle, financial compensation by tax credits and sale of tax credits between owners…

Alpeau has really to make of water protection an ecological product that foresters can sell.

- **Other ambitions for Alpeau**

Develop contracts with forest owners to give an incentive to change forest management is necessary, but it is only one step. Some Swiss managers suggest that the whole wood industry chain should be re-organised : shorten wood supply circuits, create local use of wood, help firms to settle down, promote a regional use of wood, raise public awareness…

This ambitious idea is maybe feasible within the frame of Alpeau which could start the debate, communicate heavily of this issue and implement first actions.

Alpeau raises really huge perspectives and expectations.

7. Conclusion

Forest is certainly the best cover to protect drinking water resources. But is this protection independent from the forest management applied?

Several sites in the world have answered « no »: the only presence of forest is not enough; a particular management has to be implemented.

This protection, improved by an adapted management, is an answer to both economic and ecologic considerations: it is more profitable and wiser, in a logic of sustainable development, to protect watersheds than to build huge filtration plants.

The prospective study that has been realised shows that the majority of sites applies very similar forest management concepts.

The aim of this management is to obtain stable forest stands, adapted to forest site. They are, if possible, mixed species stands, with deciduous trees, diverse in age and structure, so that soil is continuously covered by forest (continuous or selection forest). Harvest operations are made carefully, to respect soil. It is about this last aspect that sites differ mostly. In function of site vulnerability, the precautions to take are not the same. Lastly, at all sites the potential pollution sources are eliminated (use of biologic oils, absence of pesticides or chemical treatment).

Today, managing a forest to protect water implies implementing these recommendations, and adapting the « harvesting precautions » to the level of sensitivity of the given site.

Europe has chosen since long time land acquisition to implement this management, which can be very effective. But when forest remained private, countries edited regulations to impose to owners to conserve forest occupation on their land and to forbid some activities. No compensation ever accompanied these constraints, which explains that today, regulation has reached its limits, without filling all its objectives.

The United States of America have chosen to establish contracts since the beginning. Owners voluntary accept a certain restriction in exchange of an incentive financial compensation.

In front of this situation, Europe begins to implement also contracts with owners.

The ultimate goal of Alpeau is to create European tools to establish contracts to secure in the long term water resources and remunerate fairly forest owners. Water yielded from forested watersheds is cheap and, generally, of good quality. In a logic of sustainable development, it becomes crucial to protect and develop forest water, all the more as other water supply sources begin to face micro-pollution problems.

An adapted management of these forests and a positive cooperation with owners is a necessity. Contracts work very well where they have been introduced and Alpeau partners are motivated to do so. Practical recommendations have been suggested to each Alpeau site. Some forest managers wish that Alpeau project will give the occasion to think globally and re-organise the whole wood industry chain.

To conclude, drinking water in forest is not a « non-problem », not even a problem, it is a formidable asset.

8. References

Adams, M.B., Edwards, P.J., Kochenderfer, J.N., Wood, F.(2002). Fifty years of watershed research on the fernow experimental forest, effects of forest management and air pollutipon in hardwood forests. 391-396.

American Farmland Trust (2006). Fact sheet : agricultural conservation easements. Farmland information center.

American Farmland Trust (2008). Fact sheet : the farmland protection toolbox. Farmland information center.

American Farmland Trust (1999). Fact sheet : installment purchase agreement. Farmland information center.

American Farmland Trust (2001). Fact sheet : transfer of development rights. Farmland information center.

Amt für Umwelt (2006). Merkblatt, Entschädigung von Grundwasserschutzzonen im Wald, Soleure.

Attenberger, E., Bitterscohl, J., Moritz, K.,Weber, H. (2001). La ressource en eau et sa qualité dans les forêts, observations et démarches en Bavière. SHF Forêts et Eau 25-26/09/2001.

Avenir forêt bois (2006). Plan d'action et boîte à outils à l'usage des autorités publiques.

Benoît, M., Fizaine, G. (1999). Qualité des eaux en bassins forestiers d'alimentation. Revue forestière française, n° 5, 162 – 172.

Bloomberg, M., Lloyd,E. (2006). New York City 2006 Drinking Water Supply and Quality Report. New York City Department of Environmental Protection.

Breger, F., Rey, F, Chenost, C. (2005). Synthèse bibliographique de l'état des connaissances sur le rôle de protection des forêts contre les risques naturels. Publication of Cemagref Grenoble, Unité de recherches écosystèmes montagnards, 5 – 10.

BRGM (2007). Protection des captages d'eau destinés à la consommation humaine. Géosciences Buisson, G. (2005). Evaluation de l'efficacité environnementale des périmètres de protection des captages, Série Etudes, 05-E07. Document de travail, Ministère de l'écologie et du développement durable.

Bureau of water supply, New York City Department of Environmental Protection (2006). New york City 2006 drinking water supply and quality report. 18 p.

Bureau of water supply, New York City Department of Environmental Protection (2006). 2006 Long-term waterhed protection program. 66 p.

Bureau of Waterworks Tokyo Metropolitaan government (2008). The watershed forests.

CEMAGREF, Unité de recherche agriculture et forêts méditerranéennes. Usages et fonctions multiples de la forêt méditerranéenne. Guide technique du forestier méditerranéen français, chapter 8.

Choy, F. (2007). L'influence de la gestion forestière sur les eaux souterraines. Eauservice de Lausanne, 16/05/07, 30 slides.

CNRS (2004). Les liens Eaux – forêts : Eléments scientifiques pour l'aide à la décision dans le cadre de la mise en œuvre de la DCE. Report the Life project « Water and Forest »

Combe, J. (2006). Gestion des forêts à eau potable. Revue forestière française,n°4, 369 – 376.

Combe,J. (2005). Gestion des forêts à eau potable. Powerpoint presentation of 22 slides, Montricher, 15 sept 2005.

Conservation resource Center (2007). Tax credit exchange.

Cosandey, C.(2006). Conséquences des forêts sur l'écoulement annuel des cours d'eau. Revue forestière française, n°4, 317 – 328.

CRPF, région PACA, Quelles incidences d'un périmètre de protection de captage de source sur la gestion forestière . Fiche n° 356001.

Die Marke der Stadtwerke Hoanover AG, Niedersachsisched Landesalt für Okologie (2000). Waldbewirtschaftung im Zeichen des Trinkwasserschutzes.

Dissmeyer, G. E. (2000). Drinking Water from Forests and Grasslands, A Synthesis of the Scientific Literature. USDA Forest Service publications.

Dufour,S., Pigeay, H. (2006). Forêts riveraines des cours d'eau et ripisylves : spécificités, fonctions et gestion.Revue forestière française,. 339 – 350.

Eeauservice Lausanne, Direction des travaux (2007). Activités forestières : risques pour les eaux souterraines.

Engel BA, 1996: Methodologies for development of hydrologic response units based on terrain, land cover and soils data. In 'GIS and Environmental Modeling'. Oxford University Press: New York, pp. 123-128.

Fiquepron,J. (2008). Fiche de travail : Action conjointe INRA & IDF : forêt et eau.Projet Masevaux-26/03/08,8p.

Fiquepron, J. (2008). Fiche de travail : Action conjointe INRA & IDF : forêt et eau. Fiche de travail sur Saint-Etienne, 3p.

Fiquepron, J. (2006). Fiche de travail : Action conjointe INRA & IDF : forêt et eau. Fiche de travail provisoire sur Vittel, 10/10/06, 3p.

Florida game and fresh fish Commission and American Farmland Trust (1995). A landowners' strategy for protecting Florida Panther habitat on private lands in South Florida.

Food and Agriculture Organization (2000). Agricultural Landscapes and Domestic Water Supply: the Scope for Payments for Watershed Services with special reference to sub-Saharan Africa.

Food and Agriculture Organization (2000). Valuation of water-related services to downstream users in rural watersheds : determining values for the use and protection of water resources. Land-water linkages in rural watersheds, electronic workshop, 18-27 sept 2000.

Forstamt und Landwirtshaftsbetrieb MA 49 (2006). Wälder, Felder, Wiessen und Wein. Stadt Wien.

Glasser,S.P. (2007). USDA Forest Service on Managing Groundwater Resources.

Godi,F., Jenni,R. (2005). Argumentaire en faveur d'une production d'eau potable de qualité par une gestion forestière multifonctionnelle. Plan forestier régional de la Broye vaudoise et fribourgeoise

Gurtz, J., Baltensweiler, A., Lang, H. (1999) Spatially distributed hydrotope-based modelling of evapotranspiration and runoff in mountainous basins. Hydrological Processes 13, pp. 2751-2768.

Haagmans,B., Kunz,B. (2003). Les forêts de la ville de Winterthur protègent l'eau potable. Journée internationale de la forêt 2003.

Hegg,C. et al. (2006). La forêt et l'eau potable : une étude bibliographique. Institut fédéral de recherches sur la forêt, la neige et le paysage, WSL.

INRA (2001). L'acidification dans le massif vosgien, comprendre les mécanismes et apporter les solutions. publication of l'INRA Paris.

Institut fü Forstwissenschaft und Forstservice Slovenien (2007). Wald und Wasser : Projektergebnisse Interreg IIIA.

International hydrological programme of UNESCO, Hydrology and water resources programme of WMO (2007). Forest hydrology, results of rsearch in Germany and Russia. HEFT 6, Koblenz 2007.

Jordi,B. (2005). Le sol forestier : un filtre idéal. Environnement 3/05 Forêt, 32 – 35.

IUCN (2006). Establishing payments for watershed services. IUCN, Gland, Switzerland, 111 p.

IUFRO (2007). How do forests influence water ?. Fact Sheet n° 2.

Jenni, R., Maitre,V. (2006). Etude bibliographique sur la relation forêt – eau souterraine. Forum broyard de la forêt et du bois, projet pilote de partenariat entre la sylviculture proche de la nature et les distributeurs d'eau potable.

Koeck, R., Magagna, B., Hochbichler, E. (2007) KATER II Handbook – Final report regarding the land use category forestry. Technical document, available online: HYPERLINK "http://www.kater.at" www.kater.at (scientific publications).

Koeck, R., Magagna, B., Hochbichler, E. (2007a) Appendix I – Best Management Practices for the drinking water protection forests. Technical document, available online: HYPERLINK "http://www.kater.at" www.kater.at (scientific publications).

Kovac,M., Fajon, S. et al. (2007). Forest and Water – Summary of the project. Slovenian forestry institute and Slovenia forest service.

Landeshauptstadt Munchen Kommunareferat (2005). Erlebniswelt, Müncher Stadtwald, Angebote der Städtischen Forstverwaltung München.

Llloyd,E., Rush, P.(2006). Bureau of Water Supply. 2006 Long-term Watershed Protection Program. New York City Department of Environmental Protection.

Maryland Department of Natural Resources, Forest Service (2007). A comprehensive forest conservation plan for long-term watershed protection on the City of Baltimore's reservoirs.

Massachusetts Department of Conservation and Recrreation (2007). Quabbin reservoir watershed system : land management plan 2007-2017.

Maine Forest Service (2004). Best management practices for forestry : protecting Maine's water quality.

Michaud,J., Schaller,D. et al.(2003). Plan forestier régional de la Broye vaudoise et fribourgeoise, Cahier de travail.

ONF (2005). Prise en compte de l'eau et des milieux humides dans la gestion forestière, Guide de recommandations.

ONF (2006). Prise en compte de l'eau dans les travaux forestiers, Guide de recommandations.

ONF (2007). Action de recherche et développement sur les interactions entre gestion forestière et qualité de l'eau potable.

ONF (2006). Les Propriétés forestières de Nestlé Waters Vosges. fiche du 20/11/06.

Règlement de Lausanne (2005). Préavis n° 155 du 8 juin 2000 : Règlement d'utilisation du fonds communal pour le développement durable.

Santé Canada (1997) : Recommandations pour la qualité de l'eau potable au Canada. 6° edition.

Sims,B., Knopp,C. (2007). The roles of BMPs in 303(d) listed waters : a new alterantive to TMDLs

Springog,G., Zander,O. (2004). Afforestation of C-rich, sandy, arable soils in the Fuhrberg water catchment : Full/deep tillage vs. Alternative treatments. Effects on nitrate concentration of ground-water recharge. Die Marke der Stadtwerke Hanover AG.

Storelli,S. (2007). Eau potable et énergie : homélie pour un méli-mélo. Published by CREM.

SWM (2005). M-Wasser, ein erstklassiges Naturprodukt.

Treboux, E. (2006). Projet de partenariat entre les propriétaires forestiers et les distributeurs de l'eau dans la région de la Côte. Chambre des bois de l'Ouest Vaudois, 17/06/06.

Treboux, E. (2006). Projet pilote de partenariat entre la propriété forestière et la distribution d'eau potable dans la région de la Côte, « Ressources Eau-Forêt La Côte ». Chambre des bois de l'Ouest Vaudois, 13/07/06.

United Nations Economics commission for Europe (2006). Paiement des services rendus par les écosystèmes dans le cadre de la gestion intégrée des ressources en eau, quatrième réunion des parties à la convention sur la protection et l'utilisation des cours d'eau transfrontières et des lacs internationaux.

United Nations Economics commission for Europe (2005). Nature for water, protecting water-related ecosystem for sustainable development.

United Nations Economics commission for Europe (2006). Nature for water, innovative financing for the environment.

University of Natural Resources and Applied Life Sciences,BOKU (2007). KATER II hanbook, final report regarding the land use category forestry. 189 p.

University of Natural Resources and Applied Life Sciences,BOKU (2007). Appendix I, best management pratices for the drinking water protection, 34 p.

USDA Forest service (2000). Drinking water from forests and grasslands. 103- 217.

USDA Forest service (2007). Technical Guide to Managing Ground Water Resources.

USDA Forest service (2000). Water and the Forest Service.

Vacik,H., Lexer,M.J. (2001). Application of a spatial decision support system in managing the protection forsts of Vienna for sustained yield of water resources. ELSEVIER.

Vienna waterworks MA31 (2001). Drinking water for Vienna. City of ViennaVincent,H. (2007). Reconnaissance des effets de la forêt sur l'eau potable et exemples d'applications en Europe. rapport de stage effectué à l'ONF Agence départementale Isère, 41 p.

Watershed Agricultural Council, Watershed forestry programme (2008). Forestry handbook.

Wilpert, K. (2005).Gestion forestière des bassins versants boisés respectueuse de la ressource en eau et des zones de captage.

Wimmer, F. (2007). Öko-Wald schützt Münchens Trinkwasser. 06/07/07, Presseinfo Stadtwald Muenchen.

WSL (2004). Instructions pratiques pour la protection des eaux souterraines.

WSL (2005). Fiche technique : Protection des eaux souterraines en forêt.

Zander,O. Groundwater Protection Strategies of a Water Supplier. Die Marke der Stadtwerke Hanover AG.

9. Contact list

Master thesis Supervisers

Claude BARTHELON
Water and risk coordinator
ONF – DT Rhône-Alpes, France
Claude.barthelon@onf.fr
Olivier FERRY
Director of the development service
ONF – DT Rhône-Alpes, France
Olivier.ferry@onf.fr
Eduard HOCHBICHLER
Ao. Univ. Prof. Dipl-Ing. Dr. Nat.techn.
Boku University, Vienna, Austria
Eduard.hochbichler@boku.ac.at
Eric LACOMBE
ENGREF, France
Lacombe@engref.fr

Scientific contacts

Mary Beth ADAMS
USDA Forest Service Timber and Watershed Laboratory, USA
Mbadams@fs.fed.us
Hervé BADER
Bildungszentrum Wald Lyss (Centre forestier de formation Lyss), Switzerland
bader@bzwlyss.ch
Scott BAILEY
Research Geoecologist USDA Forest Service, Northern Research Station Hubbard Brook Experimental Forest, USA
Swbailey@fs.fed.us
Galia BARDARSKA
Institute of water problems at Bulgarian Academy of Sciences, Bulgaria
Galiabardarska@yahoo.com
Joshua BISHOP
IUCN, Switzerland
Jtb@hq.iucun.org
John CAMPBELL
USDA Forest Service, USA
Jlcampbell@fs.fed.us
François CHOLLET
ONF – Sud Ouest, France
Francois.chollet@onf.fr

Etienne DAMBRINE
INRA Champenoux, France
Etienne.dambrine@nanacy.inra.fr
Jimmy EQUENOT
Etudiant FIF, France
Jimmy.equenot@onf.fr
Julien FIQUEPRON
Ingénieur forêt et eau
INRA – IDF, LEF (ENGREF), France
Julien.Fiquepron@nancy-engref.inra.fr
Marc LAVANDIER
RUT Couserans ouest
ONF – Sud Ouest, France
Marc.lavandier@onf.fr
Pauline MARTY
Etudiante FIF, France
Marty.pauline@yahoo.fr
Julien PRINET
Chef de projet et expert eau
ONF – DT Alsace, France
Julien.prinet@onf.fr
Stéphanie ROUX
Technical Development Team Leader South Forest Research, United Kingdom
Stephanie.roux@forestry.gsi.gov.uk
Marie-Cécile SCHMITT
Chef de projet environnement
ONF – Sylvétude Meurthe et Moselle, France
Marie-cecile.schmitt@onf.fr
Stéphane STORELLI
Centre de Recherches Energétiques et Municipales (CREM) Martigny, Switzerland
Stephane.storelli@crem.ch
Carina SUCKER
Forstliche Versuchs- und Forschungsanstalt Baden-Württemberg Abteilung Boden und Umwelt, Germany
Carina.sucker@forst.bwl.de
Ursa VILHAR
Gozdarski institut Slovenije (Slovenian forestry Institute), Slovenia
ursa.vilhar@gozdis.si
David WELSH
Forester/Watershed/BMP/Specialist USDA Forest Service, USA
Dwelsh@fs.fed.us
Carol E. YOUELL
Natural Resources Administrator The Metropolitan District, USA
Cyouell@themdc.com

Contacts for each site

- **Areuse (gorges), Neuchâtel – Alpeau**

Pierre-Olivier ARAGNO
Service Eau de Viteos, Neuchâtel
Pierre-olivier.aragno@ne.ch
Jan BONI
Ingénieur forestier
Service forestier de la ville de Neuchâtel
Jan.boni@ne.ch
François ZWAHLEN
Directeur du centre d'hydrolgéologie de l'Université de Neuchâtel
Francois.zwahlen@unine.ch

- **Arve, Haute Savoie – Alpeau**

Hervé FAUVAIN
Directeur du SM3A
Hfauvain@sm3a.com
Jean-Luc MABBOUX
Chargé de mission projets complexes environnement et alpages
ONF – Haute Savoie
Jean-luc.mabboux@onf.fr

- **Basel, Switzerland**

Thomas MEIER
Responsable du service de l'eau de Bâle
Thomas.meier@iwb.ch

- **Baltimore, USA**

Anne HAIRSTON-STRANG
Maryland DNR Service
Astrang@dnr.state.md.us

- **Boston, USA**

Thomas D. KYKER-SNOWMAN
Environmental Analyst
DCR Division of Water Supply Protection Quabbin Reservoir
Thom.Kyker-Snowman@state.ma.us

- **Broye, Fribourg – Alpeau**

Robert JENNI
Bureau d'étude Nouvelle Forêt
jenni@nouvelleforet.ch

- **Chambéry, Savoie –Alpeau**

Etienne CHOLIN
Responsable service environnement, Chambéry Métropole
etienne.cholin@chambery-metropole.fr

Olivier LAMY
Chef de projet diversification – eau
ONF - Savoie
Olivier.lamy@onf.fr

Matthieu PERROTON
Chambéry Métropole
Matthieu.perrotton@chambery-metropole.fr

- **Côte, Vaud – Alpeau**

Eric TREBOUX
Service forestier du canton de Vaud
Eric.treboux@vd.ch

- **Hanover, Germany**

Olaf ZANDER
Stadtwerke Hannover AG - Team Water protection and forest management
olaf.zander@enercity.de

- **Lausanne – Alpeau**

Philippe MAGNENAT
Garde forestier, Lausanne
Philippe.magnenat@lausanne.ch

Linda VIGUET
Eauservice – division distribution, Lausanne
Linda.viguet@lausanne.ch

- **Masevaux, France**

Jean DE MARIN DE CARRANRAIS
RUT Doller – Basse Largue
ONF – DT Alsace
jean.demarindecarranrais@onf.fr

Pascal MASSON
Chef de triage patrimonial UT Doller – Basse Largue
ONF – DT Alsace
Pascal.masson@onf.fr

- **Moises-Forchat, Haute Savoie – Alpeau**

Bertrand DEVILLE
SIEM
Siem.deville@wanadoo.fr

Noël GENTRIC

Président du Syndicat des forestiers privés de Haute Savoie et président de la section Cofalp de la Coforêt Rhône-Alpes

Clet.gentric@orange.fr

Jean-Luc MABBOUX

Chargé de mission projets complexes environnement et alpages

ONF – Haute Savoie

Jean-luc.mabboux@onf.fr

Nicolas WILHEM

SIEM

Siem.wilhem@wanadoo.fr

- **Munich, Germany**

Jan LINDER

Service forestier de Munich

Linder@forstgotzing.de

Rainer LIST

SWM Munich (service de l'eau)

List.rainer@swm.de

- **New York, USA**

Fed GLIESING

Senior Forester/Forestry Coordinator, Division of Watershed Lands & Community Planning, NYC DEP Bureau of Water Supply

fgliesing@dep.nyc.gov

David WARNE

Chief of Staff, Bureau of Water Supply, Department of Environmental Protection, New York City

Dwarne@dep.nyc.gov

- **Saint Etienne, France**

Guillaume SABOT

Chef de projets

ONF – Agence Ain-Loire-Rhône
Guillaume.sabot@onf.fr

- **Tokyo, Japan**

Naomi TAKAHASHI

General Affairs Division, Bureau of Waterworks, TMG

Takahashi-naomi@waterworks.met

International-affairs@waterworks.metro.tokyo.jp

- **Vienne, Austria**

Werner FLECK

MA 49 - Forstamt und Landwirtschaftsbetrieb der Stadt Wien Gruppe 2 - Quellenschutz (service forestier de Vienne)

werner.fleck.wf1@wien.gv.at

Eduard HOCHBICHLER

Ao. Univ. Prof. Dipl-Ing. Dr. Nat.techn.

Boku University, Vienna, Austria

Eduard.hochbichler@boku.ac.at

Gerhard KUSCHNIG

Magistrat der Stadt Wien – Wasserwerke (service de l'eau de Vienne)

gerhard.kuschnig@wien.gv.at

Roland KOECK

Ingénieur (responsable modèle hydrotope, projet KATER)

Université de Bodenkultur de Vienne, Autriche

Roland.koeck@boku.ac.at

- **Vittel, France**

Philippe HUMBERTCLAUDE

Agent patrimonial UT Mirecourt

ONF – DT Lorraine

Philippe.humbertclaude@onf.fr

Philippe PIERRE

Directeur d'Agrivair

Tel : 03 29 07 60 30

List of appendices

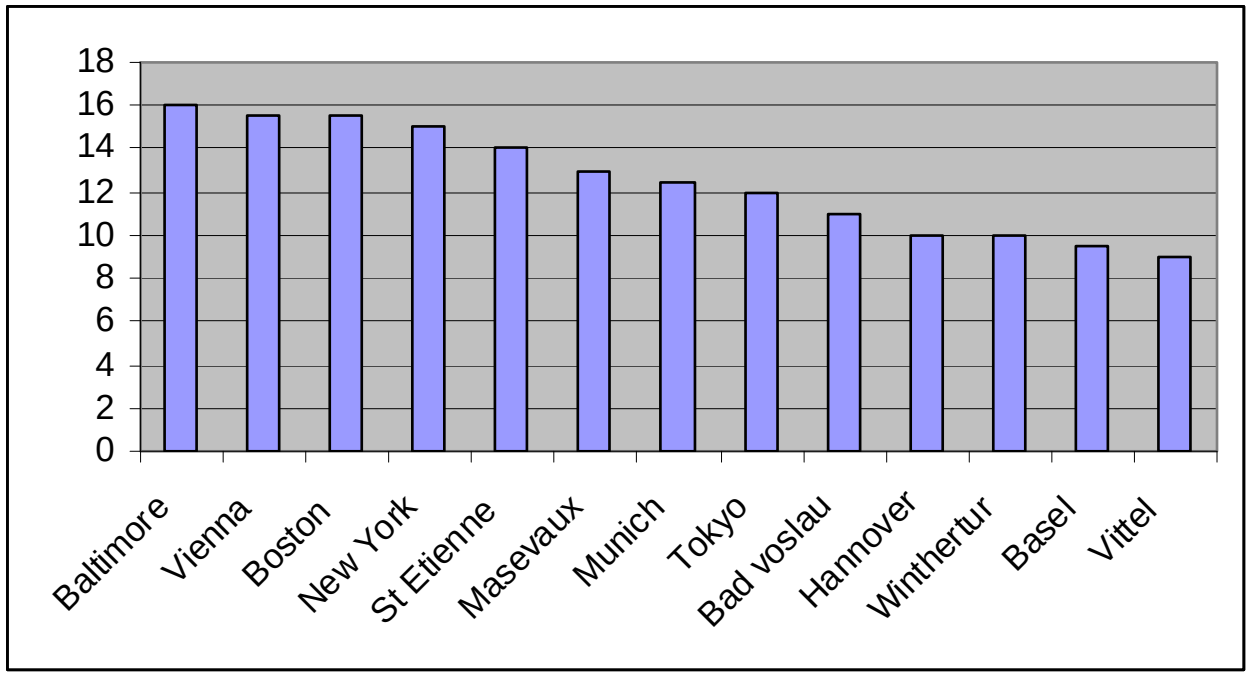
Appendix 1: Comparison table of the sites

Grading	Site/Town	Type of catchment	Number of m3/day	Total area of the watershed	Area of the protected zone of the watershed	Percentage of forest cover	Type of action	Forest management peculiarity
	Basel	0,9 M m3 come from streams; 27,6 M m3 come from re-pumping of the water table (comes initially from the Rhine river)	75000 m3/day (206000 inhab)			water is totally filtered by forest	?	water from the Rhine river is pumped and seeped into a 22 ha forest to be filtered (Lange Erlen site) and pumped again when it arrives in the water table
without weight	11	2	2		1	4	1	1
with weight	**9,5**	2	1		0,5	4	1	1
	Baltimore	catchments of rivers/streams (reservoir)	5 million pers	115 000 ha	10% is protected, of which 7100 ha belongs to Baltimore	?	land acquisition, contracts with landowners, tax credits, conservation easement	restoration of riparian zones, forest mgt around reservoirs, watershed partnership, BMP evaluation, conservation and management models
without weight	20	3	4	4		2	4	3
with weight	**16**	3	2	2		2	4	3
	Boston	catchments of rivers/streams (reservoir)	600000 m3/day	~48000 ha (of which 22000 ha controlled by the waterworks company)		87 % forest, 6 % wetlands	land acquisition, payments in lieu of taxes, land disposition, conservation restrictions, technical assistance to communities and private land owners, public education	species diversification, uneven aged forest, limited forest cut, importance of forest regeneration
without weight	18	3	3	2		4	3	3
with weight	**15,5**	3	1,5	1		4	3	3

	Hanover	110 wells	137000 m3/day (500000 inhab)	85% of water come from Fuhrberg Feld - 30000 ha		50% forest	land acquisition	broadleaved tree plantation, continuous forest cover
without weight	12	2	2	2		2	1	3
with weight	**10**	2	1	1		2	1	3
	Masevaux (France)	10 shallow catchments (3 to 4m)	700 m3/day (5000 inhabitants)		all the protection zones in Masevaux forest - 1250 ha	100%	the forest belongs to the commune of Masevaux - particular management by the State forest agency	better communication between forest managers and water works services, attention to harvesting operations, improvement of forest roads, consciousness-raising of hunters
without weight	14	4	1		1	4	1	3
with weight	**13**	4	0,5		0,5	4	1	3
	Munich	deep water extraction, catchment of surface streams, catchments of shallow water	411000 m3/day (500000 inhab.)		6000 ha	almost 50% (2900 ha of forest on 6000 ha)	land acquisition, contracts with farmers for organic farming conversion	Uneven-aged forest, limiting pollution sources, harvesting operations in winter
without weight	15	3	3		2	2	2	3
with weight	**12,5**	3	1,5		1	2	2	3
	New York	catchments of rivers/streams (reservoir)	5 M m3/day (9 M inhab)	99 % of water come from Catskill/Delaware warershed - 414000 ha		3/4 of forest	land acquisition, conservation easements, buffer strip forest and wetlands management, farming program, education/information of foresters and loggers, public information, sewage treatment	help/incentive for forest owners to have forest management plans, "Best management practises" development, education/information, research
without weight	19	3	4	4		3	3	2
with weight	**15**	3	2	2		3	3	2

	St Etienne (France)	superficial/shallow catchments (1,80 to 2m), filtering soil	29000 m3/day (60000 inhabitants)	2500 ha	1200 ha	100% for the catchment zone (75% for the total watershed)	land acquisition, contract with the waterworks company, education	Uneven-aged forest, importance of broadleaved trees, clearing just above the drainage pipes, forbidden for harvesting machines to pass over water pipes
without weight	15	4	1	1		4	2	3
with weight	**14**	4	0,5	0,5		4	2	3
	Tokyo	catchments of rivers/streams (reservoir)	7 M m3/day (27 M inhab) ?	48000 ha		100 % forest (of which 44 % belonging to Japanese State)	particular forest management only in forest belonging to the State	forest is said to be "well managed for drinking water purposes", but nothing in private forest (only "Tamagawa suigen shintai" where volunteers come to do plantations/thinning operations) + actions against game
without weight	15	3	4	2		4	1	1
with weight	**12**	3	2	1		4	1	1
	Vienna	almost all water comes from the catchment of 2 streams, kartstic area	400000 m3/day (1,78 M inhab.)		90000 ha	2/3 of forest (of which 32000 ha belonging to Vienna)	land acquisition, 2 decrees to restrict some practises for private owners, research	Uneven-aged forest, "natural forest", hydrotope model, continuous forest cover, cable yarding, limitation of pollution sources
without weight	19	4	3		4	3	1	4
with weight	**15,5**	4	1,5		2	3	1	4
	Vittel (France)	deep wells, soil sensitive to pollution (limestone)	?	5000 ha		11 % (half public forest, half private - Nestlé)	land acquisition and tenant farming with farmers	Uneven-aged forest, dynamic underlayer vegetation
without weight	10	2	1	1		1	2	3
with weight	**9**	2	0,5	0,5		1	2	3
	Winterthur (Switzerland)	water comes from water table	23000 m3/day (90000 inhab)		100 ha in protection zone (belongs to the 1900 ha of the commune)	probably 100 % forest	land acquisition, and if possible land exchange with private owners	reforestation, biodegradable oils, dynamic forest underlayer, organic farming
without weight	11	1	1		1	4	1	3
with weight	**10**	1	0,5		0,5	4	1	3

Results: classification of the « most interesting » sites for my study



Appendix 2: Questionnaire for the inventoried sites

1. Presentation of the situation

Area of the total watershed, area of the protected zone of the watershed, percentage of forest cover over the watershed, number of people relying on drinking water from this watershed, number of m^3, price of water

2. Type of action

Scientific research, land acquisition, contracts with forest owners/farmers, regulation, information of public, education, schemes of payment of environmental services…

3. Management implemented for the protection of drinking water

When did the action plan begin? Who gave the impulse ?

3.1 Particularities of the forest management over all the watershed area

Tree species composition, silvicultural treatment (even aged or uneven aged stands, clear cut regulation, type of regeneration…), harvested volume per cut, regulation/restrictions for harvesting, use of chemical products/ pesticides…

3.2 Particularities of the forest management just around the water catchments points (above the water pipes)

Same as above

3.3 Forest road network

Density, particular measures to prevent from erosion or surface water streaming

3.4 Hunting and recreation management

Any particular measure or problem?

3.5 Pasture land or agricultural land management

Any particular measure or problem?

4. Forest situation

4.1 Forest characteristics

Geologic situation, main types of soils

Topographic situation

Ecological type, natural forest communities

Actual situation (species composition, type of forest stand, volume, annual increment…)

4.2 Forest management

Actual management, articulation between forest management plans and watershed management plan (if they are different)

4.3 Ownership

Percentage of public or private owners

5. Relationships between the actors / stakeholders

Relationships with private forest owners?

Problems or conflicts?

Others actors/ stakeholders?

Relationships with research organisms?

6. Costs

Estimation of the cost (or extra-cost) linked to this drinking water objective in the forest management? How is it financed?

7. Evaluation of the action plan

Evaluation of the water quality: monitoring before/after implementation of the watershed action plan?

Further water treatment (chlorination,…) ?

Global evaluation of the action plan, improvements in the future?

8. References

Appendix 3: Filled questionnaires of the inventoried sites

1. Basel

1. Presentation of the situation

Basel drinking water supply is organised by the public company Industrielle Werke Basel (IWB).

The water supply system is rather original: water from the Rhine River is pumped and seeped into a forest to be filtered and pumped again when it arrives in the water table. Iinfiltration is made in 2 forests: Lange Erlen (22 ha) and Muttenzer Hard (208 ha) where infiltration is done in trenches and small lakes.

Annually 27.6 M m^3 come from re-pumping of the water table in Lange Erlen and Muttenzer Hard (comes initially from the Rhine river). 75, 000 m^3 of drinking water are delivered each day to Basel inhabitants.

The price of water for Basel consumer is 1. 40 CHF/ m^3.

2. Type of action

IWB owns the forest lands where water is filtered but forest harvesting is realised by private companies.

Three farmers are present in the forest areas. Their farming plan is done in co-operation with IWB to be sure that their activities will not degrade water quality. They do not receive financial compensation but the price they pay to rent the land is very low.

3. Management implemented for the protection of drinking water

This water supply system from the Rhine River began in 1963. Before, water was pumped from another river, the Wiese, and the infiltration process was less structured.

3.1 Description of infiltration process in Lange Erlen

Water is pumped from the Rhine, 2 km away from Lange Erlen forest.

The infiltration areas are separated in 3 zones. For a period of ten days, the first area will be flushed with pre-filtered water from the river Rhine. After these ten days the infiltration will be held in the second area; and after another 10 days, in the third area. In this case, after the infiltration each area will stay 20 day's without infiltration of water. During these 20 days the ground will be regenerated by itself.

The filtering is realised in the forest soil: humus + 2-3 m of sand and gravels that guarantee a mechanical, chemical and biologic purification of water. Micro-organisms of the soil play a very important role. As they need Oxygen, each infiltration zone has to be let dry during 20 days.

In all this area and in farming lands, the use of pesticides is not allowed.

Water quality is monitored at different points (in the Rhine, before the infiltration, after the infiltration, after final treatments). After the filtration in forest, water is treated to active coals and chlorinated. A degassing is also done.

3.2 Natural site characteristics

The soil lies on Rhine alluviums.

Topography is « soft » (small hills).

The precipitation in 2007 was 931.1 mm (788 mm between 1961 and 1990). The average temperature in 2007 was 11.32 °C (9.74°C between 1961 and 1990).

3.3 Management applied in forest

Forests are composed of beech (26%), ash (20%), maple (12%) and oak.

The main forest function is water protection. Wood production and recreation are limited to preserve soils.

Harvest techniques are diverse: chainsaw, harvester, extraction by tractor.

Biologic oils are recommended.

3.4 Particular forest management in infiltration zones

Forests are composed of oak, hornbeam, alder, willow, cherry, ash and black poplar.

Before, there were a lot of hybrid poplars.

Infiltration areas are fenced to prevent from dogs faeces.

Wood production is not an objective in this zone. Forest works are done manually.

3.5 Hunting and recreation

Hunting is not allowed.

The 2 forests are important recreation areas. Littering is a major problem.

4. Cost

The costs of forest management are around CHF 100, 000 per year. There are adding costs for maintenance of the paths, green maintenance, littering removal. The costs therefore are around CHF 200, 000 per year, which represents CHF 0.011/ m^3.

.

5. Evaluation of the action plan

In the next future, depending on the Rhine water quality, other water treatment processes will be discussed.

6. References

Thomas Meier (IWB) thomas.meier@iwb.ch

JORDI (B.).- Le sol forestier : un filtre idéal-3. *Environnement* 3/05 Forêt, p. 32 to 35

2. Baltimore

1. Presentation of the situation

Maryland covers 2, 500, 000 ha, of which 20 % are protected from any development. 5 million persons live in this State. The population of Baltimore and Washington DC spread around drinking water reservoirs, which threats this resource.

10 % of the reservoirs watershed areas is protected. The total surface of watersheds is 115, 000 ha. Around 7, 100 ha belongs to Baltimore city.

The forest service department of Maryland has developed a watershed forest management program with USDA and private forest associations.

This program encompasses riparian forests restoration, water reservoirs management, and BMPs evaluation. Others actions are also implemented to protect the watersheds.

2. Types of action

Baltimore city acquired more than 7, 100 ha of land around reservoirs between 1880 and 1955. In 1999, the Maryland DNR Forest service has developed a management plan of these forests (see 3.1).

But these public forests represent only a small part of the watershed. Other actions have therefore been implemented in private forests to protect watersheds.

1) Participate in and support emerging ecosystem markets and land registries to generate additional incentive for continued forest conservation and restoration;

2) Develop a Sustainable Forestry Policy in Maryland by 2008 to stimulate improved forest conservation through:

a) Tax incentives, such as income tax credit for developing a forest stewardship plan and expanded property tax rebate for having a forest stewardship plan;

b) Effective and equitable regulations, particularly related to forest harvesting;

c) Forest enterprise zones to support healthy forest product markets and technical innovation for new markets;

d) Forest health reserve fund to improve response to forest health threats; and

e) Family forest revolving loan fund for intact intergenerational transfer of forests;

3) Link forests, storm water, and water supply through Comprehensive Plan Elements like Sensitive Areas, Water Resources, and Land Protection Plans, and new requirements for prioritized environmental site design for storm water;

4) Revise the Forest Conservation Act to reduce forest loss through development, potentially to no net loss of forest;

5) Support full funding annually and bond measures for Maryland's dedicated land conservation funding through Program Open Space, including Rural Legacy and Maryland Agricultural Land Preservation Foundation;

6) Adopt a transferable and/or refundable tax credit program for donated conservation easements by 2009;

7) Support effective local Transferable and Purchase of Development Rights programs;

8) Adopt a watershed improvement benefit district to aid forest conservation and restoration by 2009;

9) Invest in coordinated tracking for forest and other vegetative cover by 2008;

10) Invest in ongoing education, outreach, and technical assistance to local jurisdictions and landowners to improve forest conservation and management.

3. Management implemented for the protection of drinking water

3.1 Particularities of the forest management over all the watershed area

The protection program implemented by USDA forest service encompasses the following measures.

- **Riparian forests restoration**

Since 1987, 1722 km of riparian buffers have been restored (2,4 % of the whole riparian buffers of Maryland).

The survival rate of seedlings plants there has increased from 60 % in 2000 to 87 % in 2003, thanks to improved maintenance. Natural regeneration is also favoured when it is present.

- **Management of protection forests around reservoirs**

A management has been established in 7, 100 ha of forests belonging to Baltimore, around 3 reservoirs (Loch Raven, Prettyboy and Liberty). The objectives are: protection of water quality, biodiversity and recreation. Forest resilience is the main goal to reach.

Diagnostic pointed out problems of insufficient regeneration, dangerous recreation activities, abusive rivers crossing, forest vulnerability to wind throws.

The management plan includes regeneration protection against game browsing (fences), forest stands evolution to have a better resistance to wind, encouragement of rapid growing species on shallow soils.

The aim, in the long term is to have diverse forest stands in species composition, age and structure (uneven-aged forest). Pine plantations require a different treatment (introduction of deciduous trees).

Invasive species are a major problem, linked to the garden proximity in forest near reservoirs.

Private owners sometime consult DNR forest service to establish management plans. Their objective is not to protect water, but they have to apply BMPs to prevent erosion and sedimentation.

- **Creation of a watershed partnership** to integrate different forest services and provide a network.
- **Evaluation of BMPs** concerning forest harvesting to test their efficiency and generalise them.

In a directive signed by the Chesapeake Executive Council on September 22, 2006, the Governor of Maryland committed state resources to “conserving those forest lands in the Bay watershed where conservation to protect water quality is most needed.” A major part of this commitment is to use the best available tools to locate areas where retention and expansion of forests is most needed to protect water quality and to set a goal, framework, and milestones for protecting forested areas of critical importance to water quality (in acres or percentage of forested lands) while considering which of those are most vulnerable to development.

To assist in setting an achievable goal for forest conservation and to locate those forests with imperative water quality functions, the Maryland DNR Forest Service is developing three geographic information models: a conservation model, a management model, and a restoration model.

Long-term Forest Conservation Goal in Maryland

Maryland’s current forest cover is estimated at 41%. The long-term goal is to retain existing levels of forest cover in the state and expand it in areas of higher benefit for water quality, habitat, and rural economies.

1. Extent Matters: Retain existing levels of forest cover in Maryland, estimated at 2.6 million acres.

2. Location Matters: Protect 20% of Maryland (1.25 million acres) in forest cover, targeting areas with high value for water quality, conserving and expanding forests located in areas such as stream and shoreline buffers, wetlands, and steep slopes.

3. Streams Matter: Protect 70% of stream and shoreline buffers from development long-term (35-ft minimum, preferably 100 feet).

4. Context Matters: Develop guidelines to retain at least 65-70% of watershed area in rural land uses, with forest targets based on landscape characteristics like steep slopes, buffers, wetlands, existing and planned developed areas, and prime agricultural soils.

5. Communities Matter: Set urban canopy cover goals in Maryland's municipalities and urbanized areas, focusing on areas developed before storm water management requirements.

2020 Forest Conservation Goal in Maryland

Maryland is committing to time-specific numeric goals and milestones that work aggressively towards the long-term desired conditions and functions.

1. Retain existing levels of forest cover in Maryland, estimated at 2.6 million acres past 2020.

2. Protect an additional 250,000 acres of forest by 2020 through legal mechanisms, with more than half in areas of high value to water quality.

3. Restore an additional 25,000 acres of forest buffers, or other areas of high value to water quality outside of prime agricultural land, by 2020.

4. Produce rural and forest land retention guidelines based on watershed indicators by 2008 that can support requirements for forest and water protection in local comprehensive plans.

5. By 2020, have urban canopy goals for 50% of the area developed primarily before storm water management regulations (pre-1984).

3.2 Particularities of the forest management just around the water catchments points

These zones correspond to riparian forests which are described above.

3.3 Forest road network

The reservoir lands contain 340 km of internal low-volume roads (covering 7 100 ha).

Drainage problems were identified along the majority of the road system, with many of the stream culverts rated as in poor condition, stream fords with silt substrates, and bridges that were unsafe or missing.

3.4 Hunting and recreation management

Despite of hunting, there are problems linked to game browsing.

Forest is an important recreation area (mountain biking, hiking, horse riding, sailing, bird watching).

3.5 Pasture land or agricultural land management

There are many farms lands on the watershed. Conservation easements are signed with farmers.

4. Forest situation

4.1 Forest characteristics

The total watershed area is 115 000 ha. 36 % are forested, 46 % are farm land, less than 1 % are wetlands and 18 % are urban areas. The forest lands owned and managed by the City of Baltimore are separated in three separate patches. Each of the forest patches completely surrounds the associated reservoir within a landscape matrix of forest, agriculture and urban land uses.

Soils are well drained.

Elevation varies from 30 to 275 m.

Annual precipitation is 1, 035 mm. Annual temperature is 12.8 °C.

Main species are chestnut oak (*Quercus prinus*) and scarlet oak (*Quercus coccinea*); the slope type, in which scarlet oak, black oak (*Quercus velutina*) and white oak (*Quercus alba*) at the higher elevations transition down to red oak (*Quercus rubra*), tulip poplar (*Liriodendron tulipfera*) and hickory (*Carya ovata*) on the lower slopes. The bottom type consists mainly of red maple (*Acer rubrum*), green ash (*Fraxinus spp.*), elm (*Ulmus spp*.), birch (*Betula spp*.) and sycamore (*Platanus occidentalis*).

4.2 Forest management

Baltimore forest objectives are :

- water quality protection,
- conservation and restoration of biodiversity around reservoirs,
- forest management to optimise forest habitats,
- public recreation.

4.3 Ownership

7, 000 ha among 115, 000 ha of watershed belong to Baltimore (6 %).

5. Evaluation of the action plan

Water from reservoirs is filtered and chlorinated.

6. References

contact : Anne Hairston-Strang from Maryland DNR Forest Service astrang@dnr.state.md.us

Web page of Maryland DNR Forest Service, conservation goals

HAIRSTRONG-STRANG (A.).- *Cooperative forest watershed management in Maryland : watershed restoration across land ownership*

HAIRSTRONG-STRANG (A.).-. *Forest conservation goals for Maryland- Summary*-2007

DEHART (H.G.), ETGEN (R.).-. *Report : The feasibility of successful TDR programs for Maryland's Eastern shore*- 2007

MARYLAND DNR FOREST SERVICE.- A comprehensive forest conservation plan for the long-term watershed protection on the City of Baltimore's reservoirs.-2007

3. Boston

1. Presentation of the situation

The Quabbin Reservoir Watersheds supplies each day 600, 000 m^3 of drinking water to the 2.2 million inhabitants of Boston region.

Water comes from rivers and is « stored » in huge open air reservoirs.

The « watershed » area is 48, 000 ha (= surface of reservoirs, rivers, with a buffer of 120 m around them). The Division of water supply protection (DWSP) owns 57 % of this zone (10, 000 ha of reservoirs + 22, 000 ha of land). 18 % of additional surface is protected by other agencies.

The watershed is forested to 87 % and has 6 % of wetlands.

Price of water is around 1$/ m^3.

2. Types of action

- Land acquisiton: Boston city owns 22, 000 ha and still wants to acquire land.

- Payments In-Lieu of Taxes (PILOT) : DWSP provides financial compensation to cities that own land situated in the protection. Money comes from a tax paid by water consumer. DWSP has no control on the use of these PILOTs, but has to pay them to compensate cities from the loss of revenue caused by the conversion of private to public lands.

- Land disposition: when private or public owners have an incompatible uses of their land with water protection, juridical tools exist to allow DWSP to buy these lands.

- Conservation easement: DWSP has signed 10 conservation easements on the watershed (300 ha) with private owners (purchase of development rights).

- Technical assistance to communities: DWSP provides assistance to realise growth management planning, master plans, land use studies…

- Technical assistance to private forest owners: DWSP encourages and finances partly private forest management plans.

- Maintenance of boundaries

- Public information and forest surveillance

- Protection against forest fires.

3. Management implemented for the protection of drinking water

The watershed is managed since 1961. The last management plan dates from 2007 and will last 10 years. It concerns the 22, 000 ha belonging to DWSP (of which 4 800 ha are not managed).

3.1 Particularities of the forest management over all the watershed area

DWSP has concluded that the forest conditions that best meet the combined objectives of the agency – to deliver predictable quantities of high-quality drinking water at a reasonable cost while protecting the fullest possible suite of associated natural resources – include vigorous trees of broad, site-suited species composition and age classes well-distributed across the watershed and capable of rapid regeneration and active growth following a wide range of both natural and deliberate disturbances.

Up to now, forest stands were even-aged. The objective is to have uneven-aged stands. Managers regenerate 1 % of forest area each year (160 ha/year).

Regeneration is done by little openings (<0,4 ha). If natural regeneration is not enough, plantations can be done.

DWSP also conserves some old stands unmanaged.

Different zones have been created, associated to different limitations of forest harvesting.

Main species are *Pinus strobus* and *Quercus rubra* ; mixed with *Acer rubrum, Tsuga, Quercus coccinea, Betula lenta, Quercus alba, Fraxinus americana, Pinus resinosa, Acer saccharum.*

Permanent log landings have to be situated on well drained soils that can carry wood weight.

Equipments prevent water to flow from skid roads to log landings.

Pesticides are not allowed (except under electric lines).

Biologic oils are recommended.

Invasive plants are controlled mechanically or chemically.

3.2 Particularities of the forest management just around the water catchments points

It corresponds to the management applied in the most sensitive zones. Timber harvest is very limited..

3.3 Forest road network

There are around 3.3 km of forest road per hectare (sufficient), mean width of 3 m.

3.4 Hunting and recreation management

Game population is kept under control with hunting.

A park has been created for public recreation on 1 200 ha belonging to DWSP, which represents 2 % of the watershed protection zone. 80 % of recreation is concentrated there.

3.5 Pasture land or agricultural land management

Farmers have to respect the Wetlands Protection Act and the Watershed Protection Act, but there are some exceptions.

4. Forest situation

4.1 Forest characteristics

Elevation varies from 161 to 421 m.

Slopes are not steep (less than 20 %).

Mother rocks have a metamorphic origin.

Soils are well drained, favourable to many tree species (*Quercus rubra, Pinus strobus, Acer saccharum* and *Fraxinus americana*). There are about 2/3 of deciduous and 1/3 of conifers.

Annual precipitation is 1, 178 mm.

4.2 Forest management

Water protection is the main objective.

4.3 Ownership

22, 000 ha belong to DWSP, 3, 300 ha belong to other governmental agencies.

18, 000 ha (34 %) is privately owned: 7, 000 ha belong to holdings which have a protective management, 11, 000 belong to « small » owners who do not have any restriction.

5. Relationships between the actors / stakeholders

Logging and forest management are very carefully regulated across the entire state by the MA Forest Cutting Practices Act, so DWSP seldom has any conflicts about private land forestry. There are minor problems with agriculture, e.g. when animals are allowed to pasture in wetlands and streams that are tributaries to our reservoirs, but most of these are corrected by the Wetlands Protection Act. The

biggest conflicts are with land developers who desire to convert privately-owned watershed forests into housing developments; DWSP is supported by the Watershed Protection Act, which limits development within 120 m of our tributaries.

DWSP has very strong relationships with the local universities, including the University of Massachusetts, Mt Holyoke College, the Harvard Forest (a research facility of Harvard University that is located within the Quabbin Reservoir watershed), the USDA Forest Service in Amherst, MA and Durham, NH, the USGS, and several smaller associations. DWSP allows research permits through a formal review process and also provide limited funds to pay researchers to answer its own questions.

6. Costs

The annual operating budget for the DWSP is currently $14 million. On top of that, annual PILOT payments are approximately $5 million and we are also currently spending approximately $7 million annually to purchase additional lands. The water from this system is valued at $100 million annually, and forest management practices provide revenue of $500,000 to $1 million annually. DWSP budget is provided to us by the Massachusetts Water Resources Authority, a separate, non-governmental authority that is responsible for the actual delivery of the water to the consumers, after it leaves watersheds.

7. Evaluation of the action plan

Quabbin water quality has been consistently extremely good throughout the life of the system. The revised forest management practices are expected to reduce the likelihood of short-term water quality changes resulting from catastrophic storms or other natural disturbances.

While water is not filtered, measured doses of chlorine are added to disinfect the water as it enters the aqueduct, and chloramines are added to continue to protect the water as it is carried through the aqueduct. In addition, the John J. Carroll Plant, located closer to Boston uses ozone as a primary disinfectant and chloramines for residual disinfection, allowing MWRA to meet current and tougher future state and federal water quality standards. The plant has the capacity to treat up to 1.5 million m3 of water from the Quabbin/Wachusett Reservoirs each day, though 1 million m^3 per day is the average. Treated water is held in covered storage along the line, to protect its quality.

DWSP managers are constantly looking to improve. While basic watershed management program seems to be working well, they are trying to address several problems:

- the impact of waterfowl, and in particular gulls and geese, on our bacteria counts
- the impact of a new and rapidly growing moose population on our forest cover
- the effects of expanding populations of invasive plants on our forest cover
- the projected effects of climate change on our species composition and other dynamics
- the pressure of residential and commercial developments throughout our watersheds
- increased recreational pressures on our properties, including mountain biking, horseback riding, and all-terrain vehicles ridden for recreation.

8. References

MASSACHUSSETS DEPARTMENT OF CONSERVATION AND RECREATION? DIVISION OF WATER SUPPLY, OFFICE OF WATERSHED MANAGEMENT.- *Quabbin reservoir watershed system : land management plan 2007-2017*. - (Sept 2007)

Contact : Tom Kyker-Snowman, thom.kyker-snowman@state.ma.us

4. Hanover

1. Presentation of the situation

The stadtwerke Hanover AG supplies each day 137, 000 m^3 drinking water to 500, 000 Hanover inhabitants. Water is pumped from 110 wells situated in a watershed of 30, 000 ha. Forests cover 50 % of this watershed.

The protection area is divided into 4 zones : zone 1 is the area of wells (46 ha), zone 2 is defined as the area of water runs up to 50 days to the wells (806 ha), zone 3a is closer than 2km to the wells (8, 536 ha) ; the remaining catchment area is zone 3B (21, 000 ha).

Taxes are taken on water (5.1 ct/ m^3 on drinking water and 1ct/ m^3 on industrial water). 40 % of theses taxes finance a fund to finance forest and agricultural measures, water supply infrastructures and consulting.

Water costs 60 ct/m3, which is very low for the region.

2. Type of action

Hanover has acquired land since 1908 and owns today 2, 000 ha of forest where all wells are situated.

3. Management implemented for the protection of drinking water

A new management program has been set up in 1996.

3.1 Particularities of the forest management on the 2 000 ha belonging to Hanover

The aim is to replace coniferous stands (pine plantations) into more « natural » forest stands. Deciduous trees (beech and red oak) are planted under pines.

3.2 Particularities of the forest management just around the wells

These zones are fenced.

3.3 Hunting and recreation management

Hunting is allowed. Deciduous seedling plantations (except beech) have to be protected from game browsing.

Recreation is very limited.

3.6 Pasture land or agricultural land management

Farming and pasture are regulated.

4. Forest situation

4.1 Forest characteristics

Soils are podzols and sandy gleys.

Annual temperature is 9.9 °C. Annual precipitation is 712 mm.

The terrain is not steep; elevation goes from 30 to 70 m.

4.2 Forest management

Water protection is the first management objective.

4.3 Ownership

2, 000 ha belong to Hanover among the 15, 000 ha of forest, which corresponds to 13 % of forested area (and 7% of the watershed).

5. Costs

A tax of 0.051 €/ m^3 finances forest management and deciduous plantations.

6. Evaluation of the action plan

Since the implementation of forest and agricultural measures, nitrate concentration in water has decreased of 15 mg/l.

Water is filtered and chlorinated when maintenance work is done in the water pipes.

7. References

ZANDER (O.).- *Groundwater Protection Strategies of a Water Supplier*.- Stadtwerke Hannover AG

Contact: Olaf Zander, Stadtwerke Hannover AG, olaf.zander@enercity.de

5. Masevaux

1. Presentation of the situation

Masevaux is a town of 5, 000 inhabitants located in the Vosges mountains (North-East of France).

10 shallow underground water catchments situated in Masevaux public forest produce 700 m^3/day.

Masevaux forest area is 1, 250 ha, the watershed area is 650 ha and the protection zones area is 240 ha.

Water costs 2.85 €/ m^3 to consumers.

Masevaux city manages water supply, ONF manages the forest according to Masevaux wishes.

2. Type of action

Masevaux already owns the forest where the catchments are.

Particular actions are implemented with ONF to optimise forest and water management.

Masevaux develops communication and information with hunters, pupils and local people coming to cut fuel wood.

Projects with research organisms are being implemented to know better forest roles on water.

3. Management implemented for the protection of drinking water

3.1 Particularities of the forest management in PPR (inner protection zones)

Regulative measures in PPR:

Road construction/modification, chemical treatments, and deforestation on more than 1 ha, wood treatments, and cullwood deposition near catchments are forbidden.

Voluntary measures (innovation of Masevaux):

- Improvement of communication between ONF and water services: exchange of GIS data, ONF has to declare in advance when a forest operation will be done in a PPR.
- Cautious harvest: cable yarding in one parcel, biologic oils given to local people coming to cut fuel wood.
- Awareness raising of pupils: visits in forest, with ONF and water service.

When a cut is located near glens where water pipes go, cullwood are burn, to give a better visibility.

PPR forest stands are even-aged but regeneration period lasts 20-40-60 years, therefore soil is always covered by forest. Main species are beech and fir, many other deciduous regenerate also.

Forest stand in a PPR (May 08)

3.2 Particularities of the forest management just around the water catchments points (above the water pipes)

PPI are dispensed of being fenced.

PPI of a water catchment (May 08)

3.3 Hunting and recreation management

A limited feeding is tolerated in PPR.

Recreation is not a problem.

3.5 Pasture land or agricultural land management

Agricultural lands are concentrated down stream.

4. Forest situation

4.1 Forest characteristics

The terrain can be steep; elevation goes from 395 to 1,190 m.

Annual precipitation is 1, 400 mm. Temperature depends on elevation (8°C in average at 620 m).

Soils are brown and rich.

Forest site is beech-fir forest.

4.2 Forest management

Managers try to have 1/3 conifers and 2/3 deciduous in all the forest.

A wind throw recently happened.

4.3 Ownership

Totally owned by Masevaux city.

5. Relationships between the actors / stakeholders

Relationships between ONF and Masevaux are good.

6. Costs

A study is being done to evaluate the over costs in forest because of water protection.

7. Evaluation of the action plan

Water is chlorinated, it may be neutralised in the future.

8. References

FIQUEPRON (J.).- *Compte rendu de la visite du site de Masevaux*.– 28 novembre 2007

Contact : Jean de Marin (ONF), Pascal Masson (ONF)

Visit in Masevaux on 13/05/08

6. Munich

1. Presentation of the situation

Munich water comes mainly from the Mangfall river watershed (80 % of Munich total drinking water): one stream catchment and underground water catchment of 10 m depth.

41, 000 m^3 are supplied each day to the 1.5 million Munich inhabitants. The Stadtwerke München (SWM) is responsible for water supply.

To protect the watershed, a protection zone, called « conversion zone » has been defined. It takes 150 days to water to go from the border of this zone to the catchments. The area is 6, 000 ha (2, 250 ha of organic farming + 2, 900 ha of forest).

Water costs 1.42 €/ m^3 to consumers.

Source : SWM. – *M-Wasser, ein erstklassiges Naturprodukt*- 2005

2. Types of action

- **Land acquisition**

Munich city has acquired forest land or reforested during the last century. 1, 500 ha (among the 2, 900 ha of the forested conversion area) are owned by Munich, they are the most sensitive zones.

- **Conversion to organic farming**

After strong nitrate pollution in the 80s and 90s, a partnership has been established with organic farming associations (Bioland, Naturland and Demeter). Farmers who join one these associations and respect the organic farming rules receive, in exchange, financing from Munich city. About 500 €/ha/year are given to the organic farmers.

Today, more than 100 farmers have signed these contracts, which represents 1, 800 ha in the conversion zone (85 % of farmers) and 500 ha outside the protection zone.

Thanks to these measures, nitrates are not detectable anymore in Munich water.

- **Public information**

There is a lot of communication about the origin of Munich water, inhabitants are well informed. Visits are organised for pupils in forest.

3. Management implemented for the protection of drinking water

When Munich bought lands at the beginning of the 20th century, they have been reforested with spruce plantations. Since the 70s Munich forest service tries to diversify these forest stands to have more resilient stands.

3.1 Particularities of the forest management over the 1, 500 ha of Munich

The management objective is water protection and therefore to have a solid ecosystem, resilient to droughts and wind throws.

Actual stands are composed of 70 % of spruce. Managers try to regenerate them:

- favour deciduous trees regeneration (mainly beech, but also oak, maple, ash), and fir;
- continuous forest cover, uneven-aged forest (little openings is spruce stands);
- timber harvest in winter to prevent from bark beetles, with chainsaw/harvester, tractor extraction (when soil are too humid, no extraction);
- 50 to 100 m^3/ha are harvested each year, rotation of 5 years (very productive site and not enough volume harvested in the past);
- pesticides are not allowed ;
- biologic oils are compulsory.

Munich forest is certified FSC.

Fir and deciduous trees regeneration under spruce (June 08)

3.2 Particularities of the forest management just around the water catchments

Three zones are defined:

- zone III: time of water transport is 150 days,
- zone II : time is 50 days,
- zone I : immediate area.

Forest management is almost the same in the 3 zones, but more surveillance is made for harvest operations in zone I and machines cannot stay there during the night.

Above water pipes catching shallow underground water, land is deforested on 10-15 m width.

Deforestation above a water pipe (June 08)

3.3 Forest road network

Road density is sufficient. Skid roads are every 40 m.

3.4 Hunting and recreation management

Hunting is realised by foresters to keep low population levels.

Recreation is abundant but is no problem (except maybe horse-riding).

3.5 Pasture land or agricultural land management

See paragraph 2

4. Forest situation

4.1 Forest characteristics

Annual precipitation is 1, 400 to 1, 600 mm. Elevation goes from 600 to 990 m. Slopes are not steep. Soils are deep and rich.

Site-suited species are beech and fir with other deciduous.

4.2 Forest management

The main objective of Munich forest is water protection.

4.3 Ownership

1, 500 ha (among the 2, 900 ha of the conversion zone) belong to Munich.

Private owners manage their forest as they want. They are informed about the water protection issues. The Land of Bavaria provides financial incentives to plant beech trees. Clear cuts are limited to 2 ha.

5. Relationships between the actors / stakeholders

Relationships with farmers are now good.

Munich city would like to define an official protection zone, but it leads to conflicts with the local cities that own this potential protection zone.

6. Costs

Costs of water supply are very low.

Prevention by organic farming costs less than 0.01 €/ m^3 (to compare, nitrate and pesticides depollution costs are 0.23 €/m3).

Each year 40, 000 to 50, 000 m^3 of wood are harvested in Munich forest (annual revenue of 3 million €/year). Revenues cover forest management costs.

7. Evaluation of the action plan

Water is not treated (except during flood periods).

8. References

Contact: Rainer List (waterworks manager) and Jan Linder (forest manager) from SWM list.rainer@swm.de and linder@forstgotzing.de

Visit on 02/06/08 in Thalham (SWM office, Mangfall)

7. New York

1. Presentation of the situation

90 % of New York drinking water comes from the Catskill/Delaware watershed. The area of this watershed is 414, 000 ha. 2 rivers, Catskill and Delaware, are caught and "stored" in 6 huge reservoirs. The watershed is mainly covered by forests (75%) and by rural lands.

5 million m^3 are produced each day to supply 9 million inhabitants.

Since 1993 (and 1997), New York City has decided to invest in watershed protection, instead of building a filtration and purification plant. Economic calculations showed that New York would spare 6 to 8 billion $ (filtration plant cost) and 200 to 300 million $ per year of maintenance cost. In 2006, the city confirmed the choice of protecting the watershed and reinforced its actions to do so.

The entire watershed is concerned by the same protection rules (land acquisition and comprehensive planning, water quality monitoring and disease surveillance, and upgrading wastewater treatment plans).

2. Type of action

- **Land acquisition**

The land acquisition program started 10 years ago. At this time, New York city owned 3.5 % of the watershed. After having solicited the purchase of 144, 000 ha, the city acquired 24, 000 ha (to voluntary owners, at the market price). Today, the city owns 5.8 % of the watershed and wished to acquire more land in the future.

The city gives public access to its land in exchange of the purchase of a visit permit. 102, 000 persons have bought this permit. 18, 000 ha are recreation area, 4, 000 ha are hunting area.

- **Reserve**

20 % of the watershed (82, 500 ha) belong to "New York State's Catskill Preserve". This reserve is totally forested but is voluntary unmanaged. It is open to public.

- **Conservation easement**

From 1997 to 2003, New York has signed conservation easements on 21, 000 ha for 131 million $. 70 % of these lands are situated in very sensitive zone (490 ha in wetland).

- **Wastewater treatment plant upgrade**

- **Stream, riparian buffer and wetland management program**

To limit erosion problems, 13 huge riparian buffers restoration projects have been set since 1997. Private owners are informed of the importance of these zones that New York tries to acquire. Scientific research is also conducted there.

- **Agricultural program**

Over 95 % of large farms in the watershed enrolled in this voluntary program of good practices, for a cost of 18.6 million $.

- **Forestry program**

Forests cover more than ¾ of the watershed and belong to thousands of private owners who have diverse management objectives. The temptation to sell or develop their land is huge. Moreover, the ecologic health of forest is threatened by invasive plants. The city has developed a partnership program to bring assistance and knowledge to forest owners. Education on BMPs and watershed ecology has been done. These trainings programs have been followed by 560 forest owners (40, 000 ha) who created after management plans on their forest, and 1, 500 forest loggers.

- **Forest management assistance program**

This program finances a part of forest work made in private forest (kind if incentive): plantation, work and improvement cuts in riparian buffers, fauna habitat conservation, invasive plants control.

- **GIS monitoring and modelling of the watershed**

- **Regulation of collect and treatment** of wastewater and fuel storing
- **Public information**

3. Management implemented for the protection of drinking water

Since 1997, 4 major orientations have been defined by the Watershed Agricultural Council (WAC) to protect the watershed.

3.1 Particularities of the forest management over all the watershed area

- **Management plans**

WAC organises educative programs to help forest owners to finance and write management plans which take into account water protection. Today, 529 owners have a management plan, covering 40,000 ha (of which 1, 200 ha in riparian buffers).

The management plans are evaluated every 10 years to see if forest owners comply with their plans. After the first evaluation, an assistance program has been created to help foresters to plan improvement cuts, realise plantations, and manage riparian buffers and habitats.

- **BMPs implementation**

WAC provides cost sharing, technical assistance and other incentives to loggers and landowners for implementing BMPs that prevent pollution during timber harvests and associated management activities. WAC developed programs to support the temporary installation of portable bridges, the proper construction of new timber harvest roads, the remediation of existing forest roads having erosion problems, the planting of riparian buffers along watershed streams… In addition, WAC recently modifies its forestry BMP eligibility requirements to provide increased incentives for loggers who are fully certified under the Trainer Logger Certification Program.

- **Forest loggers education**

WAC supports a voluntary logger training program to improve the quality of timber harvesting and promote logger safety. Between 1999 and 2002, WAC developed a “watershed qualified” training option whereby loggers who attended at least one water quality BMP training workshop would be eligible to participate in certain WAC cost-sharing programs. WAC is developing other actions to encourage loggers to receive this Trained Logger Certification (TLC).

- **Research / education**

WAC collaborates with a wide range of upstate and downstate partners to implement research, demonstration and forestry education programs throughout the watershed and within New York city.

3.2 Particularities of the forest management just around the water catchments points

WAC owns land around reservoirs, public access is not allowed. Management plans of these zones are very cautious.

3.3 Hunting and recreation management

Hunting is allowed in public and private forests. Too high deer population created regeneration problems. WAC tries therefore to organise hunting management plans.

Public recreation is very important: hunting, fishing, hiking, skiing, golfing and camping. While there have been isolated water quality problems resulting from some of these activities, there are not any widespread problems.

3.5 Pasture land or agricultural land management

95 % of farmers have signed contracts with WAC to apply BMPs.

4. Forest situation

4.1 Forest characteristics

The Catskill Mountains are the remnants of a high plateau deeply carved by water erosion. Topography is characterized by steep slopes (>15%) and deep, V-shaped valleys. The bedrock is chiefly sandstone and shale (sedimentary origin). Soils are generally stony and acidic.

The forests of the watershed are primarily Northern hardwood forests. Principal species include beech, red/sugar maple, white ash, black cherry, yellow birch and red/white/chestnut oak. Eastern hemlock, white pine and red spruce are also present. Most of the forests are in the 70-100 year age class (natural regeneration), having been harvested significantly in the past during the peak of agriculture. Many agricultural lands have been reverting back to forest cover.

High grading (cutting the best, leaving the rest) has traditionally been a common practice, so many of the forest stands are uneven-aged.

4.2 Forest management

The City, both internally as well as in partnership with many local organizations, actively supports long-term forest management on both City-owned and privately owned forest lands. The latter category comprises most of the forest land (~70%), so one primary objective of the voluntary NYC Watershed Forestry Program is to encourage/support the adoption of long-term forest management plans written for private landowners by trained professional foresters. These plans are written to strict watershed specifications which exceed NYS standards for plans developed pursuant to the NYS Forest Tax Law. As such, watershed forest management plans are required to include a thorough description of soil and water conditions/issues on the property, erosion control (BMP) recommendations, riparian management recommendations, and numerous other detailed descriptions regarding the status of current forest roads, stream crossings, and other erosion or water quality problems. The plans are voluntary, so it is the landowner's responsibility to follow these prescriptions.

Watershed forest management plans also contain very detailed information about the health, status, stocking volume, and species composition of all forest stands on the property, as well as as a 10-15 year work schedule of proposed silvicultural prescriptions which address the forest type/composition based on the landowner's long-term property management goals. Thus, there is no uniform standard for what individual plans recommend in terms of silviculture - each plan is site specific and tailored to the property/landowner. Again, because the plans are voluntary, it is the landowner's responsibility to implement any silvicultural recommendations.

4.3 Ownership

Forest is mainly private. With land acquisition recently realised, New York City owns around 10 % of the watershed. The Department of Environmental Protection (DEP) will soon define a management plan for these forests.

5. Relationships between the actors / stakeholders

In terms of private forest landowners, the audience has been generally extremely responsive in a positive way, to various watershed protection efforts. Conservation easements are certainly a sticky subject, but landowners have a number of options to choose from and all options are voluntary.

It should probably be noted too, that forestry/silviculture in New York State (including the watershed) is a non-regulated and generally exempt activity, at least in terms of nonpoint source pollution. Regulations are generally triggered by the need to develop storm water pollution prevention plans for land clearing activities (building forest roads that impact a specific minimum acreage).

6. Costs

To date, NYC has spent or committed about $1.5 billion to watershed protection. All DEP funds come from rates paid by water and sewer users. The watershed protection program is just a small portion of

the average consumer's bill – and watershed protection is considerable cheaper than filtration would be.

7. Evaluation of the action plan

DEP has a robust water quality monitoring program in place. This program has always formed the basis for water quality protection activities. New York City water quality has always been extremely good. In the 15 years that watershed protection programs have been actively engaged, there has been no degradation of water quality. In some localised areas monitoring has detected improvements in water quality. In short, the data confirms that programs are effective.

DEP reviews and revises its water quality protection plans every 5 years. These reviews are based on a comprehensive data set of water quality monitoring results, as well as professional judgement in managing the programs. The next scheduled to update programs is in 2011/2012.

Water is chlorinated, and fluoride is added to prevent tooth decay.

8. References

LLOYD (E.), RUSH (P.) (Bureau of Water Supply*).-2006 Long-term Watershed Protection Program-*. New York City Department of Environmental Protection, December 2006

BLOOMBERG (M.), LLOTD (E.*). -New York City 2006 Drinking Water Supply and Quality Report-*. New York City Department of Environmental Protection.

WATERSHED AGRICULTURAL COUNCIL WATERSHED FORESTRY PROGRAM. *-Forestry handbook-*. January 2008

Contact: David Warne (Chief of Staff, Bureau of Water Supply, Department of Environmental Protection, New York City, dwarne@dep.nyc.gov)

8. Saint Etienne

1. Presentation of the situation

30 to 50 % of the drinking water that supplies the city of Saint Etienne (France) comes from the Furan watershed. The area of this watershed is 1, 200 ha watershed for the catchment area (of which 600 ha belong to St Etienne city) and of 2, 500 ha for the reservoir. The forest cover is 100 % for the catchment area and 75 % for the reservoir.

Shallow catchment pipes (1.8 to 2.5 m of depth) catch underground water. Today, 31 km of water pipes are working. Water from these pipes supplies the 650 inhabitants of Rochetaillée and the surplus is mixed in a reservoir where rivers arrive (this very good quality water is "polluted" with the water of the reservoir and everything is filtered after). But water from these water pipes could supply 60, 000 persons (29, 000 m^3/day).

Water supply is organised by a private company, the Stéphanoise des eaux.

Cost of water is very high (4.32 €/m3) but it is because of this polluting mixing of water.

2. Type of action

Since 1880, the city has acquired lands in the Furan watershed. Today, land acquisitions are still made (about 7 ha/year in average), near catchment zones or outside to exchange later the land with owners situated near the catchment zones.

The Stéphanoise des eaux has passed a contract (provision of services) with ONF for 22, 000 €/year. In exchange, ONF has to do a regular surveillance of harvesting activities nearby water pipes and of recreation, program the maintenance work of the pipes (master building), deforest just above the water pipes. Other services can be done by ONF under punctual estimate.
This provision of service is not equivalent to a contract where ONF would be remunerated for its protective forest management.
For information, another contract is passed between ONF and the city of St Etienne (2, 000 €/year) to increase surveillance against motorised circulation in forest.

Public information is done through notice boards in forest and pupils visits in forest.

No contract is passed with private owners. Their forest management is closed to the one applied in public forest managed by ONF. In addition, an ONF agent is always present in the watershed and checks that harvest operations are correctly done.

No contract is passed with farmers for the moment, but there is a project of land acquisition and tenant farming with farming restrictions (Life project).

3. Management implemented for the protection of drinking water

3.1 Particularities of the forest management over all the watershed area

Forest stands are mainly composed of firs. Ecologically, conditions indicate that the forest site should be beech-fir forest. Beech trees have been eliminated by foresters since a long time. Now foresters favour beech and deciduous trees.

Forest are uneven-aged (tree selection management), which is the traditional silvicultural treatment in this region.

Forest cut have a maximum volume of 50 to 80 m^3/ha.

Pesticides are not allowed. Biologic oils are compulsory in public forests.

There is no real constraint for wood harvesting, except that machines are not allowed to pass over water pipes and no cullwood has to be deposited there.

3.2 Particularities of the forest management just around the water catchments points (above the water pipes)

These zones (PPI) have been dispensed to be fenced. Water pipes network is materialised with milestones and blue painting on trees.

Above water pipes, trees are cut. Deforestation width is 10 m for deciduous trees and 6 m for conifers (because they have smaller roots).

The water pipes network is being progressively renewed (they were made in sandstone, they are replaced by PVC). Each year, around 800 m of water pipes are renewed; up to now, 67 % of the network has been renewed. This work is realised by contractors, but ONF provides the master building.

Deforestation above a water pipe, with a milestone
Picture from Guillaume Sabot, ONF

3.3 Forest road network

No road is build above catchment areas.

3.4 Hunting and recreation management

Hunting is allowed, game populations are monitored.

Recreation is abundant in the forest. Motorised circulation is particularly controlled and repressed.

3.5 Pasture land or agricultural land management

25 % of the reservoir watershed is farm land (mainly pastures). Contracts with farmers are in project.

4. Forest situation

4.1 Forest characteristics

Mother rock is granitic, soils are deep and brown. Annual precipitation is 1, 000 mm. Elevation goes from 800 to 1, 250 m. Forest site type is fir-beech.

4.2 Forest management

Management objectives in public forest are 1) water protection and protection against flooding, 2) wood production and recreation.

4.3 Ownership

Half of forest in the catchment area is public. The rest is privately owned (small forest parcels and one big of 120 ha).

5. Relationships between the actors / stakeholders

Relationships between private forest owners and forest harvest enterprises are good, thank to the presence of one ONF agent in the watershed.

Forest management in public and private are very similar, except that private owners do not make forest work in young stands that. But this has no impact on water protection.

6. Costs

The over costs linked to water protection can be estimated by:

- the price of the contract with ONF (22, 000 €/year),
- the lost of forest area above water pipes (22 ha),
- the restrictions for harvest operations.

7. Evaluation of the action plan

Water “produced” by this forest has a very good quality. It is supplied to Rochetaillée inhabitants with just a preventive chlorination. But it is regrettable that after this water is mixed (and therefore polluted) with a water of bad quality.

8. References

Visit in Saint Etienne on 10/04/08 with Guillaume Sabot (ONF)

9. Tokyo

1. Presentation of the situation

Tokyo (27 million inhabitants) water supply comes from a 48, 000 ha watershed (rivers arriving in reservoirs). This watershed is totally forested. 44 % of forests belong to the Tokyo Metropolitan Waterworks Bureau (TMWB) and is specifically managed. The rest of forests (56 %) is privately owned is not managed.

About 4, 400, 000 m^3 of water are produced each day.

Water costs around 2 €/m3 to consumers.

2. Type of action

TMWB manages the forests it owns.

No management is done in private forest, although important problems are known. These forests are almost "abandoned" because of forest industry decline. Only events like "Tamagawa suigen shintai" happen there: volunteers come in private forests to plant trees and do some selective cuts.

Tokyo inhabitants are aware of this forest protective function. Information and education are diverse: educative forest trails, projects with schools…

A demonstration forest has been created to train TMWB staff to forest management.

3. Management implemented for the protection of drinking water

The particular management of this forest started in 1901.

3.1 Particularities of the forest management over all the watershed area

TMWB manages 21, 630 ha of forest in the watershed. 15, 000 (70 %) are "natural" forests, and the rest, 30 %, are plantations.

Natural forests are located in mountains. On deep soils, they are composed of broadleaved trees (beech, oak, chestnut, ash, maple). On rocks, they are coniferous (*Tsuga diversifolia, Picea jezoensis*).

Plantations, aged from 0 to 100 years, are composed of *Chamaecyparis*, *Larix kaempferiet* and *Cryptomeria japonic.* They are managed in 2 different ways :

- « Natural » forest (44 %), in less favourable forests sites; some conifers are cut to allow deciduous regeneration, forest stands are supposed to evolve to natural forest stands.
- Multi-layer forests (56 %) on favourable forest sites; a multi layered stand is re-created to evolve to uneven-aged forest (cutting, pruning, thinning, weeding…). Harvested timbers are sold. Pesticides are not allowed.

Natural forests are not managed (except sometimes to protect regeneration from game). Natural succession is expected to forward in natural forests.

3.2 Particularities of the forest management just around the water catchments points

There is no specific action to protect riparian buffers.

3.3 Forest road network

There are about 780 km of mountain trails to investigate the forest situations, to take care of plantations and to prevent emergencies like forest fires. Trails functions are maintained by weeding and building wood bridges along them.

46 km of firebreak belts are set on the main ridges to prevent from fire spreading.

12 forestry roads (72 km) are used for transportation of residents and timber.

3.4 Hunting and recreation management

There are important regeneration problems because of game (*Cervus nippon*). Protections are used.

Many tourists use trails to discover forest and participate to organised field visits. Tokyo inhabitants feel concern by forest management. Volunteers participate to different actions is private forest (plantation, cut). Some others grow saplings in their gardens and plant them after in forest.

4. Forest situation

4.1 Forest characteristics

Elevation varies from 500 to 2, 100 m (alpine temperate zone to alpine subartic zone). The terrain is steep. The geologic situation consists of mainly 3 types; granodiorite whose geological age is estimated Tertiary, sandstone and shale of Mesozoic and Paleozoic strata distributed eastern part. Soil types are categorized into 3 groups; brown forest soil, podzol and black earth. Annual temperature ranges from 8.5 to 13.1 °C; annual precipitation from 1, 552 to 1, 684 mm.

4.2 Forest management

See 3.1

4.3 Ownership

44 % of forest is public (56 % private).

5. Costs

The management of watershed forest contributes to the conservation of the raw water quality and thus, it enables to save the cost for water treatment at purification plants. However, the quantification of the contribution by the watershed forest is difficult.

7. Evaluation of the action plan

Water quality is monitored periodically. It is impossible for managers to compare the quality between before and after implementation because the management begun over 100 years ago.

Though, the survey shows that mitigation of surface soil spillage is essential for the water quality conservation. Therefore, managers result that conservation of water quality attributes to the fosterage of sound forest.

Water is filtered before distribution to Tokyo inhabitants.

8. References

contact : Naomi Takahashi, General Affairs Division, Bureau of Waterworks,TMG

BUREAU OF WATERWORKS TOKYO METROPOLITAN GOVERNMENT. – *The watershed forests*. – 2008

10. Vienna

1. Presentation of the situation

Almost all Vienna drinking water comes from the catchment of 2 main spring water pipelines, coming from 3 mountainous Karstic areas (Hirschwang, Nasswald and Wildalpen).

Approximately 400, 000 m^3 of water are consumed each day by the 1.78 millions inhabitants of Vienna.

The protection zone of the watershed has an area of 60, 000 ha of which approximately 33, 000 ha belong to the city of Vienna. 2/3 of this zone is covered by forests. The last third is composed of pasture lands, alpine meadows and rock formations.

Water costs approximately 1.2 €/m3 to Viennese people.

2. Type of action

Since 1870, the city of Vienna has been buying lands situated in the watersheds and therefore has built 2 pipelines to bring the spring water to Vienna.

Today, the city owns about 33, 000 ha and has adopted since the late 80s new forest management practices in accordance with nature-near silviculture with the primary aim to protect drinking water resources.

The rest of the zone belongs to private owners that apply a conventional productive forest management, but 2 federal legislative decrees restrict some land practises (for example, it is forbidden to store oil or polluting materials, build new infrastructures without authorization, transport dangerous materials…).

Scientific research plays an important role. The implementation of the new forest management has been done in partnership with Boku University and different projects have been lead there (like Kater projects – see www.kater.at).

Communication and public information is largely available over the protection zone. Authorities try to keep a « soft tourism » there.

3. Management implemented for the protection of drinking water

Since the late 80s, a new forest management has been implemented in the area owned by Vienna: nature-near silviculture, no clear-cutting, fostering natural regeneration, careful harvesting and extraction (cable-yarding), no chemical agents (herbicides, pesticides, fertilisers etc.), and regulation of game.

A site-classification inventory has been realised on the entire protection zone to know the actual forest stands characteristics, and also ecological parameters, like information about natural vegetation, soils, exposition, elevation…

The hydrotope model has been applied to determine which natural forest stand would be the most adapted to protect drinking water resources. GIS has been used for this purpose.

Since then, in function of these results, foresters manage the stands to bring them as close as possible to their optimum defined by the hydrotope model.

3.1 Particularities of the forest management over all the watershed area owned by the City of Vienna

The management objective is to obtain uneven-aged forest stands (group selection system), with diverse tree species. The majority of stands is for the moment spruce plantations.

Managers try to open them and bring regeneration, by using the following methods.

- No clear cut, only small intrusions to the canopy to the maximum extent of 0.5 ha.
- Continuous forest cover → uneven aged forest.

- The silviculture institute of Boku university recommends to have a forest cover between 70 and 90 % (60 to 80 % in subalpine zone).
- Continuous forest regeneration by natural rejuvenation.

If possible, natural regeneration by the group selection method is used. The silvicultural institute of Boku university recommends that the diameter of openings should not be larger than 1/3 of tree height, but the total regeneration area must be 10-20 % of the total area. All species recommended by the hydrotope model must be regenerated.
Light-demanding species like larch are important species and regenerated by strip cutting on the "edges" of old stands.

- Different layers and different ages of trees.
- Improve tree vitality and stability by forest tending and structure thinning.
- Limit the harvested volume.

The silvicultural institute of Boku university recommends that not more than 10-15 % of the stand volume should be harvested for each cut. Forests (and other land types) are managed with the aim of maximum protection of watersheds and not with the objective to gain maximum yield (on average only about 2/3 of the possible yield is actually harvested).

- Hunt sufficient game to have enough regeneration.
- Keep some old trees.
- Let some dead wood.
- Restore buffer forest along dolines, wetlands and rivers.
- Adopt more environment-friendly harvesting systems : cable yarding. Tractor skidding only on so-called green zones when weather condition are good (GIS-based site classification model).
- Introduce all species recommended by the hydrotope model.
- Use of biodegradable oils, no use of pesticides.
- Permanent sample plot inventory to monitor the stands evolution.

3.2 *Forest road network*

The forest roads density is pretty sufficient for primarily using cable crane systems (about 20-30 meters per hectare thus about half of the average road density in Austria).

Road planning and construction are in accordance with the MA49&MA31 guidelines. Hydro geologist of the Vienna Waterworks (MA31) inspects the site first. Road-building is realised with excavators only. Sometimes fleece in the base course / layer of the forest road is used to buffer possible effects during construction or further traffic on the roads.

3.3 Hunting and recreation management

Hunting is a great tradition in Austria and it is difficult for foresters to accept to feed game less and shoot it more. A zoning has been created to limit areas where game can stay without being shot, and where it cannot (regeneration zones for example).

But game browsing induces big problems of regeneration (very difficult to regenerate tree species except spruce without protection).

Tourism is limited in the protection zone, but not forbidden. Authorities try to keep it soft (only hiking, no trail in sensitive zones, only one camping area, delivery of waste, subsidies for sewage systems to tourist lodges and huts). Hikers are well informed and there is no particular problem.

3.4 *Pasture land or agricultural land management*

There are pasture lands in the protection zone. Some farmers have historical rights to come there with their cattle. But today, less and less farmers use these pasture lands, they receive subsidies as incentives to do so. In very sensitive areas grazing is forbidden.

Forest managers try to respect the equilibrium between forest stands and *Pinus mugo* zones, because the characteristics of these 2 ecosystems towards water retention are different (higher snow accumulation in *Pinus mugo*).

Spruce stands opened 6 years ago by cable yarding. Regeneration comes with difficulty (May 08)

A mosaic of vegetation in higher elevation (May 08)

4. Forest situation

4.1 Forest characteristics

The protection zone is situated in the North East of the calcareous Austrian Alps. The elevation varies from 470 to 2, 277 m a.s.l.. The aquifer is Karstic, the rock types are limestone and dolomite.

The main soils are rendzic leptosols and cambisols.

The average annual temperature varies from 6.7 and 9.4 °C, the annual rainfall between 614 and 1, 071 mm.

Forest stands were mainly composed of spruce (60 %) and far from the « natural potential associations » that could have been there.

4.2 Forest management

Practices in forest management have totally changed since the late 80s. But this management is only applied in the forest owned by Vienna; private owners do what they want in their forest. Since 2001 there are basic guidelines for the management of the protection areas – a joint venture of MA49 (Forestry Office) and MA31 (Vienna Waterworks) covering the themes of forest management, tourism and agriculture.

4.3 *Ownership*

Vienna owns 33, 000 ha of the 60, 000 ha protection zone that is 2/3 forested. Therefore, the share between public and private forest is approximately 50 %.

5. Relationship between the actors / stakeholders

The relationships with private owners do not seem to cause any problem or conflict.

The City of Vienna gained step by step ownership of the most important and sensitive areas concerning protection of mountainous spring water in history of about 140 years. Large areas in the Hochschwab region (Styria) are protected by law for the purpose of providing drinking water to Styrian communities (including the provincial capital Graz) and are not of primary interest to the City of Vienna.

Forest clear cuts are limited to 1 ha (2 ha normally in Austria).

Scientific research has always played an important role. Studies are still being conducted to optimize forest management and also to face the challenges of tomorrow, like global warming or society evolutions (for example, there are less and less alpine pastures, but they are more and more concentrated in some areas).

6. Costs

The cost of forest management is financed by Vienna City.

6% of the price of water is used to compensate for these extra-management costs.

7. Evaluation of the action plan

It is difficult to determine if this new forest management has an impact on water quality, because, before the 80s, the assessment of water quality was really different from now. Nevertheless, a recent storm, Kyrill, has devastated some forest stands and effects to the water quality could be mastered because of a online-quality management using only those springs within the very tight limits of quality parameters. Managers compare this storm to the effects of a clear cut, which reinforces their management choices.

The Wildalpen forest management in Styria (2nd spring water conduit) was affected by about the 4th of the average annual yield or timber production (~35,000 m^3). Primarily scattered wind throw and wind break damages. The largest site affected by the KYRILL-wind-throw was about 20 hectares in a impassable, subalpine region and there about 6, 000 m^3 were only debarked with the help of the Austrian army soldiers (a so-called “Assitenzeinsatz” to prevent a bark-beetle outbreak by the Austrian army because of the public interest and importance of the area to the water supply of the capital city of Austria). Private forests were rarely affected.

Water is chlorinated to a very small, computer-controlled amount before being supplied to people because of sanitary reasons (about 3, 800 kilometers of total length of water supply system) – not because of any quality reasons of the spring water

Authorities find this global management plan performing but they are always looking for possible improvements.

8. References

Personal interviews with Werner Fleck, Eduard Hochbichler and Gerhard Kushnig in January 2008 in Vienna, visit with Werner Fleck and Bernhard Mang in Hirshwang forest on 23/05/08

HOCHBICHLER (E.), KOECK (R.), MAGAGNA (B.).- Kater II Handbook : final report regarding the land use category forestry-. BOKU University,2007

HOCHBICHLER (E.), KOECK (R.), MAGAGNA (B.).- Kater II Handbook, Appendix I : Best management practises for the drinking water protection forests-. BOKU University, 2007

http://www.wien.gv.at/english/environment/watersupply/index.html

11. Vittel

1. Presentation of the situation

Nestlé Waters owns the mineral water of Vittel, Contrex and Hépar, situated on a watershed of 10, 000 ha in the Vosges, on 9 different cities. 310 ha of forest belong to Nestlé and are managed by ONF. Forest cover in the watershed is approximately 11 %.

A branch of Nestlé, called Agrivair, has been created in 1992. This society organises water production and watershed management.

Water comes from deep wells situated in Nestlé forest or in other public forest.

2. Type of action

After nitrates pollution problems in the 70s and 80s, Nestlé acquired farm lands since 1987.

These lands are freely given to farmers (tenant farming of 18 or 30 years), who have to respect rules not to pollute.

Since the nitrate pollution decreased in water.

3. Management implemented for the protection of drinking water

Since 1999, ONF manages Nestlé forest. The management objectives are 1) water protection, 2) public recreation, 3) wood production (but a financial balance is wished), 4) hunting.

3.1 Particularities of the forest management in Nestlé forest

Forest stands are mainly composed of oak (coniferous stands have been harvested). To guarantee continuous forest cover, uneven-aged forest (group selection system) is applied. The aim is to have mixed species stands, with big oak trees and other deciduous trees in under layer.

Before, forest stands were even-aged. They are progressively converted (little regeneration openings of 0.1 to 0.2 ha).

One to two dead trees per hectare are let for biodiversity.

Harvest operations have to respect environment: biologic oils, respect of soil, harvest in winter or along skid roads, horse extraction if necessary, surveillance by ONF agent. Pesticides are not allowed.

Oak and deciduous trees forest stand, coming progressively uneven-aged (May 08)

3.2 Particularities of the forest management just around the water catchments points (above the water pipes)

No specific rule (deep wells, not very sensitive).

3.3 Forest road network

Forest road density is about 2.4 km/100 ha.

Runoff water on roads (outside forest) are collected to prevent from infiltration in water table.

3.4 Hunting and recreation management

There is no particular problem because of game.

Recreation is important: cycling, horse riding. A golf in forest is very popular.

3.5 Pasture land or agricultural land management

Farm lands are regulated by tenant farming contracts.

4. Forest situation

4.1 Forest characteristics

Annual precipitation is 923 mm, annual temperature is 8.7°C.

Elevation goes from 330 m to 450 m. Slopes are not steep.

4.2 Forest management

The first objective is water protection.

4.3 Ownership

Forest covers 11 % of the watershed. 2/3 are public forests and 90 % of private forest belong to Nestlé (310 ha).

Public forests are made of uneven-aged or even-aged (with 15 years of regeneration period, progressive cuts) forest stands, and are composed of oak mainly.

5. Relationships between the actors / stakeholders

Problems are mainly solved by communication and negotiation.

6. Costs

It is very difficult to estimate over costs due to water protection in forest because of the golf area that brings also a lot of harvest restrictions (no timber extraction from 15 April to 15 October).

7. Evaluation of the action plan

The nitrates concentration in Nestlé forest underground water is below 10 mg/l.

Water is not treated (mineral water).

8. References

FIQUEPRON (J.).- *Fiche de travail : Action conjointe INRA & IDF : forêt et eau*. – Fiche de travail provisoire sur Vittel.- 10/10/06, 3p.

Contact : Philippe Humbertclaude (ONF) philippe.humbertclaude@onf.fr, Agrivair 03 29 07 60 30

Visit in Vittel on 14/05/08 (Philippe Humbertclaude from ONF and Philippe Pierre from Agrivair)

12. Winterthur

1. Presentation of the situation

The city water service of Winterthur supplies 90, 000 inhabitants, 27, 000 m^3 are delivered each day.

8 (out of 9) wells are situated in Winterthur forest. They catch water form the alluvial water table of the river Töss.

Winterthur is one of the most forested cities of Switzerland, with 2, 635 ha of forest, of which 1, 900 belong to the city. 100 ha are in protected zone.

Water is delivered without any treatment.

2. Type of action

Winterthur has acquired forest lands since long time and is still purchasing new ones today.

3. Management implemented for the protection of drinking water

In 1950 huge areas belonging to Winterthur have been reforested. In the 80s and 90s, protection zones have been defined around catchment areas.

3.1 Particularities of the forest management over all the watershed area

Winterthur forest service has a "close to nature" management on the 1, 900 ha of forest. Natural regeneration is favoured and no big clear cuts are made. Biologic oils are used; machines circulate only on skid roads.

In the beginning of the 20th the river Töss has been corrected and riparian forest transformed in beech stands. Now, natural flooding zones have been re-created and Winterthur forest service tries to re-create riparian forests.

Today, there are 63 % conifers and 37 % deciduous trees in forest.

3.2 Particularities of the forest management just around the water catchments points

In protection zones, particular precautions are taken for timber harvest.

Log landings are not allowed, which induces over costs of transport. Storing and manipulation of fuels and lubricants is forbidden.

Since 2002, these over costs are not part of the city forestry budget, but they are attributed to a budget for "nature, landscape and water protection".

3.3 Pasture land or agricultural land management

In the protection zone, the city has recently modernised a farm to produce organic milk.

It is not allowed to use fertiliser and give antibiotics to cattle.

A lot of information is missing on this site because no one of the managers I contacted answered to me.

4. References

HAAGMANS (B.), KUNZ (B.).- Les forêts de la ville de Winterthur protègent l'eau potable-. *Journée internationale de la forêt 2003*

Appendix 4: Description of « Best management practices »

Best Management Practices (BMPs) are effective, practical, structural or non-structural methods which prevent or reduce the movement of sediment, nutrients, pesticides and other pollutants from the land to surface or ground water, or which otherwise protect water quality from potential adverse effects of silvicultural activities. These practices are developed to achieve a balance between water quality protection and the production of wood crops within natural and economic limitations.

A thorough understanding of BMPs and the flexibility in their application are of vital importance in selecting BMPS which offer site specific control of potential nonpoint source pollution. With each situation encountered at various sites, there may be more than one correct BMP for reducing or controlling potential nonpoint source pollution. Care must also be taken to select BMPs that are practical and economical while maintaining both water quality and the productivity of forest land.

The Federal Water Pollution Control Act Amendments of 1972, Public Law 92-500 (and as amended by Sec. 319, 1986), require the management of nonpoint sources of water pollution from sources including forest-related activities. BMPs have been developed to guide forest landowners, other land managers and timber harvesters toward voluntary compliance with this act. Maintenance of water quality to provide "fishable" and "swimmable" waters is central to this law's objectives. The Environmental Protection Agency (EPA) recognizes the use of BMPs as an acceptable method of reducing nonpoint source pollution.

Nonpoint source is diffuse pollution that comes from almost everywhere; it even occurs naturally to a certain extent. The amount of pollutants from any particular spot is small and insignificant, but when combined from over the landscape, can create water quality problems. Although it is unrealistic to expect that all nonpoint source pollution can be eliminated, BMPs can be used to minimize the impact of forestry practices on water quality. These practices must be reasonable, achievable and cost effective. The adoption and use of BMPs will provide the mechanism for attaining the following water quality goals:

- to maintain the integrity of stream courses;
- to reduce the volume of surface runoff originating from an area of forest management disturbance and running directly into surface water;
- to minimize the movement of pollutants i.e. pesticides, nutrients, petroleum products, etc. and sediment to surface and ground water;
- to stabilize exposed mineral soil areas through natural or artificial revegetation means.

In practise, BMPs focus on:

- the creation and maintenance of forest roads,
- rivers and streams crossing,
- recommendations of timber harvesting in wetlands.

The monitoring and evaluation of BMPS application and efficiency has very recently started to be implemented.

Appendix 5: questionnaire for Alpeau sites

1. Presentation of the situation

Type and number of catchment points, area of the total watershed, area of the protected zone of the watershed, percentage of forest cover over the watershed, number of people relying on drinking water from this watershed, number of m^3, price of water

2. Current water supply system

Current water supply system, actors

Current prescriptions/management around catchment points

Current water quantity and quality? Water treatment? Any encountered problem (pollution…)?

3. Current forest situation

3.1 Forest characteristics

Geologic situation, main types of soils

Topographic situation

Ecological type, natural forest communities

Actual situation (species composition, type of forest stand, volume, annual increment…)Tree species composition, silvicultural treatment (even aged or uneven aged stands, clear cut regulation, type of regeneration…), harvested volume per cut, regulation/restrictions for harvesting, use of chemical products/ pesticides…

3.2 Forest management

Management objectives

Actual situation (species composition, type of forest stand, volume, annual increment…), tree species composition, silvicultural treatment (even aged or uneven aged stands, clear cut regulation, type of regeneration…), harvested volume per cut, regulation/restrictions for harvesting, use of chemical products/ pesticides…

3.3 Ownership

Percentage of public or private owners

3.4 Forest road network

Erosion/runoff problems?

3.5 Hunting and recreation management

Any particular measure or problem?

3.6 *Pasture land or agricultural land management?*

4. Relationships between actors

Relationships between water and forest managers?

With private owners? Problems or conflicts?

Any contract with private owner?

5. Expectations of Alpeau managers

Why taking part in this interreg project?

Objectives ?

6. References

Appendix 6: Filled questionnaires of the Alpeau sites

1. Areuse gorges

1. Presentation of the situation

Neuchâtel water supply comes mainly (85 %) from the Areuse gorges, situated at 14 km in the North West of the city.

The watershed is mainly forested. The area is about 4x2 km². Neuchâtel water catchments are located on the left side of the river.

22, 000 m^3 of water is delivered each day to 50, 000 persons.

Water costs about 1.50 CHF/m3 for supply (total cost of 4.50 CHF/ m^3).

The terrain is Karstic, several small streams are caught. There is also a water catchment in the Areuse water table (alluvium).

2. Current water supply system

The public company Viteos manages Neuchâtel water supply (and also gas and electricity).

Water is chlorinated (but not filtered like water from the lake).

Water quality is globally good but one part of water catchments is in contact with Areuse River (up to 12 % of water from the river in some catchments). When there is too much suspended matter, the stream is deviated. But there is a risk of pollution in Areuse River (industries upstream) and therefore a risk of water catchment pollution. Studies are implemented to understand better this phenomenon.

3. Current forest situation

3.1 Forest characteristics

Elevation goes from 400 to 1, 000m.

3.2 Forest management

The management objective is forest multifunctionnality with a silviculture “close to nature”.

Forest stands are mixed and multi-layered (uneven-aged), with 25 % of spruce, 25 % of fir, 40 % of beech, 8 % of maple and 2 % of other broadleaved. The standing volume is about 300 m^3/ha. Increment is 6 m^3/ha/year.

Harvest techniques are traditional. Logs are treated outside of S1 and S2 zone. A big part of the forest is in protection zone and as a consequence, wood treatment is almost impossible.

Biologic oils are used.

The forest is certified PEFC.

Forest stand in the Areuse gorges (June 08)

3.3 Ownership

Forest belongs mostly to Neuchâtel city (95 %).

3.4 Forest road network

The soil is permeable; there are few problems of erosion and runoff.

3.5 Hunting and recreation management

This forest is a reserve. Game populations are high.

Recreation is important (cycling, hiking). A recreation management plan is being done.

3.6 Pasture land or agricultural land management

There are some farmers on the right side of the Areuse gorges.

4.Relationships between actors

Relationships between different partners are good. Viteos has organised meetings with farmers to raise awareness about water protection. Good practices are now applied without financial compensation.

5. Expectations of Alpeau managers

Alpeau manager's expectations (University of Neuchâtel) are only scientific. Research studies will be implemented during Alpeau project:

- Interpret data collected since 40 years on water quality, link it with past forest harvest and soil vulnerability;
- Make some experiments to measure physic-chemical quality of infiltration water, in function of forest type and forest management.

6. References

Visit in Areuse gorges on 11/06/08 with Pierre-Olivier Aragno from Viteos and François Zwahlen from Neuchâtel University

Contact : Jan Boni from Neuchâtel forest service

2. Arve watershed

1. Presentation of the situation

The Arve watershed represents about 40 % of the department of Haute Savoie, so around 1, 750 km². 250 to 300 water catchments are concerned, mainly shallow underground catchments and wells in Arve water table. They supply about 250 000 persons with water, but population can increase a lot there during winter and summer holidays.

Water costs about 2.70 €/m3.

The water pipes network yields are very low: 53 % in average (some at 30 %), although water agency recommends yields of 70 %.

Forest cover is 35-40 % over the watershed: 170, 000 ha, of which 100, 000 ha are private forest which is much divided (100, 000 ha owned by 100, 000 owners who have in average 3 parcels → average parcel area in private forest is 3, 000 m², so very difficult to manage).

2. Current water supply system

Water supply is organised by city services or inter-city services that can manage water supply by themselves or delegate this competence. 42 joint associations manage different aspects linked to water in the Arve watershed (river management, wastewater, drinking water...).

Half of water catchments do not have any treatment (it corresponds to 11 % of the total volume of water). The majority of the other half is only disinfected.

Water has globally a good quality (bacteriologic and chemical).

Some problems of shortage during winter recently happened. Water tables levels decrease progressively.

The town of Annemasse is an interesting case. One part of its drinking water is bought in Switzerland, but this water is very expensive. Annemasse decided to develop shallow underground water catchment in Salève Mountains. Water pipes have been renovated and yields increase a lot. The city also acquired forest land around water catchments to protect this little watershed.

The SM3A (Syndicat mixte de l'aménagement de l'Arve et de ses abords) is partner of the Alpeau project in this Arve watershed. This joint association gathers several city or inter-city services dealing with water, but not drinking water.

3. Current forest situation

3.1 Forest characteristics

Forest is mainly coniferous (majority of spruce stands above 1, 000 m, fir-beech stands between 800 to 1, 000m, and oak-ash forest below 800 m).

Spruce have always been favoured by foresters every where, but because of recent dieback (wind throws, bark beetles), spruce is not recommended below 1, 000 m.

Geologic substrates are very diverse, slopes are steep.

Water is abundant (1, 300 to 1, 500 mm of annual precipitation). Annual temperature varies from 5 to 9°C.

3.2 Forest management

In public forest, management objectives are production and protection.

The silivicultural treatment is uneven-aged forest (group or single tree selection system). No clear cut superior to 1 ha is planned. Timber is extracted by tractor (by cable very seldom). Biologic oils are used and pesticides are not allowed.

During a visit near the town of Arraches, it has been possible to see some PPI (immediate protection zone) in a communal forest. PPI are fenced, trees are let, but grass is mowed every year. Big diameter trees have been recently harvested in the PPI. The fence had to be removed for the operation and re-instaled after. No cullwood has been let on the PPI ground. The town which owns the water catchment do not want that deciduous trees regenerate on the PPI “because they fear that deciduous tree litter bring to much organic matter to the soil”.

A forest road is just above the PPI. Runoff from ski tracks upstream “flow” in this road and arrive in the PPI, which can be a problem.

ONF, that manages the forest, ignores which type of catchment it is, where the pipes are and what their depth is.

In the PPR (inner protection zone), there is no particular constraint. ONF is transforming since 10 years spruce plantations by uneven-aged forest stand of mixed species (spruce and some deciduous). ONF managers open progressively spruce stands around natural regeneration patches. This silvicultural treatment requires very cautious harvest operations, not to damage the remaining trees. This is why an ONF agent is always present when the forest cut is being done.

PPI in Arraches public forest (July 08)

Private forest is much divided. Forest parcels are or unmanaged, or cleared-cut.

3.3 Ownership

60 % of forest is private.

3.4 Forest road network

The forest road network is correct. When managers plan new roads in PPR, a hydro geologist has to give his/her agreement.

3.5 Hunting and recreation management

Game is present but has little impact on regeneration.

Touristic frequentation is high, which induces constraints (cities cannot harvest their forest in July and August). Regulations are taken against motorised circulation in forest. It can be difficult to answer all the recreation wishes, as the demand is very diverse.

3.6 Pasture land or agricultural land management

In valleys, cattle could have a negative impact on water quality (nitrates, pesticides…).

In alpine pastures, animal faeces and liquid resulting from altitude milking (cheese fabrication) can pollute also water catchments downstream. Pasture concentration is not equally distributed.

4. Relationships between actors

When water catchments are situated in private forest, owner identification can be a difficulty. Sometimes, if they do not cooperate, they can be expropriated.

There are very few relationships and communication between water managers and foresters. They are much more developed with famers.

Pollution from urban areas and industries remain a problem, despite improvements.

5. Expectations of Alpeau managers

With Alpeau, SM3A wished to extend its competences in the field of drinking water. This joint association plans to write a global water plan management for the Arve and therefore needs to acquire knowledge and competences in drinking water aspects.

The goal is to know more about the impact of forest on drinking water quality and to quantify economically this impact.

During Alpeau, SM3A plans to:

- realise an inventory and a typology of all catchments,
- evaluate the impact of a good or bad forest management on water quality (economic valuation),
- develop contract between foresters and water managers to adopt good practices,
- improve forest management in PPI.

6. References

Visit in Bonneville on 05/06/08 and 23/07/08 with Hervé Fauvain (SM3A) and Jean-Luc Maboux (ONF)

3. Broye region

1. Presentation of the situation

The research office Nouvelle Forêt situated in Freiburg (Switzerland) is partner of Alpeau project in the Broye region (cantons of Vaud and Freiburg). The precise water catchments-forests to be studied during Alpeau have not been determined yet. Different forest areas are possible, like Mont-Gibloux.

In Switzerland, drinking water protection is a duty for forest owners. Restrictions due to this protection cannot be compensated (but they are compensated for farmers).

Drinking water comes from lakes (1/3 of total water volume), water table pumping (1/3) and streams or shallow underground water catchment (1/3), of which 40 % are located in forest. Water from lake presents problems of micro-pollution. Pumped water presents problems of agricultural pollution. It seems therefore necessary to invest in forest water protection.

Nouvelle Forêt has participated to the elaboration of a forest regional management plan in 2003. After, the "Forum Broyard de la forêt et du bois" has been created to implement and monitor the evolutions of this regional management plan.

One of the commissions of the forum deals with water and forest. It has been tried to establish contracts between foresters and water managers, but no one has been signed for the moment. This commission edited three publications.

For information, a study is being realised by the WSL on costs and yield decrease in forest due to water protection.

2. Current water supply system

Water supply is the responsibility of cities that can gather in intercity associations. Communes own the water catchments.

In Broye region, the majority of water is not treated. However, many catchments in farming areas are polluted in nitrates.

Usually, protection zones are both on forest and farm lands.

In forest, chemical treatments on logs during May and June can induce pollution.

For the moment, there is no risk of water shortage.

Water costs 1 to 3 CHF/m^3 (without wastewater treatment).

3. Current forest situation

3.1 Forest characteristics

Terrains are from molasses, sometimes covered by moraines. Soils are brown typed;

Except few steep valleys, slopes are soft.

Elevation ranges from 430 to 800 m.

Forest site is beech with *Galium odoratum*.

3.2 Forest management

Forest management objective is multifunctionality.

During the last century, there were many spruce plantations. But they have nearly been also devastated by wind throws in 1999, followed by drought in 2003 and bark beetles.

Today 50 % of forests stands are young, mainly composed of deciduous trees (natural regeneration or plantations of beech, oak, ash…). Some plantations of larch and Scott pine have been done. Forest management is more and more extensive because of these young stands.

The other half of forests stands are even-aged beech stands (but beech tree is sold at a very low price in Switzerland).

Harvester is seldom used. Extraction is done with forwarder (sometimes with tractor or cable yarding).
Silviculture is close to nature, cuts are usually small.
Biologic oils are uses. The only polluting products are chemical wood treatments.

3.3 Ownership

Forest is public at 53 %. Private forest is very divided.

3.4 Forest road network

Forest roads are usually sufficient.

3.5 Hunting and recreation management

Recreation is important near the lake, but there is no water catchment there.
Game populations are not high, there is no problem for regeneration.

3.6 Pasture land or agricultural land management?

There are many farms in the area.
For information, Nestlé recently bought the Henniez mineral water and acquired forest land around.

5. Relationships between actors

The forum broyard commission tried to raise awareness on over costs linked to water protection in forest, but water managers have not been very receptive.
However, systems of financial compensation already exist to remunerate forest diversity or recreation.

5. Expectations of Alpeau managers

With Alpeau project, managers wish:

- know better about forest impact on water quality,
- establish contract between foresters and water suppliers.

6. Case of Mont-Gibloux (potential Alpeau site)

This 750 ha forest is situated on 5 towns (public forest). There are many water catchments supplying with water 5, 000 inhabitants. Water is delivered without any treatment.
More than 1/3 of forest is classified as protection zone.
Soils are from molasses and moraines. Elevation goes from 950 to 1, 300 m. Forest site is beech-fir.
Main constraints linked to water protection are the forbidding of wood treatment, of road construction in S1 zones and parking machines in protection zones.

Water catchment under a spruce stand in Mont Gibloux (June 08)

7. References

Visit in Freiburg with Robert Jenni on 09/06/08

4. Chambéry

1. Presentation of the situation

Chambéry water supply comes mainly from pumping in water table (85 %). The other 15 % come from 68 shallow underground water catchments. Actions will be implemented on 7 of them during Alpeau project and 4 are already defined:

- Dhuy water catchment in St Sulpice,
- Pierre Rouge water catchment in Vimines,
- Fontaine Froide water catchment in St Badolph,
- FontaineNoire water catchment in St Jean d'Arvey.

2. **Water catchments descriptions**

2.1 Dhuy water catchment

The PPI is 235 m², the PPR is 504, 126 m². It gives water to 600 persons (flow from 1.72 to 4.44 l/s in 2006).

The elevation is 662 m. the aquifer is Karstic.

Forest sites go from oak-beech, beech, fir.

A part of the PPR is in public forest. Forest stands have been recently destroyed by bark beetles, standing volume is very low. No forest cut is scheduled before 2021. Stands are composed of beech and firs, with some other broadleaved.

2.2 Pierre Rouge water catchment

The PPI is 7, 851 m², the PPR is 30, 543 m². It gives water to 700 persons (flow from 0.6 to 10,.5 l/s in 2006). Water is treated to UV.

The elevation is 600 m. the aquifer is Karstic.

Forest sites go from oak (*Quercus pubescent*) to beech-fir.

The public forest situated in the PPR is composed of deciduous trees (beech, maple, oak…) and managed as coppice and standards (4 year rotation). Dolines are fenced. There are also pastures on the PPR.

PPI is deforested and grass is mowed 2 times a year.

→ Change prescriptions on PPI, make an experimental cut on PPR.

2.3 Fontaine Froide water catchment

This water catchment is situated near from another catchment. They give water to 50 persons (water flow in Fontaine Froide from 0.42 to 3.37 l/s). Water is chlorinated.

The elevation is 1, 290 m. Geology is limestone. Forest site is beech-fir.

Forest stands on PPR are even-aged and composed of spruce, fir and beech.

PPI is deforested and grass is mowed 2 times a year.

→ A forest cut is scheduled in 2008 and 2012 on different parcels of the PPR. Water quality could be monitored during harvest operations.

PPI of Fontaine Froide (June 08)

2.4 Fontaine Noire water catchment

The PPI is 15, 411 m². It gives water to 1, 100 persons (flow from 3.71 to 9.69 l/s).

The soil is made from sandstone, clay, and shale.

Some parcels of the PPR are public forest. They are uneven-aged forest stands, of spruce and fir, with some beech and maple. Forest site is beech-fir.

Forest cuts are planned in 2008 and 2010, water quality could be monitored.

The decree for the PPI prescriptions has not been taken yet. Chambéry managers would like to keep forest on it.

Currently, there is a spruce plantation (in the future PPI). As spruce is not optimal for water protection, this plantation could be opened to regenerate beech and fir under spruce, like it is done in Munich or Vienna.

Water from the catchment has a lot of suspended matter and too many bacteria (pasture). There is too much Iron in water (sandstone). Therefore water is ultra-filtered. Maybe these problems will hide the potential good forest management effects on water quality.

3. Relationships between actors

Chambéry water managers and ONF do not communicate enough. There is almost no relationship with private owners, except conflicts (owner problems in PPI).

Relationships are more formal with farmers.

4. Expectations of Alpeau managers

Chambéy managers wish with Alpeau to:

- know more about the impact of good/bad forest management on water quality,
- adapt better prescriptions in PPI and PPR,
- monitor water quality and quantity thoroughly near forest harvest.

5. References

Visit in Chambéry on 18/06/08 with Etienne Cholin (Chambéry water manager) and Olivier Lamy (ONF)

5. Côte region

1. Economic and politic context

The forest service of Vaud canton has lead a group thinking in 2004 with public forest owners (forest is 80 % public) because of wood revenue decrease. An action plan has been created in 2006 to promote wood uses. Another group studied the valuation/remuneration of water protection by forests, like it has been done in the Broye region.

2. Geographic context water supply

The Leman Lake dominates the valley. Above there are vineyards on moraines, and above there is the Jura forest, on Karstic soils.

An important part of drinking water comes from steams in Karstic forests and some in moraines. Globally water quality is good. Quantity is enough but this region is developing a lot, demographic pressure increase. As a consequence, towns begin to link their water networks.

The farming demand for water increases also and cities have to pump water in the lake. But pumping is very expensive and consumers do not appreciate to drink water from the lake.

Cities try to promote water from forests which is cheap and of good quality. They inform inhabitants about the origin of water. For example, the city of Gland deliver to its 10, 000 inhabitants a water almost exclusively from forest.

Constraints in forest due to water protection are very high. In Karstic area, almost all the forest is in protection zone. The main difficulty is that it is not allowed to treat wood and to park vehicles. Timber harvest is only possible in spring and autumn. The logistic forest-sawmill cannot absorb all the logs on time, and therefore wood treatment remains a necessary alternative, which induces problems.

3. Identification of 2 interesting sites

Two particular sites have been identified for the Alpeau project.

- City of Gland

This city is very motivated to promote water from forest. Water comes mainly from streams in Karstic area. Another stream is located on moraines, in a small forest where the only access road has been classified as S1 zone, which makes timber harvest almost impossible. In these 2 cases, forests do not belong to the city of Gland (but to other cities or private owners).

Moreover, the city of Gland feels very concerned by sustainable development and wishes to acquire a good image in this field.

- City of Aubonne

This city owns 450 ha of forest in Jura and in the plain, but these forests do not directly protect water resources. Aubonne water comes from a artesian well. Except the immediate protection zone around the artesian well, there is no S2 or S3 protection zone.

Like Gland, Aubonne would like to develop renewable energy (hydraulic electricity already) and extend it to water supply.

4. Possible projects

These 2 towns could create a global project linked to sustainable development and promote a regional use of wood, reorganise the wood industry chain, provide favourable and incentive frames, reduce supply circuits, create new local markets, raise awareness of public on timber harvest and other forest functions.

Such project implies credits and financing. A sustainable development fund, like in Lausanne, could be created for that.

Another role of this fund could be to allocate land to soil transformation entreprise at a cheap price. The land price is going higher and higher is this region and a sawmill, for example, could not be built in the region because land is too expensive.

Alpeau could give a start to the implementation of these projects.

5. Description of the 2 Alpeau sites

5.1 Gland

Water supplying 10, 000 comes from many streams in karst and moraines. The city of Gland manages its own water supply.

The protection zones of these streams are situated in forests that belong to other cities for the majority. The total surface is very high.

Water quality is good and available in quantity. Streams on moraines are very low treated (UV) and streams from karst are chlorinated.

Moraines elevation goes from 400 to 800 m and karst elevation from 800 to 1, 500 m. Forest site is beech forest and beech-fir forest in higher altitude.

Currently, stand composition is 50 % spruce, 30 % fir, 15 % beech and 5 % of other broadleaved.

Up to 1 200 m, forest stands are almost uneven-aged (large group selection system). Above, managers apply a plenter forest system.

Increment in Karstic zones is very low (~ 4 m^3/ha/year). Tree growth is therefore very low.

Management objectives differ in function of altitude. In lower elevation, foresters want to have a mix of 50 % deciduous (beech) and 50 % conifers. In higher altitude, only conifers (with some maple) are favoured, beeches remain in under layer and are cut at 20 cm diameter (too bad quality).

Timber harvest is realised with chainsaw and harvester. Extraction is made by tractor. Conifers are treated from April to May but foresters try to reduce treatment. During the two last years, no log was treated (very good organisation between loggers and sawmills) but this was possible only because the market was favourable.

Annually, the harvested volume is 150, 000 m^3, of which 15, 000 m^3 in spring. Biologic oils are used systematically.

Forest is certified PEFC and FSC.

No problem of water pollution (suspended matter) linked to timber harvest has been detected. This can be explained because soils are very shallow (mother rock appears on the ground). The risk of pollution does not come from material transport, but from an accidental infiltration of polluting liquids in karst.

Constraints come from the forbidding of log treatment and machines parking. Bur legislation is not very clear and foresters have different interpretations.

Forest road network is sufficient.

Hunting is allowed. Game population make fir regeneration more and more difficult.

Recreation is important, but stays reasonable.

There are pastures above forest stands, also situated in protection zones. A faecal pollution accident happened in the 80s. Since then, a pasture management program with good practices has been implemented and no accident ever happened anymore.

Forest stand in Karstic Jura mountain (June 08)

5.2 Aubonne

In this case, no direct relationship exists between forest and water.

Water from the artesian well has a very good quality, except it has too much Iron.

Water is supplied to 2, 700 inhabitants.

However, Aubonne city is conscious that forest plays a very important protective role: artesian water comes from Jura Karstic forest and Aubonne owns there an agroforestry farm of 500 ha.

Therefore the city feels concerned by this issue that is included in a wider sustainable development view.

6. References

Visit in Saint George with Eric Tréboux (forest service of Vaud canton) on 12/06/08

6. Lausanne

The precise Alpeau site in Lausanne has not been defined yet.

1. Presentation of the situation

8 to 10 % of Lausanne water comes from shallow underground water catchments situated in a forest called Jorat. This forest belongs to Lausanne city. About 60 catchments are located in this 1, 900 ha forest (95 % of S1 zones are in forest). Water flow is around 3, 000 m^3/day, supplying 18, 700 persons.

Water catchments S1 zones are materialised by milestones in forest.

Water costs 1.95 CHF/m3.

A tax of 2 cents CHF is taken on each consumed m^3 of water, as well as a tax on gas and electricity and also on industrial city services benefits. For information, this fund receives each year around 3 million CHF (~1, 800, 000 €).With this money, Lausanne develops several actions:

- Use and promotion of wood (« un arbre-un enfant », sawmill, bus shelter, pedagogic hut, parking, promotion of deciduous trees …);
- Research and studies ;
- Public relations, communication, information ;
- Support to associations ;
- Education (sport, obesity prevention, waste recycling…);
- Other isolated realisations (children council, subsidy for gas vehicles, bio ethanol for public services, batrachians « roads »…).

For information, this fund finances a part of Alpeau project.

2. Current water supply system

Lausanne water service organise water supply. Relationships with forest service are now established (after a long inexistence).

Water from catchments is chlorinated. Water pipes networks are connected with water pumped from the Leman lake. Water managers prefer to use water from the forest catchments during the day and pump water during night (because electricity is cheaper).

Water quality and quantity are satisfying. However micro-pollution problems are happening in water from lake.

Concerning forest catchments, water is deviated during storms to prevent from suspended matter problems.

3. Current forest situation

3.1 Forest characteristics

Forest stands on molasses partially covered by moraines. Elevation varies from 600 to 900 m. Annual precipitation is 1, 200 mm. Forest covers different watersheds. Main forest site is beech-fir forest.

3.2 Forest management

This public forest has a multifunctional objective: recreation, timber production (15 to 20, 000 m^3 of wood per year), protection (water, erosion). Conifers dominate (old fir and spruce plantations) but deciduous trees regenerate naturally actively. Managers want to increase the deciduous trees proportion but keep a majority of conifers. Forest is almost uneven-aged (large group selection system).

Timber harvest is made with harvester in conifer stands, extraction is realised by tractor.

Conifer logs are treated after harvest; foresters try to reduce more and more this treatment.

Biologic oils are used systematically.

Forests are certified FSC and PEFC.

Constraints linked to water protection in forest are low. They do not induce over costs, except S1 zones materialisation and wood treatment forbidding. But these over costs are very low compared to over costs linked to recreation and biodiversity. For information, Lausanne forest service has an annual deficit of 3 million CHF (because of not-remunerated activities).

Forest stand in S1 zone (June 08)

3.3 Ownership

Forest belongs to Lausanne city.

3.4 Forest road network

Forest road network is sufficient.

3.5 Hunting and recreation management

Hunting is allowed. There is no regeneration problem because of game.

Recreation is very important but does not induce problems to protect water.

3.6 Pasture land or agricultural land management

Very few farm lands are concerned by water protection zones downstream.

4 Relationships between actors

Water and forest services begin to communicate and exchange experience.

Some contracts are signed with farmers to compensate for restrictions due to water protection.

Scientific studies are being implemented, in particular on micro-pollutants.

5. Expectations of Alpeau managers

Lausanne Alpeau managers wish to :

- Participate to a research project and promote water from forests,

- Maybe sign contract with foresters,
- Develop exchanges between water and forest managers,
- Maybe extend the water catchment network in forest,
- Monitor thoroughly some water catchments.

6. References

Visit in Lausanne with Philippe Magnenat (forest service) and Linda Viguet (water service) on 10/06/08

7. Moises-Forchat

1. Presentation of the situation

The Alpeau site of Moises-Forchat is composed of 8 water catchments, located on 3 watersheds (Moises, Pamphiot-Orcier, Menoge-Habère Poche).

The Syndicat Intercommunal des Eaux des Moises (SIEM) is a joint association of cities which manages water supply of 15 towns near the Leman Lake, which represents 23, 000 to 35, 000 persons. More than 50 % of water comes from forest shallow underground catchments; the rest comes from pumping in the lake and water table.

Forest cover of protection zones is about 85 %.

The mean flow of water catchment is 6, 000 m^3/day, which gives water to 30-35, 000 persons.

Water produced by the SIEM is sold 1.17 €/m3 to consumers.

2. Current water supply system

The SIEM owns 4 out of the 8 water catchments part of Alpeau. The other water catchments are managed by the towns where they are located (Habère Poche and Lullin).

Water catchment treatments differ: some are chlorinated, some other not.

The prescriptions in the protection zones are:

- in PPI : it is not allowed to go there, except for the water catchment maintenance.

- in PPR : motorised circulation (except authorized vehicles), deforestation, soil excavation, new road creation, pollutants introduction in the soil are not allowed.

Concerning forest management in PPR, uneven-aged forest is recommended and no clear cut > 50 ares are allowed.

Problems of suspended matter load and bacteria occur regularly in water, but it is difficult to identify the origin of the pollution.

During summer, water catchment flows can be very low. The SIEM pumps more in the lake and water table during this period.

An accident happened in 2002 after non-authorized maintenance work on a forest road in a PPR. Suspended matter and bacteria loads increased in water.

The SIEM wishes to develop water form forest because it is cheap and sustainable.

The SIEM has acquired some forest lands situated in protection zones and owns today 30 to 40 ha. These forests are unmanaged for the moment. Alpeau project could be the occasion to establish management plans.

3. Current forest situation

3.1 Forest characteristics

The aquifer is Karstic, the hydro geologic system is very complex.

Soils are brown (acidic on moraines or alkaline on limestone).

The terrain is very diverse (different slopes and expositions).

Precipitations are abundant in spring and summer. About 1 m rain falls on Thonon les Bains (400 m). The elevation gradient is + 60 to 80 mm every 100 m.

Water catchment elevation ranges from 990 to 1, 180 m.

Annual temperature is 11.26 °C in Thonon les Bains (400 m). The elevation gradient is – 0.5 °C every 100 m.

Main forest site is beech-fir forest.

3.2 Forest management

Forest stands are mainly composed of spruce, fir and beech (with maple and ash in lower altitude).

Increment is 12-13 m^3/year.

Pesticides are not used.

Private forest is much divided and the parcels are very small (3, 000 m² in average). When owners manage their forest, which are mainly spruce plantations, they clear cut them. Normally, in protection zone PPR, clear cuts superior to 5, 000 m² are not allowed. But forest cooperatives manage to group owners that have contiguous parcels, each one smaller than 5, 000 m², but realise on each one clear cut. Therefore, the cumulated area cleared cut can reach several hectares, which represents a real danger for water protection. In addition, they usually to clear the soil after, gather cullwood on strips, and plant spruce between, although natural vegetation works perfectly (natural seedlings come into artificial plantation).

Clear cut, just above a PPR (July 2008)

The association of private forest owners of Haute Savoie organises trainings to encourage owners to manage better their forest. A lot of actions are made to group forest owners together, to have sufficient forest area to manage it after in a sustainable way. But owners' grouping is very difficult.

Some PPR are situated in public forest managed by ONF. These forests are uneven-aged (group selection system) of spruce, fir and beech. The same forest management is applied by ONF on the whole department of Haute Savoie, independently from water catchments.

3.3 Ownership

2/3 of forest are private (100, 000 ha of private forest, that belong to 100, 000 different owners who have each one 3 parcels in average). The mean parcel size is 3, 000 m².

In protection zones, private forest area is superior to public forest areas, but the situations are very different from one water catchment to another.

3.4 Forest road network

Many forest roads cross PPR. But road network is not enough to apply an uneven-aged forest management everywhere.

3.5 Hunting and recreation management

Recreation is very important. There are some problems with horse-riding and motorised circulation.

3.6 *Pasture land or agricultural land management*

There are some pasture zones in watersheds which bring pollution into water. Studies are being done to determine the origin and how it can be solved.

4. Relationships between actors

The SIEM wishes to have more relationships and to exchange information with public (ONF) and private foresters.

Two demonstration forests are in project to raise foresters' awareness to water protection.

The SIEM communicate more with farmers. There are some projects of contracts for pastures.

Conflicts could occur about timber harvest in protection zones and some recreation activities.

The SIEM collaborates with many research organisations for different studies.

5. Expectations of Alpeau managers

With Alpeau, the SIEM wishes to:

- know better about the hydro geologic processes in this region,
- optimise forest roles for water protection (on scientific view and then to create contracts),
- make an economic study to evaluate water supply costs from different origins and with different forest management,
- adapt prescriptions in PPI and PPR.

For information, the SIEM has also the project to create a hydro geologic park in this region (same area as Alpeau site) to optimise water resource protection.

6. References

Visits in Perrignier (Haute Savoie) with Bertrand Deville (SIEM), Nicolas Wilhem (SIEM) and Jean-Luc Maboux (ONF) on 17/06/08 and 22/07/08

Visit in Annecy with Noël Gentric (President of private forest owner association) on 15/07/08