Systemic impact study

Life4Fish Project – LIFE16NAT/BE/000807

Luminus

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sertius

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I GENERAL INFORMATION

1. INTRODUCTION

As part of the operation of its hydroelectric power plants on the Meuse river, the company Luminus (the Applicant hereafter) and its partners (UNamur, Uliège, Profish technologies, EDF R&D) are involved in a project financed by the European Commission called "Life4Fish", aimed at implementing and testing various solutions to protect two species of migratory fish in the Meuse, namely the European eel and the Atlantic salmon during their downstream migration. Indeed, infrastructures such as dams, locks and hydroelectric power plants interrupt the continuity of rivers like the Meuse, preventing fish migration.

As part of this project, the Applicant commissioned Sertius to carry out an Ecosystem Impact Assessment (EIA) of the solutions tested.

The LIFE programme is the European Union's main funding framework for policies relating to the environment and climate change. It finances projects that benefit the environment and/or the climate in line with the following priorities:

- Environment
  - Environment and rational use of resources: water, waste, air quality and emissions, etc.
  - Nature and biodiversity: preserving natural sites and species;
  - Governance and information: dissemination of best practices, awareness-raising campaigns ;
- Climate
  - Mitigating climate change: reducing greenhouse gas emissions ;
  - Adapting to climate change: improving resilience ;
  - Governance and information: dissemination of best practices, awareness-raising campaigns ;
- Selected projects must also have at least one of the following characteristics, including innovative character: prerequisites for pilot or demonstration projects ;
- Dissemination of best practices (nature and biodiversity projects only) or information (governance and information projects only);
- Responding to certain needs concerning the implementation and development of EU climate and environment policy (preparatory projects required) ;
- Implementation of an environmental or climate strategy or action plan on a large territorial scale (regional, multi-regional, national or transnational): a prerequisite for integrated projects, which are more extensive than traditional projects due to the expected impact.

As defined in the legal basis of the LIFE+ program (European Regulation No 614/2007), in addition to regular technical and financial reports on the progress of work, the beneficiary must submit a final report to the Commission within three months of completion of the project.

As part of the Life4Fish project, there are two main components:

- Analyses the socio-economic impact of the solutions implemented to facilitate the passage of the two considered species in the project through the hydroelectric facilities during their downstream migrations;
- Analysis of the ecosystemic impact of the solutions implemented as part of this project.

This study includes the analysis of the ecosystemic impact.

2. INTRODUCING LUMINUS

The Applicant's contact details are given below.

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Luminus produces electricity and supplies energy (gas and electricity) and energy services. Luminus is number 1 in onshore wind power and run-of-river hydroelectric power in Belgium. Luminus also plays a key role in Belgium's security of supply thanks to several natural gas-fired power plants that compensate for the fluctuating nature of renewable energies. With an installed capacity of 2,352 MW in December 2021, it represents around 10% of the country's total installed capacity. The company sells electricity, gas and energy services to 2 million private and business customers, representing a market share of around 20%. Luminus is investing to meet tomorrow's energy challenges by offering its customers innovative energy efficiency solutions, and is pursuing its developments in renewable energies. The Luminus group employs over 2,000 people. Most of them devote their time to developing energy efficiency services and renewable energies. For the sixth year running, the company the company ranks among the 64 Belgian companies voted Top Employer. Luminus benefits from its strong local presence and the expertise of the EDF Group, one of the major players in the global energy sector.

Luminus attaches great importance to the environmentally-friendly production of energy, as well as to the health and safety of its employees (HSE policy statement). All its sites have an environmental, safety and energy management system certified to ISO 14001, ISO 45001, ISO 50001 and OSHAS 18001. Green energy is one of the pillars of its production base. With renewable energy accounting for 27% of its total production capacity, Luminus is proportionally the greenest of Belgium's major energy producers.

3. STRUCTURE OF THE STUDY OF SYSTEMIC IMPACTS

This Systemic Impact Assessment (SIA) contains the final texts of the SIA and its appendices. It contains the following sections:

- Part I: General information

The first section briefly presents the background to the project.

- Part II: Description of the study area

This section of the EIS provides a brief description of the study area for the project.

- Part III: The project

This third part of the EIS describes the project under study, based on the information provided by Luminus. It is important to stress that this part is strictly descriptive. It describes the species targeted, the solutions tested and the reasoning behind the choice of pilot sites.

- Part IV: Study of the impact of the project

This part of the EIS analyses the impacts of the project in each environmental sector. For each environmental sector covered by a chapter, the following sub-chapters are systematically included as a minimum:

  - IV.x.1 Introduction
  - IV.x.2. Description of the local environment
  - IV.x.3. Impact assessment

- Part V. Conclusions

The final part of the EIS summarises the main conclusions drawn from the assessment of the systemic impact study.

4. THE AUTHOR OF THE STUDY

Sertius S.A. is a specialist consultancy firm with sites in Leuven, Drongen and Louvain-la-Neuve in Belgium.

Sertius is active throughout Belgium. For assignments outside Belgium, Sertius has an extensive network of contacts, established when the group was still part of Deloitte (Deloitte & Touche).

Sertius S.A. is made up of 4 departments. Each department deals with a specific segment of environmental services. These departments work together in a multidisciplinary way, which adds value to the work carried out.

These are the following departments:

- A 'legal' department: legal support, monitoring and assessment of regional environmental, federal and European legislation, carrying out due diligence, monitoring appeal procedures, tax assessments, etc. ..;
- A 'soil' department: soil expert approved in the 3 regions (Wallonia, Brussels, Flanders);
- An 'external safety' department: SEVESO issues, safety studies, risk analyses ;
- An 'environmental management' department: environmental administration (single permit application, EIA, environmental data, etc.), 'environmental coordinator' support, ADR advisor, implementation of management systems (EMAS, ISO 14001, OHSAS 18001, etc.), etc.

Our various services are presented on our website: https://www.sertius.be/fr/index.html.

Sertius also worked on the permit applications, including environmental impact assessments, for several Luminus hydroelectric power plants, including those at Floriffoux, Marche-les-Dames, Monsin, Ivoz-Ramet and Ampsin.

The Sertius contact person for this dossier is Mr Xavier Musschoot.

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II SITE DESCRIPTION

The Meuse is a 950 km-long European river with a catchment area of 36,000 km²; it rises in France, flows through Belgium and then into the Netherlands. In Wallonia, the Meuse is 128 km long and provides water for a wide range of commercial and industrial activities: commercial shipping, nuclear power (Tihange nuclear power plant, hereinafter referred to as NPP) and hydroelectric power (9 hydroelectric power plants, hereinafter referred to as HPP).

The Life4Fish project has been set up in connection with the operation of 6 Luminus hydroelectric power plants on the Meuse River, which constitute major obstacles to fish migration; these are the Grands-Malades power plant (dam, lock and power plant), the Andenne power plant (dam, lock and power plant), the Ampsin-Neuville power plant (dam, 2 locks and power plant), the Ivoz-Ramez Ramet power plant (dam, 2 locks and power plant), the Monsin power plant (dam and power plant) and the Lixhe power plant (dam and power plant). The study area covers the Meuse between Namur and the Belgian-Dutch border, from the Grands-Malades hydroelectric power plant upstream to the Lixhe hydroelectric power plant downstream. The figures below show the location of these various power plants on the Meuse and the profile of the river, including the various reaches affected by the project.

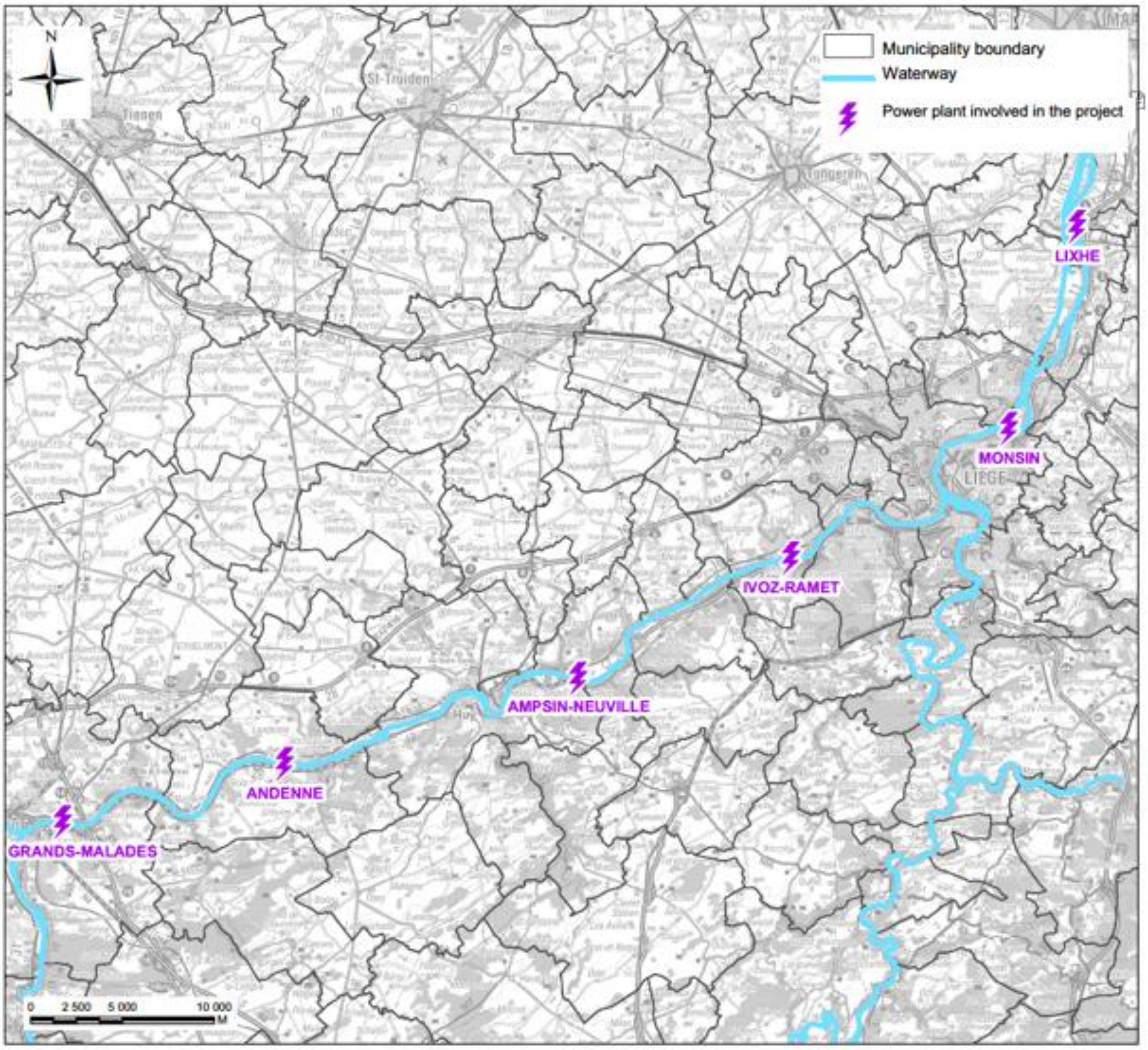


Figure II- 1: Location of the various hydroelectric power plants included in the Life4Fish project

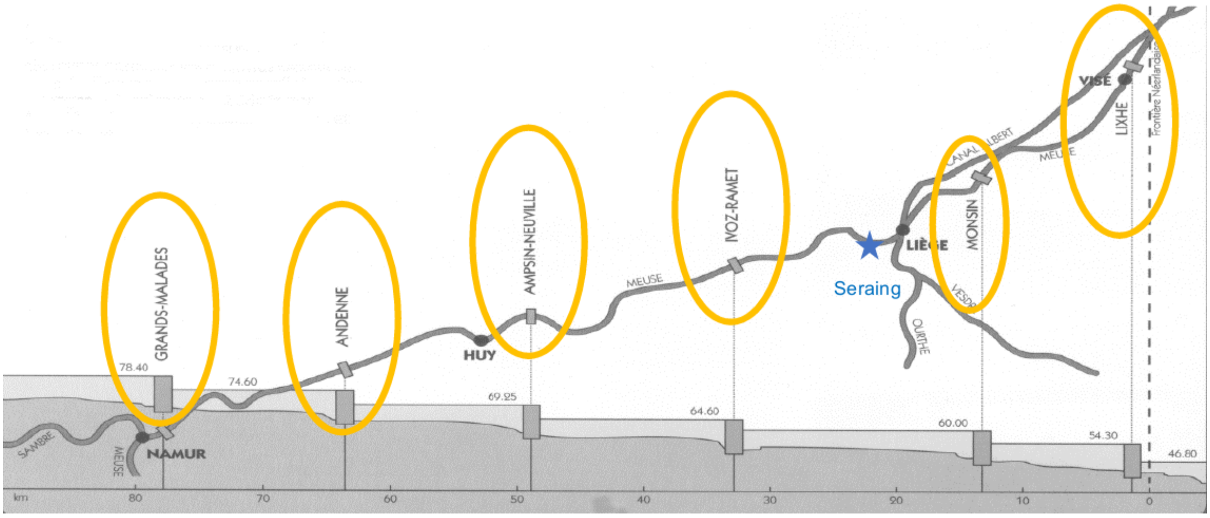


Figure II- 2: Profile of the Meuse and location of the various power plants affected by the project

On this section, the river is heavily canalised and the study area includes :

- 2 major tributaries, the Ourthe and the Mehaigne ;
- 3 outlets, the Meuse downstream of the Lixhe hydroelectric power plant, the Albert Canal and the Tihange NPP cooling water intake system.

III THE PROJECT

1. PROJECT BACKGROUND

As part of its authorizations to operate its hydroelectric power plants on the Meuse river, Luminus is required to reduce the impact of its plants on fish fauna, and more specifically on migratory fish such as the European eel and the Atlantic salmon. These are two species that benefit from protected status and recovery programs.

In order to test the best solutions for reducing the impact of turbines on migratory fish fauna, a study and research program funded by the European Commission has been set up under the Life4Fish project. The objectives of this project are to :

- Increase the survival rate of silver eels and downstream migrating smolts to 80% and 90% respectively along the lower Meuse[1] ;
- Optimize the renewable energy produced and the balance between the loss of green energy (< 5% as a target) and biodiversity;
- Integrate ecological processes or devices into the operational management of hydroelectric power plants. Downstream migration periods become an industrial variable that influences production periods;
- Demonstrate the performance and transferability of the solutions deployed;
- Increase the level of knowledge and demonstrate the value of a Meuse stakeholder committee.

As part of this project, various techniques designed to reduce the impact of turbines on the migration of European eel and Atlantic salmon have been installed and tested. The project focuses on the smolt stage for Atlantic salmon and the silver eel stage for European eel.

2. TARGET SPECIES

The two target species are endangered migratory species that benefit from protected status and stock recovery programs in the Meuse. Furthermore, because of their migratory behaviour, these species are sensitive to the obstacles posed by dams and turbines. Generally speaking, two impacts are encountered:

- These obstacles can block or slow down the upstream migration of individuals, ultimately leading to a decline or even extinction of migratory fish populations. It should be pointed out that, at the concerned power plants, it is impossible for fish to swim upstream through the turbines, as the only possible upstream route is via the devices set up and managed by the Public Service of Wallonia (SPW), while passage through the locks is virtually non-existent.
- As they make their way down to the sea, individuals may be forced to pass through the turbines of hydroelectric power plants, or pass through dams or locks, causing injuries of varying degrees of severity that may even lead to the death of some individuals.

The aim of the project is to reduce the risks incurred during the descent period of the two target species and to prevent individuals from entering the turbines.

[1] According to the analysis carried out at the start of the project, the escape rate is around 0% for salmon smolt and 62% for silver elver (see chapter IV.2.2.2).

2.1 ATLANTIC SALMON

The Atlantic salmon is a fish that thrives in the salty waters of the North Atlantic, but breeds in the fresh waters of European rivers between November and January. The figure below illustrates the species' life cycle.

The eggs are laid in oxygen-rich freshwater and hatch between February and April. Between March and May, after spending between one and two years in freshwater, the smolts begin to migrate to the sea off the coasts of Greenland and the Faroe Islands, where they reach adult size in one to four years. They then begin their migratory journey back to their native rivers, where they reproduce. Atlantic salmon are capable of completing the migration and spawning pattern two or three times in their lifetime.

As mentioned above, the project aims to protect the species when it migrates downstream towards the ocean, i.e. during the smolt phase. It should also be noted that during their downstream migration, smolts swim on the surface of the water.

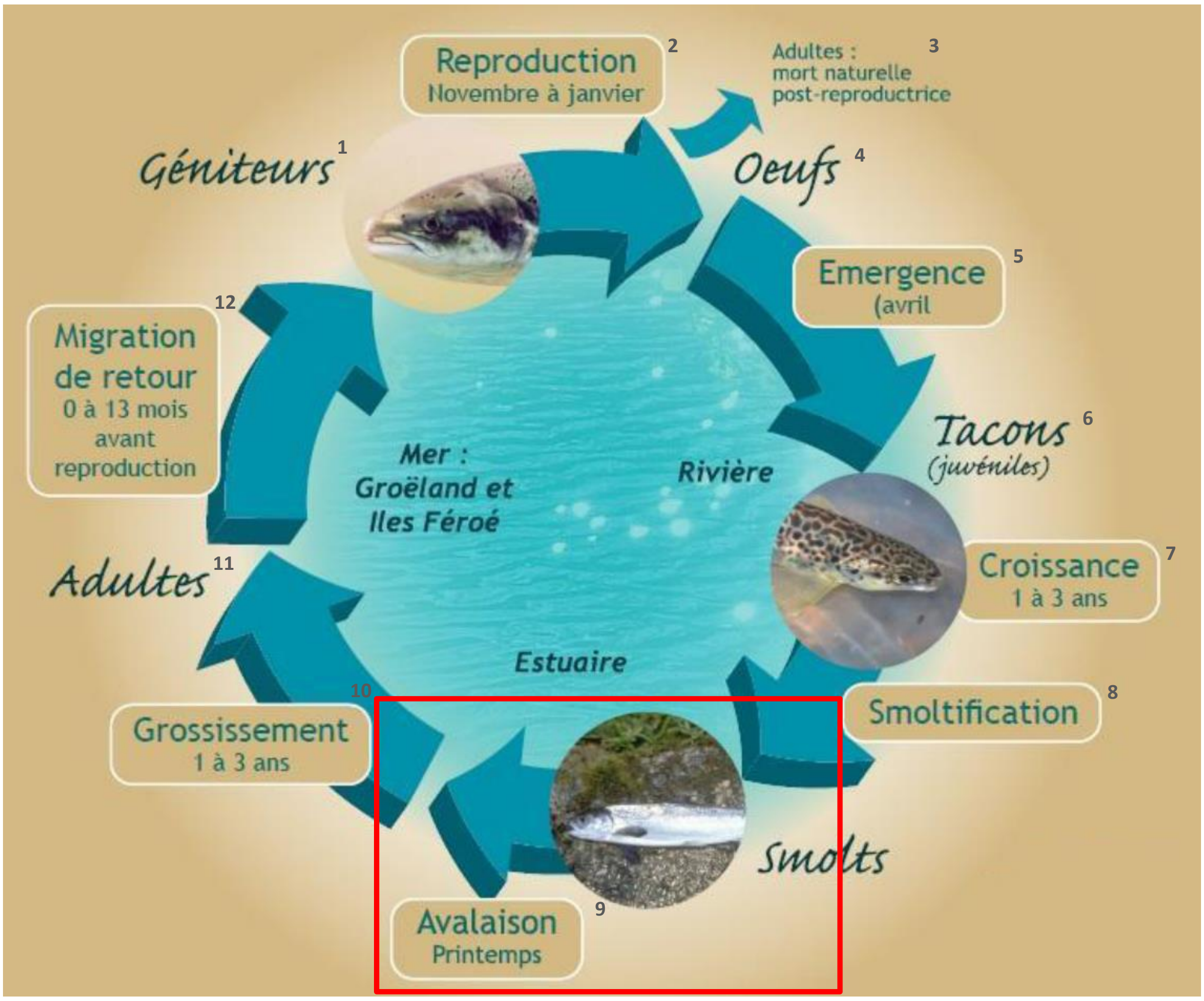


Figure III-1 Life cycle of the Atlantic salmon (source: https://www.logrami.fr/qui-sommes-nous/poissons-migrateurs/saumon/**)**

1. Breeders, 2. Breeding (November to January), 3. Adults: natural post-reproductive death, 4. Eggs, 5. Emergence (April), 6. Parr (juveniles), 7. Growth (1 to 3 years), 8. Smoltification, 9. Dowstream migration (spring), 10. Growth (1 to 3 years), 11. Adults, 12. Return migration (0 to 13 months before breeding)

2.2 EUROPEAN EEL

European eels begin their life cycle as transparent larvae, called leptocephali, in February or March in the Northeast Atlantic. The larvae are transported passively by the Gulf Stream towards the European coasts (from Norway to Morocco). The duration of the oceanic drift is not perfectly known, but estimates vary from 7 months to over 2 years[2]. The larvae then metamorphose into "elvers" when they reach the continental shelf.

As they approach European coasts, they enter estuaries and gradually become "pigmented yellow eels"[3] and colonise the fresh waters of the Meuse. The European eel continues to grow, becoming a "yellow eel" 6 to 8 cm long, cylindrical in shape and transparent to lightly pigmented, and settling in the rivers and estuaries that connect them[4] . The continental growth phase lasts between 3 and 30 years, depending on region and sex[5]. Under the influence of environmental factors, yellow eels metamorphose again into silver eels ready to migrate.

When environmental factors generate higher water flow and low light conditions[6], migration is triggered and silver eels return to their Atlantic spawning grounds. There are still many mysteries surrounding their life cycle, in particular the factors affecting colonization and the start of the migratory period. As previously mentioned, the project aims to protect the species during its downstream migration, i.e. the silver eel stage.

During their downstream migration, silver eels move along the bottom of the water.

This cycle is shown in the diagram below.

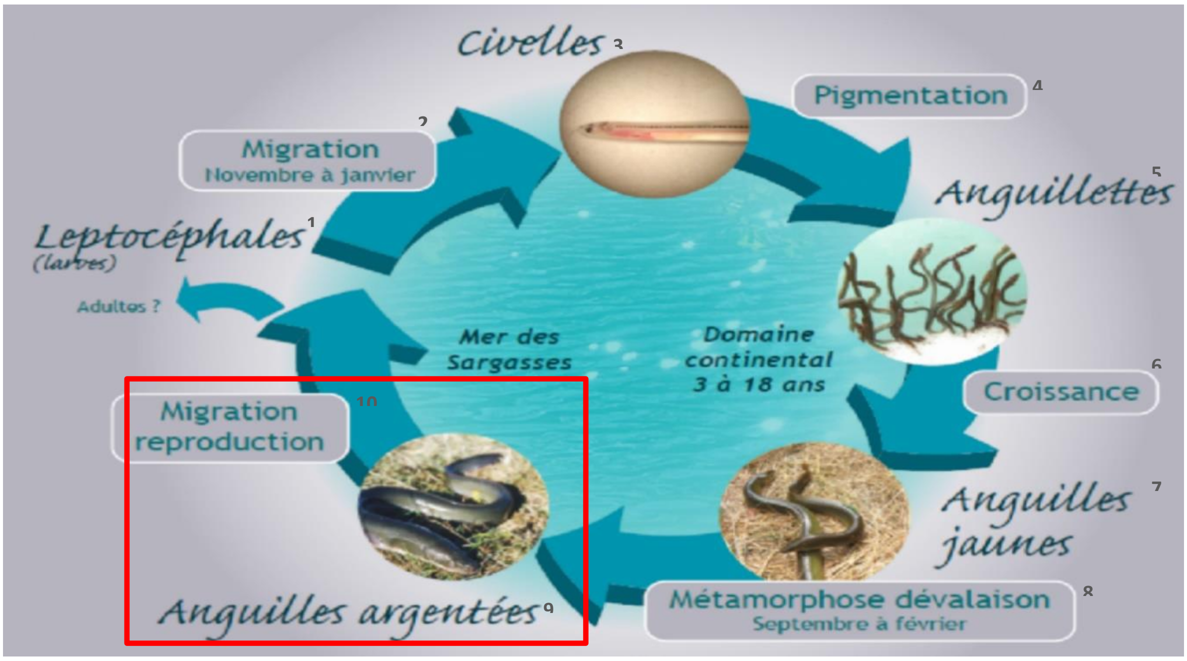


Figure III-2 Life cycle of the European eel (source: https://www.logrami.fr/qui-sommes-nous/poissons-migrateurs/anguille/**)**

1. Leptocephalus (larvae), 2. Migration (November to January), 3. Elvers, 4. Pigmentation, 5. Young eels, 6. Growth, 7. Yellow eels, 8. Metamorphosis - downstream (September to February), 9. Silver eels, 10. Migration - reproduction

[2] Bonhommeau S., Castonguay M., Rivot M., Sabatié E. & Le Pape O. (2010). The duration of migration of Atlantic *Anguilla larvae*. Fish and Fischeries, 11 : 289-306

[3] Tesch F.W. & Rohlf N. (2003). Migration from Continental Waters to the Spawning Grounds. In: Aida K., Tsukanomoto K. and Yamauchi K. 'eds) Eel Biology. Springer, Tokyo

[4] Keith P. Allardi J. & Moutou B. (1992). Livre rouge des espèces menacées de poissons d'eau douce de France. Coll Patrimoines naturels, vol 10, Secrétariat Faune-Flore (Muséum National d'Histoire Naturelle), Paris 111 pp.

[5] VØllestad, Leif AsbjØrn (1992). Geographic Variation in Age and Length ant Metamorphosis of Maturing European Eel: Environmental Effects and Phenotypic Plasticity. Journal of Animal Ecology, vol 61 N)1, pp 41-48.

[6] Trancart T., Feunteun E., Danet V., Carpentier A., Mazel V. Charrier F., Druet M. & Acou A. (2017). Migration behaviour and escapement of European silver eels from a large lake and wetland system subject to water level management (Grand-Lieu Lake, France): New insights from regulated acoustic telemetry data. Ecololgy of Freshwater Fish, 27 : 570-579

3. SOLUTIONS TESTED

3.1 SOLUTIONS WORLDWIDE

Various protective measures exist for downstream fish:

- Fish friendly turbines: the impacts of "conventional" turbines on ichthyofauna are due to mechanical shocks on the fixed (guide) or moving (blade) parts of the turbine, sudden variations in pressure, shearing (sudden acceleration and deceleration) or cavitation (formation of an air or gas bubble caused by a drop in liquid pressure). The principle behind fish-compatible turbines is therefore to minimize these three sources of impact. Fish can pass through these turbines, whose morphology and rotation speed are adapted to allow them to pass safely. According to the French National Office for Water and Aquatic Environments, these fish friendly turbines have, overall, much lower mortality rates than conventional turbines. However, their range of use does not cover all hydroelectric scheme configurations in terms of head and flow (particularly for medium to high heads). The fish friendly turbines are mainly used for new developments, as their installation on existing structures generally requires major civil engineering modifications ;
- Grid: the spacing between the bars of a water intake screen to prevent the passage of a few species of fish of different sizes is relatively well known. The maximum recommended spacing between the vertical bars of a grid is 1.2 to 1.5 cm for salmon smolts (Solomon, 1992), 2.0-2.5 cm for silver eels (according to studies in France; Durif, pers. com.), 3.5 and 4.2 cm respectively for sea trout and adult salmon in Scotland[7] (Solomon, 1992). To be effective, fine grid designs must meet two criteria, firstly a vertical or lateral inclination to guide the fish upwards or sideways, respectively, and secondly, a maximum velocity of 0.5 m/s at the grid. A first type of deflector grid consists of grid planes installed obliquely in the upper and/or lower part of the water intake. These grids are made up of grids with 2 mm triangular section bars spaced 2 mm apart. The upper grid is used to guide salmon towards an upper outlet that opens into the screen waste collection channel, while the lower grid can guide eels towards an outlet opening beneath the turbine;
- Fishway: this is a structure bypassing the power plant, which fish use from upstream to downstream, avoiding the need to pass through the turbines. For power plants without fish friendly turbines, fishways are necessarily associated with suitable physical barriers (fine screens, concrete sails). Their effectiveness will depend on the permeability of the physical barriers and the position of the fishway in relation to them. These may include outlets, denil or slow-moving fishways, fishways with successive basins, fish elevators, lock-fishway combinations, bypass rivers, natural rock ramps, fishways adapted to specific species (eels, lampreys), mixed fish/boatways, etc;
- Hydraulic regulation during downstream migration: many European countries are considering the complete shutdown of hydroelectric power plants during the downstream migration of eels. This measure should be considered as the last resort, because if it is not combined with an accurate model for predicting downstream migration peaks, it will result in a loss of hydroelectric production that could be offset by another non-renewable energy source;
- Regulation of water levels at dams: this method consists of increasing the height of the water level at certain openings in a dam in order to increase its attractiveness to migratory fish and encourage them to pass through these openings rather than through the turbines;
- Transport capture method: this measure can be considered in short term as it could be deployed pending the development of more effective technical solutions at power plant level. If a power plant is technically unable to reduce the impact of mortality to the level expected by the authorities, it would still be possible to set up a compensation fishery aimed at capturing the equivalent number of eels corresponding to the excess mortality in the intake canal;
- Behavioural barrier: this refers to the creation of a zone of influence on fish behaviour through the emission of a stimulus leading to a behavioural response of avoidance or attraction. The ability of different stimuli to frighten fish has been tested for several decades, mainly in North America and Europe. The main stimuli

[7] Solomon, D.K. 1992. Diversion and Entrapment of fish at water intakes and outfalls. National Rivers Authority, Bristol. R&D Report 1.

tested are: continuous light, strobe lights, bubble screens, sound emissions, pneumatic explosions, hydrodynamic screens and electric fields. The main species tested were salmonids, with a lot of data on Atlantic and Pacific salmon smolts. Some trials have also been carried out on eels and cyprins. The effectiveness of these methods is highly dependent on the target species (each species will not respond in the same way to the various stimuli) and the type of environment with its own specific characteristics.

3.2 CHOICE OF SOLUTIONS TESTED

As part of the project, the solutions tested were chosen so as to be suitable for eels and/or salmon and not to involve any significant modifications to the facilities (replacement of turbines, for example). The power plants involved in the project are already equipped with screens. In view of the above, the solutions tested are :

- Turbine management by setting up a downstream flow model;
- Behavioural barrier with, on the one hand, the electrical barrier and, on the other, the bubble barrier.
- Installation of a by-pass known as the downstream outlet;
- Management of water levels through a dam opening, although passage through the dam was not evaluated.

The different solutions tested are presented in more detail below.

3.2.1 Turbine management

This solution consists of implementing turbine-specific rules defined on the basis of eco-hydraulic migration models, which is equivalent to turbine shutdowns controlled by a downstream migration model. These specific turbine rules therefore depend on the target species and are explained in sections 4.1.3 and 4.2.3. This solution involves a loss of producibility, assessed in chapter IV.6.

This solution does not involve any modification to the installations.

3.2.2 Electric barrier

The principle of this system is to create a behavioural barrier via a non-uniform pulsed electric field that causes stress and a change in the trajectory of the individuals, thus preventing them from passing through the turbines, as illustrated in the figure below.

Procom's Neptun system was chosen for this purpose, with the barrier consisting of two submerged chains forming two parallel lines to which an electric cable and electrodes are attached; the electrodes are negative and positive in order to create an electric field. The location of the barrier and the arrangement of the anodes and cathodes within the barrier differ depending on the target species. It should be noted that this choice was made after a complete study taking into account various criteria such as the fixing system used for waste management, electricity consumption and guaranteed efficiency.

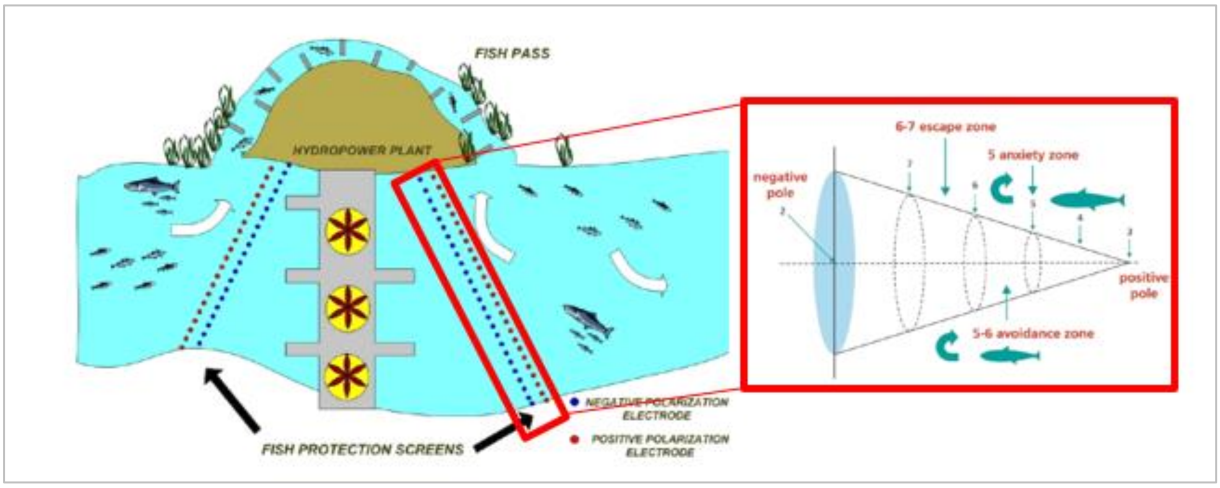


Figure III- 3: Operating principle of the electric fish barrier (Source: Neptun 2022)

The figure below illustrates the system.

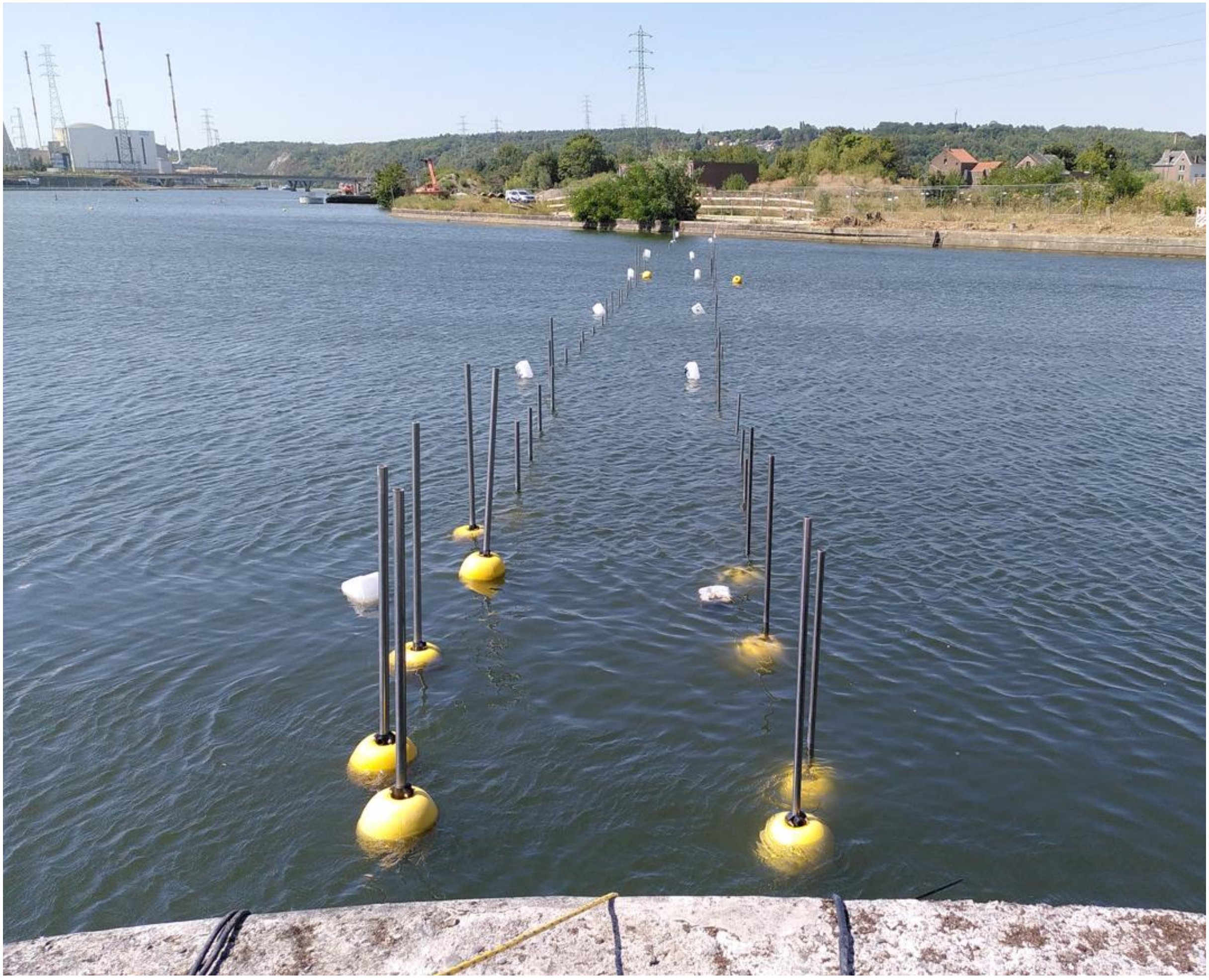


Figure III- 4: Illustration of an electrical barrier (source: Luminus - Ampsin-Neuville power plant)

The installation of an electric barrier therefore involves :

- Placing electrodes in the water (with bars and floats) upstream of the inlet channel to the turbines;
- Installing a ground-mounted electrical box (< 1 m³ in volume) ;

- And, in the case of salmon, an outlet[8] through the existing concrete slab to encourage the passage of the species through it rather than through the turbines. In fact, facilities must always allow for a downstream route, either via the dam, the turbines or a dedicated outlet.

With the exception of the creation of an outlet, these elements did not involve any excavation of the ground or modification of the relief, and therefore did not require any planning permission.

3.2.3 Bubble barrier

The principle behind this system is the creation of curtains of submerged air bubbles forming a linear barrier used to control the movements of fish and direct them away from the hydroelectric plant. The barrier consists of a pipe pierced with holes and positioned at the bottom of the channel. Compressed air is forced through the pipe, creating a curtain of bubbles with sound, light from the bubbles and the bubbles themselves, which discourages fish from passing through the curtain, the aim being to redirect the fish away from the turbines, towards a correctly calibrated pass.

Before being used to protect fish fauna, this system was tested in 1907 as a wave barrier and was used in fisheries from the 1960s onwards to direct fish into a defined fishing zone. It is currently used to protect fish fauna at the turbines of hydroelectric power plants. It is also used for a variety of other purposes (noise curtains, trapping plastic debris, etc.). The figure below illustrates this system.

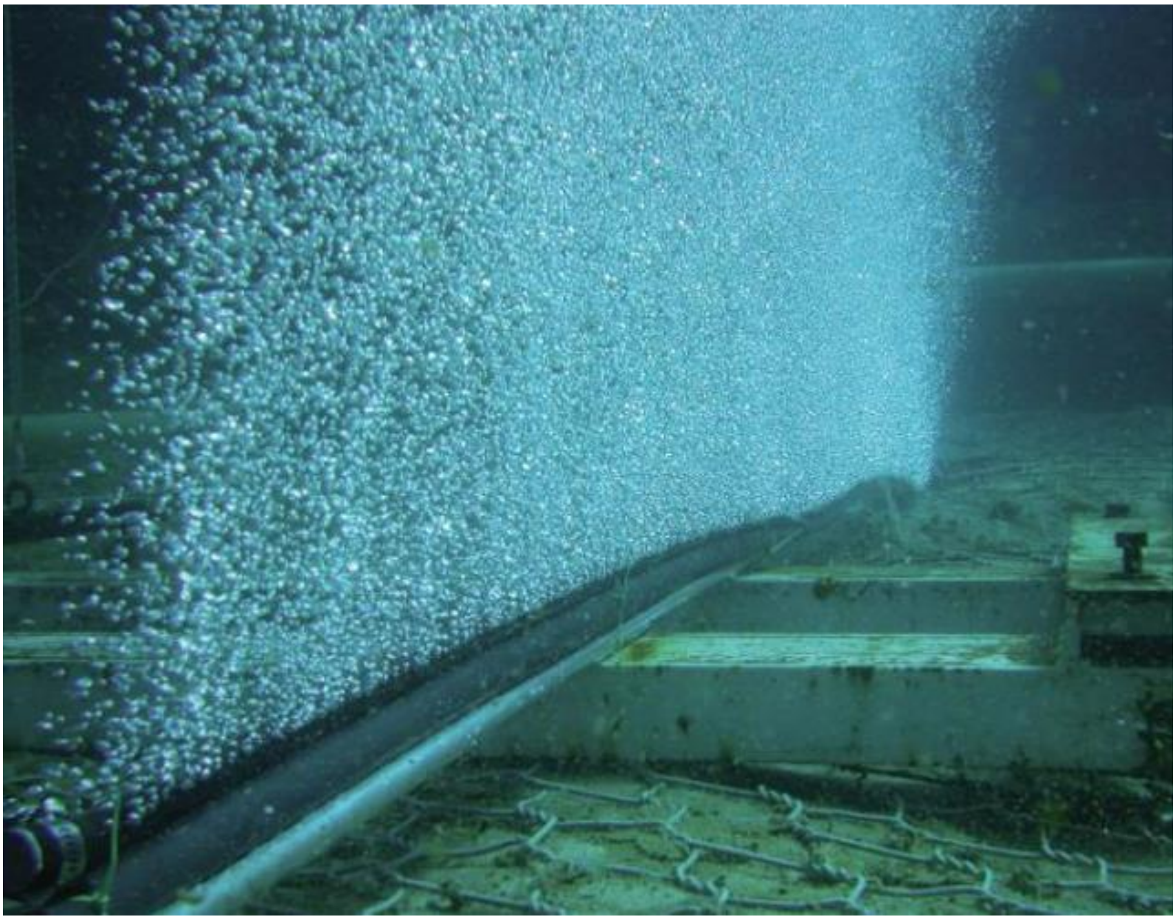


Figure III-3 Illustration of a bubble barrier in operation (source: Des bulles pour couper le son | Espace des sciences (espace-sciences.org))

Apart from the air supply pipes, no installations are located outside the plant's infrastructure, as shown in the figure below.

[8] According to the analyses and models of smolt movement routes at the various power plants analysed, only the Grand-Malades power plant requires the creation of an outlet.

Setting up a bubble barrier therefore involves :

- Positioning and securing the bubble barrier upstream of the inlet to the turbines;
- Installing a compressor and air inlets to the barrier.

These elements did not involve any excavation of the ground or modification of the relief and therefore did not require any planning permission.

3.2.4 Managing water levels

This solution consists of maintaining a certain height of water in a sluice to increase its attractiveness and thus prevent fish from passing through the turbines.

It should be noted that this solution has not been tested for eels. As eels move along the water bottom, this solution is not relevant for this species.

This solution does not involve any modification to the installations.

4. CHOICE OF PILOT SITES

4.1 ASSESSING THE SUITABILITY OF SITES

The criteria for setting up pilot sites are detailed below.

The choice of sites was validated by the project partners and the European Commission, taking into account the impact on fish fauna and the ability to analyze the physical conditions of the site. The results of the test campaigns will be used to determine downstream migration patterns and the impact of the sites on fish mortality.

Pilot site 1 is planned for the Grands-Malades plant. The site was shortlisted for its impact, being the first site to receive fish from the upstream section, and for its reproducibility, given its simple configuration and operating conditions, similar to the Andenne, Ampsin-Neuville and Lixhe plants.

Pilot site 2 was approved using the same procedure as pilot site 1. Pilot site 2 is Ivoz-Ramet. The site was selected for its reproducibility potential as it is equipped with vertically mounted Kaplan turbines, which is the same configuration as those at the Monsin site. The selection of Ivoz-Ramet also takes into account the various improvements planned for the Monsin site (turbine replacement, dam renovation) which could distort the measurement campaigns at this site.

As part of the initial analysis of the project, the first step was to assess the potential zones of arrival of stocks in the study area, as well as the zones of exit. Three entry zones for fish stocks were identified, namely the Meuse upstream and the confluences with the Mehaigne (Huy) and Ourthe (Liège) rivers. Three outflow zones were identified: the Meuse downstream at Lixhe, the water intake of the Tihange power plant (Huy) and the Albert Canal in Liège. The rate of influence of the various power plants on eel and salmon migration was then assessed, divided between the influence of the turbines and the fact that fish do not pass through the power plants. These rates of influence are shown in the table below. This initial analysis is detailed in chapter IV.2.2.1.

Table III- 1: Rate of influence of hydroelectric power plants affected by the project

		Seniors	Andenne	Ampsin-Neuville	Ivoz-Ramet	Monsin	Lixhe
Salmon	No crossing	18%	16%	20%	14%	100%	42%
	Turbines	1%	5%	5%	7%	0%	1%

Eel	**No crossing**	0%	0%	0%	0%	0%	0%
	Turbines	9%	2%	4%	7%	7%	0,4%

This table shows that no solutions for eels will be tested at the Andenne and Lixhe sites, as the impact of these sites on the eel escape rate does not exceed 2%. It should be noted that the priority remains navigation on the Meuse, so none of the solutions tested will have any impact on this.

It should be noted that the choice of sites was approved by STEERCO taking into account the impact of the structure on fish fauna and the ability to reproduce site conditions. STEERCO used the results of a campaign on downstream migration patterns and mortality, started in 2016 prior to the Life4Fish project, to make its decision.

4.2 FOR EELS

4.2.1 Turbine management

The silver eel migration model was initially implemented at Andenne and in 2022 at the Grands-Malades, Ampsin-Neuville, Ivoz-Ramet and Monsin sites.

After a sensitivity analysis, it seemed easier and more relevant in terms of the project's objectives (fish survival and green energy production) to shut down the turbines completely when migration peaks occur rather than mitigating discharges over a longer period.

In order to set the shutdown criteria, the minimum value of the migrating stock ratio for which the turbines must be shut down had to be determined. For each day, the migrating stock ratio for each night window was modelled and the hourly equivalent downstream migrating stock ratio was calculated. The turbines are then shut down for each period (each day and night window) that has hourly migration ratios on the shutdown criteria. These have been set to ensure that the green energy production targets are also met. The shutdown criterion defined for the pilot test is therefore 0.6% of the migrated stock per hour. This criterion limits downtime to 4.1% of the period.

Concerning the prediction of downstream migration peaks, out of 10 environmental factors analysed (water level flow, delta flow value, water conductivity, oxygen concentration, turbidity, water temperature, precipitation, sunshine duration, lunar phase), some showed a relative importance in influencing migration, namely delta flow value and water turbidity. Consequently, it appeared that the use of delta flow values could provide appropriate indicators for predicting eel migration.

These different variables have been integrated into an existing forecasting model developed on the Dordogne river in France[9] , a river with a good hydrological proximity to the Meuse. The final operational sequence of the model for the Meuse is as follows:

- Date between 20/8 and 28/2 ;
- Meuse flow of 200 m³/s ;
- Flow gradient greater than 35 m³/s in the Meuse compared with the previous 5 days or flow gradient greater than 15 m³/s in the Ourthe compared with the previous 7 days;
- Once an eel migration event is forecast, the hydroelectric turbines should be shut down during the night of day D until the end of the alarm.

Eel migration implies the shutdown of the Andenne power plant. The dam must therefore compensate for the flow of the hydroelectric turbine. The flow compensation system has been automated by SPW in response to the shutdown of the hydroelectric group. The regulation of the Meuse then shifted from reach height regulation to flow regulation.

4.2.2 Electric barrier

To test the effectiveness of this technique on eels, the Grands-Malades hydroelectric power plant was selected[10]. It was shortlisted for its impact on target species, the fact that it is the first site to receive fish from the upstream section, for its reproducibility and given its simple configuration and operating conditions, which are similar to the Andenne, Ampsin-Neuville and Lixhe sites.

As shown in the figure below, the barrier was installed at the entrance to the channel leading to the turbines in order to divert the eels towards the dam.

[9] Courret D., Chanseau M., De Oliveira E., Lionel D. & Rigaud C. (2016). Note on the modalities and on the evaluation of the effectiveness of turbine stoppages at Tuilières with respect to the downstream migration of eels. Tuilières Scientific Committee. Version 5

[10] Given the results of the initial tests, an electric barrier has also been installed at the Ampsin-Neuville site.

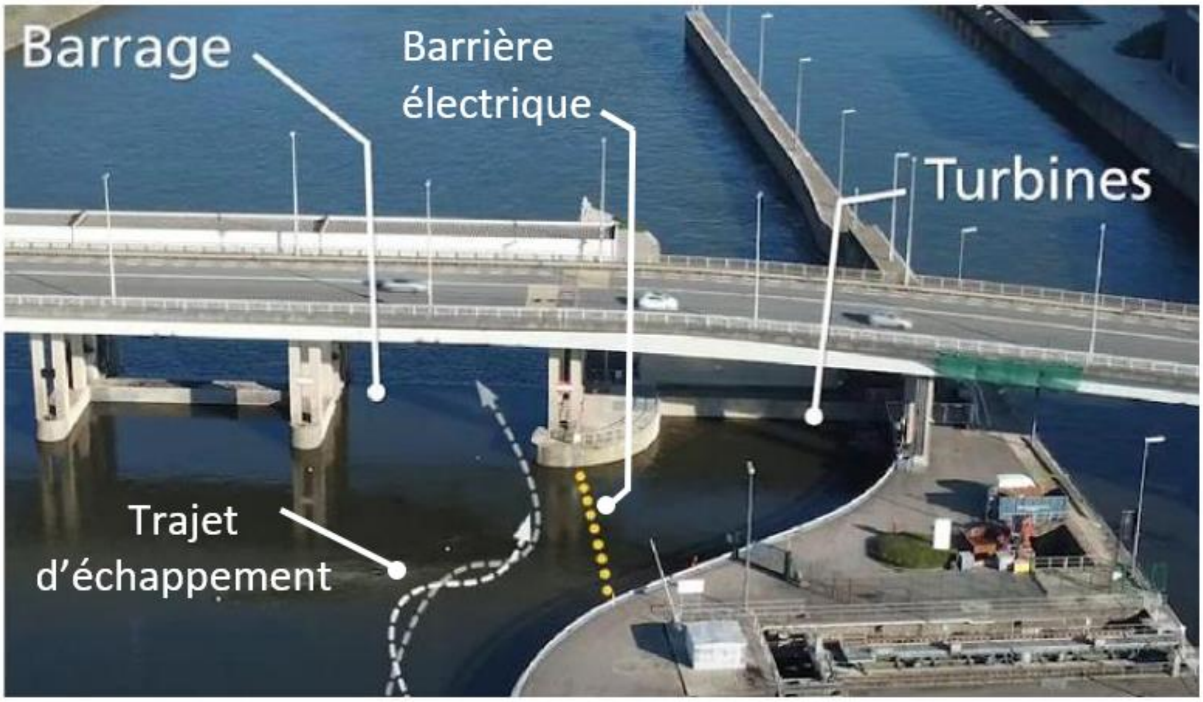


Figure III- 6: Location of the electric barrier for eels at the Grand-Malades hydroelectric dam (barrage = dam, barrière électrique = electric barrier, turbines = turbines, trajet d'échappement = exhaust path)

For this species, the barrier consists of a row of anodes and cathodes and a second row of anodes, as shown in the figure below.

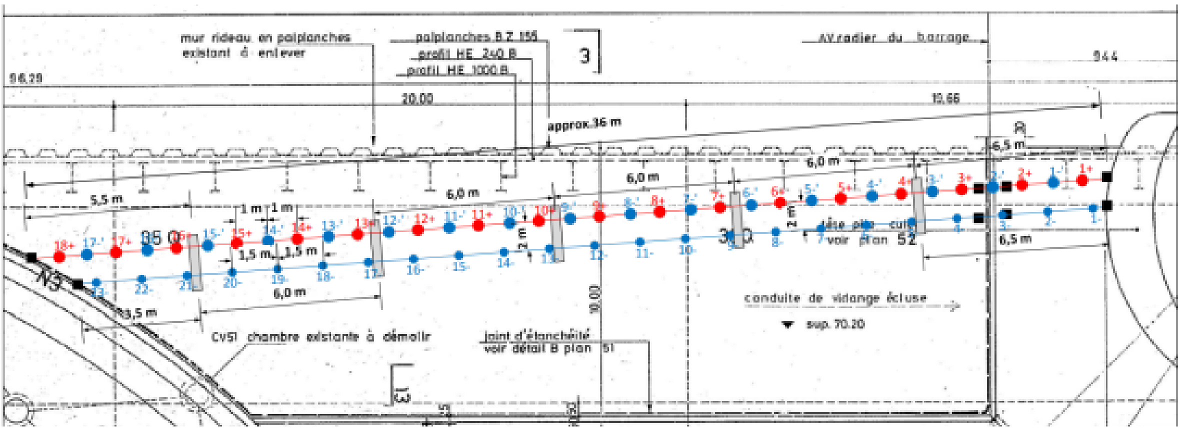


Figure III-4 Composition of the electric barrier for eels

The barrier in place is illustrated in the figure below.

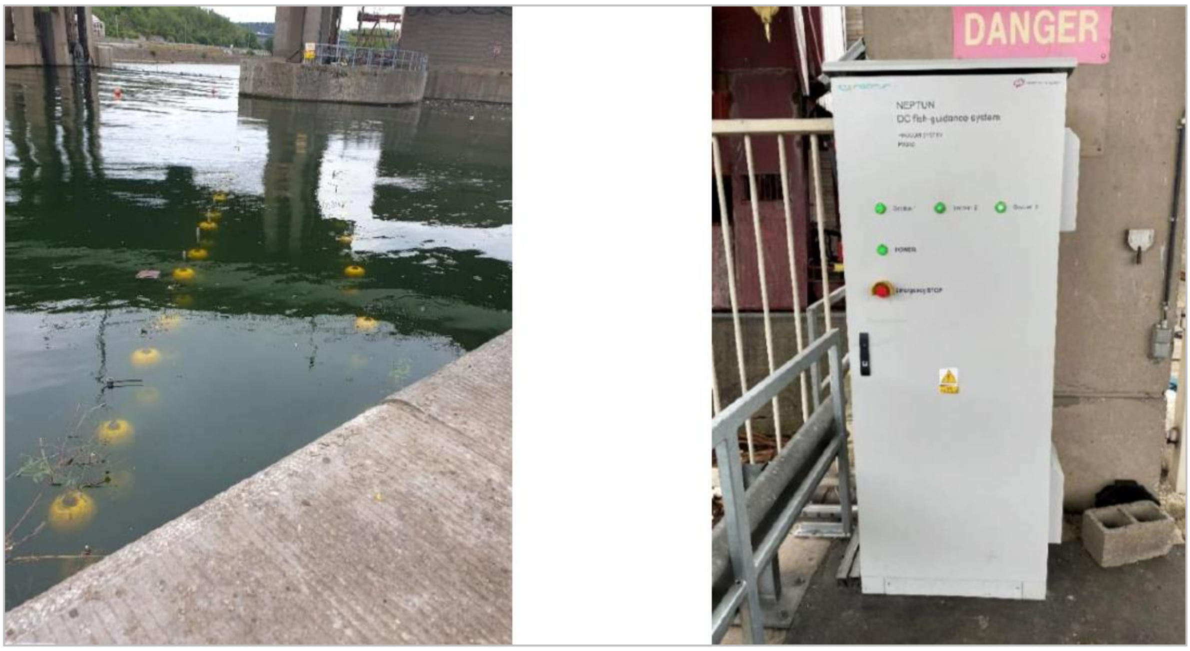


Figure III- 8: Electrical barrier and associated electrical cabinet at the Grands-Malades site

The barrier comes into operation during the eel's migration to the sea, i.e. during the silver glass eel stage, between late August and February, when flow conditions in the Meuse are favourable for migration.

Given the initial results, an electric barrier has also been installed at the Ampsin-Neuville site.

4.2.3 Bubble barrier

To test the effectiveness of this technique, the Ivoz-Ramet power plant was selected; it was shortlisted for its reproducibility potential, with its two large sites equipped with vertically mounted Kaplan turbines, which is the same configuration as those at the Monsin site. The selection of Ivoz-Ramet also takes into account the various improvements planned for the Monsin site (replacement of the turbines, renovation of the dam) which could distort the measurement campaigns at this site.

The system is in operation during the eel migration period. The figure below shows the location of the system.

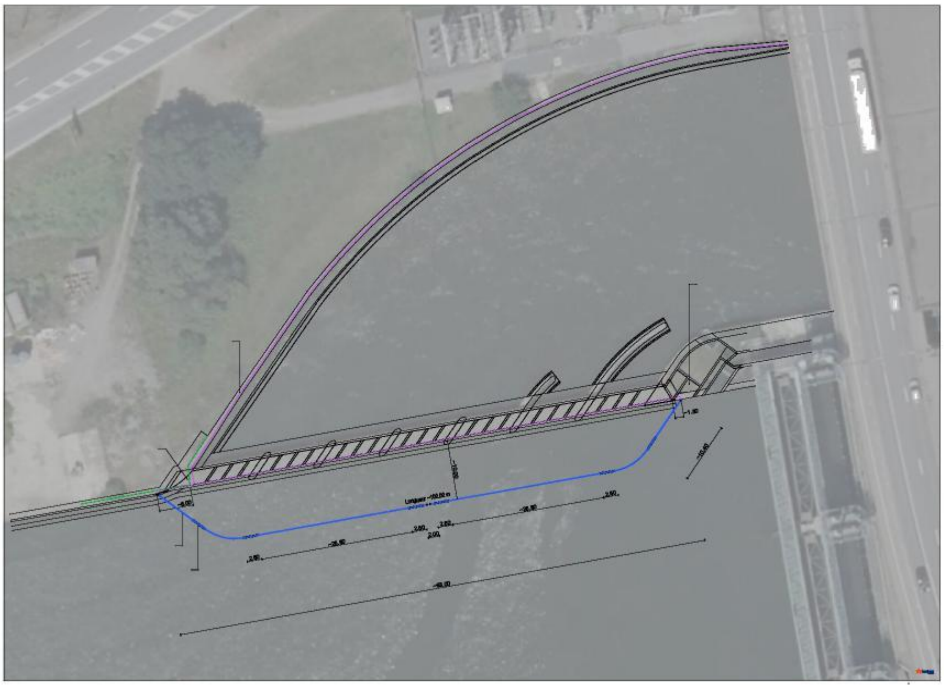


Figure III-5 Schematic view of the bubble barrier installed along the water intake at Ivoz-Ramet.

Figure III-6: Bubble barrier ready for installation at the Ivoz-Ramet site

4.3 FOR THE SALMON

4.3.1 Turbine management

The Monsin dam was chosen as the pilot site for the smolt migration model.

It was estimated that shutting down the turbines completely during the smolt migration period identified at the power plant (around 30 days) would result in energy losses that would be too high in relation to the project objectives (-5%). The pilot test was therefore carried out by supplying a minimum flow to one of the dam gates, enabling it to be passed during the migration period defined by the model. The turbine flow is then attenuated accordingly to guarantee the dam flow.

The minimum flow rate is currently defined according to:

- The study carried out by the University of Liège on the influence of the dam's discharge on fish passage;
- The dam capacity set by the Walloon Region according to the dam's working hours;

The project's objectives in terms of fish survival (increasing the survival rate of young eels and downstream migratory smolts to 80% and 90% respectively along the lower Meuse) and green energy production (less than 5% energy losses). In addition, at this site, a comparison was made between new-generation turbines and an old turbine in order to estimate the survival and injury rates of fish passing through the turbines.

4.3.2 Electric barrier

As with eels, the Grands-Malades hydroelectric dam was initially selected to test the effectiveness of this technique on salmon.

In this case, the installation of the electric barrier was combined with the installation of an outlet, as a high concentration of salmon had been observed during the initial monitoring carried out for the University of Liège[11]. This is illustrated in the figure below.

Figure III-7: Entrance and exit of the outlet set up for the passage of salmon smolts

Therefore, as illustrated in the figure below the location of the barrier is not the same as for the eels since it has been installed just before the turbines to divert the smolts' trajectory towards the outlet.

[11] Action A3, Modeling of the passages through the hydraulic work in order to design the solutions

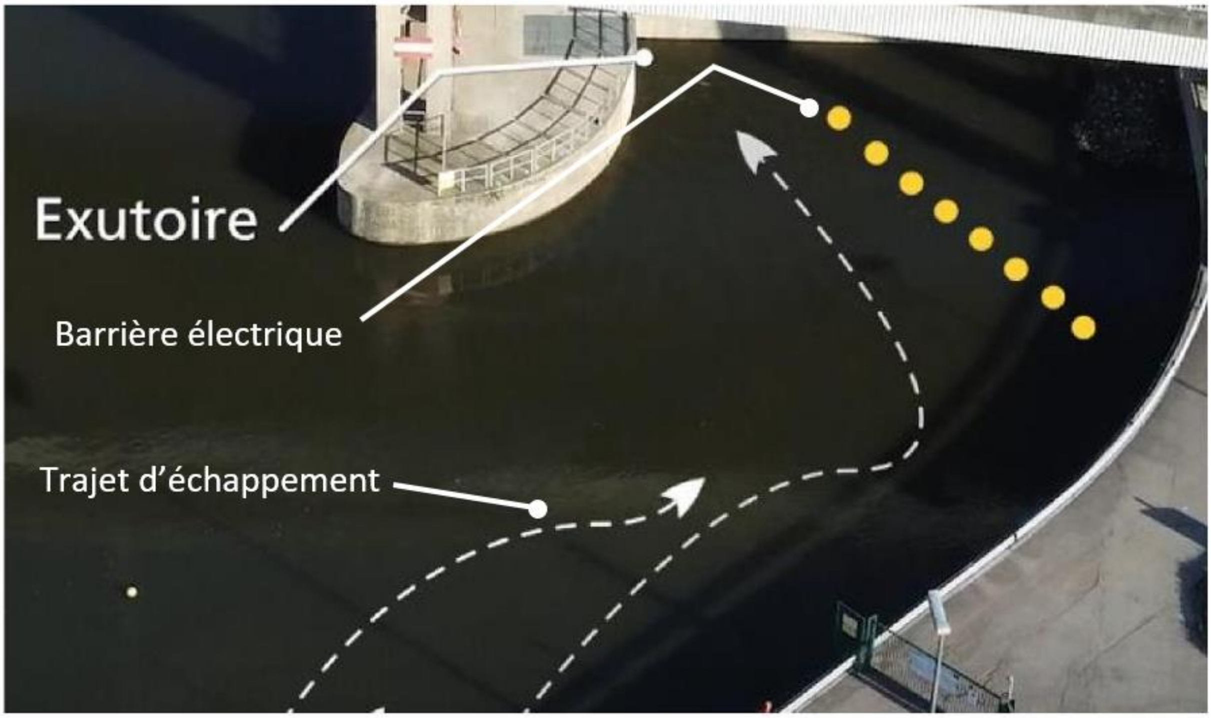


Figure III-8: Location of the electrical barrier for salmon at the Grand-Malades hydroelectric dam (exutoire = outlet, barrière électrique = electric barrier, trajet d'échappement = exhaust path)

For salmon, the barrier is made up of a row of anodes and a row of cathodes, as shown in the figure below.

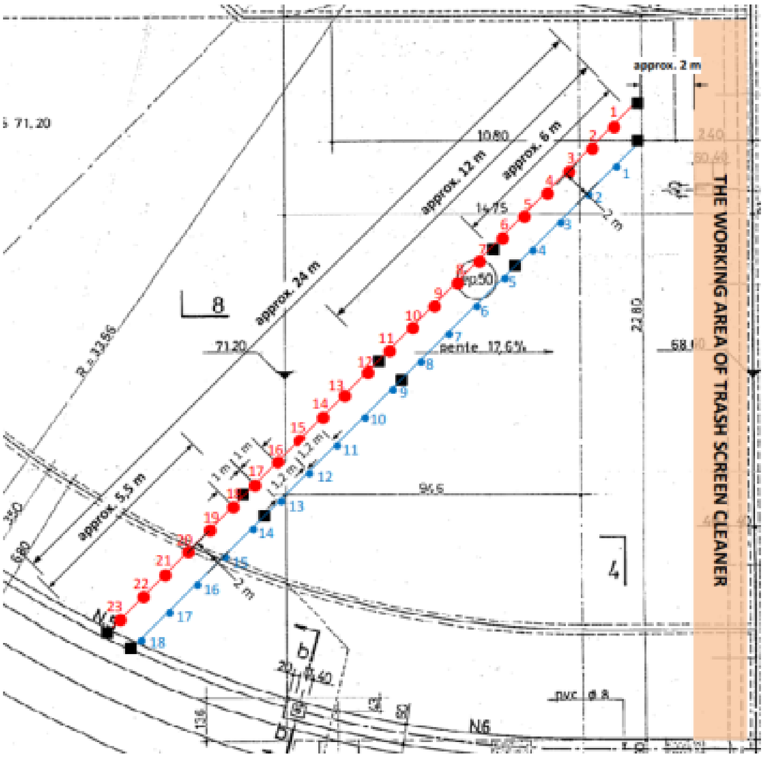


Figure III-9 Composition of the electrical barrier for salmon

The barrier is put into operation during the salmon smolt migration period, i.e. between March and June when flow conditions in the Meuse are favourable for the migration of the species.

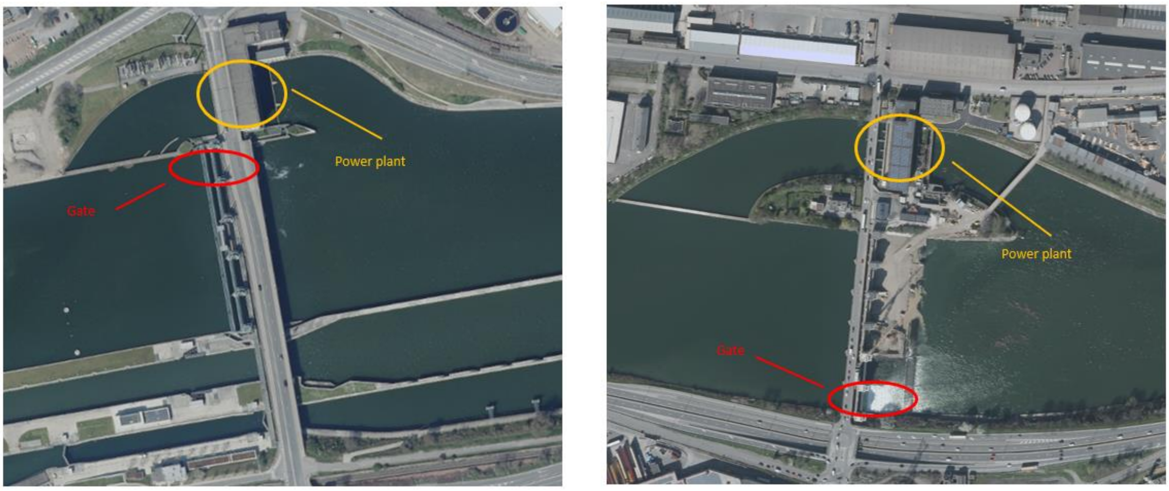
4.3.3 Bubble barrier

As the solution is identical for eels and salmon, the Ivoz-Ramet dam was also selected to test this solution on salmon migration; only the period of activity differs for the two species (from late August to February for eels and from March to June for salmon).

4.3.4 Water level management

In accordance with the various permits, a 20 cm blade is maintained at the level of the openings in the Grands-Malades power plant (the right bank opening closest to the power plant) and the Lixhe power plant (the opening closest to the dam). As these blades already exist, they were not among the solutions tested.

However, 50 cm and 90 cm blades were tested at the Ivoz-Ramet dam (the gate closest to the power plant) and 90 cm at the Monsin power plant (the gate furthest away). The figure below shows the location of the openings concerned by the tests.



Ivoz-Ramet power plant | Monsin power plant

Figure III-10 Location of the openings concerned by the test on the height of the water level in relation to the power plants.

5. BRIEF DESCRIPTION OF THE PLANTS COVERED BY THE MEASURES

5.1 INTRODUCTION

Luminus currently operates 7 hydroelectric power plants, all located in Wallonia on the Meuse and Sambre rivers, and remotely controlled and monitored from the central control station in Seraing (Rue Pont du Val, 1, 4100 Seraing). The location of the power plants are shown in the figure below.

Figure III-11 Location of Luminus electricity generation sites

Run-of-river hydroelectric power plants are mainly located in the Meuse, Amblève and Semois-Chiers sub-basins. The six power plants on the Meuse downstream of Namur have a total capacity of 67 MW, representing 60% of the installed capacity of the Belgian fleet.

Thanks to a centralized supervision and remote control system based at the Seraing power plant, staff can monitor the operation of each hydroelectric unit on the Sambre (Floriffoux) and Meuse (Grands-Malades, Andenne, Ampsin, Ivoz-Ramet, Monsin and Lixhe) as if they were on site.

Average annual production of all the Luminus hydroelectric power plants is around 227 GWh (ten-year reference), which supplies green energy to the equivalent of 50,000 households, or around 180,000 people.

5.2 HOW A HYDROELECTRIC POWER PLANT WORKS

Each power plant has its own specific features, but the operating principle remains the same.

The basic principle is as follows: the river's potential energy is transformed into mechanical energy by turbines, then into electrical energy by alternators coupled to the turbines. The only condition for this production is a sufficient difference in height between two water levels. This is known as the "head". The speed of the water flowing from the upper reach 1 to the lower reach 2 drives the rotation of a propeller known as a water turbine. The higher the head, the greater the power available. And the greater the flow through the turbine, the higher the alternator's power output.

A certain amount of water is also drawn from upstream of the plant to feed the screenings discharge channel. The hydroelectric plant's installations channel the river water through a screen. This prevents large debris such as tree branches from passing through the turbines. Elements retained on the grid is removed by a screen, which removes the debris using a claw. The debris is drawn into a water channel that bypasses the plant and empties into a waste pit. The waste is retained in the waste pit and removed by a fixed crane (see figure below), while the water flows into the river downstream of the plant.

After screening, the water flow arrives in the horizontal duct and passes through the turbine wheel. This can either have a vertical or horizontal axis (see figures below). The water rotates through the turbines and then exits via the aspirator into the tailrace. Some turbines have steerable impeller blades that allow the propeller to adapt to variations in water flow, guaranteeing optimum efficiency whatever the flow.

The water-driven turbine (transformation of kinetic energy into mechanical energy) is coupled to its alternator. Alternators convert mechanical energy into electricity. The electromagnetic field created by the moving rotor induces an electric current in the stator. The electricity produced is then fed into the electricity transmission grid.

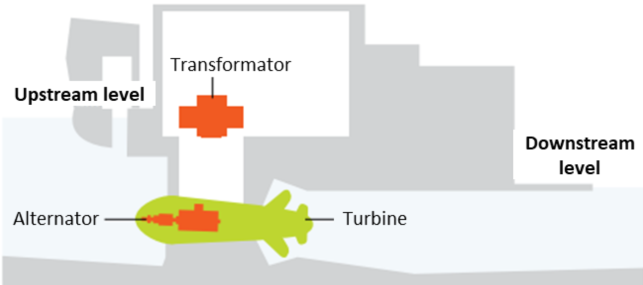


Figure III-12 Schematic diagram of a hydroelectric plant - horizontal axis turbines

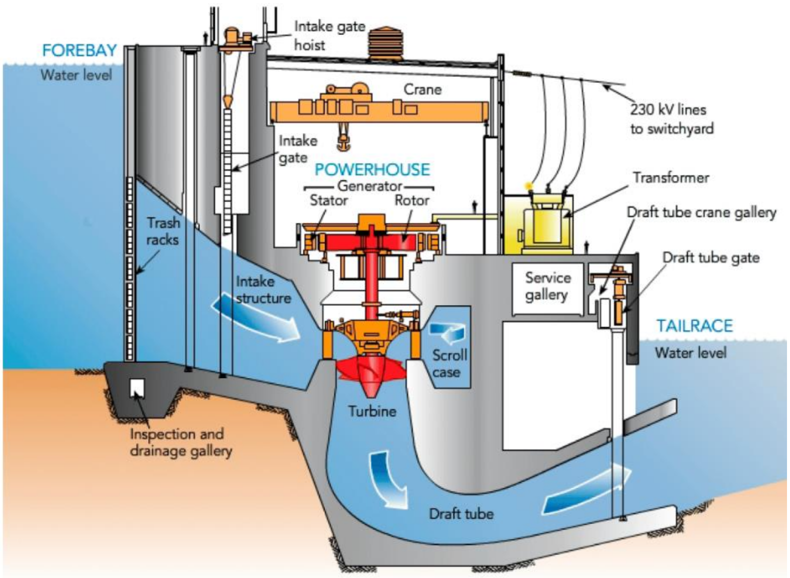


Figure III-13 Schematic diagram of a hydroelectric power plant - vertical axis turbines

The characteristics of the hydroelectric power plants concerned by the project are listed in the table below. The technical details of these power plants and their operation will be specified in the various environmental themes studied, should this prove necessary.

Table III- 2: Characteristics of the hydroelectric power plants concerned by the Life4Fish measures

Central stations	Types and number of turbines	Installed capacity	Waterfall	Average electricity production
Grands Malades (CHG)	4 horizontal axis Straflo turbines	5 MWe	5,70 m	22 GWh/year
Andenne (CHA)	3 horizontal axis Straflo turbines	7 MWe	5,40 m	33 GWh/year
Ampsin (CHN)	4 horizontal axis turbines	10 MWe	4,70 m	35 GWh/year
Ivoz-Ramet (CHR)	3 vertical-axis Kaplan turbines	10 MWe	4,60 m	39 GWh/year
Monsin (CHM)	3 vertical-axis Kaplan turbines	20 MWe	5,70 m	60 GWh/year
Lixhe (CHL)	4 horizontal axis Straflo turbines	16 MWe	7,5 m	63 GWh/year

IV PROJECT IMPACT ASSESSMENT

1. PHYSICAL ENVIRONMENT

1.1 INTRODUCTION

1.1.1 Difficulties encountered

None.

1.1.2 Detailed impact assessment methodology

The aim of the Physical Environment chapter is to assess the project's impact on soil, groundwater and surface water.

1.2 ANALYSIS OF THE EXISTING SITUATION

1.2.1 Geology

According to the respective geological maps, both the power plants and the Meuse are located in modern alluvium. "The bottom of the present-day valleys of the Meuse and its tributaries is covered with a carpet of alluvium. The Meuse's minor bed consists mainly of coarse deposits: boulders, pebbles, sometimes reworked from previous terrace levels, and sand.

The alluvial plain, which used to be regularly flooded during floods, is mainly covered with silt and clay. The channelling of the Meuse no longer allows this silty-clay mantle of the valley floor to increase.

1.2.2 Pedology

According to the digital soil map of Wallonia, the soils at the various dams, as along the entire length of the Meuse, are not mapped.

1.2.3 Soil condition

As part of the implementation of the decree of March 1, 2018 on soil management and remediation ("soil" decree), the Walloon Public Service has developed a Soil Condition Data Bank (BDES).

The BDES lists, for each cadastral parcel, the available data relating to a possible state of soil pollution. This data is supplied by various public bodies known as "Reference Sources", which have access to it as part of their activities.

The database distinguishes between two types of parcel:

- Blue/lavender parcel: parcel concerned by information of a strictly indicative nature leading to no obligation;
- Peach/brown parcel: parcel for which soil management measures have been taken or are planned.

In the case of a single permit or planning permission application, if the parcel is of peach colour in the BDES and the project involves a change in the footprint impacting soil management and/or a change of use to a more sensitive use, then the Applicant is expected to submit an orientation study (soil study enabling a ruling to be made on whether or not the soil and/or groundwater is polluted).

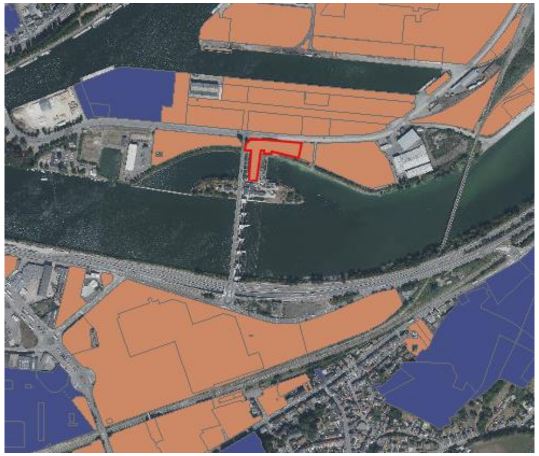
As illustrated in the following Figure, the Monsin power plant is located on parcels of land shown in peach colour in the Walloon soil condition database, as a part of the Lixhe power plant, whereas the parcels of land for the other power plants are not shown in the Walloon soil condition database.

Grand-Malades

Andenne

Ampsin-Neuville

Ivoz-Ramet



Monsin

Lixhe

Figure IV- 1: Extract from the ESDB for the various plants involved in the project (Source: WalOnMap).

1.2.4 Geological risks

The Université de Liège (Laboratoire de Géomorphologie et de Télédétection), the Faculté Polytechnique de Mons (Service de Géologie Fondamentale et Appliquée) and the Commission wallonne d'Étude et de Protection des Sites souterrains (CWEPSS) were commissioned, on the basis of the inventory carried out in the Atlas du Karst wallon, selective bibliography and field studies, to define areas on and near karstic phenomena, where construction must be subject to special conditions.

These institutions have highlighted two types of constraint:

- Karst sites and surface karst in the Atlas du Karst wallon: karst phenomena in the Atlas are represented by a symbol covering a 50 m diameter zone within which it is recommended to prohibit construction. The same applies to perimeters covering the surface area of phenomena (coalescing karstic depressions, chantoirs with a vast depression around the point of loss, etc.) with surface diameters greater than 50 m;
- Karstic constraint perimeters: zones of moderate or severe constraint have been defined by the Walloon public service, on the basis of studies, depending on the nature of the karstic phenomenon (sinkhole, doline, rock shelter, etc.), the topography (dry valley, limestone plateau), the size of the phenomenon (small settling doline, vast chantoir, etc.), the density of these (isolated cavity or field of dolines) and the evolving nature of the phenomenon (recent appearance of losses, hydrological activity).

The Grands-Malades and Andenne power plants are underlain by Carboniferous limestone, while the other power plants are not underlain by any carbonate formations (no karstic risk).

The known karstic phenomena closest to the Grands-Malades and Andenne power plantsare :

- A cavity 280 m to the north and a doline-depression 350 m south-west of the Grands-Malades power plant;
- A cavity 980 m to the north-west of the Ivoz-Ramet power plant.

For the other power plants, no karstic phenomena have been identified within 1 km.

1.2.5 Seismic hazard

The seismic hazard is the probability of occurrence of potentially dangerous strong ground movements as a result of earthquakes. It is expressed as a function of maximum ground acceleration.

It should not be confused with seismic risk, which quantifies the amount of damage or casualties that could be caused by earthquakes. Seismic risk depends not only on the seismic hazard but also on the degree of exposure and vulnerability (densely urbanised area, poor quality buildings, etc.).

The seismic hazard can be calculated as a function of the probability of an earthquake of a given magnitude on the Richter scale and the probability of a given level of ground acceleration being reached as a function of earthquake distance and magnitude.

The SESAME project has calculated the seismic hazard in Belgium. The result is a map of the maximum ground acceleration that is likely to occur over a period of 475 years. Based on this map, Belgium has been divided into five different zones for the application of the European seismic standard (Eurocode 8). Within each zone, the seismic hazard is considered to be uniform. The regions where the hazard is highest are the east of the country (Liège and the Fourons region, Limbourg and Hautes Fagnes) and Hainaut.

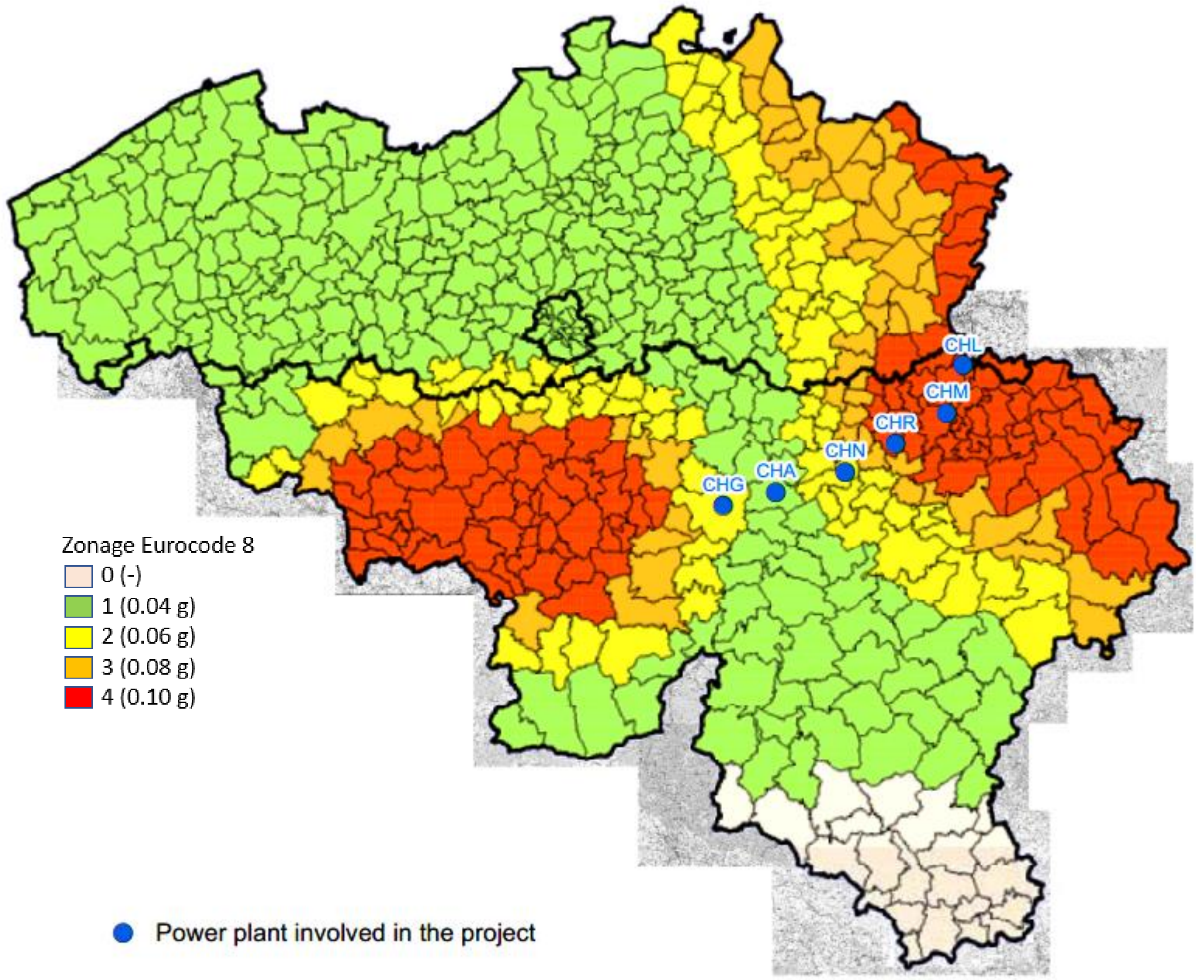


Figure IV- 2: Location of the various hydroelectric power plants concerned on the seismic hazard map of the Walloon Region (www.seismology.be).

The zoning of the area shows that the Andenne power plant is located in a level 1 seismic hazard zone (corresponding to a low hazard zone in Belgium), the Grands-Malades and Ampsin power plants are located in a level 2 seismic hazard zone (medium hazard zone), while the Ivoz-Ramet, Monsin and Lixhe power plants are located in a level 4 seismic hazard zone (the highest seismic hazard zone in Belgium).

1.2.6 Hydrography

The two parameters essential to good hydrological management are the flow and the water level in the various watercourses. The average monthly flow follows the rhythm of the seasons. The hydrological regime of the Meuse is known as a simple pluvial regime, as the river has the following characteristics:

- High water (with a more or less marked maximum) in winter and low water in summer. Although rainfall during the low-water season is often equal to or greater than during the high-water season, high temperatures mean that evaporation is high;
- Inter-annual irregularity: the period of maximum high water shifts significantly from one year to the next depending on the "whim" of the rainfall.

In an unmanaged watercourse, during periods of high flow (flooding), water levels are high and the watercourse sometimes overflows its minor bed, causing flooding. During low-flow periods, the water level is low.

On the other hand, when a river is anthropized, as is the case with the downstream Meuse, hydraulic structures counterbalance this flow-water level relationship. Dam and lock complexes make it possible to control and maintain water levels within narrow limits, allowing river navigation. The water level in a reach is controlled by the dam located downstream of the reach. Since the water level is virtually fixed, the flow-velocity relationship is linear.

1.2.7 Flow and water level management

The Meuse, from the French border to the Lixhe dam, and the Sambre along its entire length are open to navigation. To ensure that water levels are compatible with navigation, SPW manages a number of run-of-river lock dams: 15 on the Meuse and 19 on the Sambre. Some of these dams are equipped with hydroelectric power plants to exploit the renewable energy potential of the waterfalls between the upstream reach and downstream reach.

The Floriffoux, Grands-Malades, Andenne, Ampsin, Ivoz-Ramet, Monsin and Lixhe power plants are managed and remotely monitored from the control centre at the Seraing power plant. Bringing the control of the various units together in one place means that management of the Meuse as a whole can be better coordinated, while optimizing the production of renewable energy and improving operating safety.

Water levels in the various navigation reaches are managed in collaboration with the SPW staff responsible for dam management. In order to ensure navigation, SPW sets the water levels and flows to be respected by operators of hydraulic structures (locks, dams, power plants, etc.), thereby limiting turbines operation. SPW may at any time request changes to power plant operation. When changes are made to the turbine operating regime, Luminus operators notify the SPW. These warnings are usually preventive.

If the limits cannot be complied with, the Applicant must notify the SPW. The latter requires the power plants to generate as little flow variations as possible and to align themselves as closely as possible with the river’s natural flow.

The reaches level regulation of each dam is based on the measurement of the upstream level of the dam and its comparison with one or more set point values specific to each dam and determined in the protocol specific to the dam, according to the observed and forecast flows, as well as the trend in the levels observed.

Regulation is currently based solely on water level. In the long term, SPW plans to notify Luminus of the authorised flow rate at each power plant at any time. Luminus informs SPW at all times of the turbined flow at each power plant. Flow variations caused by a power plant are automatically compensated for by the dam concerned.

The authorised flow is calculated in such a way as to be maximised, while meeting the various operating constraints, including the permits and conditions linked to the operation of the power plant concerned.

By adjusting the height of the dam fuse gates, SPW regulates the flow through the dam by acting on the height of the spillway. By adjusting the power produced by the hydraulic turbines, Luminus regulates the flow through the power plant.

In order to optimize the production of renewable energy, Luminus gives priority to the river's natural flow, regulating the level upstream of the facility according to the minimum and maximum values set out in the Meuse River operating instructions. These instructions are defined in consultation with the SPW Direction of Waterways and are included in the table below for all Luminus hydroelectric power plants on the Meuse.

	Flow m3/s	Pmin kW	P max kW	Openin g max	Openin g min	Low level	High level	Yield	Qmin m3/s	Fall avge mov (m)	Lower fall stop (m)	Lower fall start (m)	Losses (MWh)	Rrque
FLORIFFOUX (ORES)	**24**		**800**										**50**	***Electricity value per MWh***
CHF 1-2	12		400										**65**	***Valuation of Green Certificates per MWh***
GRANDS-MALADES (AIEG)	**160**		**5000**			**78.45**	**78.55**			3.8				Simple setting
CHG 1-2-4	40	800	**1250**	95%	70%			88%	30		2	2.4	50	Double setting (priority)
CHG 3	40	500	**1250**	95%	50%			88%	20		2	2.4	50	
ANDENNE (RESA)	**167**		**7050**			74.1	74,30			5.25				
CHA 1-2	45	500	2000	95%	**45%**			92%	10		2	2.4	115	Double setting + CV (priority)
CHA 3	77	1500	3050	95%	70%			75%	30		2	2.4	55	Simple setting
AMPSIN-NEUVILLE (RESA)	**220**		9000			69.15	69.35			4.4				Minimum 18 m3/s for Tihange
CHN 12 3 4 (25m3/MW)	55	**500**	**2250**	85%	40%			85%	15		1.8	2.2	50	Pmax :2,25 MW limited for gearbox
IVOZ-RAMET (RESA)	**270**		**10350**			64.55	64.75			4.4				Double setting (Kaplan vertical)
CHR 1-2-3 (27m3/Mw)	90	500	3450	90%	30%			80%	20		1.8	2.2	50	**Stop below 50 m3/s**
MONSIN (RESA)	**450**		**19500**			60.00	60.15			5.6				Pmin G1-G3 :1000 kW at 3m and 1500 kW at 6m
CHM 1-3	150	**1500**	6500		30%			93%	30		3	3.3	115	**Stop below 70 m3/s at Amay+Ourthe**
CHM 2	150	1000	6500	95%	30%			80%	22		1.5	1.8	50	
LIXHE (ELIA)	**280**		**16100**			54.36	54.50			7.3				Stopped if CHM stopped for minimum flow
CHL 1-2	55	1000	3000	95%	**45%**			92%	15		2.5	3.0	115	Double setting + CV (priority)
CHL 3-4	85	3000	5000	85%	65%			75%	30		2.5	3.0	50	**Stop at the same time than Monsin**

Maximum limits for technical reasons

Figure IV- 3: Operation data for hydroelectric power plants on the Meuse river

1.2.7.1 Low-water period

During low-water periods, the flow is lower than the design flow and there is no turbining. The power plants are shut down and any regulation is provided by the dam.

1.2.7.2 Normal operation

During normal operation (equipment flow), the power plant regulates the level of the reach by increasing or decreasing the turbined flow. When the equipment flow is exceeded, the flow is not turbined and passes to the dam.

1.2.7.3 Flood period

If the high water level is exceeded (flood), the dam will provide the necessary flow as a back-up. In other words, the dam will open to increase the flow through the scheme and lower the level of the forebay.

During periods of flooding, the flow of the Meuse greatly exceeds the flow of the power plant equipment, resulting in a significant increase in the downstream level of the power plant. This period is characterised by a falling head and decreasing production, which may even lead to power plant shut down.

Beyond the power plant's design flow, the hydroelectric plant alone is unable to lower the forebay level, even when its turbines are operating (maximum turbine flow exceeded). In this case, the dam is responsible for controlling the water level in the forebay. The units will be shut down if the head is below the height of the equipment, and all the flow passes through the dam. It should be noted that floods are often accompanied by a period of intensive screening before the power plants are shut down and restarted.

When floodwaters recede, the units are restarted according to the minimum starting head.

The dams are also equipped with bottom gates to discharge the flow in the event of flooding. The position of the bottom gates is not transmitted back to the power plant, so the dam discharge displayed is no longer consistent in the event of flooding. At this point, the total flow of the Meuse can be estimated via the data on the SPW website and/or up to a certain limit via the downstream facilities, which provide consistent data. At this point, it is the dams (also known as spillways) that regulate the levels of the Meuse.

1.2.7.4 Low-water period

If the water level falls below the low water mark, it is the Luminus's responsibility to reduce or stop electricity production in order to guarantee a minimum draught for navigation.

In the event of low flow, care must be taken to shut down the units for flows below the technical minimum listed in the Table of operating instructions above. In addition, attention should be paid to the constraints specific to each plant:

- Maintain a minimum flow of 18 m³/s at Ampsin for cooling the Tihange nuclear power plant;
- Maintain the level in the reach between Ramet and Monsin to keep the Albert Canal supplied;
- Complete shutdown of Monsin if average flow over 6 hours at Liège (Meuse + Ourthe) is less than 65 m³/s;
- Complete shutdown of Lixhe when Monsin is shut down due to minimum flow;
- Monsin start-up authorized for a 6-hour average flow at Liège (Meuse + Ourthe) greater than 70 m³/s.

1.2.8 Water quality

The water body affected by the hydroelectric power plants is the "Meuse II" (code: MV35R). This is a "heavily modified" water body, with a surface area of 425 km² (336.6 km² in the Meuse downstream sub-basin and 87.9 km² in the Meuse upstream sub-basin). It includes the Meuse, from its confluence with the Ruisseau de Tailfer to the Dutch border. The typology of this water body corresponds to "Very large, gently sloping Condrusian rivers". It is a heavily modified body of water.

As part of the Hydrogeographical District Management Plan (HDMP), an assessment of biological status is carried out every 6 years. The ecological status of water bodies is assessed using biological indicators such as macro-invertebrates, diatoms, fish and macrophytes, physico-chemical indicators (oxygen balance, pH, nitrogen and phosphorus matter, specific pollutants) and hydromorphological indicators such as the continuity of watercourses and the nature of banks. Chemical status is assessed by taking into account environmental quality standards for 45 priority substances.

The assessment as part of the 2nd river basin management plan (2016-2021) is based on the results of measurements from 2005-2013 . The status of the water body is described in the *"MV35R Meuse II water body characterization sheet"* (SPW-ARNE, 2016) and summarized in the following Table.

Table IV- 1: Ecological and chemical status of the MV35R water body (2013)

MV35R	Ecological quality		Ecological status	Chemical state	
Meuse II	Biology	Good and more	Medium	Non-PBT* quality	Good
	Physico-chemistry (general parameters)	Good			
	Physico-chemistry (specific pollutants)	Bad		Quality with PBT	Not good
	Hydromorphology	Mediocre			

**ubiquitous PBTs: Persistent, Bioaccumulative and Toxic substances*

As this table illustrates, the status of the water body can be characterized as average. The characterization sheet states that, on the basis of the analysis of the status of the water body and in projection of the application of the program of measures of the second management plans, the ecological and chemical objectives have not been achieved.

The assessment under the 3rd river basin management plan (2022-2027) is based on the results of the 2016-2018 measurements.

Table IV- 2: Ecological and chemical status of the MV35R water body (2018)

MV35R	Ecological quality		Ecological status	Chemical state	
Meuse II	Biology	Mediocre	Mediocre	Non-PBT* quality	Not Good
	Macropollutants (BOD_5 , COD, SS, N_{TOT} and P $)_{TOT}$	Good			
	Physico-chemistry (specific pollutants)	Good		Quality with PBT	Not good

There are exceedances for Bifenox, Cypermethrin, ubiquitous PBT : Mercury (Biote), Heptachlor /heptachlor epoxide (Biote), PBDE (Biote)[12] .

The overall ecological status of the Meuse II has remained unchanged (average to mediocre) over the last decade, with an improvement in the physico-chemical status of specific pollutants.

1.2.9 Rivers and lakes

As mentioned above, all the power plants concerned by the project are located on the Meuse, a navigable waterway.

[12] Projet des Troisièmes Plans de gestion des Districts Hydrographiques Wallons, DEE - SPWARNE

No bodies of water are affected by the project.

1.2.10 Flood risk

As the various power plants are located on the Meuse, they are at high risk of flooding.

1.2.11 Groundwater catchments

Numerous water catchments are present in the vicinity of the various power plants; however, none of them is affected by a catchment prevention zone.

1.2.12 Local relief

The elevation of the various power plants ranges from 78 m to 54 m. The Meuse has a gentle slope, and it is at the dams that the slopes are broken to create the gradient and allow the water to flow through the turbines.

1.3 IMPACT ASSESSMENT

The impact of each solution tested is assessed on the elements likely to be affected, i.e. :

- Soil quality;
- Hydrography, and more specifically the flow of the Meuse.

1.3.1 Turbine management

As a reminder, this solution consists of shutting down the turbines when certain conditions favourable to the migration of silver eels and smolts are met; consequently, no construction work is required and no impact on the soil is expected. Furthermore, when the turbines are shut down, the water continues to flow; no impact on the hydrological conditions of the Meuse is therefore expected.

In view of the above, no impact on the physical environment is expected.

1.3.2 Electric barrier

As a reminder, installing an electric barrier involves :

- Placing electrodes in the water (with bars and floats) upstream of the power plants;
- Installing a ground-mounted electrical box (< 1 m³ in volume) ;
- And, in the case of salmon at the Grands-Malades power plant, an outlet through the existing concrete slab to encourage the species to pass through it rather than through the turbines.

As this solution does not involve any excavation work, no impact on the ground is expected.

As shown in the figure below, the creation of the outlet diverts a small proportion of the Meuse river water from the inlet channel to the outlet, rather than to the turbines, without impeding its circulation. It therefore appears that the creation of the outlet does not alter the flow of the Meuse or its hydrological conditions. Furthermore, as the outlet is positioned directly in the flow stream, downstream fish are directed directly towards the outlet, as is floating waste. As a result, the outlet has to be regularly cleaned and the waste removed, which means cleaning the Meuse.

Outlet upstream of the power plant

Outlet downstream of the power plant

Figure IV- 4:Illustration of the outlet created at the Grands-Malades power plant

In view of the above, no impact on the physical environment is to be expected from the installation of an electric barrier.

1.3.3 Bubble barrier

As a reminder, installing a bubble barrier involves :

- Laying compressed air supply pipes from the plant's facilities to the position of the barrier, located upstream of the plant;
- Installing a compressor within the plant's infrastructure.

This solution does not therefore involve any building work, apart from the installation of light installations within the dam, air supply pipes or the barrier itself. No excavation is therefore required, and it is estimated that this solution will have no impact on the ground.

In addition, the bubble barrier simply creates a curtain of bubbles in the water without causing any change in flow; consequently, no impact on the hydrological conditions of the Meuse is expected.

The installation of a bubble barrier is therefore not expected to have any impact on the physical environment.

It should also be noted that the system was damaged quickly, so the submerged parts were removed.

1.3.4 Water height

As a reminder, this solution consists of increasing the water level in a sluice to encourage the passage of salmon through it; it should be noted that this solution is only implemented if it does not hinder the navigability of the Meuse, which remains the priority.

As a result, no construction work is required to install this solution and no impact on the ground is expected.

In addition, the increase in the water level at an opening (sluice) diverts a small quantity of water from the Meuse towards this opening rather than towards the dam or the turbines. In the end, the quantity of water upstream and downstream of the power plant is identical, so no impact on the flow of the Meuse or its hydrological conditions is expected.

It should be noted that the increased head of water passing through the dam results in greater oxygenation of the water, which is positive during the smolt's downstream migration, whereas eels are indifferent to this difference in oxygenation.

In view of the above, no negative impact on the physical environment is expected.

2. BIOLOGICAL ENVIRONMENT

2.1 INTRODUCTION

2.1.1 Difficulties encountered

None.

2.1.2 Assessment methodology

The "Biological environment" section of this study aims to determine the impact of the various solutions tested on both eels and salmon.

First, the project's local environment is described, including an inventory of sites of biological interest within a radius of 2,500 m around the various power plants and diversion bays, with a focus on sites that are particularly relevant to the aquatic environments potentially affected by the project.

An analysis of the initial situation is then carried out before assessing the various solutions tested as part of this project.

2.2 ANALYSIS OF THE EXISTING SITUATION

2.2.1 Sites of biological interest near the project

The sites of the various power plants do not benefit from any special protection status as natural areas, nor are they recognized as areas of biological interest. In fact, the sites of the various power plants are neither nature reserves (state-owned - RND or approved - RNA) nor forest reserves (RF), nor wetlands of biological interest (ZHIB), nor underground cavities of scientific interest (CSIS), nor parts of Natura 2000 sites, nor sites of great biological interest (SGIB).

However, no fewer than 10 Natura sites are present within a radius of 2,500 m of the various power plants and the Meuse between the Grands-Malades and Lixhe power plants. They are shown in the following figures, reach by reach.

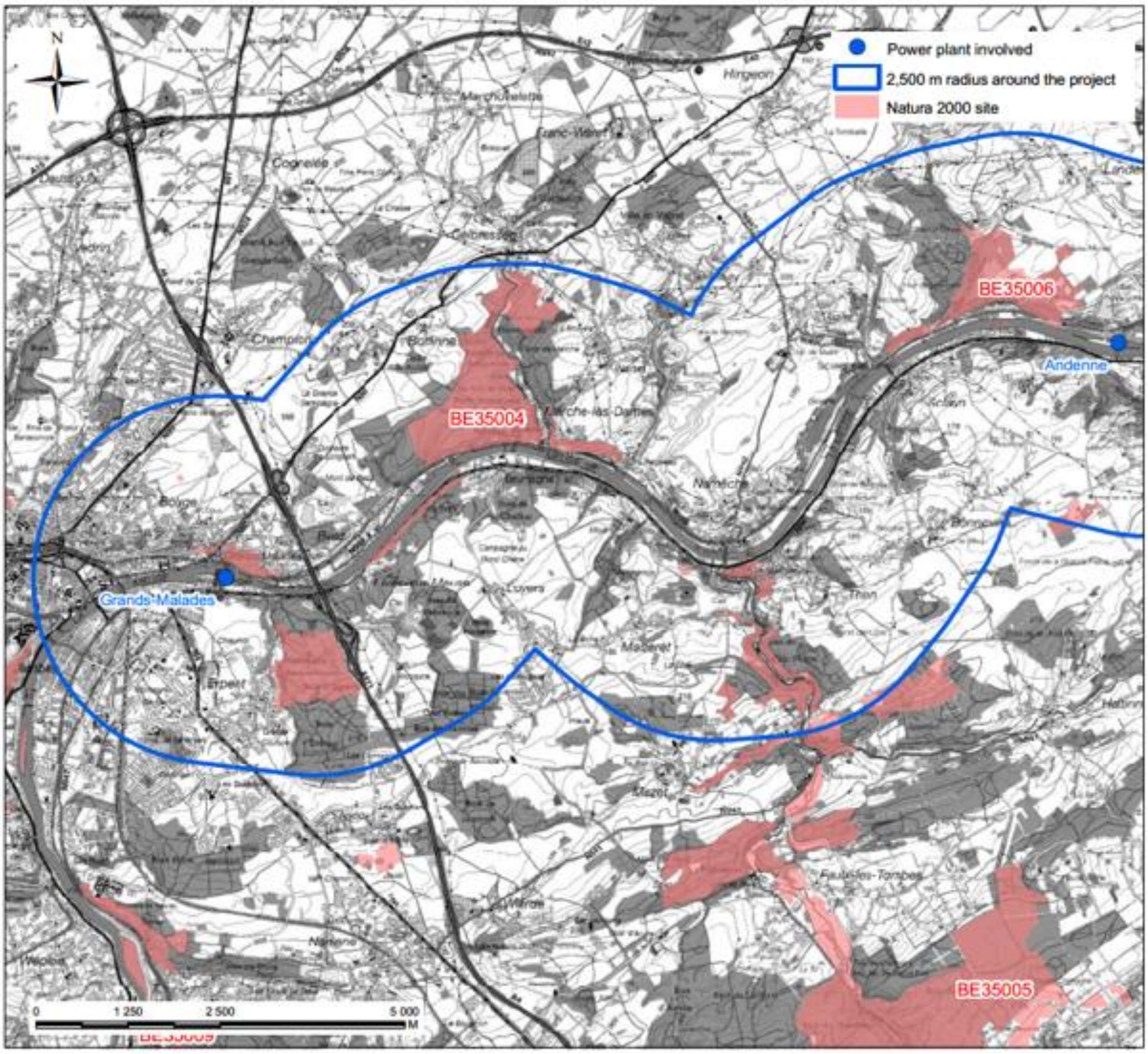


Figure IV- 5: Natura 2000 sites within a radius of 2,500 m, reach between the Grands-Malades and Andenne power plants

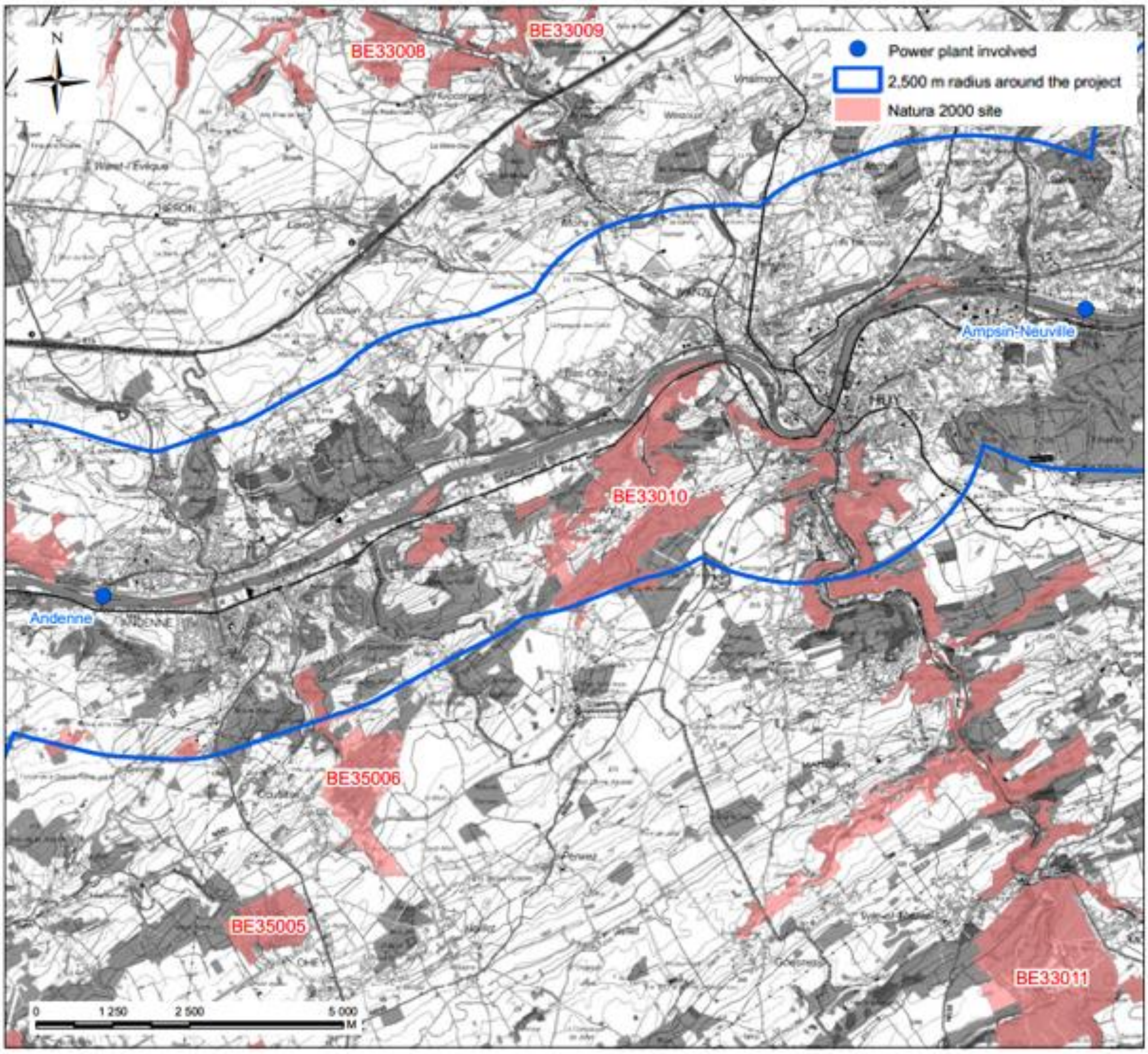


Figure IV- 6: Natura 2000 sites within a radius of 2,500 m, reach between the Andenne and Ampsin power plants

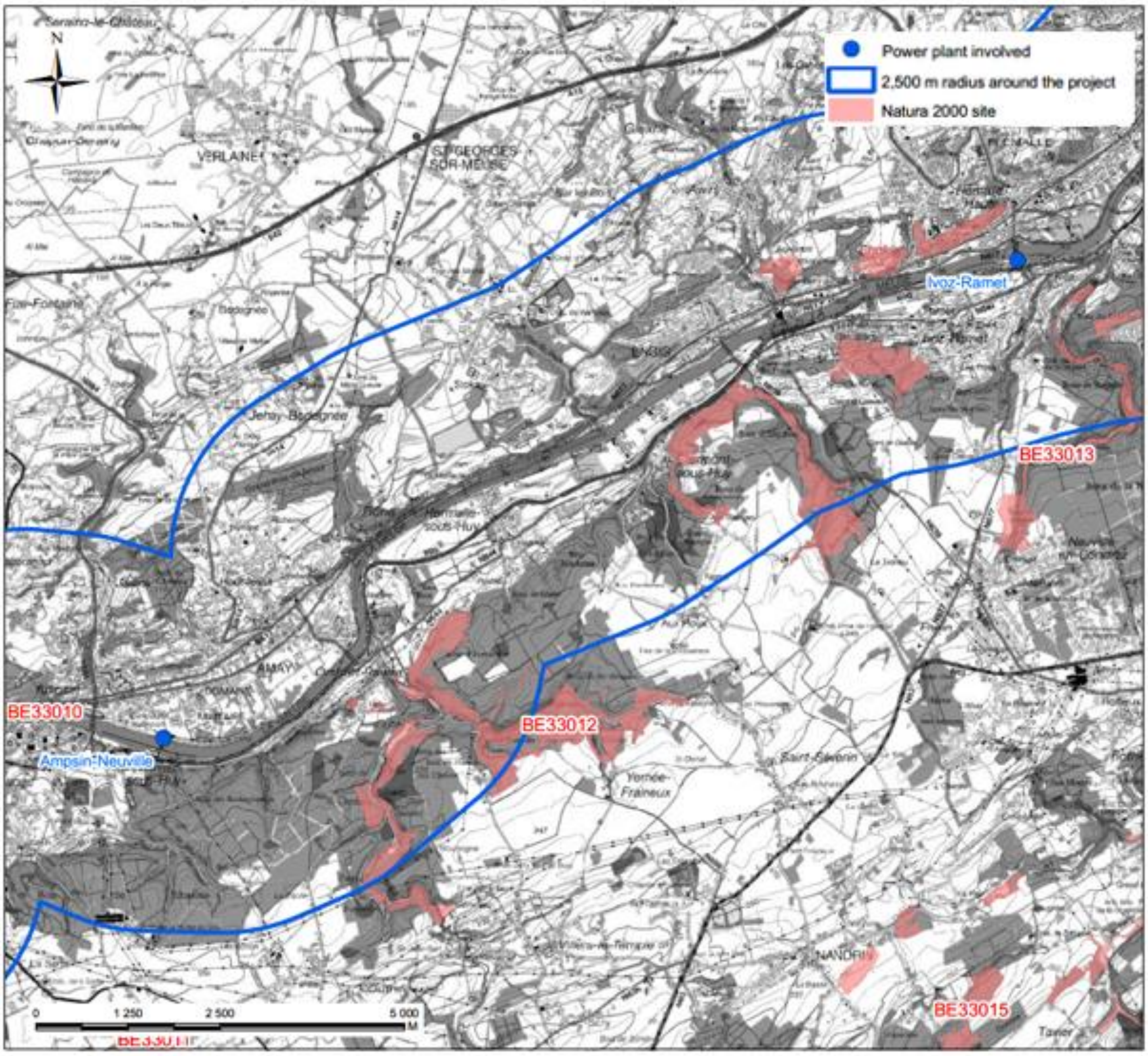


Figure IV- 7: Natura 2000 sites within a radius of 2,500 m, reach between the Ampsin and Ivoz-Ramet power plants

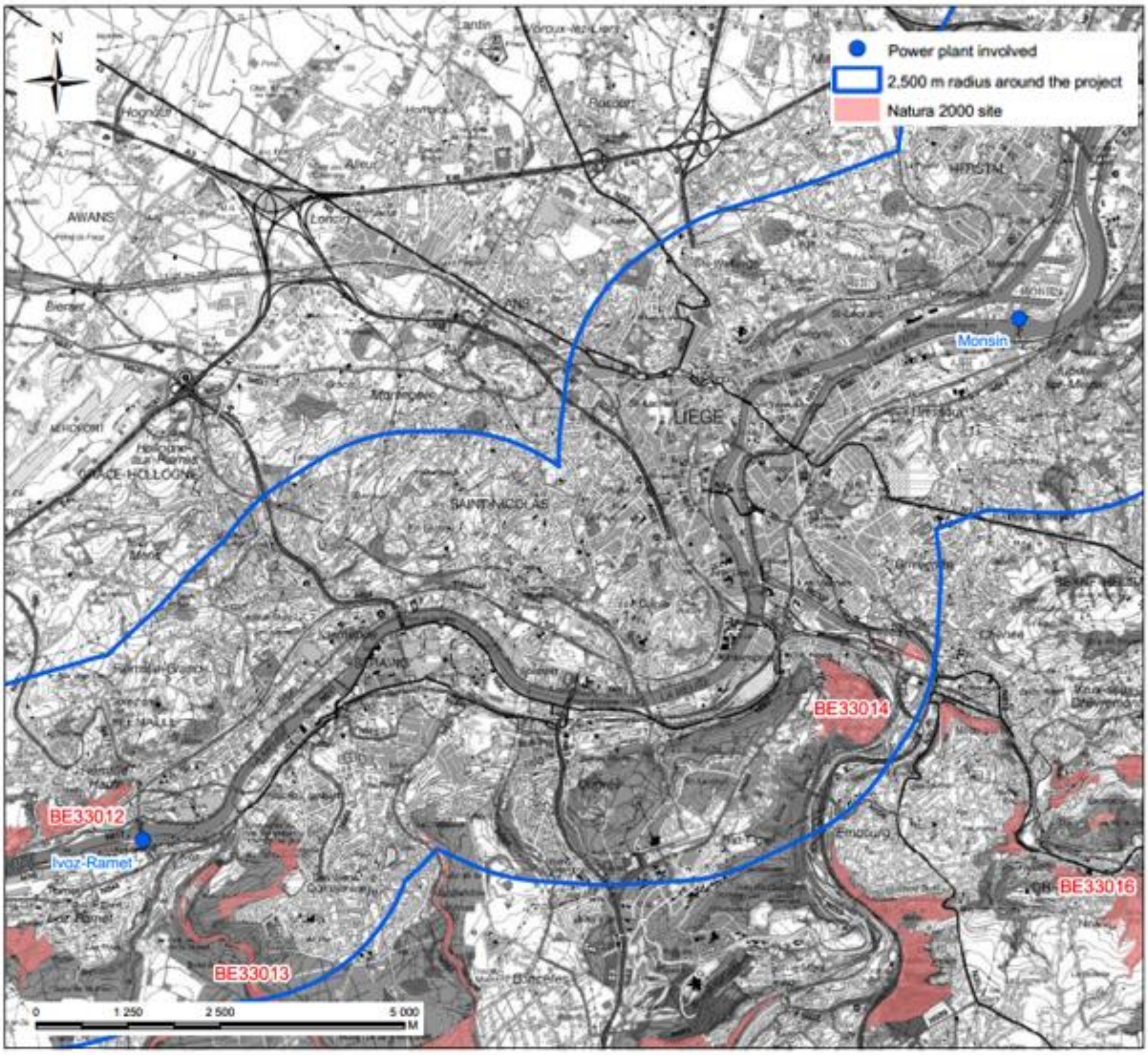


Figure IV- 8: Natura 2000 sites within a radius of 2,500 m, reach between the Ivoz-Ramet and Monsin power plants

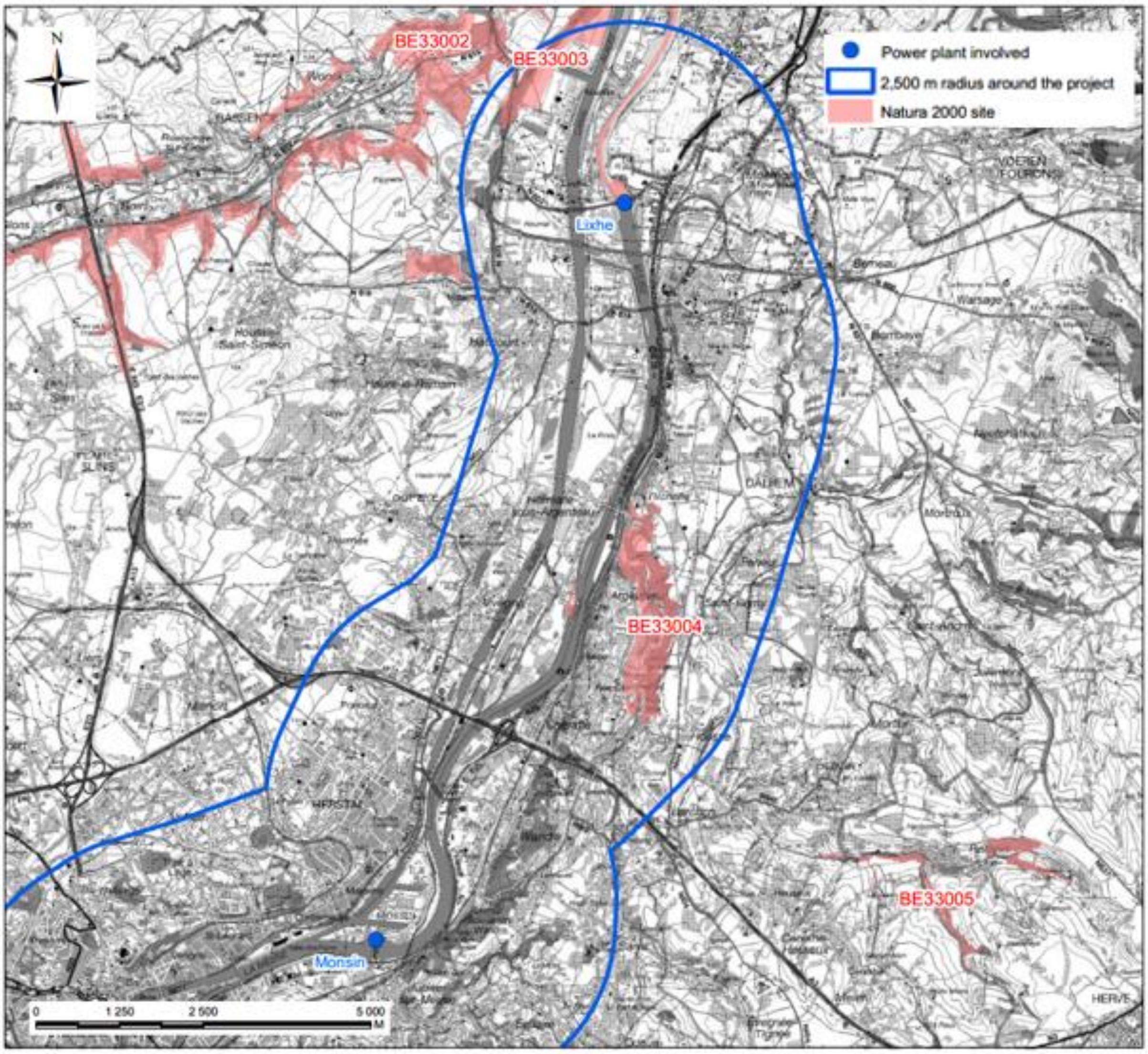


Figure IV- 9: Natura 2000 sites within a radius of 2,500 m, reach between the Monsin and Lixhe power plants

Of these, 7 concern aquatic environments and therefore aquatic fauna, while the others mainly concern cliffs, dry grasslands and forests. The species identified in the 7 sites potentially affected by the project are listed in the table below.

Table IV- 3: Natura 2000 sites identified within a radius of 2,500 m around the project and concerning aquatic environments and/or fauna

Name and code of Natura 2000 site	Surface area (hectares)	Communes	Distance from the Meuse (m) Reach	Targeted species of Community interest (aquatic fauna)
Bassin du Sanson BE35005	1,235.8	Andenne, Assesse, Gesves, Namur, Ohey	± 90 CHG-CHA	Planer lamprey (*Lampetra planeri*) Sculpin (*Cottus gobio*)
Vallée de la Meuse à Huy et vallon de la Solières BE33010	491.7	Amay, Huy, Wanze	0 CHA-CHN	European Bitterling (*Rhodeus sericeus amarus*)

Name and code of Natura 2000 site	Surface area (hectares)	Communes	Distance from the Meuse (m) Reach	Targeted species of Community interest (aquatic fauna)
Vallée d'Hoyoux et du Triffoy BE33011	1,308.1	Clavier, Huy, Marchin, Modave, Ohey	± 420 CHA-CHN	Planer lamprey (*Lampetra planeri*) Sculpin (*Cottus gobio*)
Affluents de la Meuse entre Huy et Flémalle BE33012	537.2	Amay, Engis, Flémalle, Modave, Nandrin, Neupré	± 190 CHN-CHR	Sculpin (*Cottus gobio*)
Bois de la Neuville et de la Vequée BE33013	381.2	Flémalle, Neupré, Seraing	± 585 CHR-CHM	Sculpin (*Cottus gobio*)
Vallée de l'Ourthe entre Comblain-au-Pont et Angleur BE33014	706.9	Chaudfontaine, Comblain-au-Pont, Esneux, Liège, Neupré, Sprimont	± 960 CHR-CHM	Planer lamprey (*Lampetra planeri*) Sculpin (*Cottus gobio*) European Bitterling (*Rhodeus sericeus amarus*)
Basse Meuse et Meuse mitoyenne BE33004	222.8	Blégny, Oupeye, Visé	0 CHM-CHL	Thick mussel (*Unio crassus*) European Bitterling (*Rhodeus sericeus amarus*) Salmon (*Salmo salar*)

Similarly, there are a large number of SGIB sites within a radius of 2,500 m of the project, i.e. 97; however, only 3 of these sites concern the Meuse or its tributaries and report fish species. These sites are :

- Iles des Bouries (code 49), on the Andenne-Ampsin reach, which reports eels;
- Canal de l'Ourthe (code 1860), on the Ampsin-Monsin reach, which reports the European Bitterling ;
- Noue de Hemlot (code 353), on the Monsin-Lixhe reach, which also reports the European Bitterling.

2.2.2 Initial situation

In terms of the study area as a whole, three entry points for individuals are considered, namely upstream of the Meuse (Namur), the confluence with the Mehaigne (Huy) and the Ourthe (Liège). In addition, individuals spawned in the five reaches affected by the project are also considered in this study. Three outlets are also considered, namely the downstream Meuse (Lixhe) and the water intakes at the Tihange power plant (Huy) and the Albert Canal (Liège). The graph below shows a schematic view of these inlets and outlets.

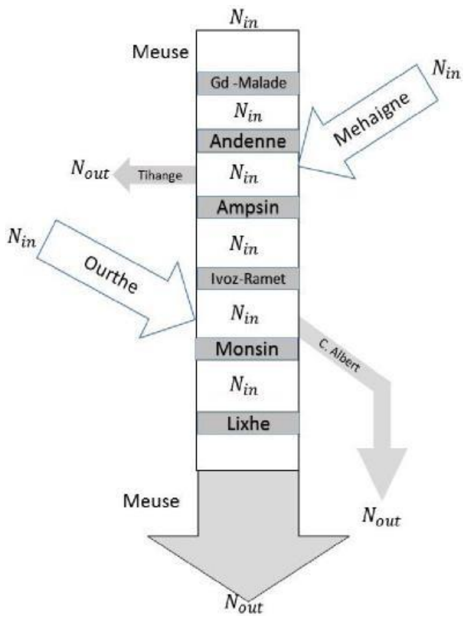


Figure IV-1 Schematic view of the entry and exit of individuals in the study area (source: De Oliveira et al 2018, in LIFE16NAT/BE/000807/LIFE4FISH "1st study report on estimation and biological status of resident stocks").

Initially, in order to monitor the downstream migration of eels and smolts and to characterize the biological and health status of the fish during migration, an assessment of the stocks present in different sectors of the Meuse basin was carried out. This analysis also aimed to describe the health status of the fish, estimate their migration capacity and cope with obstacles encountered during their downstream migration.

To carry out this study, the technique used to assess stocks is the capture-recapture method with individual marking. In this technique, a known number of individuals are tagged with PIT Tag[13] and released into the population (the population is defined here as the fish of a given species occupying the area of interest). The population is then sampled and its size estimated from the ratio of tagged to untagged individuals.

For smolts, the capture method used is electric fishing[14] while for eels, a combination of electric fishing and hoop netting[15] is used.

Stock distribution for smolts is assessed on the basis of reintroduction data from the Saumon 2000 program. On the basis of the data provided, it is estimated in this study that the number of individuals upstream, mainly from the Lesse and Samson ($N_{en\ upstream}$), represents 20% of the stock, while the number in the Ourthe ($N_{dans\ l'Ourthe}$) represents 80% of the stock.

For eels, the eel management plan for Belgium (Vlietinck et al. 2007) provides an assessment of the distribution of eels by river basin in the non-channelled rivers of the Belgian Meuse catchment and an estimate of stocks in the channelled rivers (Meuse, Sambre and Albert Canal). Based on the following two assumptions:

- The annual silvering rate is similar throughout the catchment (the spatial distribution of yellow and silver eels is equivalent);
- The biomass of the Meuse is evenly distributed in proportion to the length of the sections (a conservative assumption, as the stock is greater downstream (near the sea) than upstream).

It is assessed[16] that :

- $N_{en\ upstream} = 56$
- $N_{in\ reach\ 1} = 2$
- $N_{in\ reach\ 2} = 6$
- $N_{in\ reach\ 3} = 2$
- $N_{in\ reach\ 4} = 17$
- $N_{in\ reach\ 5} = 5$
- $N_{downstream} = 7$
- $N_{in\ the\ Albert\ Canal} = 5$

A study of migration at the 6 project sites identified the passageways for the two species targeted by the project.

For smolts, based on field observations and certain hypotheses concerning unidentified passages in particular, the passage routes are shown in the table below.

Table IV- 4: Smolt passageways identified (number of individuals)

	Grand-Malades	Andenne	Ampsin-Neuville	Ivoz-Ramet	Monsin	Lixhe
Upstream presence	55	38	15	14	7	12
Passage through the dam	17,5	0,5	0,33	0	0	6

[13] Easy, permanent marking technique, with an internal identification code that is always recognizable because it consists of 10 characters (letters and numbers) that can be read with a hand-held reader.
[14] An electric field is set up to stun the fish, which can then be fished by an operator using a landing net.
[15] Hoop nets consist of cylindrical or cone-shaped net bags mounted on rigid rings or other frames and secured to the ground by anchors, ballast or stakes. One or more vertical sections of net, called leaders, extend from the mouth of the net and guide the swimming fish into the net.
[16] Deliverable of LIFE16NAT/BE/000807/LIFE4FISH "Final study report on estimation and biological status of resident stocks")

	Grand-Malades	Andenne	Ampsin-Neuville	Ivoz-Ramet	Monsin	Lixhe
Passage through the power plant	26	28,5	9,33	9,5	0	1
Passage through the lock	1,5	3	2,33	2,5	-	-
No crossing	10	6	3	2	7	5

It appears that crossing rates vary greatly from one site to another, as does the distribution of individuals between the different passageways; however, the 6 monitoring sites can be grouped into 3 classes:

- Power plants (Grands-Malades, Andenne, Ampsin-Neuville and Ivoz-Ramet), where a large number of individuals pass through the power plant and a few cross through the other structures; the crossing rates for these sites are over 80%. These power plants therefore allow downstream passage;
- The Lixhe power plant, where the majority of crossings take place via the dam. This is due to the presence of a permanent water depth of at least 20 cm at the site. This entrainment of fish at the dam reduces the direct impact of the power plant at this site, but also increases the rate of non-crossing. The fish passage rate falls below 60%. The power plant no longer offers a preferential route and downstream migration is therefore partially interrupted at the site;
- At the Monsin site, only 1 individual ventured into the plant’s water intake before returning to the Albert canal, while the other individuals remained stuck in front of the dam in a closed position most of the time. The crossing rate at this site is zero, which is a major obstacle to the species’ descent. However, the low water flow and low number of fish observed at this site during the survey may influence these results.

The difference in smolt behaviour upstream of the power plants must be sought in the approach conditions specific to each site. Factors that can influence the passage rate include the presence of plunging girders, the position of the plant inlet channel upstream of the dam and the depth of the water intake.

For eels, based on field observations and certain hypotheses concerning unidentified passages in particular, it has been estimated that the passage routes are those listed in the table below.

Table IV- 5: Passage routes identified for silver eels (number of individuals)

	Grand-Malades	Andenne	Ampsin-Neuville	Ivoz-Ramet	Monsin	Lixhe
Upstream presence	45	47	54	94	89	83
Passage through the dam	24,5	38	42,5	59,33	58	81,5
Passage through the power plant	19,5	7	11,5	32,83	31	1,5
Passage through the lock	1	2	0	1,83	-	-
No crossing	0	0	0	0	0	0

Overall, therefore, it appears that the distribution between crossing zones is relatively constant for the different sites studied. It should be noted, however, that at the Grands-Malades site, a higher proportion of individuals passed through the power plant, probably due to the greater presence of individuals.

At the Lixhe site, the rate of passage through the power plant is very low. This may be due to the constant presence of about 20 centimetres of water over the dam or to hydrodynamic conditions specific to the site (large vortex upstream of the turbines).

The impact of the Grands-Malades and Andenne turbines is deduced directly from the field studies. The Ampsin-Neuville and Lixhe sites have similar configurations to the two previous sites, so the most significant impact rate measured on each species of the two sites tested is conservatively considered.

For the Monsin and Ivoz-Ramet sites, in the absence of results characterizing the impact of the large vertical Kaplan turbines, the impact rates on each of the two species have been determined arbitrarily. Given the larger size of the machines and the lower rotation speeds, it is reasonable to expect that the turbines will have lower impacts than the other groups. The proposed values therefore appear to be largely conservative.

The impact of the various power plants on smolts and silver eels is shown in the table below.

Table IV- 6: Impact of various power plants on smolts and silver eels

		Grand-Malades	Andenne	Ampsin-Neuville	Ivoz-Ramet	Monsin	Lixhe
Salmon	Direct impact	2,0%	6,7%	6,7%	10%	10%	6,7%
	In addition impact after 72h	0,5%	0,6%	0,6%	0%	0%	0,6%
Silver eels	Direct impact	2,0%	0,7%	2,0%	0%	0%	2,0%
	In addition impact after 72h	19,1%	10,6%	19,1%	20%	20%	19,1%

It should be noted that passage via the dam or lock is considered to have no impact on downstream migration.

As a result, the influence of each site on fish migration is divided between the influence of turbines and non-crossing. Overall, the following rates of influence are shown in the table below.

Table IV- 7: Rates of influence of various power plants on smolts and silver eels

		Grand-Malades	Andenne	Ampsin-Neuville	Ivoz-Ramet	Monsin	Lixhe
Salmon	No crossing	18%	16%	20%	14%	100%	42%
	Turbines	1%	5%	5%	7%	0%	1%
Silver eels	No crossing	0%	0%	0%	0%	0%	0%
	Turbines	9%	2%	4%	7%	7%	0,4%

In addition, an individual is considered to have crossed the reach (zone of influence) if it is present both upstream and downstream. If the last detection of an individual is at one of the water intakes (Tihange or Albert Canal), it will be categorized as a non-crossed "water intake". In the case of individuals that have crossed the site upstream but are not present on the site downstream or in a water intake, the number of individuals concerned will be compared to the expected impact rate of crossing the turbine upstream. These individuals will not be taken into account when calculating the rates of passage and impact at the reach scale, as they are already considered at the site scale. Finally, for fish present upstream and not falling into any of the above categories, it will be considered that their descent has been interrupted.

Migration can be interrupted for a number of reasons:

- Reduced swimming ability after crossing the upstream site due to external or internal injuries;
- A deteriorated state of health and stress, with a potential depletion of the eel's energy reserves due to stress and the effort required to swim through the turbine;
- Predation;

- A physiological halt to migration, particularly for smolts if they are confronted with a change in temperature which can accelerate the desmoltification process.

The influence of the diversion bays is therefore divided between water intakes and non-crossings. Overall, the rates of influence considered are shown in the table below.

Table IV- 8: Rates of influence of different power plants on smolts and silver eels

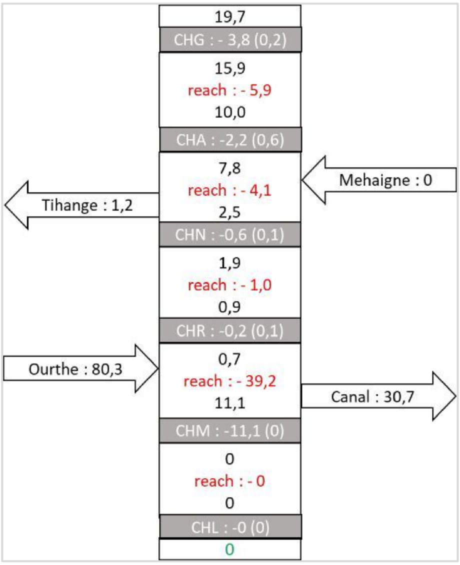
		CHG-CHA	CHA-CHN	CHN-CHR	CHR-CHM	CHM-CHL
Salmon	**Water intake**	-	15%	-	38%	-
	No crossing	37%	52%	52%	48%	33%
Silver eels	**Water intake**	-	8%	-	8%	-
	No crossing	11%	4%	7%	3%	12%

Using these different elements, the downstream migration capacity along the study area was assessed for the two target species. Based on the distribution of stocks and the successive influence of the various elements, the percentage of the stock ending its migration within each element could be defined.

Salmon

As shown in the diagram opposite,

- 1% of the stock would be impacted by the turbines ;
- 17% of the stock would end up upstream of the sites (non-crossing);
- 1% of the stock would end up in the Tihange water intake;
- 31% of the stock would end up in the Albert Canal;
- 50% of the stock would end up in the various reaches;
- 0% of the stock would arrive downstream of Lixhe.



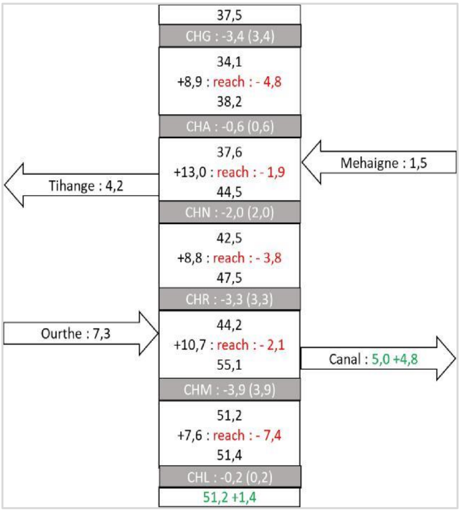
Therefore, if we consider that only downstream of Lixhe is a potential migration route for smolts, 0% of the stock in the Belgian lower Meuse would have an assured escapement, largely due to the fact that smolts do not cross the various obstacles.

The major impacts are the disappearance of individuals upstream of the Monsin site (reach, Albert canal water intake and crossing of the Monsin power plant). These factors are all linked to the management and distribution of flows within this particularly complex junction. The extremely low flow conditions during the survey period necessitated such special management conditions, the impact of which can be seen in the results presented.

Silver eels

For silver eels, as shown in the figure opposite,

- 13% of the stock would be affected by the turbines;
- 4% of the stock would end up in the Tihange water intake;
- 10% of the stock would end up in the Albert Canal;
- 20% of the stock would remain blocked within the study area;
- 53% of the stock would arrive downstream of Lixhe.



If we consider that for eels, downstream of Lixhe and the Albert Canal are potential migration routes, 62% of the stock in the Belgian Lower Meuse would have a guaranteed escape route to these migration routes. The remaining 20% of the stock blocked in the various reaches may consist of individuals still able to migrate the following season.

Only the impacts of the power plants and the Tihange water intake make it possible to define a confirmed impact on the migration of 18% of the silver eel stock.

2.3 IMPACT ASSESSMENT

The impact of each solution tested is assessed on :

- Eel downstream migration ;
- Smolt downstream migration ;
- Other fish species in the Meuse.

2.3.1 Eel

2.3.1.1 Turbine management

Turbine management based on the prediction model was tested at the Grands-Malades power plant, and given the results is/will be implemented at the sites requiring action, namely the Ampsin-Neuville, Ivoz-Ramet and Monsin power plants.

In this context, the predictive model triggered an alarm on 32 dates spread over the study period. These alarms caused the turbine to shut down for varying length of time during the night. The shutdown delay did not follow the 18h-06h shutdown initially predicted since EDF R&D improved its model by predicting the proportion of eels passing within a shorter delay in relation to hydrological conditions (Teichert et al. 2019, unpublished data). The final period used in the model is as follows:

- 20h-04h ;
- 19h-05h ;
- 21h-03h.

The shutdown duration was always timed during the night, with the total duration varying from 06:00 to 10:00.

Several problems occurred at different stages of the process between the software prediction alarm and the turbine shutdown, requiring coordination with the SPW-DGO2 for synchronized weir management:

- Alarm not followed by actual shutdown due to a coordination problem with dam operator (SPW DGO2);
- Alarm missed due to a character problem in the algorithm or an internal communication problem.

In total, only 12 alarms were successfully managed by shutting down the turbine, including 2 dates when the turbine was already shut down due to high flow conditions in the Meuse.

Considering all passage data, the model failed to predict 40.6% of migration dates. Of the 59.4% predicted successfully, 39.1% of eels passed within the 18-06h period and 20.3% within the operational timeframe of the stops.

On the basis of these considerations, the prediction model seems to confirm the possibility of achieving an initial level of efficiency greater than 50% within a period of 18h-06h (UT). It should be noted that the Andenne and Lixhe power plants are sites where the majority of eels are already migrating over the weir, which means that these sites are not target sites for implementing turbine management as a final solution. Two of the Luminus park's hydroelectric power plants have a capacity greater than the river's average flow : Ivoz-Ramet and Monsin. At these two sites, the proportion of eels passing through the turbine is higher than at the other 4 sites. These sites could therefore be targeted for implementation of the turbine management model, by adjusting the delay from 18-06h to 24h depending on the required efficiency in the range of 50% to 80%.

The actual turbine shutdown procedure requires better coordination with SPW-DGO2 services, as the opening of the dam spillways must be synchronised to avoid emptying the diversion bays on the river's axis. While the model can be validated, operational implementation seems to require serious progress.

2.3.1.2 Electric barrier

As a reminder, the electric barrier was initially tested at the Grands-Malades power plant and, given the initial results, will also be installed at the Ampsin-Neuville power plant in 2022.

Eel passage routes as a function of the ratio between dam discharge and Meuse discharge were analyzed in the initial situation and after installation of the electric barriers at the Grands-Malades and Ampsin-Neuville sites. The results are shown below.

Table IV- 9: Escape rate of eels at the Grands-Malades and Ampsin-Neuville sites, with and without an electric barrier, as a function of the ratio between flows at dam level ($_{Qdam}$) and at Meuse level (Q).$_{Meuse}$

	Grand-Malades		Ampsin-Neuville	
Qbarrage/Q_{Meuse}	**Barrier-free**	**With barrier**	**Barrier-free**	**With barrier**
0 - 0,01	0%	0%	0%	0%
0,01 - 0,25	0%	33%	20%	100%
0,25 - 0,5	33%	52%	64%	73%
0,5 - 0,75	78%	72%	93%	93%
0,75 - 0,99	92%	88%	97%	100%
0,99 - 1	100%	100%	100%	100%

It therefore appears that the electric barrier has a positive effect on the eel escape rate, especially when the discharge from the Meuse is low, i.e. when the flow from the power plant is greater than that from the dam.

An analysis also confirms that the barrier has no selective effect on fish size in the range of our eel sample (741-1076 mm).

2.3.1.3 Bubble barrier

As already mentioned, the bubble barrier installed at the Ivoz-Ramet site failed to withstand an increase in river flow and was only operational for a short time.

Based on the observations made during this period, the bubble barrier revealed no obvious effect on silver eels, but the sample size is probably too small to demonstrate this. The installed barrier did not withstand a normal winter flood, which weakens confidence in the applied technology for the future.

2.3.2 Salmon

2.3.2.1 Turbine management

In 2020 and 2021, the application of a minimum flow to one of the dam gates, enabling it to be crossed, according to the predictive model, at the Monsin site, showed a reduction in the site's impact of 40 to 10%. In 2023, this minimum flow is ensured by installing a water level of 50 cm on 22/03/23, 10:21 and 20 cm on 09/05/2023, 10:21.

2.3.2.2 Electric barrier combined with an outlet

As a reminder, as for eels, the electric barrier has been installed at the Grands-Malades site.

Smolt passage routes were analyzed in the initial situation and after installation of the electric barrier and the outlet at the Grands-Malades site. The results are shown below.

Table IV-1: Smolt escape rate at the Grands-Malades site, initial situation and with and without electric barrier/outlet

	Initial situation	With outlet	With outlet and electric barrier
Exhaust rate	35%	54%	24%
Passage through the turbines	47%	39%	71%

The above data tends to show that the presence of the outlet alone increases the escape rate at the expense of passage through the turbines, whereas when the electric barrier is in operation the escape rate is much lower than in the initial situation.

It therefore appears that the electric barrier tested failed to guide the smolts towards the outlet; however, analyses showed that the presence of the outlet alone provided a passage efficiency of around 50%.

It should be noted that it is not impossible that other adjustments to the electric barrier could lead to different conclusions, but no tests on these adjustments were planned as part of this study.

It should also be noted that a recurring problem with the outlet is the accumulation of waste at its inlet grate, causing it to clog up and making it impossible for the smolts to use it. To avoid this problem, the grate had to be cleaned regularly.

2.3.2.3 Bubble barrier

As this system did not withstand the flow of the Meuse and the waste carried along during the eel migration test, this technique was not tested for salmon.

2.3.2.4 Water height

The escape rates studied for the different water levels at the Ivoz-Ramet and Monsin sites are shown in the table below.

Table IV-2: Smolt escape rate at the Grands-Malades site, initial situation and with and without electric barrier/outlet

	Ivoz-Ramet			Monsin		
	Initial situation	50 cm high	Height of 90 cm	Initial situation	50 cm high	Height of 90 cm
Exhaust rate	12%	56%	85%	0%	19%	48%
Passage through the turbines	75%	41%	9%	17%	64%	45%

It therefore appears that the escape rate is improved by increasing the water level at a dedicated smolt passage.

2.3.3 Other fish species

This section assesses the possible impact of the various solutions tested on other fish species frequenting the Meuse. It should be pointed out that the species of Community interest targeted by the Natura 2000 sites in the Meuse (Planer lamprey, Sculpin and European Bitterling) are not migratory species like the two species targeted by the project, and that given their preferred habitats, their presence at the power plants included in the Life project would appear to be occasional at best.

2.3.3.1 Turbine management

As the turbines are shut down at certain times of the year, this solution could reduce the risk of mortality for other species that occasionally pass through the turbines, and would therefore have a positive impact on the Meuse's fish fauna.

2.3.3.2 Electric barrier

The installation of the electric barrier, via its electro-magnetic field, could cause behavioural differences and trajectory deviations in the other fish species present. Given the location of the barrier in the channel leading to the turbines, it appears that at most these trajectory deviations will reduce the number of fish passing towards the turbines, thereby reducing the risk of mortality. It should be pointed out that the field produced by these barriers is not strong enough to cause any impact other than a difference in fish behaviour to avoid it.

It should be noted that for small fish (< 5-10 cm), the barrier is unlikely to be very effective, but they are less affected by turbines due to their small size.

In view of the above, the installation of an electric barrier could only have a positive impact on the Meuse’s fish fauna.

2.3.3.3 Bubble barrier

Given the position of the bubble barrier in the entrance channel to the turbines and the fact that, at most, it will result in a deviation of the trajectory and avoidance of the turbines, only a positive impact on fish fauna can be expected.

2.3.3.4 Water height

Increasing the water level at one of the dam's openings may at most increase the passage of various species through it rather than through the turbines, but it seems that implementing this solution could also have a beneficial effect on the Meuse's fish fauna.

2.3.4 Conclusions

The monitoring results during the different periods showed :

- The bubble barrier is not a strong enough system to withstand the flows and waste carried by the Meuse in winter;
- The electric barrier set up to prevent salmon migrating downstream is not as effective as expected;

The other solutions tested proved effective and increased the escape rate for both eels and salmon.

During the 2022-2023 downstream migration season, for which all the solutions tested were deployed, the overall impact rate of the 6 power plants fell from 20 to 12.7% for silver eels and from 40.9 to 22.5% for smolt.

3. LANDSCAPE AND HERITAGE

3.1 INTRODUCTION

3.1.1 Difficulties encountered

None.

3.1.2 Detailed impact assessment methodology

The aim of this chapter is to describe the landscape and heritage context in which the various power plants are integrated and to assess whether the implementation of the tested solutions is perceptible.

3.2 ANALYSIS OF THE EXISTING SITUATION

3.2.1 General description of the landscape

The landscape areas of Wallonia (Conférence permanente du Développement territorial - CPDT, 2004) define landscape areas, portions of space that are differentiated from adjacent spaces by the landscapes they present according to three main criteria: relief, vegetation cover and urbanization. Landscape areas specify the division of groups, landscape territories and facies. As illustrated in the following figure, the various power plants concerned by the project are located in *the Mosan Ensemble*, and more specifically in the landscape areas of *the Namur Urban Area* for Grands-Malades, the *Middle Meuse Valley* for Andenne and Ampsin, the *Liège Urban and Industrial Area* for Ivot-Ramez and Monsin, and the *Lower Meuse Industrial Valley* for Lixhe.

According to the Atlas des Paysages de Wallonie "La Vallée de la Meuse" (CPDT), the Meuse Valley landscape ensemble covers the deep trench dug by the river through the Condrusian plateau upstream of Namur and then, from this town to the Dutch border, between the Hesbignon plateau and the Condrusian and Hervian plateaus. It also includes the downstream part of the Sambre valley, from the Mornimont lock to the confluence with the Meuse. It also includes the edges of the adjacent plateaux, cut by the deep valleys of the Sambro-Mosan tributaries.

The *urban area of Namur is* covered by a dense built-up area that stretches continuously across the wide basin formed by the meeting of the alluvial plains of the Meuse and Sambre rivers. Narrow lanes, punctuated by a succession of houses in traditional Mosan architecture, wind through the old central districts dominated by fortifications and the wooded spur of the citadel. Strings of wider, regularly laid-out streets, lined with rows of neo-classical to modernist terraced houses, characterise the extensions to the town planned in the 19th and 20th centuries. Churches, large private or public buildings, industrial buildings, blocks of flats and regional government offices all add their markers and diversity to these urban landscapes, which are criss-crossed by the narrow Sambre and the much wider Meuse rivers.

The territory of the *Vallée de la Moyenne Meuse* is divided into two distinct areas: between Namur and Huy and between Huy and Liège. The Meuse Valley area from Namur to Huy is a landscape of contrasts, where natural features coexist with industrial and commercial elements. Cliffs and wooded slopes line the river, alternating with mining operations and the associated industrial infrastructure. The valley, which is initially quite deep, widens from Andenne onwards, offering different perspectives. In addition to Andenne, there is a series of villages and hamlets, some of which are traditional, working-class houses built of limestone rubble, while others are urban, brick buildings. The transport infrastructure is also highly visible. The infrastructure between Huy and Liège is characterised, especially on the left bank of the Meuse, by a partitioning of the landscape. Views can be particularly short and limited by vegetation and infrastructure. The alluvial plain has been heavily artificialized by housing and industry, and the river is often barely visible. Past and present quarries are very prominent on the left bank of the Meuse. Energy infrastructure (cooling towers and very high and high voltage power lines) can be seen from very far away. The urban built-up areas (Huy, Amay and Engis) have very specific and varied features: the old centre, working-class housing and social housing estates, suburban areas on the slopes and new districts. Some localities have retained a village character (Ombret, Hermalle-sous-Huy and Clermont-sous-Huy). Forts, castles, collegiate churches, abbeys and caves dot the valley and its slopes.

The Liège conurbation encompasses the vast conurbation[17] that extends around the city of Liège and its industrial valley, on the terraced Mosan slopes and the edges of the plateaux. The built environment here is virtually uninterrupted along the streets and main roads, with sequences of brick terraced houses. These buildings are complemented by numerous workers' and social housing estates and suburban housing estates. Several high wooded slag heaps and large agricultural areas stand out between these urban areas. Extensive business parks are located close to the motorways, while large shopping centres line the roads radiating out from Liège.

The *Basse Meuse Industrial Valley* is at the downstream end of the landscape. The very wide Meuse valley features a vast alluvial plain and relatively low slopes, some gently sloping, others steeply sloping and dotted with limestone and chalk outcrops. The Meuse, rectified upstream, retains a natural appearance downstream where it borders Flanders and the Netherlands. The Albert Canal, which runs parallel to the Meuse, is situated on embankments overlooking the plain before entering the deep Tranchée de Caster. Visé, with its town centre rebuilt after 1918, and the other towns spread out loosely along the main roads. A few large factories add an industrial component to the landscape.

[17] a group formed by the juxtaposition of several independent but spatially contiguous and functionally associated urban units.

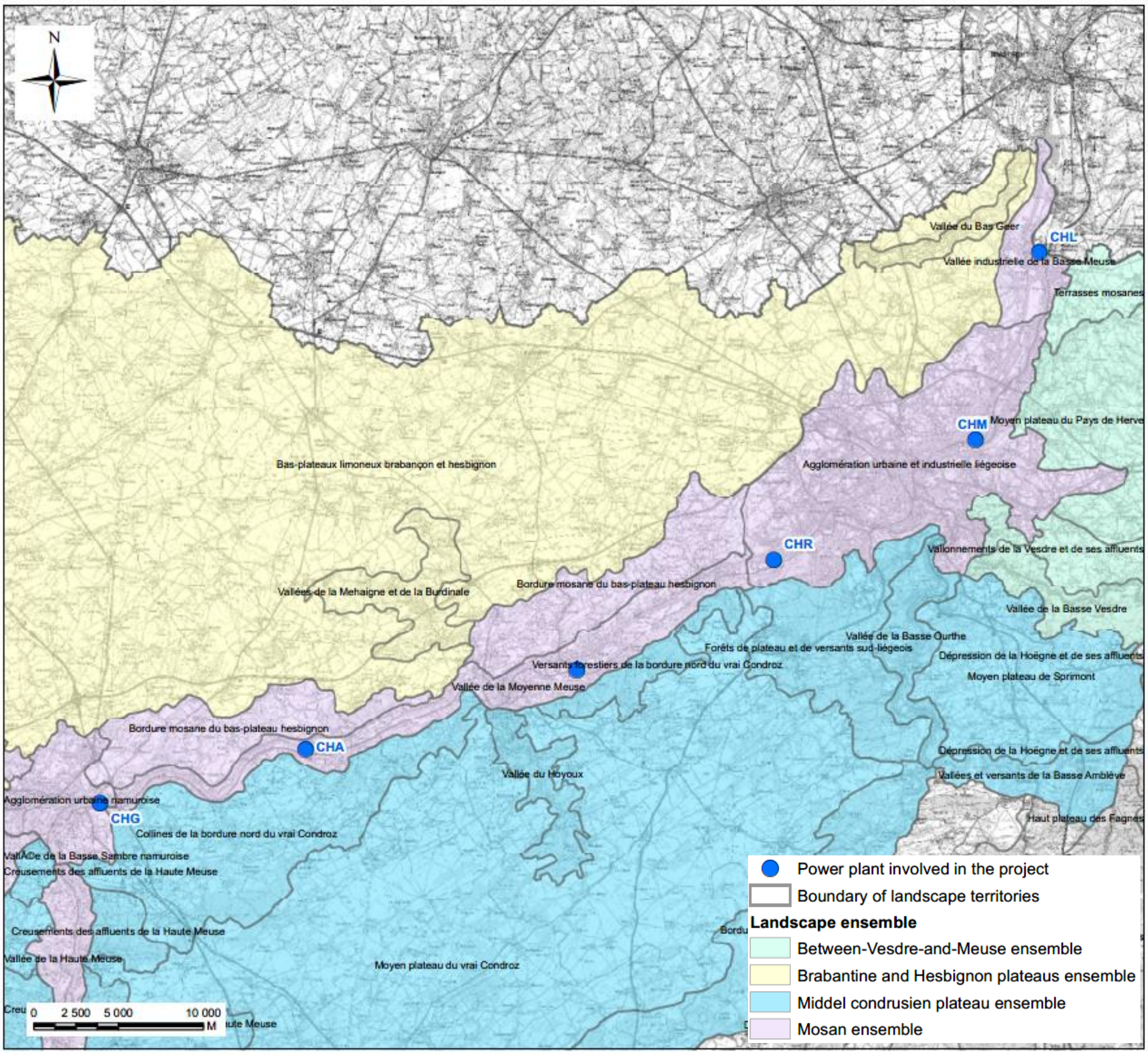


Figure IV-2: Map of landscape areas (ensembles and territories) according to the Walloon Landscape Atlas

3.2.2 Areas of landscape interest, remarkable lines and viewpoints

The landscape interest perimeter (PIP hereafter) delimits an area within which landscape elements are harmoniously arranged. These areas are defined in the Sector Plan.

The inclusion of many landscape interest perimeter in the Sector Plan is often due more to their ecological than their landscape qualities. This is why, as part of the application of the European Landscape Convention, ADESA ASBL is currently updating the landscape interest perimeter in the Sector Plan for the entire Walloon Region. This association has also identified the remarkable points and lines of sight (PVR/LVR) generally associated with the PIPs. Of these, only the most significant for the study (facing the project or located in its direct vicinity) are analyzed in this study.

The PIPs as well as the remarkable lines and viewpoints in the vicinity of the various power plants affected by the project are shown in the following Figures and described in the Tables below.

3.2.2.1 Centrale des Grands-Malades

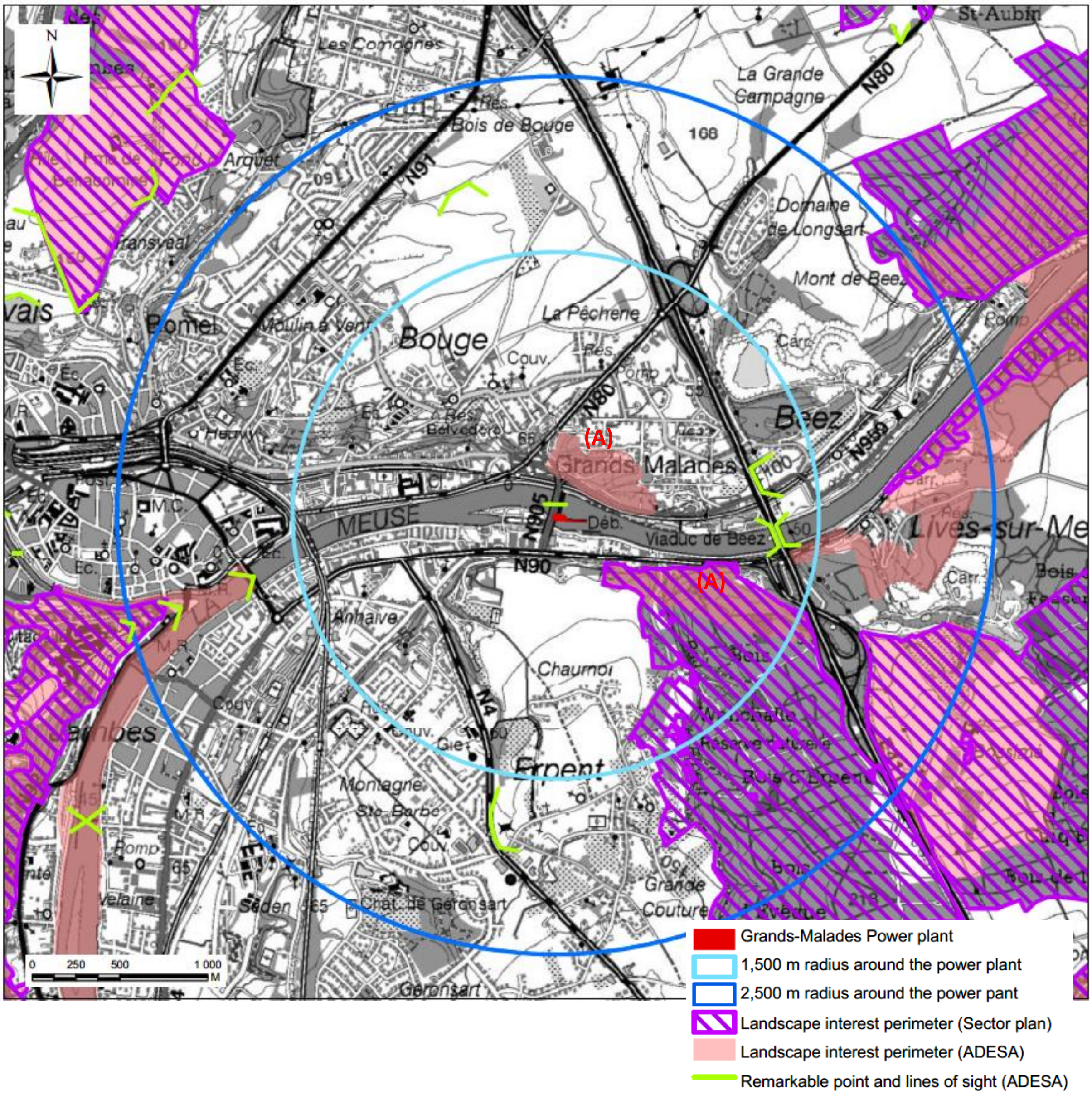


Figure IV-3 : Location of areas of landscape interest and remarkable lines of sight and viewpoints in the vicinity of the Grands-Malades power plant

The Grands Malades power plant is not covered by a landscape interest perimeter and a single landscape interest perimeter, made up of three separate elements, is present within a 1.5 km radius of the power plant. Portions of this PIP are also part of the landscape interest perimeters in the Sector Plan.

Table IV-3: Description of the ADESA landscape interest areas near the Grands-Malades power plant (1.5 km radius)

Identifying the perimeter on the map	Distance from site	Description
A	165 m	*Mosane Valley PIP in the municipality of Namur* This PIP is divided into a number of areas, and "groups together essential and characteristic elements of the Mosan landscape that can be seen when travelling through the valley or from the heights of the slopes. The PIP includes the former Grands Malades quarry, at a distance of 165 m, which is now reforested and part of the Grands Malades and Lives classified sites. The Meuse is also an essential part of the Mosan landscape, particularly when the banks are not concreted over. Certain sections of this PIP are also included in the Sector Plan PIP.

In the area surrounding the site (< 1.5 km), ADESA has identified four remarkable viewpoints and lines of sight. One overlooks the power plant dam and three from the motorway, two of which face the power plant. The Beez viaduct offers lovely views over Beez and the Meuse valley, as shown in the figure below. The dam-bridge is visible and blends in with the nearby buildings.

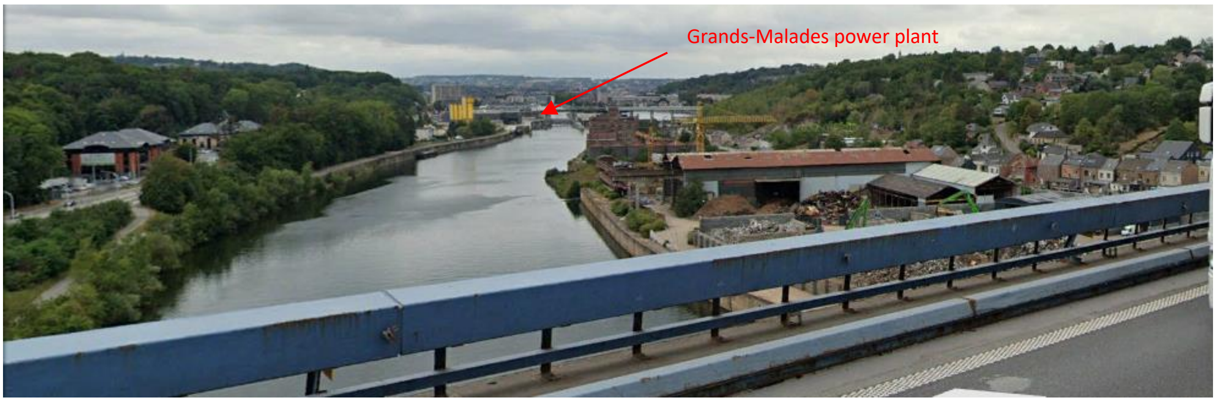


Figure IV-4: View of the power plant from the Beez viaduct (source: GoogleEarth)

Similarly, the PR on the dam bridge (orientation not defined by ADESA) provides a view of the Meuse and some of the power plant's facilities, as illustrated in the following Figure.

Figure IV-5: View from the PR on the dam bridge (source: GoogleEarth)

3.2.2.2 Andenne power plant

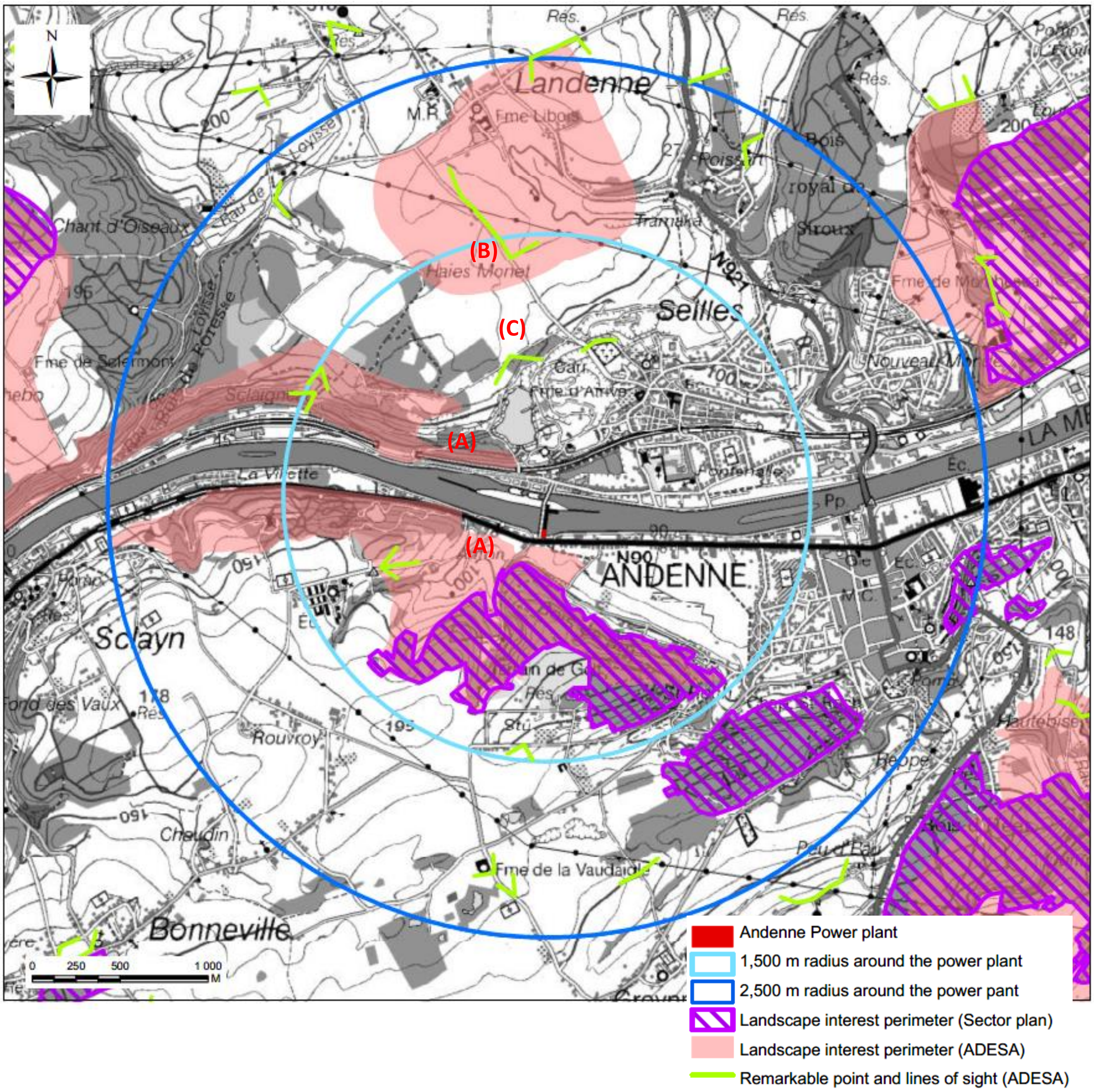


Figure IV-6: Location of areas of landscape interest and remarkable lines of sight and viewpoints in the vicinity of the Andenne power plant

The power plant is not covered by a landscape interest perimeter and two landscape interest areas, comprising three separate elements, are present within a 1.5 km radius of the power plant.

Table IV-4: Description of the ADESA landscape interest areas near the Andenne power plant (1.5 km radius)

Identifying the perimeter on the map	Distance from site	Description
A	170 m	*Mosane Valley PIP in the municipality of Andenne* This PIP, which can be found on both sides of the Meuse, "brings together the essential and characteristic elements of the Meuse landscape, which can be seen from the valley or from the heights of the slopes. The Meuse is also an essential element in the Meuse landscape, particularly when the banks are not concreted over". Certain sections of this PIP are also included in the Sector Plan.
B	1.335 m	*PIP de Landenne* According to ADESA, "the pretty village of Landenne, which includes a very fine group of listed buildings, is an essential element in the landscape of the Hesbignon plateau to the north of Seilles. The landscape surrounding Landenne is harmonious, disturbed only by two high-voltage pylons. The ZACC on the Houssaie slope is included in the PIP because it forms part of Landenne's landscape environment.

In the area surrounding the site (< 1.5 km), ADESA has identified seven remarkable viewpoints and lines of sight, only one of which is directed towards the power plant (C). As shown in the figure below, it affords a fine view down to the Seilles quarry, where turquoise waters of the settling pond are a real eye-catcher. The view over Andenne is also interesting. Almost all of the meadows below the wooded slope opposite the lock are part of the Andenne ZACC. They are therefore likely to be urbanized one day (arrows in the following figure). The Meuse and the power plant are not visible from these areas. Moreover, as the power plant is located in a heavily built-up area, it blends into the local environment.

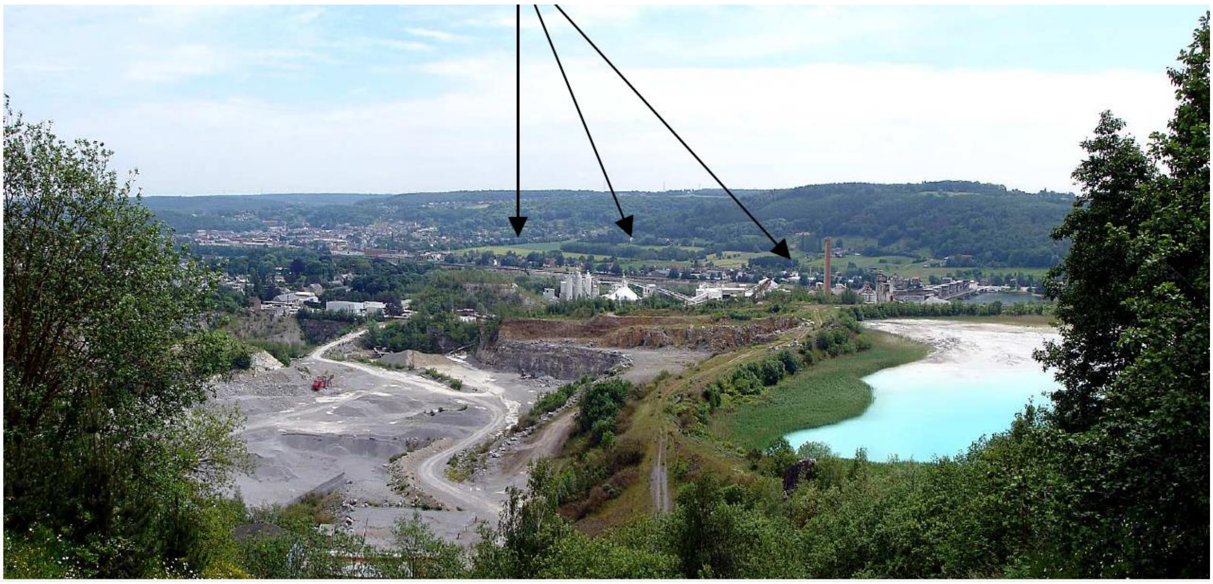


Figure IV-7: View from the PVR (C) towards the power plant (source: ADESA)

3.2.2.3 Ampsin-Neuville power plant

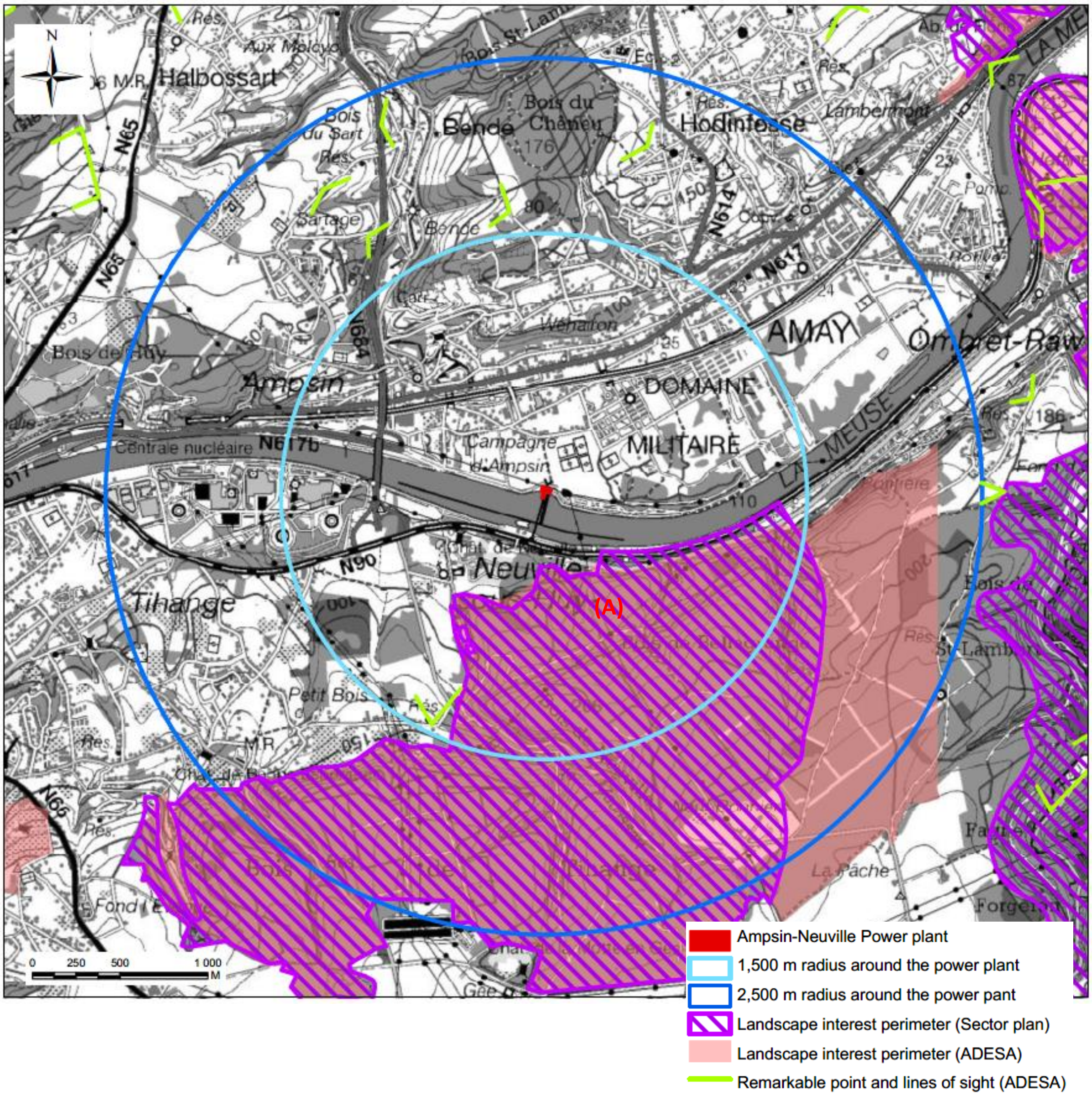


Figure IV-8: Location of areas of landscape interest and remarkable lines of sight and viewpoints near the Ampsin-Neuville power plant

The power plant is not covered by a landscape interest perimeter and a landscape interest perimeter registered with ADESA is present within a 1.5 km radius of the power plant.

Table IV-5: Description of the ADESA landscape interest areas near the Andenne power plant (1.5 km radius)

Identifying the perimeter on the map	Distance from site	Description
A	295 m	*PIP for the Meuse valley downstream of Huy* According to ADESA, "the large wooded areas around this PIP contribute to the quality of the landscapes seen from the valley floor and especially from the opposite slope. Certain sections of this PIP are also included in the Sector Plan PIP.

In the area surrounding the site (< 1.5 km), ADESA has identified a remarkable line of sight towards the Meuse, but not towards the power plant.

3.2.2.4 Ivoz-Ramet power plant

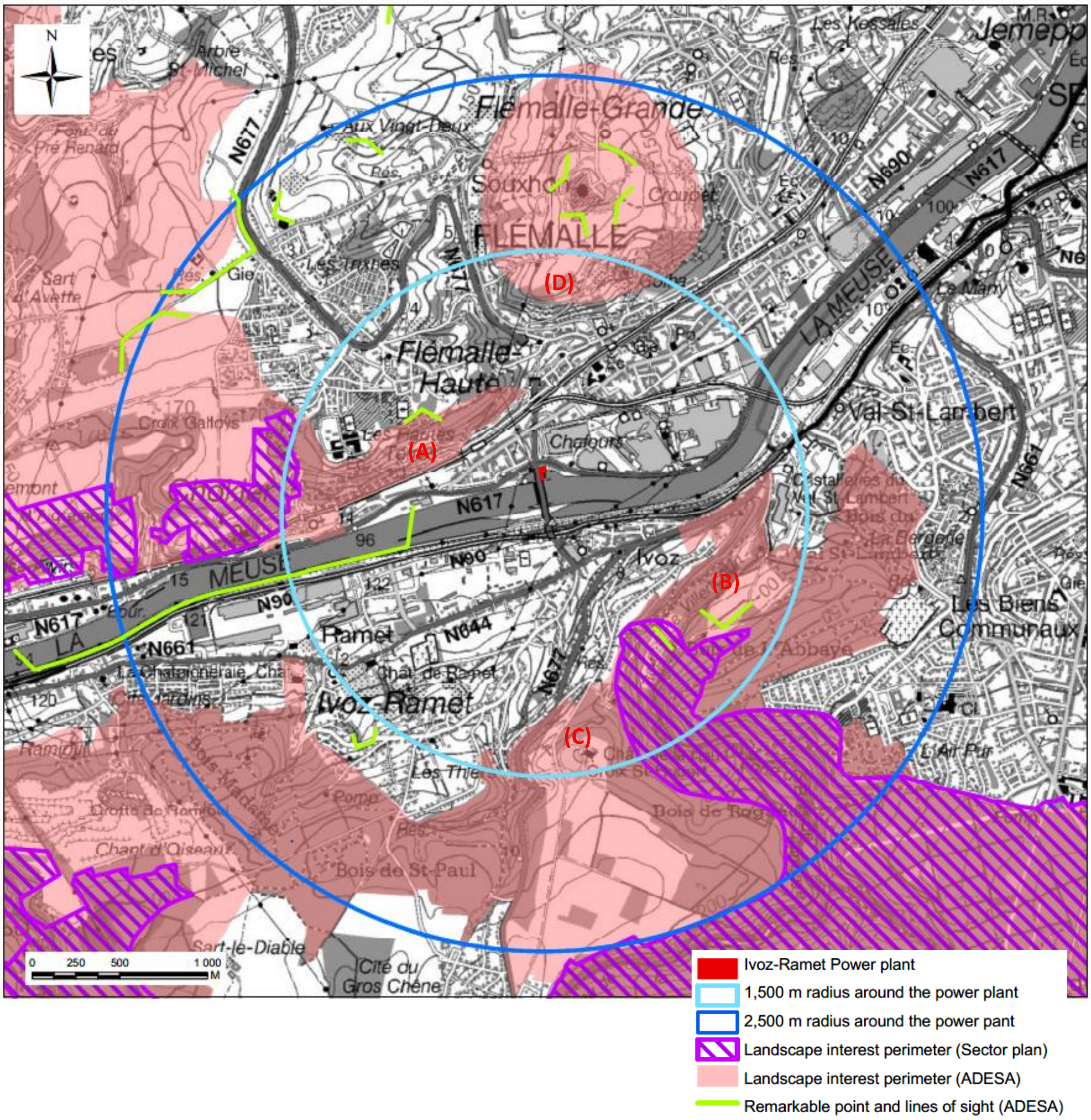


Figure IV-9: Location of areas of landscape interest and noteworthy lines of sight in the vicinity of the Ivoz-Ramet power plant

The power plant is not covered by a landscape interest perimeter and there are three landscape interest perimeters within a 1.5 km radius of the power plant.

Table IV-6: Description of the ADESA landscape interest areas near the Ivoz-Ramet power plant (1.5 km radius)

Identifying the perimeter on the map	Distance from site	Description
A	500 m	*Awirs Valley PIP* This PIP includes woodlands, cultivated areas, hedges and tree lines dividing up agricultural areas and deep, wooded depressions. Certain sections of this PIP are also included in the Sector Plan.
B	860 m	*Meuse Valley PIP - South side of the Meuse river* According to ADESA, the PIP includes the woods that line the southern slopes of the Meuse, which "form part of the superb landscapes seen from the other side of the Meuse and in particular from the Gort de Flémalle-Haute. They also contribute to the quality of the landscape seen from the bottom of the Mosane valley. Certain sections of this PIP are also included in the Sector Plan.
C	1.125 m	*Bois de Halledet PIP* According to ADESA, "this wood forms part of the wooded massifs lining the southern slopes of the Meuse valley; it therefore contributes to the quality of the landscape seen from the heights on the opposite side of the Meuse. Parts of this PIP are also included in the Sector Plan, but more than 1.5 km from the power plant.
D	1.130 m	*Meuse Valley PIP - North side of the Meuse river* According to the ADESA, the Fort of Flémalle-Grande should be treated as a unique site, allowing visitors to discover the Mosane valley and its two sides, the whole of the ascent from Flémalle towards the Hesbaye and a glimpse of part of Seraing. To discover so many different land uses is very rare.

In the area surrounding the site (< 1.5 km), ADESA has identified five remarkable viewpoints and lines of sight, none of which are directed towards the power plant.

3.2.2.5 Monsin power plant

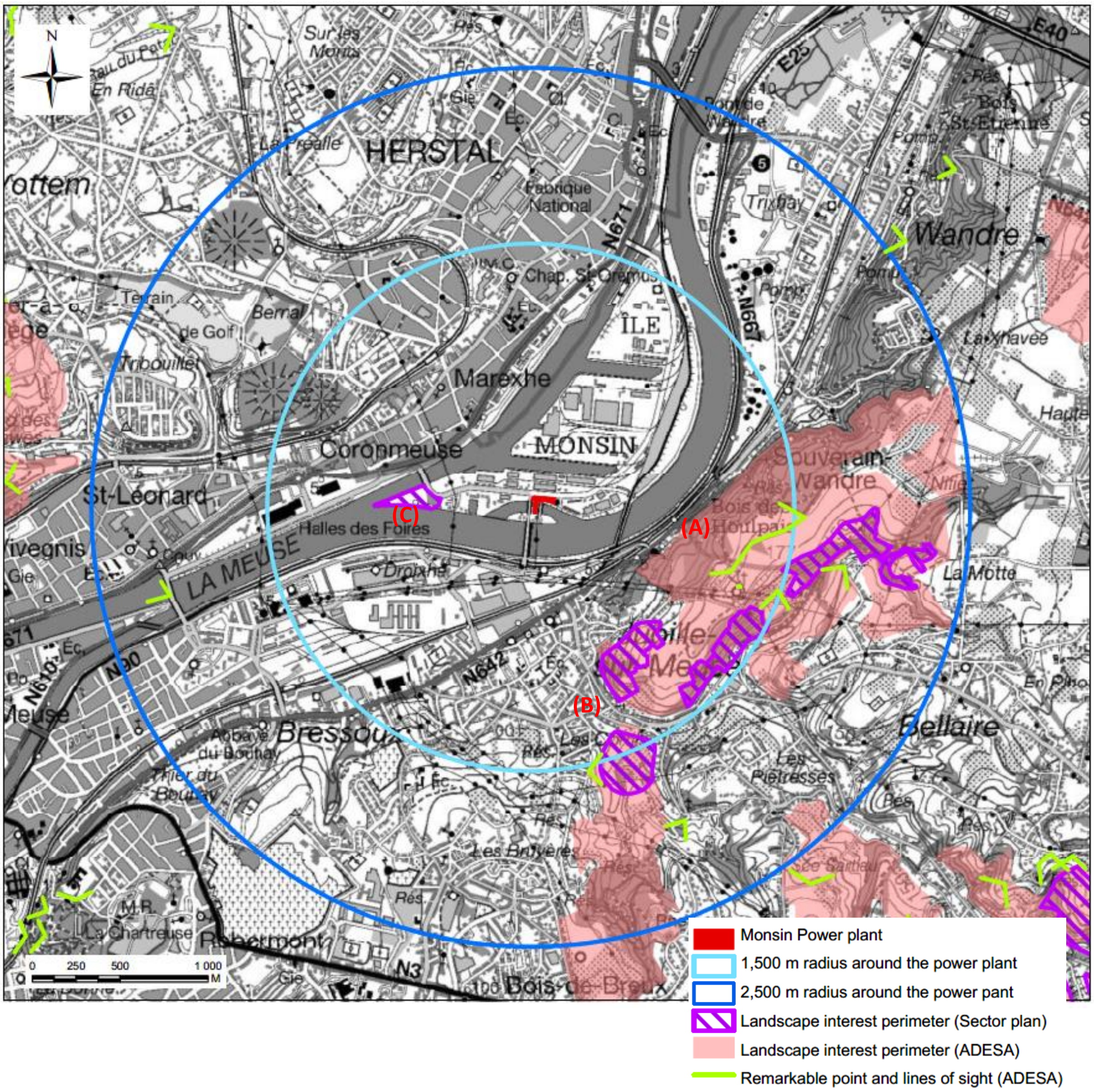


Figure IV-10: Location of areas of landscape interest and noteworthy lines of sight and viewpoints near the Monsin power plant

The power plant is not covered by a landscape interest perimeter and there are two landscape interest perimeters within a 1.5 km radius of the power plant.

Table IV-7: Description of the ADESA landscape interest areas near the Monsin power plant (1.5 km radius)

Identifying the perimeter on the map	Distance from site	Description
A	680 m	*Valleys of the Meuse and the Coyi stream* ADESA has defined a PIP on "the N slope and the wet valley floor of the Coyi stream. Nifiet Wood covers the slope that can be seen from the side of Beyne-Heusay. This extensive woodland, on the edge of the town centre, is bordered and crossed by paths and tracks. Together with the wetland at the bottom of the valley, it forms a green lung that should be preserved for its ecological and landscape value. The Houplais interfluve is a rural area with meadows, orchards, copses and hedges. Certain sections of this PIP are also included in the Sector Plan.
B	1.260 m	*Valleys of the Fond du Houlleu and Fondrivaux streams* According to ADESA, "this PIP has a very harmonious, well-preserved and varied rural landscape with a marked relief and should also extend downstream of the two valleys to the south, over : - the meadows bordering the "Tambour" farm on the ridge separating the two valleys; - Fayembois wooded park upstream of the Fond du Houlleu stream valley; - the large orchard adjoining the park. Certain sections of this PIP are also included in the Sector Plan.

In addition to these two perimeters, there is also a PIP shown in the Sector Plan on Monsin Island (C), at a distance of approximately 495 m.

In the area surrounding the site (< 1.5 km), ADESA has identified four remarkable viewpoints and lines of sight, none of which are directed towards the power plant.

3.2.2.6 Lixhe power plant

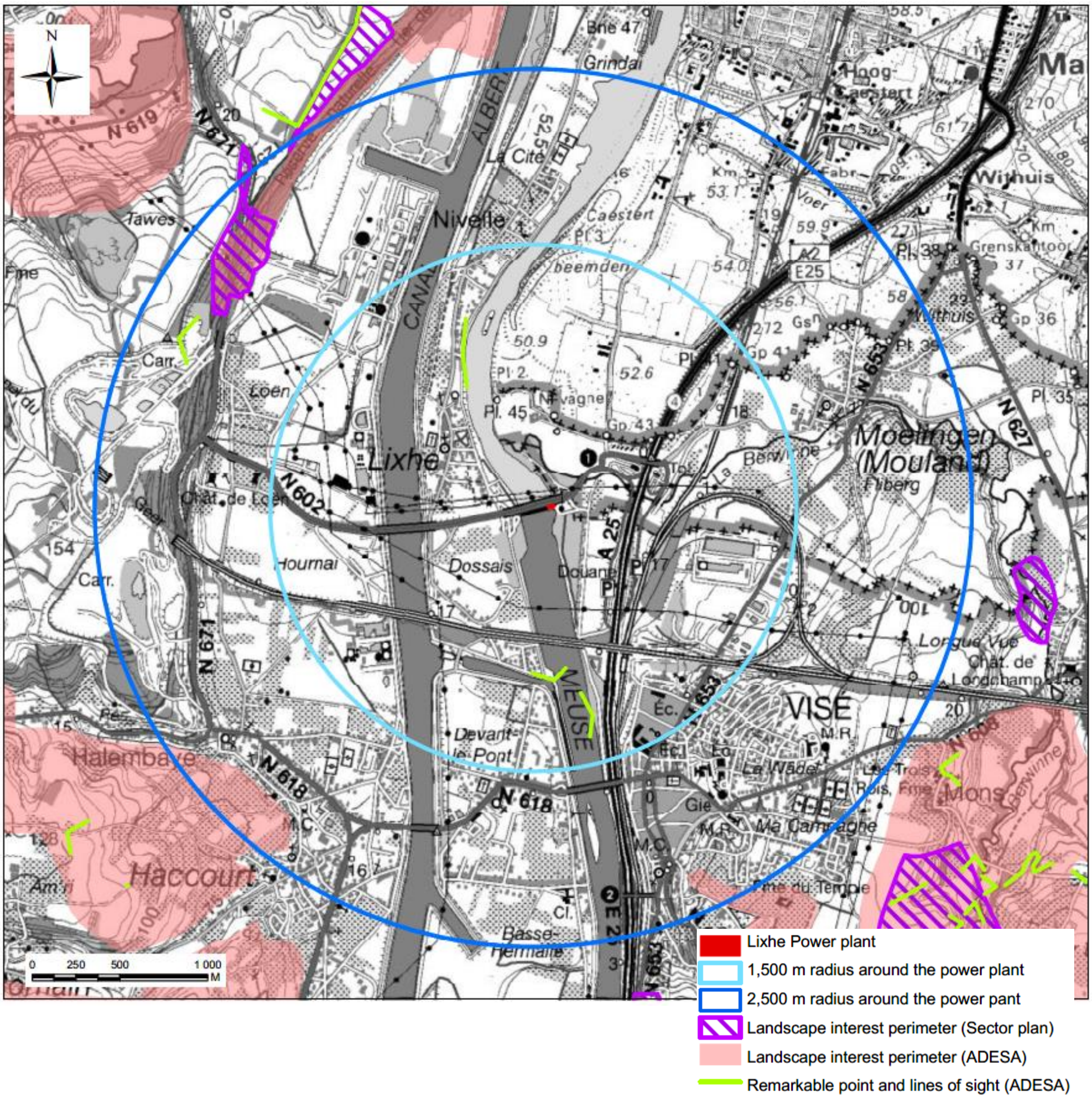


Figure IV-11: Location of areas of landscape interest and remarkable lines of sight and viewpoints near the Lixhe power plant

The power plant is not covered by a landscape interest perimeter and there are no landscape interest perimeters listed by ADESA or in the Sector Plan within a 1.5 km radius of the power plant.

However, in the area surrounding the site (< 1.5 km), ADESA has identified three remarkable viewpoints and lines of sight, none of which are directed towards the power plant.

3.2.3 Listed sites and monuments

The various classified, exceptional or world heritage sites and monuments contained within a 2.5 km perimeter around the various dams are illustrated in the figures below. Note that remarkable trees and hedges are not included in these figures, but their presence or absence is mentioned in this chapter.

3.2.3.1 Centrale des Grands-Malades

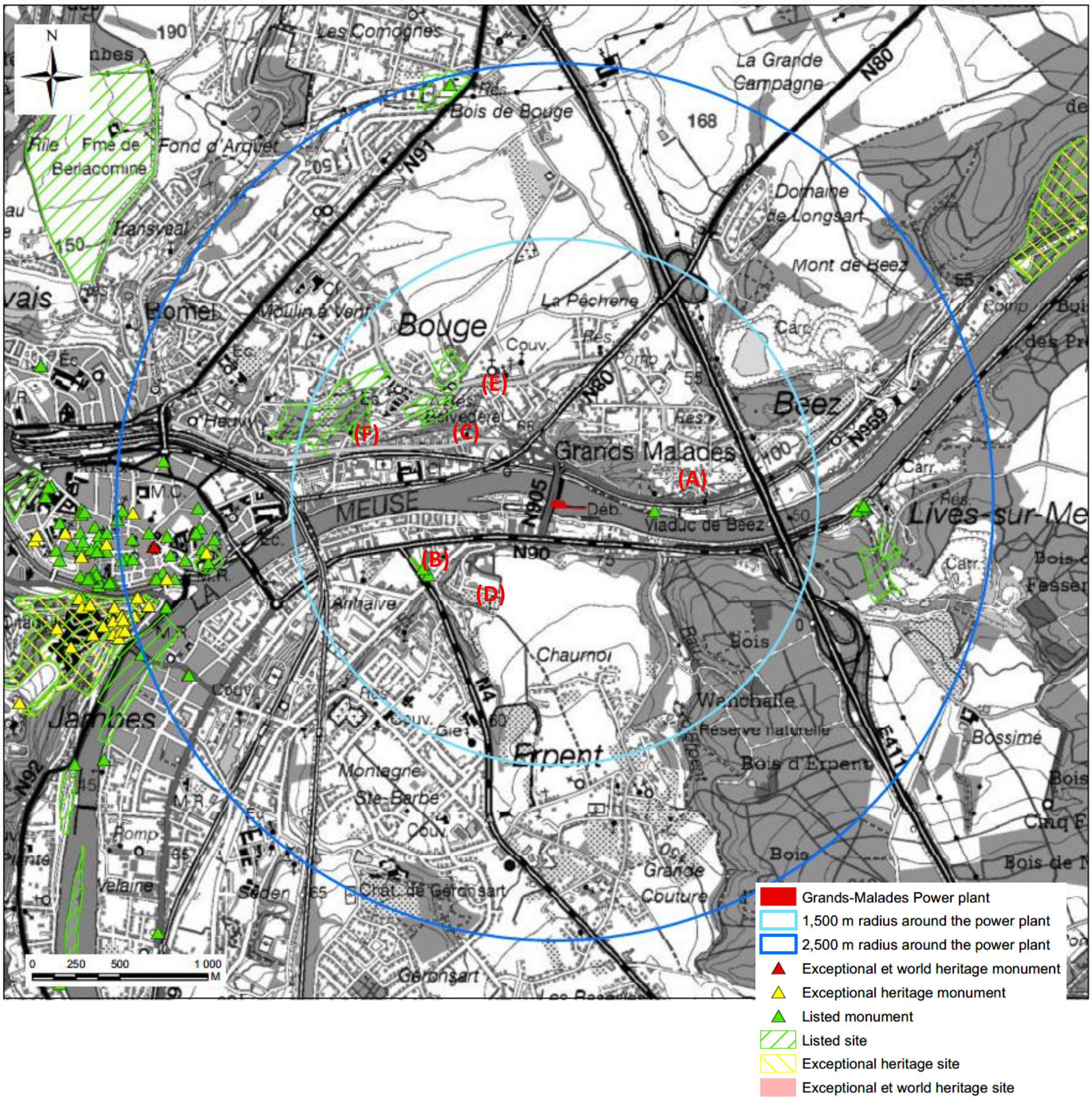


Figure IV-12: Location of listed/exceptional/world heritage sites and monuments in the vicinity of the Grands-Malades power plant

Table IV-8: Description of listed monuments and sites within a 1.5 km radius of the Grands-Malades

Number on card	Description	Exceptional heritage	World heritage	Monument or site	Distance ± (m)
A	The former Moulins de et à Beez (M), namely: a) the main wing and two perpendicular wings of building A to the east (facades, roofs, window frames and the entire cast iron and iron interior structure - columns and beams); b) the facades, roofs and windows of building B to the west; c) the footbridge linking buildings A and B;	-	-	M	575

Number on card	Description	Exceptional heritage	World heritage	Monument or site	Distance ± (m)
	d) the facades and roofs of the head miller's house Establishment of a protection zone (ZP)				
B	The facades and roofs and, inside, four original bluestone fireplaces of the former Ahhaive farm, the facades and roofs of the former sheepfold and the boundary walls in Jambes (M) and the ensemble formed by these buildings and the surrounding land (S).	-	-	S & M	760
C	The land forming the viewpoint at Bouge	-	-	S	770
D	The keep at Anhaive, known as "Enhaive	-	-	S & M	775
E	The centre of the village of Bouge	-	-	S	825
F	Bois du Coquelet, in Bouge	-	-	S	1.120

Within a radius of between 1.5 and 2.5 km of the power plant, there are a number of listed sites and monuments, mainly in the town of Namur. These include five outstanding monuments:

- The entire Notre-Dame Church, with the exception of the organ, 1,950 m from the power plant;
- The old butcher's shop known as the "al Chair" market, now an archaeological museum, 2,194 m from the power plant;
- The belfry, 2,243 m from the power plant, also a UNESCO World Heritage Site;
- Various parts of the Citadel of Namur, namely the walls, excluding the retaining walls built to establish the Route merveilleuse and the old tramway line, and the fortification and defence elements, located 2,327 m from the site.
- The stuccoed facades of the front of the Hôtel de Gaiffier, 2,354 m from the power plant.

The nearest remarkable trees or hedges are 505 m away, to the east of the power plant. They are two Purple Beech trees located on Chaussée de Liège, in Namur.

3.2.3.2 Andenne power plant

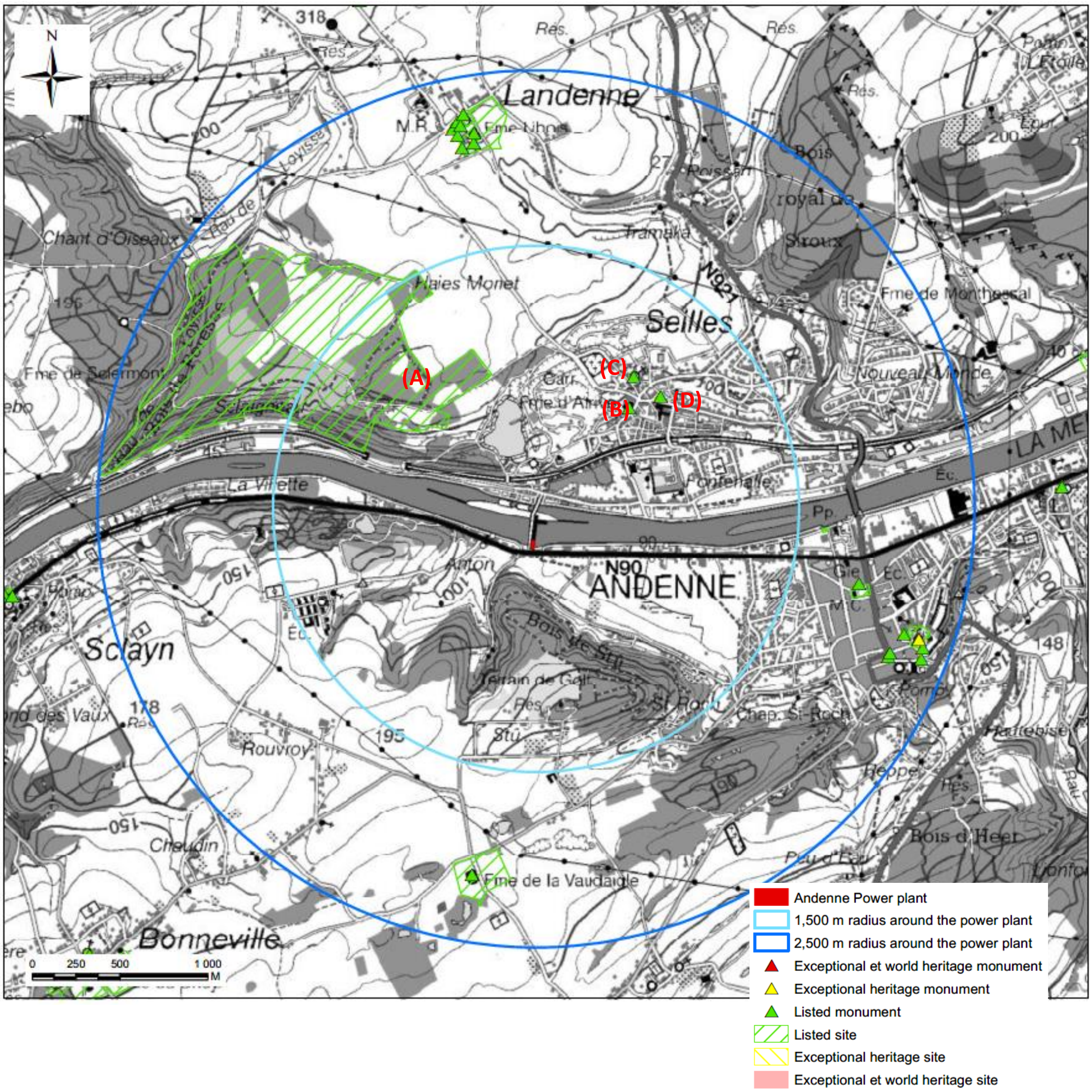


Figure IV-13: Location of listed/exceptional/world heritage sites and monuments in the vicinity of the Andenne power plant

Table IV-9: Description of listed monuments and sites within a 1.5 km radius of the Andenne power plant

Number on card	Description	Exceptional heritage	World heritage	Monument or site	Distance ± (m)
A	Sclaigneaux" and "Haies Monet" sites	-	-	S	740
B	Ferme d'Atrive, rue du Château, no. 2	-	-	M	760
C	The Church of Saint-Etienne	-	-	M	915
D	Bandstand on Place Wauters (M) and establishment of a protection zone (ZP)	-	-	M	935

Within a radius of between 1.5 and 2.5 km of the power plant, there are around fifteen other listed sites and monuments, including one exceptional monument, the collegiate church of Sainte-Begge, located around 2,260 m from the power plant.

The nearest remarkable trees or hedges are 280 m away, to the west of the power plant, and consist of a trimmed hawthorn hedge in Rue d'Anton in Sclayn.

3.2.3.3 Ampsin-Neuville power plant

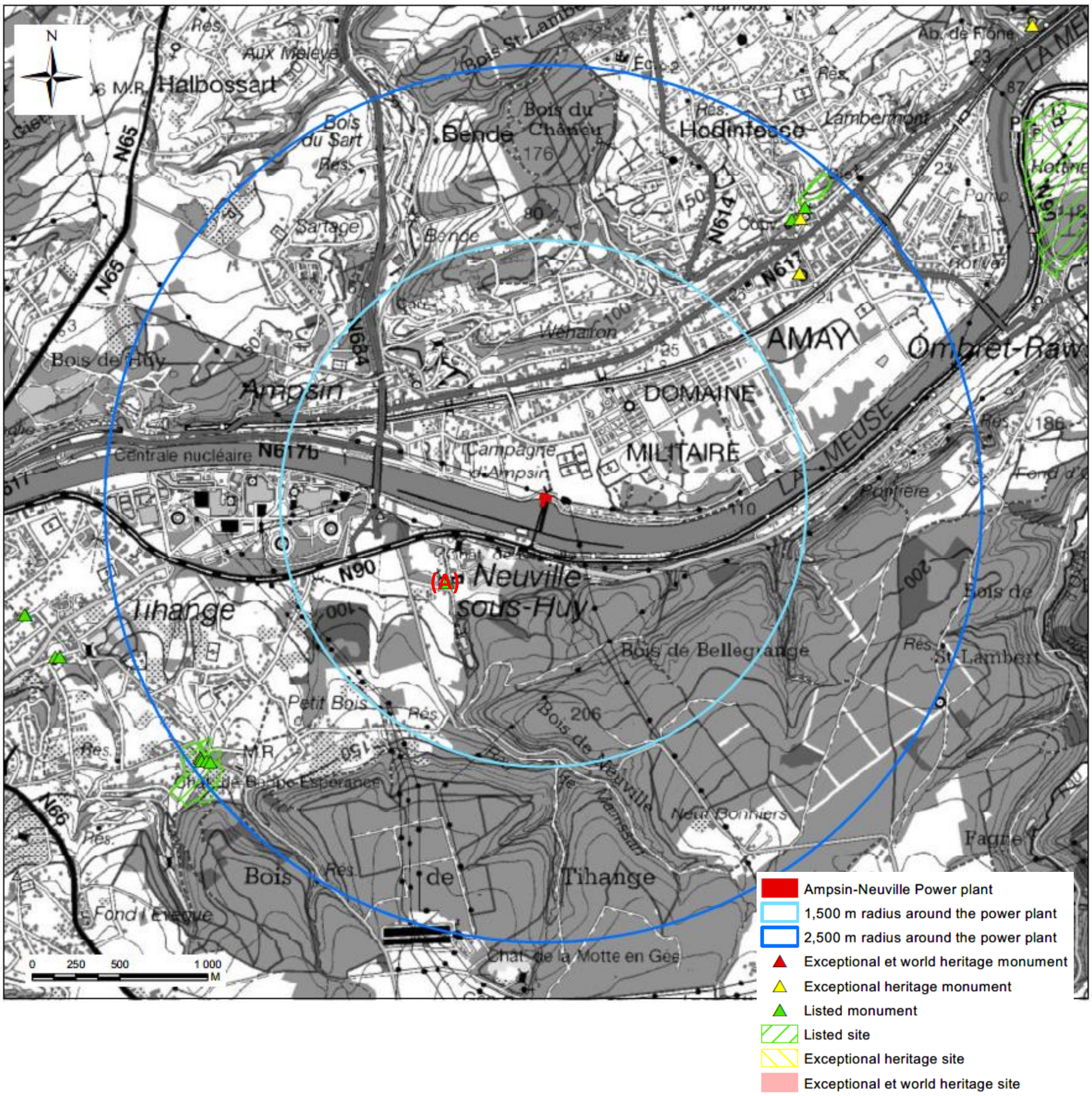


Figure IV-14: Location of listed/exceptional/world heritage sites and monuments in the vicinity of the Ampsin-Neuville power plant

Table IV-10: Description of listed monuments and sites within a 1.5 km radius of the Ampsin-Neuville power plant

Number on card	Description	Exceptional heritage	World heritage	Monument or site	Distance ± (m)
A	The church of Sainte-Gertrude	-	-	M	655

Within a radius of between 1.5 and 2.5 km of the power plant, there are around ten other listed sites or monuments, including two exceptional monuments:

- The ancient medieval tower, located about 2,015 m from the power plant;
- The entire Collégiale Saint-Georges and Sainte-Ode, with the exception of the organ, ± 2,250 m from the power plant.

The nearest remarkable trees or hedges are about 450 m away, to the south-west of the power plant. They include several species in the park of the Château de Neuville in Huy.

3.2.3.4 Ivoz-Ramet power plant

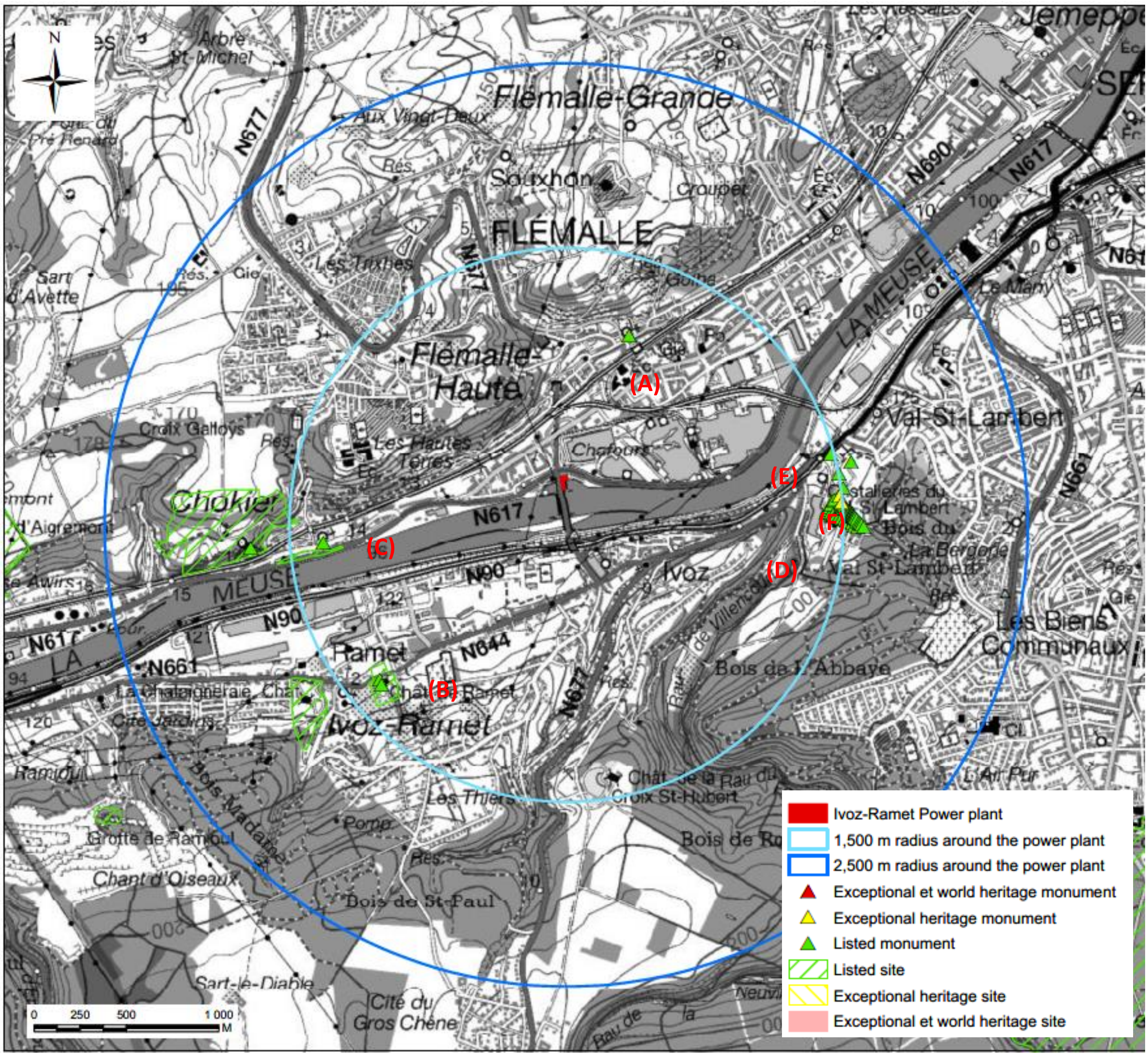


Figure IV-15: Location of listed/exceptional/world heritage sites and monuments in the vicinity of the Ivoz-Ramet power plant

Table IV-11: Description of listed monuments and sites within a 1.5 km radius of the Ivoz-Ramet power plant

Number on card	Description	Exceptional heritage	World heritage	Monument or site	Distance ± (m)
A	Organs of Saint-Mathias Church	-	-	S	855
B	Château de Ramet and its outbuildings (facades and roofs) as well as the moat and boundary walls (M) and the ensemble formed by this castle and the surrounding land (S)	-	-	S & M	1.300
C	The Church of Saint-Marcellin, with all its furnishings and the entrance punctuated by four pillars with a grille.	-	-	M	1.315
D	Houses (facades and roofs) forming the courtyard of Val-Saint-Lambert	-	-	S	1.385
E	Val Saint-Lambert abbey: entrance portico, château (north and west facades, monumental staircases in the abbot's and prior's quarters and wrought iron banisters); facade of the building enclosing the courtyard of honour on the south side; former chapter house; buildings, now a shop (facades and roofs); concert hall (facades), rue du Val Saint-Lambert, no. 245 (M) and complex formed by the courtyard of the Val, comprising the courtyard and the facades of the surrounding buildings (S).	-	-	M & S	1.435
F	The scriptorium and fragments of plasterwork from the former abbey of Val-Saint-Lambert	Yes	-	S	1.460

Within a radius of 1.5 to 2.5 km of the power plant, there are a number of other listed sites and monuments, none of which are exceptional or UNESCO World Heritage Sites.

The nearest remarkable tree or hedge is 240 m away, to the west of the power plant, and is a horse chestnut tree located Quai du Halage, in Flémalle.

3.2.3.5 Monsin power plant

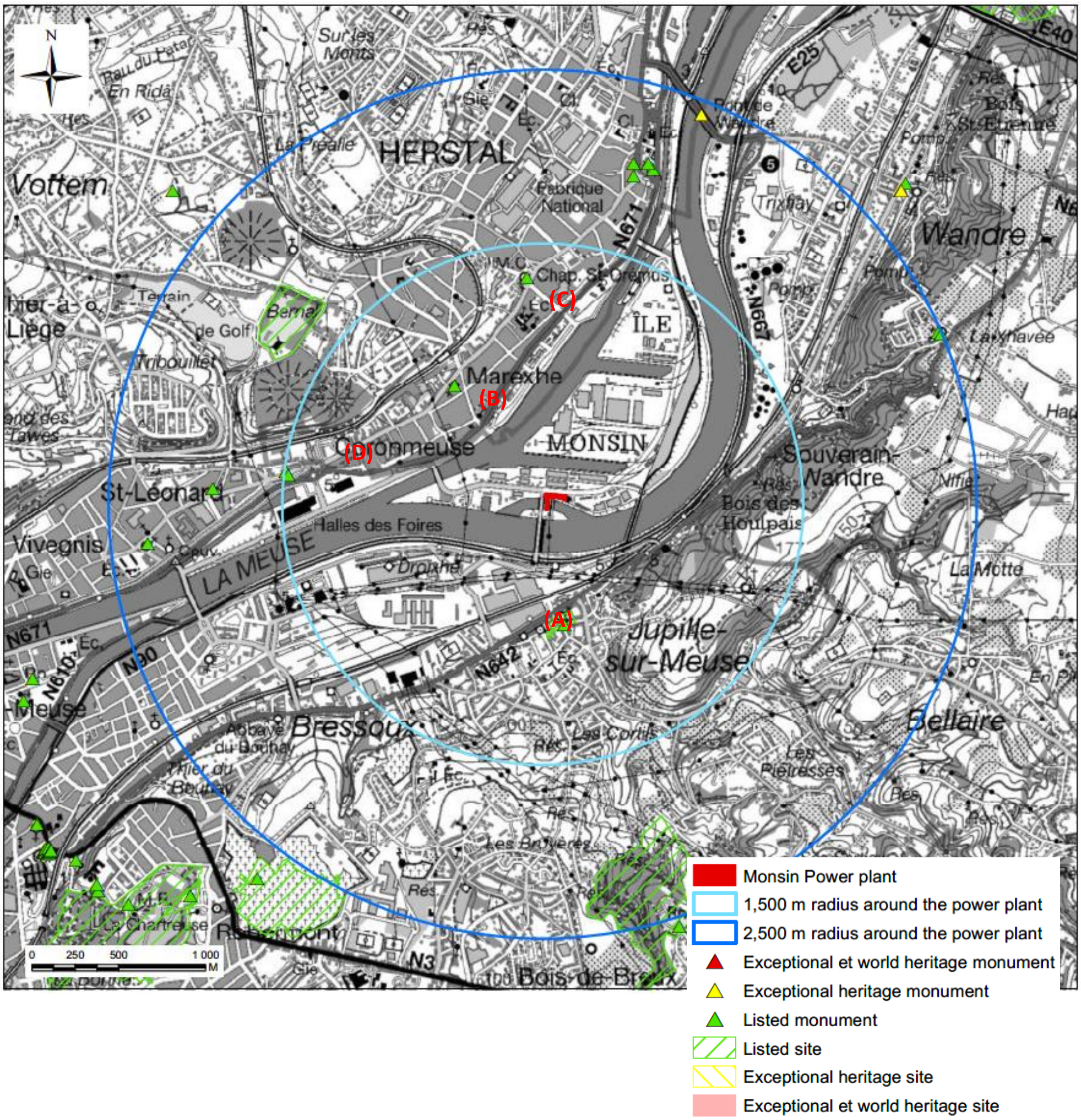


Figure IV-16: Location of listed/exceptional/world heritage sites and monuments in the vicinity of the Monsin power plant

Table IV-12: Description of listed monuments and sites within a 1.5 km radius of the Monsin power plant

Number on card	Description	Exceptional heritage	World Heritage	Monument or site	Distance ± (m)
A	Vicarage at Jupille-sur-Meuse	-	-	S & M	440
B	Organs (Arnold Clérinx - 1870) in the Church of Saint-Lambert	-	-	M	820
C	Saint-Lambert chapel	-	-	M	1.270
D	House (Breuer), place Coronmeuse, no. 26	-	-	M	1.460

Within a radius of between 1.5 and 2.5 km of the power plant, there are a dozen other listed sites and monuments, including an exceptional one, the Wandre bridge, 2,375 m from the power plant.

The nearest remarkable tree or hedge is ± 830 m away, to the south-east of the power plant. It is a Purple Beech, located on Place Havard in Liège.

3.2.3.6 Lixhe power plant

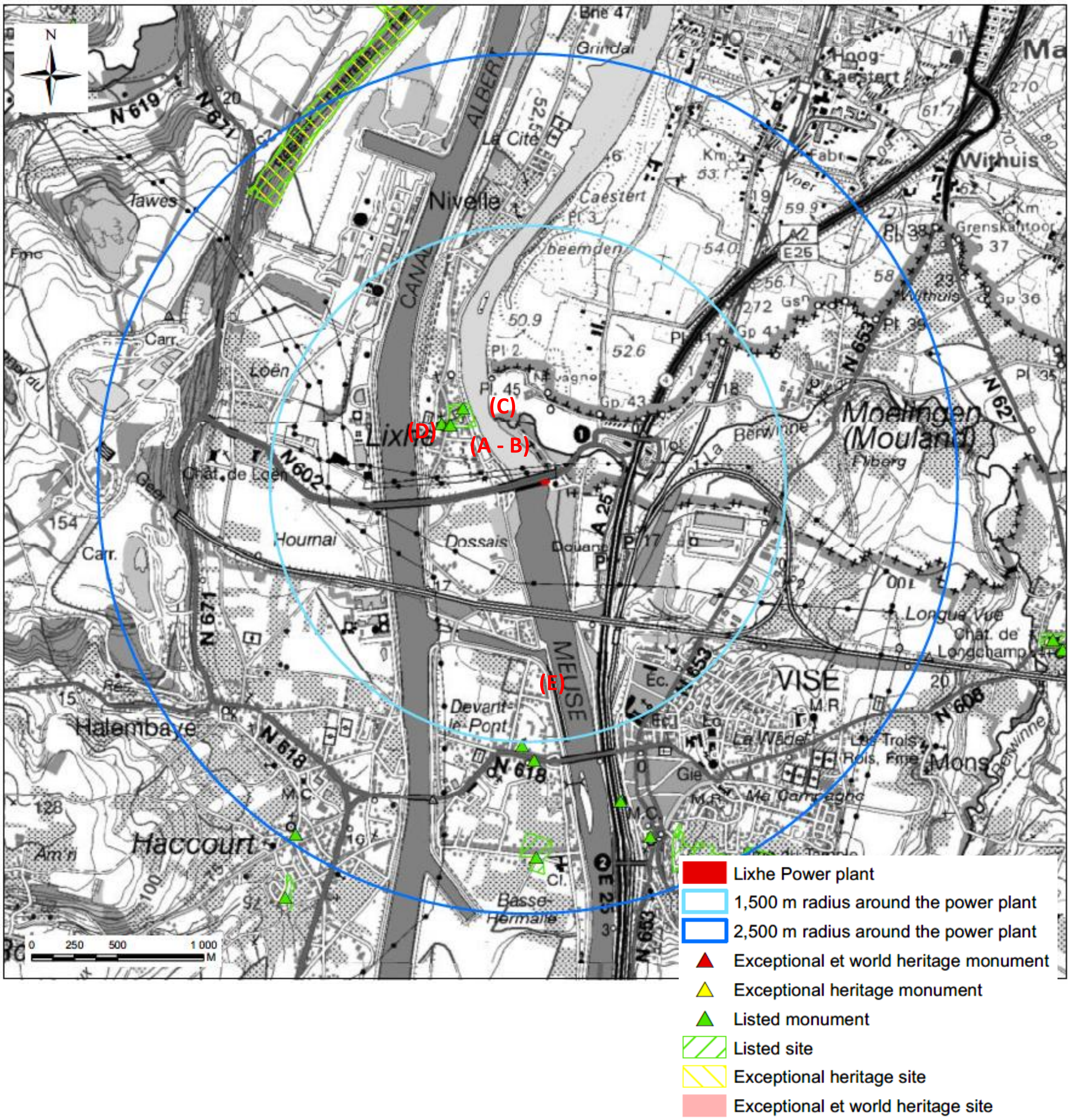


Figure IV-17: Location of listed/exceptional/world heritage sites and monuments in the vicinity of the Lixhe power plant

Table IV-13: Description of listed monuments and sites within a 1.5 km radius of the Lixhe power plant

Number on card	Description	Exceptional heritage	World heritage	Monument or site	Distance ± (m)
A	House (facades and roofs) and pebble pavement, rue de la Halle, no. 171	-	-	M	490

Number on card	Description	Exceptional heritage	World heritage	Monument or site	Distance ± (m)
B	House (facades and roofs) and pebble pavement, rue de la Halle, no. 172	-	-	M	495
C	Maison de la Tour (facades and roofs), rue de Lixhe, no. 186 (M) and ensemble formed by the house, park, towpath and bank of the Meuse (S)	-	-	S & M	520
D	Saint-Lambert Church	-	-	M	535
E	The Church of Our Lady of Mount Carmel			M	1.485

Within a radius of between 1.5 and 2.5 km of the power plant, there are just under a dozen other listed sites and monuments, including one exceptional site, the Thiers de Lanaye, des Vignes et de Nivelle, on the eastern slopes of the Montagne Saint-Pierre, ± 2,190 m from the power plant.

The nearest remarkable tree or hedge is approximately 550 m away, to the north-west of the power plant. It is a Purple Beech, located in Rue de Lixhe in Visé.

3.2.4 Archaeological map of Wallonia

The Walloon Heritage Code (CoPat), which comes into force on June 1, 2019, provides a body of specific rules on heritage matters. This new code is more in line with current practices and reflects a user-oriented approach, with a view to simplifying and speeding up decision-making processes.

The objectives of this code are as follows:

- Set up prevention measures ;
- Managing Wallonia's archaeological sites and assets ;
- Planning archaeological operations prior to construction sites;
- Delineate the areas for which requests for opinions are required by the authorities responsible for issuing planning permits and certificates.

The archaeological map is a cartographic decision-making tool for information, prevention and management of archaeological finds and identified archaeological sites.

The archaeological map provides information on the boundaries of any group of properties, whether or not they are built on, which, in whole or in part, have been subject to the discovery of one or more archaeological objects, or which have been identified as having concealed, are concealing or are presumed to conceal archaeological objects. This is a mapped transposition of the archaeological heritage inventory.

As shown in the following figure, the various hydroelectric power plants do not contain any areas included in the archaeological map drawn up for the Walloon Region.

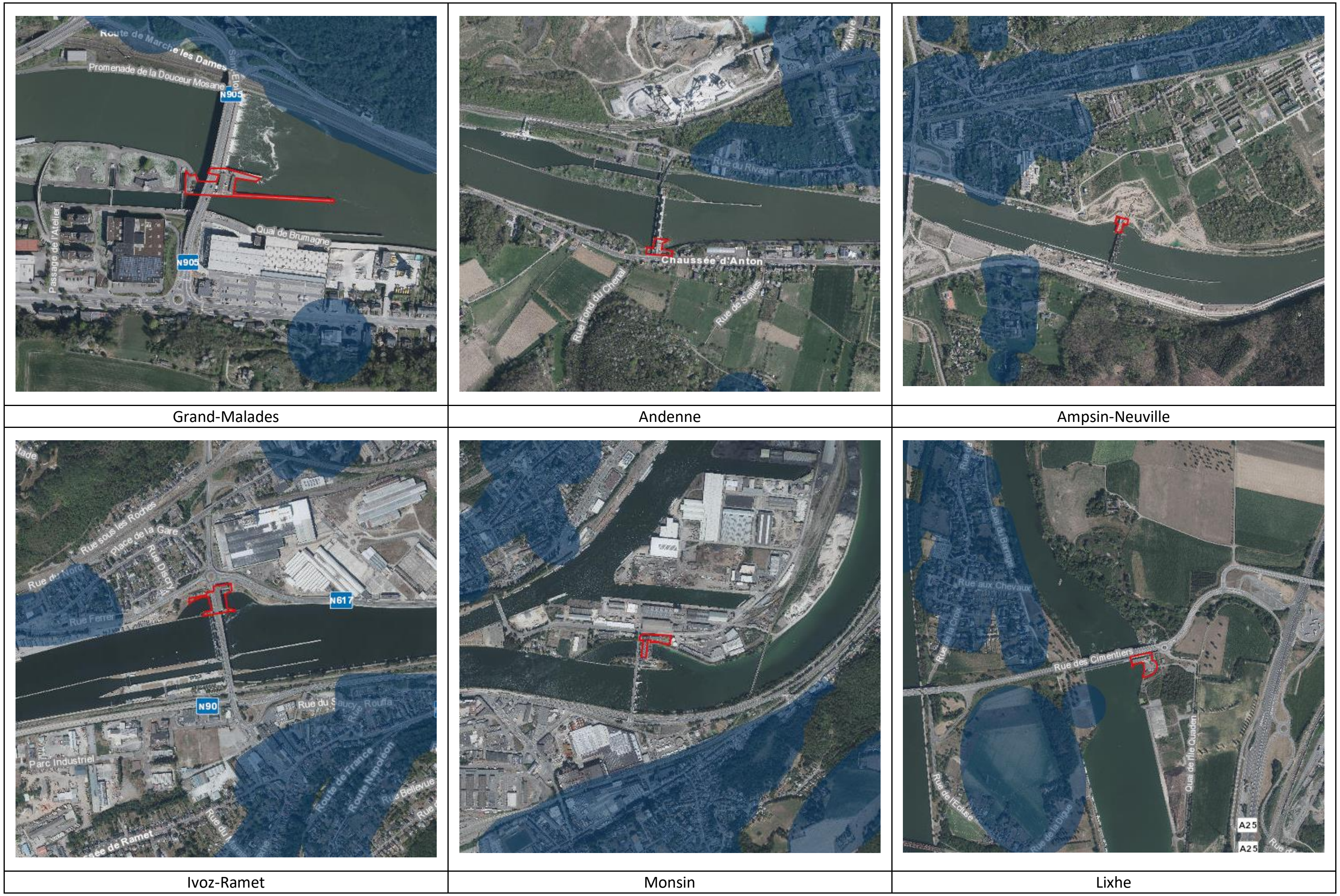


Figure IV-18: Archaeological map around the various power plants affected by the project (Source: WalOnMap)

3.2.5 Walking routes

A RAVeL runs along the towpath north of the Grands-Malades and Andenne power plants and east of the Lixhe power plant. A cycle path (EuroVelo) also runs along the towpaths south of the Grands-Malades, Andenne and Ampsin-Neuville power plants, north of the Monsin power plant and west of the Lixhe power plant.

The GR 575 runs approximately 715 m south-west of the Grands-Malades power plant, on the towpath, the GR 421 runs over the dam bridge at the Monsin power plant and the GR 5 runs approximately 980 m south of the Lixhe power plant.

3.2.6 Villages, hamlets and localities

The way housing is organised has a significant influence on how residents perceive their living environment. Villages are always built around existing axes (a road, a river, etc.). These lines of force dictate the layout of buildings and have a strong influence on how the landscape is perceived. They set perspectives, direct the eye and sometimes widen the field of vision. By analysing these lines of force, it is possible to characterize how the landscape is perceived from the home.

From the habitat, the local landscape is marked by built components, such as buildings, roads, pylons, etc., and natural components, such as tree lines, woods, isolated trees, valleys, hedgerows, etc.

As shown in the figure below, the various power plants are located in areas that are largely populated, with residential areas and/or areas of economic activity.

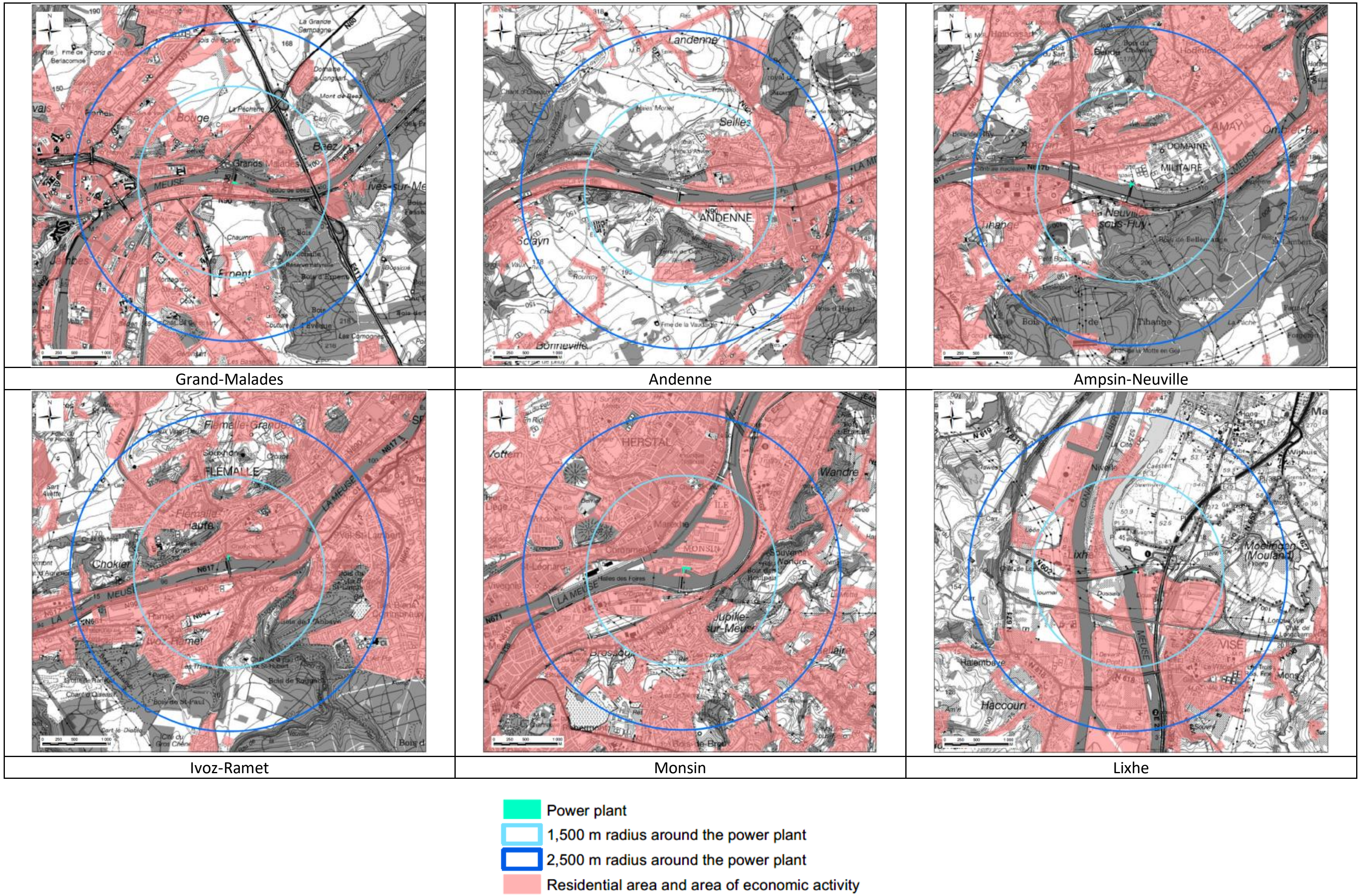


Figure IV-19 Residential and business areas near the power plants concerned by the project

3.3 IMPACT ASSESSMENT

- For the purposes of this chapter, the impact assessment focuses on The perception of the solutions tested in the local environment;
- Heritage close to power plants.

3.3.1 Turbine management

Stopping the turbines at certain times will have no impact on the landscape or heritage. In fact, stopping the turbines does not involve any change in water levels, as the water passes either through the channel of the non-rotating turbines or through the dam.

3.3.2 Electric barrier

As shown in the figure below, at the barrier itself, the electrodes are held in place by buoys, the immersion depth of which varies according to the water level of the Meuse; in periods of high flow, the electrodes are fully immersed and therefore not visible. At low water levels, they are only visible from a very short distance.

Low water | High water

Figure IV-20: Illustration of the electrical barrier installed at the Grands-Malades power plant

In addition, ancillary installations, such as the electrical box illustrated above, are reduced in size and installed on existing infrastructure at the dam.

Figure IV-21: Illustration of the electrical box installed at the Grands-Malades power plant

Similarly, as illustrated below, the inlet to the outlet is located at the turbine intake channel, under the N904 trunk road, while the outlet is located at the turbine outlet channel, so that both inlet and outlet are only visible in the immediate vicinity.

Outlet upstream of the power plant	Outlet downstream of the power plant

Figure IV-22: Inlet and outlet of the outfall at the Grands-Malades power plant

In view of the above, it appears that the electric barrier will only be visible at very short range, particularly from the roads closest to the power plants and possibly from the Ravels or cycle paths passing in the direct vicinity of the power plants, particularly on the towpath quays.

The electric barrier will not be visible from nearby landscape interest perimeters or from listed heritage features.

In view of the above, no significant impact on landscape and heritage is expected.

3.3.3 Bubble barrier

This solution involves installing a compressor within the dam facilities and air supply pipes along the towpath quay, also at the power plant. These installations will only be visible in the immediate vicinity, if at all, of the power plant site.

Furthermore, during operation, the bubble barrier is only visible through the bubbling of the bubbles at the surface, as shown in the figure below.

Figure IV-23: View of the bubble barrier in operation

In view of the above, no impact on the landscape or heritage is expected.

3.3.4 Water height

Like the previous solution, increasing the water level (to a maximum of 90 cm) at one of the dam's openings will have no impact on the landscape or heritage. In fact, this would not involve any overflowing of the Meuse.

4. HUMAN BEING

4.1 INTRODUCTION

4.1.1 Difficulties encountered

None.

4.1.2 Detailed impact assessment methodology

In terms of human beings, the chapter will address the following topics:

- The local population ;
- The socio-economic context ;
- Site accessibility.

4.2 ANALYSIS OF THE EXISTING SITUATION

4.2.1 Local population

As mentioned in Chapter 3.2.6 *Villages, hamlets and localities*, the various power plants concerned by the project are located in highly developed areas, with residential areas in the immediate vicinity. The table below shows the minimum distance from residential areas.

Table IV-14: Minimum distance from residential areas

Central	Residential area	Note
Grand-Malades	± 190 m - Namur	Rural residential area at a minimum distance of ± 755 m
Andenne	± 120 m - Andenne	Rural residential area at a minimum distance of ± 1,050 m
Ampsin-Neuville	± 190 m - Amay	No rural settlements within a radius of 1.5 km
Ivoz-Ramet	± 25 m - Flémalle	No rural settlements within 1.5 km
Monsin	± 450 m - Herstal	No rural settlements within 1.5 km
Lixhe	± 270 m - Lixhe	Rural residential area, like most of the residential areas within a radius of 1.5 km.

4.2.2 Socio-economic context

4.2.2.1 Demographic situation

The table below shows a description of the demographics based on data available on the CAP Ruralité website[18] and the Institut Wallon de l'Évaluation, de la Prospective et de la Statistique (IWEPS). This description is given for the municipalities concerned by the various power plants. The table also includes demographic statistics for Wallonia.

[18] Cellule d'Analyse et de Prospective en matière de Ruralité - Gembloux Agro-Bio Tech (ULg) - SPW

Table IV-15: Demographics of the municipalities concerned (source: CAP ruralité; Walstat)

Demographics	**Unit**	**Namur (CHG)**	**Andenne (AMP)**	**Huy (CHN)**	**Flémalle (CHR)**	**Liège (CHM)**	**Aimed (CHL)**	**Walloon Region**
Population (at 01/01/2022)	Resident	112.559	27.863	21.405	26.677	195.278	17.973	3.692.465
Surface area (at 01/01/2022)	Km²	176,0	86,1	47,6	36,6	68,6	27,7	16.901,2
Population density (at 01/01/2022)	inhabitants/km²	639,8	323,6	449,3	729,5	2.844,5	648,2	216,7
Total number of households: private and collective (at 01/01/2022)	Cleaning	52.537	12.026	10.250	11.856	99.344	7.940	1.614.466
Average size of private households (at 01/01/2022)	Resident	2,09	2,28	2,03	2,23	1,93	2,25	2,24

The population densities of the various municipalities where the power plants concerned by the project are located range from 323.6 to 2,844.5 inhabitants per km², which is considerably higher than the Walloon average of around 217 inhabitants per km². The number of inhabitants per household is roughly equivalent to the Walloon average, with the exception of the municipality of Liège, which is significantly lower.

4.2.2.2 Economic, agricultural, forestry and industrial situation

The table below shows the various socio-economic parameters for the various municipalities affected by the project's power plants.

As the information in the table below indicates, the municipalities affected by the project are relatively artificially developed, with between 17.8% (Huy) and 55.0% (Liège) of the municipal territory. However, a significant proportion of this communal land is devoted to agriculture, with at least 34% arable land, permanent crops, grassed areas and agricultural wasteland, with the exception of the municipality of Liège (with only 15.3%).

Table IV-16: Economic and agricultural situation (source: IWEPS, CAP Ruralité)

	Unit	Namur (CHG)	Andenne (AMP)	Huy (CHN)	Flémalle (CHR)	Liège (CHM)	Aimed (CHL)
Land use at 01/01/2022 (IWEPS)							
Developed area	%	26,1	17,8	20,6	27,9	55,0	25,1
Residential land	%	17,7	10,3	12,7	18,8	27,3	14,4
Shops, offices and services	%	1,0	0,3	0,6	0,7	2,7	0,8
Public services and community facilities	%	2,5	1,0	2,3	1,9	7,6	2,2
Leisure and urban green spaces	%	1,1	0,6	0,8	0,4	8,4	0,6
Industrial and craft use	%	1,8	2,3	2,3	4,1	6,6	4,3
Quarries, landfill sites and abandoned areas	%	0,4	2,4	0,4	0,3	0,3	1,3
Transport infrastructure	%	1,1	0,3	0,6	1,0	1,6	0,8
Arable land and permanent crops	%	24,6	33,9	13,6	20,5	5,7	29,2
Grassed areas and agricultural wasteland	%	17,1	20,7	20,7	19,8	9,6	8,7
Forests	%	21,2	17,9	34,0	15,4	6,8	6,5
Semi-natural environments	%	2,0	2,9	2,0	5,6	2,9	7,6
Economic situation							
Average net taxable income per inhabitant (2018)	Euros	18.602	17.083	17.399	16.533	15.203	17.639
Total number of employees (2019)	Resident	48.947	12.594	9.658	11.500	85.098	7.868
Employment rate (2019)	%	68,8	70,7	70,4	69,0	65,5	69,2
Unemployment rate (2019)	%	14,8	11,8	18,5	13,9	23,2	12,2

4.2.3 Accessibility

The Meuse is bordered throughout the project by the N90 trunk road from the Grands-Malades power plant, which from Monsin becomes the A25 motorway to the Dutch border. The Lixhe power plant is accessible via the N602 trunk road.

4.3 IMPACT ASSESSMENT

- For the purposes of this chapter, the impact assessment focuses on the potential socio-economic benefits of the solutions tested;
- Mobility.

As a reminder, priority is always given to navigability, so no impact is assessed on this parameter.

4.3.1 Turbine management

With regard to the socio-economic spin-offs of this solution, as it involves internal management of the Luminus hydroelectric power plant networks, no jobs will be created. Consequently, no positive or negative impact is expected from the implementation of this solution.

In terms of mobility, this solution will not result in any additional traffic. No impact on mobility is therefore expected.

4.3.2 Electric barrier

As far as the socio-economic impact of this solution is concerned, apart from installation, no jobs will be created. Furthermore, the installation of the electric barrier will be carried out by a team already in place and will not create any local jobs either.

In view of the above, no positive or negative socio-economic impact is expected from the installation of the electric barrier.

In terms of mobility, apart from during installation, this solution will not generate any additional traffic. During installation, only a few light vehicles will need to visit the site and will park on the existing infrastructure. No impact on mobility is therefore expected.

4.3.3 Bubble barrier

As far as the socio-economic impact of this solution is concerned, apart from during installation, no jobs will be created. The installation of the bubble barrier will be carried out by a team already in place, and no local jobs will be created either.

In view of the above, no positive or negative socio-economic impact is expected from the installation of the bubble barrier.

In terms of mobility, apart from during installation, this solution will not generate any additional traffic. During installation, only a few light vehicles will need to visit the site and will park on the existing infrastructure. No impact on mobility is therefore expected.

4.3.4 Water height

As far as the socio-economic impact of this solution is concerned, no jobs will be created. In view of the above, no positive or negative impact is expected from the implementation of this solution.

In terms of mobility, this solution will not result in any additional traffic. No impact on mobility is therefore expected.

It should be noted that, as mentioned above, none of the solutions tested will create jobs directly; however, given the interest in the methodology used, it is estimated that there will be positive spin-offs for the University of Liège, EDF R&D and Profish.

5. NOISE

5.1 INTRODUCTION

5.1.1 Difficulties encountered

None.

5.1.2 Detailed impact assessment methodology

The purpose of the Noise chapter is to assess the impact of the project on the noise environment in terms of the dwellings and residential areas in the immediate vicinity of the project.

As part of the description of the local environment, the Study Manager presents the noise context in which the project is located.

With regard to impact assessment, the Design Manager will carry out a qualitative assessment of the noise nuisance caused by the various measures put in place.

5.1.3 Theoretical background

Noise amplitude is measured in Pascal, but in order to represent the ear's sensitivity to amplitude, a logarithmic unit is used: the decibel. This is known as the sound pressure level, L_p . Since sound fluctuates, it is usual to consider an average value over an evaluation period T, which is noted $L_{eq,T}$.

The ear’s sensitivity is not the same at all frequencies. Hearing is particularly sensitive between 500 and 4000 Hz, which correspond to speech frequencies. Below this frequency, the lower the frequency, the more difficult it is to hear sounds. The situation is similar above 4000 Hz. To take account of this sensitivity, the sound is weighted. Measuring equipment is fitted with an A filter that reduces the amplitude of low or very high frequency sounds. The A curve is standardised. Amplitude is expressed in dB(A). This is known as the L-weighted sound pressure level$_{pA}$ or LA or $L_{Aeq,T}$.

The following table gives examples of noise levels expressed in decibels.

Table IV-17: Examples of noise levels

Niveaux de bruit dB(A)	Quelques références
140	Banc d’essai de turboréacteur
130	Marteau riveur
120	Burin pneumatique
110	Atelier de presses, d’emboutissage
100	Atelier de tôlerie
90	Poids lourds à quelques mètres
80	Trafic important dans la rue
70	Pool dactylographique
60	Conversation courante
50	Bureau
40	Bibliothèque
30	Chambre à coucher
20	Studio de radio diffusion
10	Bruissement d’une feuille
0	Seuil d’audition pour un son pur de 1.000 Hz

Noise levels, regardless of the indicator used, are expressed in A-weighted decibels (dB(A)). The decibel is used to take account of the perception of noise amplitude. A-weighting is used to take account of the frequency perception of sound, as very low-pitched and very high-pitched sounds are less well perceived by the ear. A-weighting gives a result that best reflects the human ear's perception of noise. Regulations require noise measurements to be carried out with this weighting.

Noise is, by its very nature, fluctuating. The same sound environment can be quantified on the basis of different acoustic quantities. For the purposes of this project, the most relevant are as follows:

- $\underline{L_{Aeq}}$: A-weighted equivalent continuous sound pressure level. This indicator corresponds to the average sound level over a given period. This average can be calculated at intervals of 1s (LAeq,1s), 5min (LAeq,5min) or 1h (LAeq,1h).
- LA90 fractile sound level: equivalent continuous A-weighted sound pressure level LAeq,1s exceeded for 90% of the measurement interval. Following the same logic, the levels LA95, LA50 or LA10 correspond to the equivalent continuous A-weighted sound pressure levels exceeded for 95, 50 or 10% during the measurement interval. The LA90 level is more representative of the background noise present on a continuous basis, as this indicator eliminates noise that fluctuates over short periods, such as passing cars. This means that noise peaks are not taken into account, leaving only the noise that is continuously present.

The figure below, based on an example of an LAeq,1s curve measured over 1 hour, shows what these different indices represent.

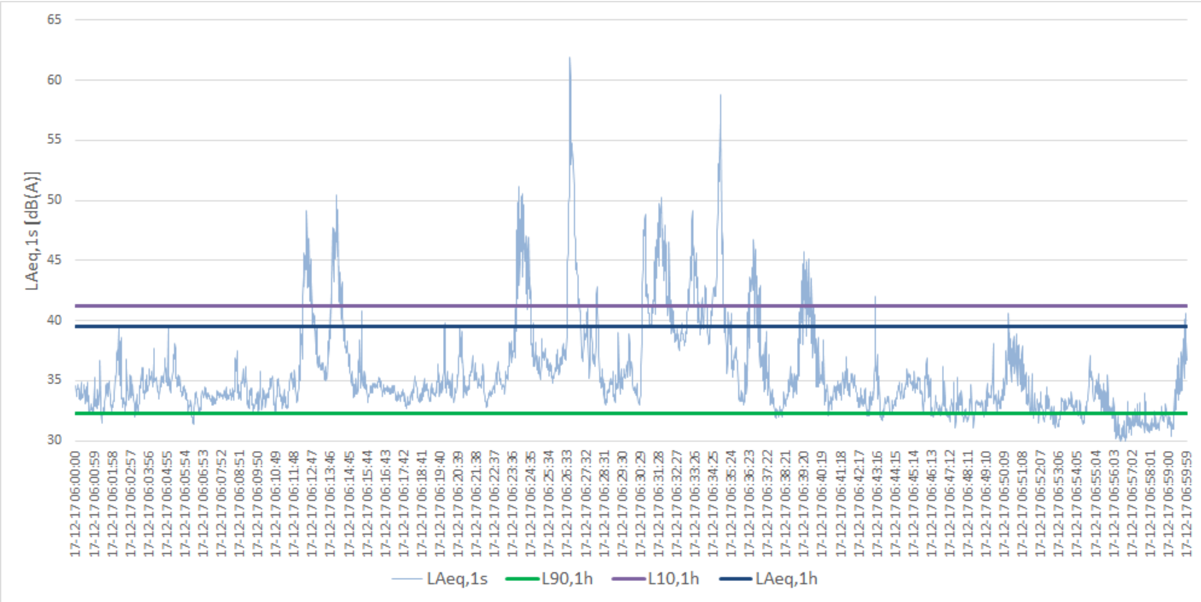


Figure IV-24: Definition of the LAeq sound level and the most commonly used noise indices

The $_{LAeq,1h}$ level (dark blue) represents the average total noise present during the measurement. It can be seen that it is strongly influenced by one-off events such as passing cars, planes, trains, etc. The L level$_{A90}$ (green) corresponds to the noise level exceeded for 90% of the time. It is used to filter out one-off noise peaks (trains, planes, local carts, etc.) and only retains noise that is present almost continuously. When the difference between the L_{Aeq} and the L_{A90} is significant, this means that the noise environment is conditioned by intermittent point source noise.

In the following assessment, the $_{LAeq,1h}$ and the $L_{A90,1h}$ will be used mainly as reference values.

The perception of environmental noise can be summarised in the table below. This table is based on the L indicator$_{Aeq}$.

Table IV-18: Indicative perception of the environment as a function of noise level L_{Aeq}

Perception	Equivalent level L_{Aeq} [dB(A)]		
	Daytime (7am-7pm)	Evening (7-11pm)	Night (23-7h)
Silent	<40	<35	<30
Very calm	41-45	36-40	31-35
Calm	46-50	41-45	36-40
Slightly noisy	51-55	46-50	41-45
Noisy	56-60	51-55	46-50
Very noisy	>60	>55	>50

5.1.4 Regulatory context

The Walloon Government Order of July 4, 2002 laying down the general operating conditions for establishments covered by the decree of March 11, 1999 on environmental permits specifies the permissible limit values for the noise level generated by an establishment as a result of its operation (referred to in the regulations as the “specific noise level”).

Limit values are set according to the time of year and the zone in which the measurements are taken (zones defined in the Sector Plan), and differ depending on whether the establishment is an existing one or a new one (after the entry into force of the AGW of July 4, 2002).

The permissible limit values for existing and a new plants are given in the following tables.

Table IV-19: General noise limit values applicable to a classified establishment

Immission zone (area where measurements are taken)		Limit values (dBA) per Period		
		Day 7am-7pm	Transition 6-7am and 7-10pm 6am-10pm Sundays and public holidays	Night 22h-6h
I	All areas, where the measurement point is less than 500 m from the extraction area, extraction outbuildings, industrial economic activity or specific economic activity, or less than 200 m from the mixed economic activity area in which the establishment is located.	55	50	45
II	Housing zones, communal and rural housing zones, except I	50	45	40
III	Agricultural, forestry, green and natural areas, parks, except I	50	45	40
IV	Areas for leisure, public services and community facilities	55	50	45

Table IV-20: Limit values for noise levels that may be applied under special conditions relating to an existing establishment that was the subject of an operating permit before the entry into force of this Order.

Immission zone (area where measurements are taken)		Limit values (dBA) per Period		
		Day 7am-7pm	Transition 6-7am and 7-10pm 6am-10pm Sundays and public holidays	Night 22h-6h
I	All areas, where the measurement point is located less than 500 m from the extraction area, extraction outbuildings, industrial economic activity or specific economic activity, or less than 200 m from the mixed economic activity area in which the establishment is located.	60	55	50
II	Housing zones, communal and rural housing zones, except I	55	50	45
III	Agricultural, forestry, green and natural areas, parks, except I	55	50	45
IV	Areas for leisure, public services and community facilities	60	55	50

According to Article 19, "the limits are applicable to the specific noise assessment level of the establishment and must be complied with for any one-hour observation interval in the reference period considerated". The noisiest hour is therefore taken into account.

The limit values apply according to the zones in the Sector Plan (Art 21):

- At all points in residential and rural residential areas,
- In agricultural, forestry, green space, natural, park, leisure, public service and community facility zones, the limits are respected within a perimeter of four metres around inhabited premises, validly authorised on the date of the permit or declaration,
- The limit values do not apply within economic activity zones, extraction areas or industrial development zones.

It should be remembered that Article 17 of the Order specifies that noise from vehicle traffic entering and leaving the site is not included in the assessment of specific noise.

5.1.5 Project location in Sector Plan and applicable noise limits

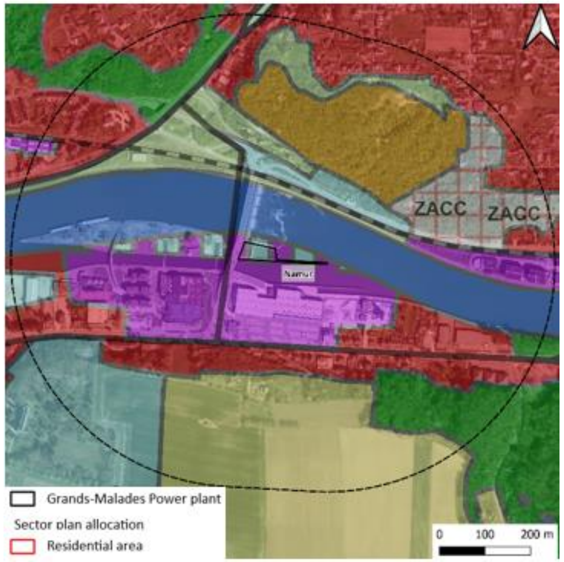
As mentioned above, the limit values to be respected depend on the location of the site on the sector plan. In order to determine the limit values applicable to each hydroelectric power plant concerned by the present study, these have been located on the sector plan (see Table below).

A priori, as these are existing establishments (authorized to operate before the AGW came into force), the noise limits applicable are those in Table 2 of the Walloon Government Decree of July 4, 2002 laying down the general operating conditions for establishments covered by the Decree of March 11, 1999 on environmental permits. An exception is made for the Monsin power plant, whose class 1 permit refers to table 1 of the above-mentioned decree.

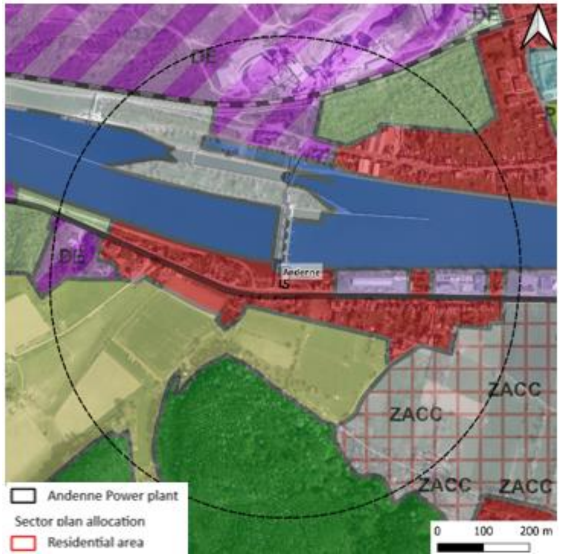
The sector plan allocations, immission zones and limit values applicable to each plant are shown in the table below. For plants located in Zone I, the specific noise limit values to be complied with in residential areas depend on their distance from the industrial zone. This is specified in the table below.

Table IV-21: Limit values applicable to each plant

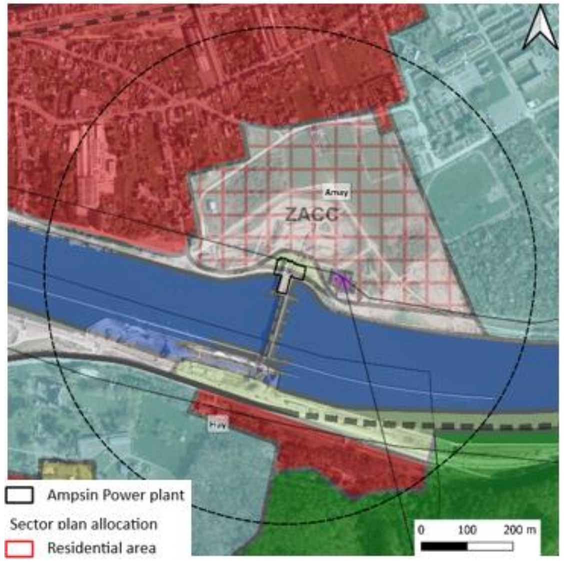
Central	Sector plan allocation	Zone	Distance from residents to the industrial estate	Limit values (dBA) per Period		
				Day 7am-7pm	Transition 6-7h and 19-22h	Night 22h-6h
Grand-Malades	Public services and community facilities Industrial economic activity	I	< 500 m	60	55	50
			> 500 m	55	50	45
Andenne	Residential habitat	II	-	55	50	45
Ampsin-Neuville	Green spaces	III		55	50	45
Ivoz-Ramet	Industrial economic activity	I	< 500 m	60	55	50
			> 500 m	55	50	45
Monsin	Industrial economic activity	I	< 500 m	55	50	45
			> 500 m	50	45	40
Lixhe	Lake	-	-	-	-	-



Grand-Malades

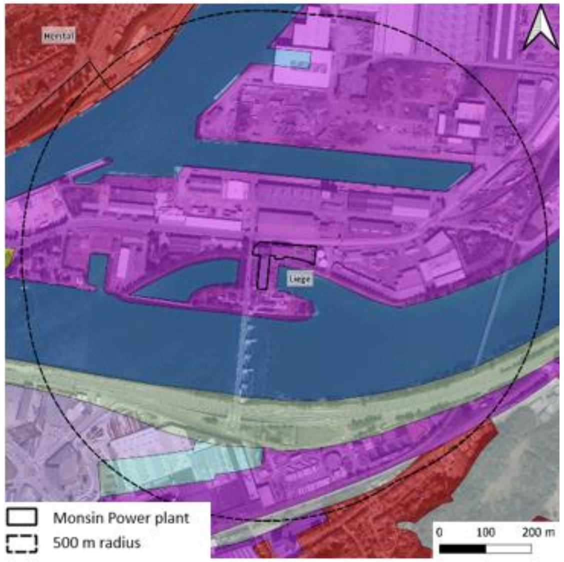


Andenne

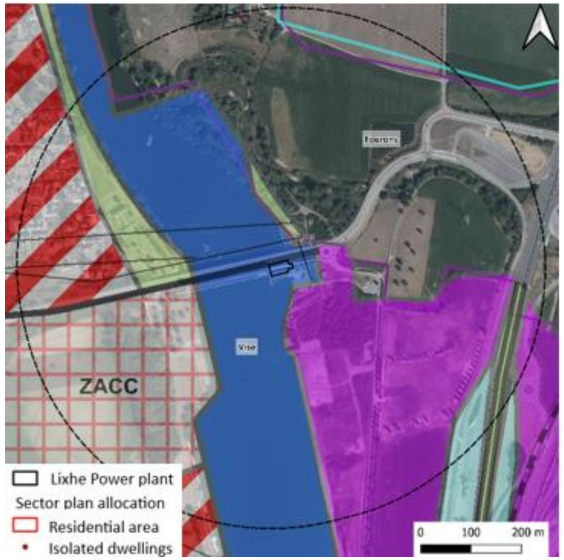


Ampsin-Neuville

Ivoz-Ramet



Monsin



Lixhe

5.2 DESCRIPTION OF THE LOCAL ENVIRONMENT

Under European Directive 2002/49/EC relating to the assessment and management of environmental noise with a view to preventing and reducing exposure to noise, an approach common to all Member States has been defined.

This directive defines environmental noise as unwanted or harmful external sound resulting from human activities, including noise emitted by means of transport, road, rail or air traffic and from industrial activity sites.

In line with this directive, Wallonia periodically draws up noise maps showing the main sources of traffic-related noise.

The following figure shows a map produced by the Walloon region showing the propagation of sound waves from the road network. It represents the index L_{den}wich corresponds to an average noise level over a 24-hour observation period. To take account of the more disturbing nature of noise in the evening (7pm - 11pm) and at night (11pm - 7am), penalties of 5 dB(A) and 10 dB(A) are added to these periods respectively.

Similarly, the L_{night} index, representing the average noise level at night, is mapped.

There are two important points to note about these maps:

- They only show an average level for long periods;
- They do not distinguish between weekday and weekend noise levels, which are different.

From the table and figures below, it can be seen that, generally speaking, residents living near power plants are affected by motorway traffic. It should be noted that the map showing the location of the Monsin power plant appears to be incomplete. There is a gap in the data along the E25 motorway at the Monsin dam bridge. Given the size of the road and the data mapped in the vicinity of the area in question, it can be expected that the isolated dwelling and part of the residential area to the south of the bridge will also be affected by noise pollution caused by the cars.

Table IV-22: Lden and Lnight noise levels at the power plants

Central	Sector plan allocation	Low and high values (dBA)	
		Lden	Lnight
Grand-Malades	Public services and community facilities Industrial economic activity	-	55 - 59
Andenne	Residential area	55 - 74	50 - 64
Ampsin-Neuville	Green spaces	55 - 59	-
Ivoz-Ramet	Industrial economic activity	55 - 74	50 - 64
Monsin	Industrial economic activity	n.d.	n.d.
Lixhe	Lake	-	55-59

Lastly, acoustic studies have been carried out at the Ivoz-Ramet (2011) and Monsin (2013) power plants as part of the environmental impact assessments (EIA) attached to the permit applications.

The conclusions of the acoustic study carried out at the Ivoz-Ramet hydroelectric power plant are as follows (extract from the non-technical summary of the 2011 EIS):

"A short-term acoustic measurement (15 minutes) showed that the hydroelectric power plant is inaudible in front of the residents and that the residents are subject to heavy road traffic with an equivalent noise level measured at around 65 dB(A), i.e. 5 dB(A) more than the regulatory limit value applicable during the day.

Based on the observations made on site, and even if the specific noise level of the activity could not be established due to its inaudibility, it is possible to state that the current operation of the Ivoz-Ramet hydroelectric power plant does not involve exceeding the limit values in force and does not generate any nuisance for the neighbourhood in acoustic terms".

With regard to the Monsin site, given the geographical proximity of the thermal power plant and the Luminus hydroelectric power plant, the acoustic study covered both plants. It should be noted that the thermal power plant has since been shut down, in 2015. The conclusions of the study are as follows (extracts from the non-technical summary of the 2013 EIA):

"Short-term measurements enabled the project manager to observe that the hydroelectric and thermal power plants are not audible in front of the residents (CD2 and CD4). The latter are subject to heavy road traffic, with an equivalent noise level LAeq measured at 67.5 to 74 dB(A) during the day and 66 to 68.5 dB(A) at night, i.e. 7 to 14 dB(A) more than the regulatory limit value applicable during the day and 16 to 18 dB(A) more than the limit value at night.

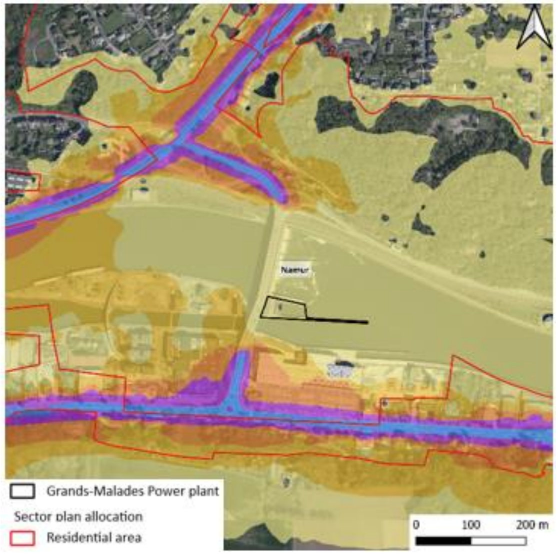
[...]

These measurements were also used to estimate the noise generated by the power plants in the area of the first potential resident (300 m):

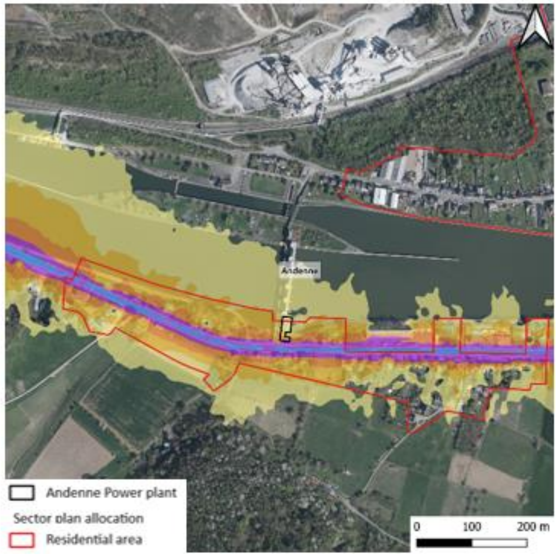
- *CHM: the specific noise level is estimated at 39.8 dB(A) ;*
- *TG2: the specific noise level is estimated at 35.8 dB(A) ;*
- *CHM + TG2: the cumulative specific noise level is estimated at 41.2 dB(A).*

[...]

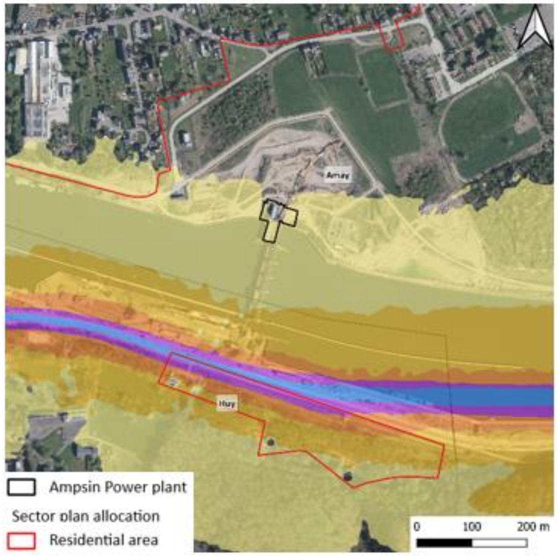
In conclusion, on the basis of the measurements and observations made on site, it can be stated that the current operation of the Ile Monsin hydroelectric and thermal power plants does not exceed the limit values in force and does not cause any nuisance to the neighbourhood in terms of noise.



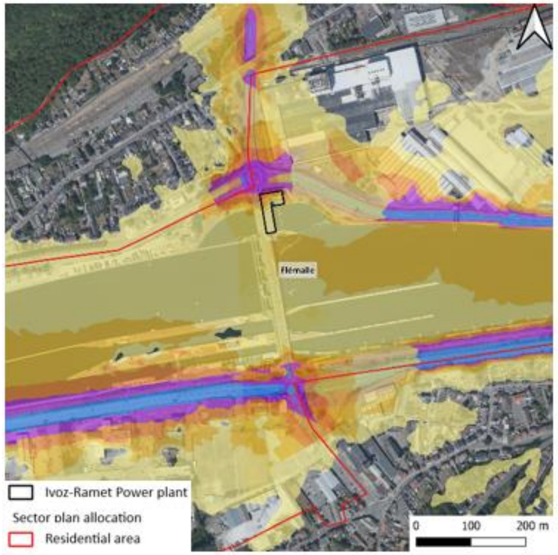
Grand-Malades



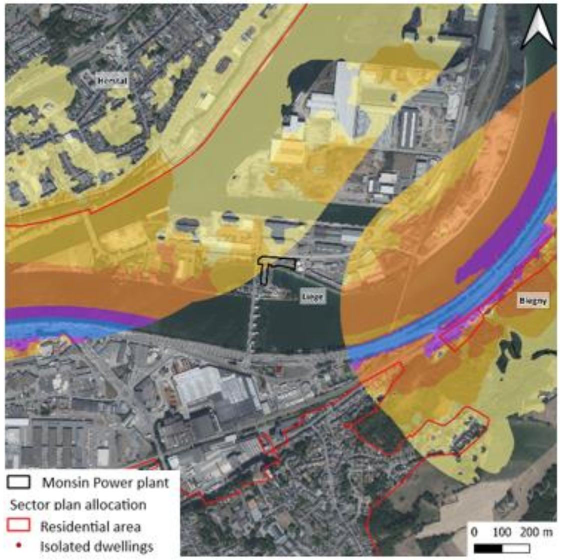
Andenne



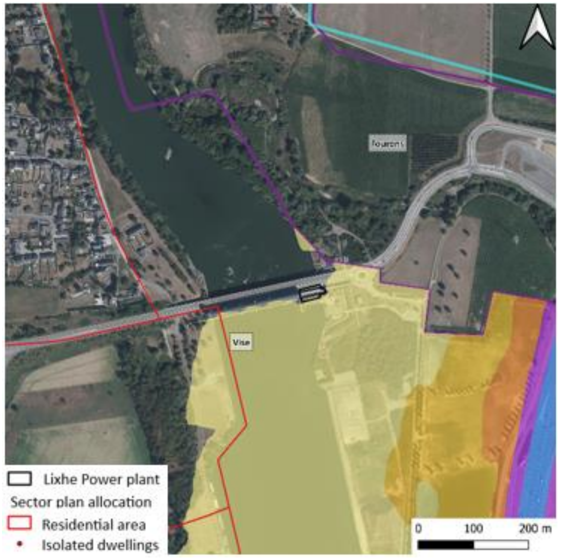
Ampsin-Neuville



Ivoz-Ramet

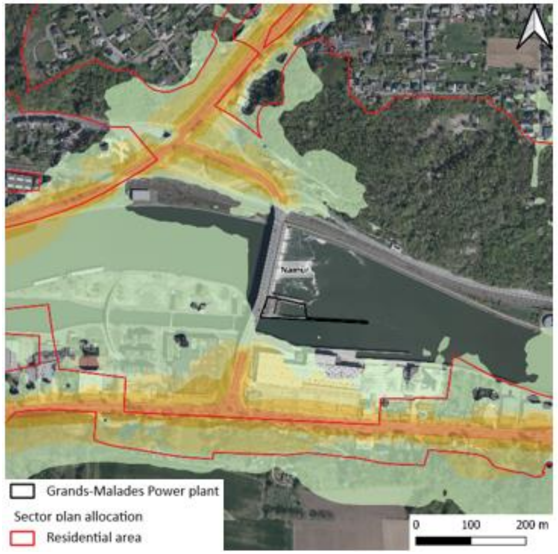


Monsin

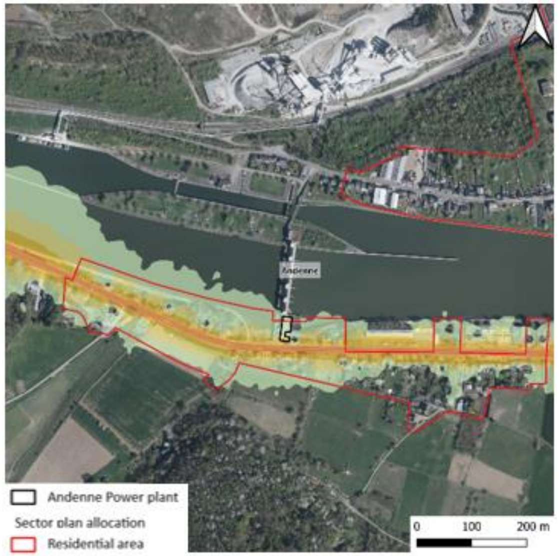


Lixhe

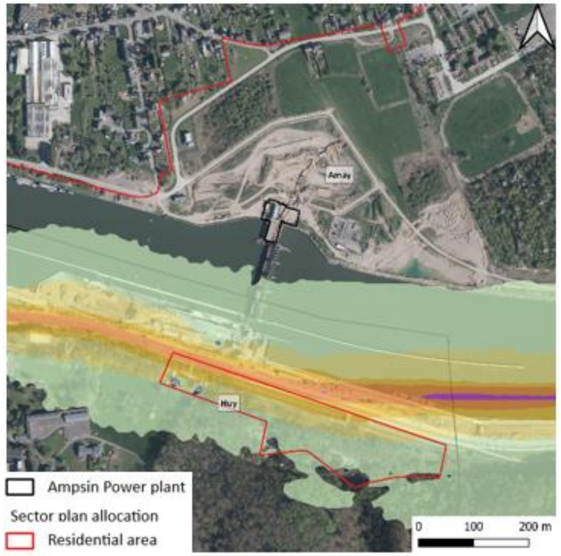
Figure IV-25: L_den map produced by the Walloon Region



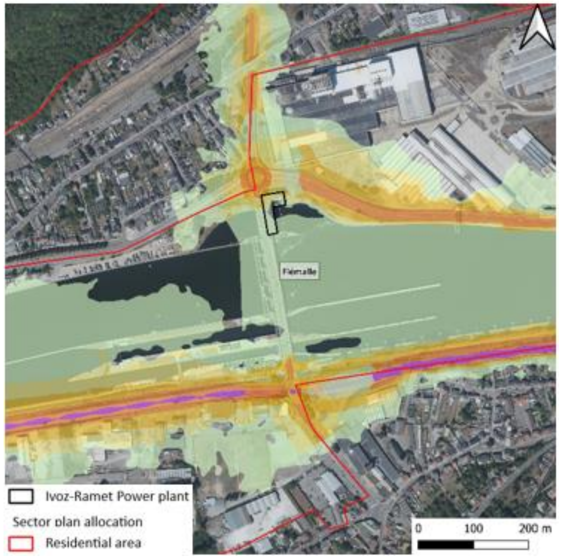
Grand-Malades



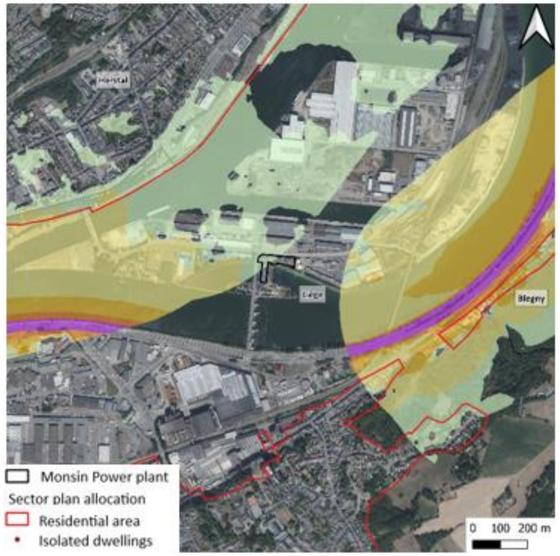
Andenne



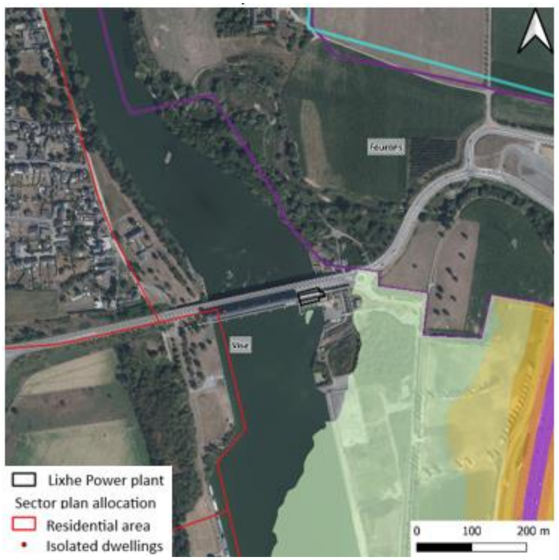
Ampsin-Neuville



Ivoz-Ramet



Monsin



Lixhe

Figure IV-26: L_night map produced by the Walloon Region

5.3 IMPACT ASSESSMENT

As a reminder, this study aims to implement 4 types of test measures at 6 power plants, as shown in the table below.

Table IV-23: Measures tested per power plant

Hydroelectric power plants	Measures tested			
	Turbine management + forecasting model	Managing water levels	Bubble barrier	Electric barrier
Grands Malades (CHG)	X	X*		X
Andenne (CHA)				
Ampsin (CHN)	X			X**
Ivoz-Ramet (CHR)	X	X	X	
Monsin (CHM)	X	X		
Lixhe (CHL)		X*		

* Existing measures required by permits.
** Implemented following initial positive results at CHG

5.3.1 Turbine management

This measure consists of implementing turbine-specific rules defined on the basis of eco-hydraulic migration models, which are equivalent to turbine shutdowns controlled by a downstream migration model. This measure has been implemented at the **Grands Malades**, **Ampsin**, **Ivoz-Ramet** and **Monsin** power plants.

It therefore only involves differentiated turbine management, taking into account a biological factor, which constitutes an additional operating constraint for the power plant. This measure does not involve the installation of any additional infrastructure or equipment. No additional nuisance compared to normal power plant operation is therefore expected with the implementation of this measure as far as noise levels are concerned. Only the turbining periods will be modified. Depending on certain factors (flow of the Meuse and certain flow gradients) during migration periods (from late August to February for eels and from March to June for salmon), an alarm is triggered and the turbines are shut down. As a result, the periods of potential noise pollution from the operation of the power plants are therefore reduced throughout the year.

In view of the above, no aggravating additional nuisance, in terms of noise level or time period, is expected in relation to normal power plant operation.

Finally, it should be noted that no noise-related complaints from local residents have been recorded at the two hydroelectric power plants targeted by this measure (Grands Malades, Ampsin, Ivoz-Ramet and Monsin).

5.3.2 Managing water levels

This solution consists of maintaining a certain height of water in a sluice to increase its attractiveness to the hydroelectric power plant and prevent fish from passing through the turbines. This measure was implemented at the Grands-Malades and Lixhe power plants, in accordance with their respective permits. At both sites, a 20 cm high water level is maintained at all times. During the smolt outflow period, in addition to turbine management, the water level is increased to 50 cm at the **Lixhe** and **Monsin** power plants. However, the water level is not modified at the Grands-Malades power plant during the downstream migration, as there is an outlet.

This measure does not involve the installation of infrastructure or equipment that could cause noise pollution. The acoustic impact of this measure is therefore considered non-existent.

5.3.3 Bubble barrier

The principle of the bubble barrier is to create curtains of submerged air bubbles forming a linear barrier used to control fish movements and direct them away from the hydroelectric power plant. The system consists of a perforated pipe positioned at the bottom of the watercourse and a compressor that injects compressed air into the pipe to form the air bubbles.

This system was tested at the **Ivoz-Ramet** hydroelectric power plant and is no longer in operation due to the inefficiency of the system.

The acoustic impact of this measure mainly concerns compressor operation. It is considered that the potential noise produced by the bursting of bubbles on the surface is low and covered by the noise of the water eddies in the vicinity of the plant.

To estimate the noise nuisance for local residents, a free-field noise propagation calculation was carried out using the formula below.

Free-field noise propagation calculation formula :

$$Lp(d) = Lw + 10log(\frac{Q}{4\pi d^2})$$

Lp(d) : Resulting sound level at a distance d (in meters) from the noise source in dBA
Lw : Sound power level in dBA
Q : Source directivity (Q=2)

Considering a sound source of 70 dBA (for a 45 kW compressor) and a distance of 70 m (estimated distance between the power plant and the nearest resident), according to the above formula, the sound level at home would be 25.1 dBA. As an indication, this sound level would be perceived as a silent environment, as shown in Table IV-21.

As a reminder, in accordance with the Walloon Government Decree of July 4, 2002 laying down the general operating conditions for establishments covered by the Decree of March 11, 1999 on environmental permits, the standards set out in the table below must be complied with.

Central	Sector plan allocation	Zone	Distance from residents to the industrial estate	Limit values (dBA) per Period		
				Day 7am-7pm	Transition 6-7h and 19-22h	Night 22h-6h
Ivoz-Ramet	Industrial economic activity	I	< 500 m	60	55	50
			> 500 m	55	50	45

It is not possible to determine whether the above standards are met in the vicinity of residents without noise measurements during the power plant's operation.

As a reminder, the acoustic study carried out in 2011 when the power plant's permit was renewed concluded that "*the hydroelectric power plant is inaudible in front of local residents and that local residents are subject to heavy road traffic with a measured equivalent noise level of around 65 dB(A), i.e. 5 dB(A) more than the regulatory limit value applicable during the day".* This is confirmed by the noise maps for road transport in Wallonia, which show that the plant is located in an area where night-time noise (L_{night}) varies between 50 and 64 dB(A). Assuming a noise level of 65 dB(A) at the nearest resident and adding the 25.1 dB(A) generated by the compressor, this equates to 65 dB(A). There is therefore no aggravating situation linked to the compressor operation.

It should be noted that the Ivoz-Ramet power plant is located within an economic activity zone in the sector plan and is separated from residential areas by a road network (crossing of the N617 and N667 main roads via a roundabout). According to the Walloon region maps showing the propagation of sound waves from the road network presented above, these residential areas are affected by noise generated by road transport.

In addition, the compressor has been installed inside an enclosed building. Since the calculation of noise levels in the vicinity of residents was based on the assumption of free-field noise propagation (maximalist hypothesis), the actual noise level is lower, since there are obstacles (building walls, road, etc.).

In addition, the barrier, and therefore the compressor, will only be activated during eel and salmon migration periods.

Finally, no noise complaints have been recorded since the start of operations at any of the plants.

In view of the above, it is considered that the additional noise generated by the compressor operation is not likely to significantly worsen the noise environment for local residents. In addition, and as a reminder, the system has been shut down due to its lack of performance.

5.3.4 Electric barrier

The barrier consists of two immersed chains forming two parallel lines to which an electric cable and electrodes are attached; these are negative and positive in order to create an electric field and modify the trajectory of the individuals. This type of barrier has been tested at the **Grands-Malades** and **Ampsin** power plants and is in operation during migration periods (from late August to February for eels and from March to June for salmon).

The installation of such a barrier requires the installation of an electrical panel. Such equipment does not generate any perceptible noise pollution. It is therefore considered that this measure will not cause any additional nuisance compared with the normal operation of the plant.

Finally, it should be remembered that the electric barrier installed for the smolts was combined with the installation of an outlet due to the high concentration of salmon found in this area of the power plant. The outlet is located approximately 2 m above the level of the Meuse (which varies according to the water level in the Meuse). The waterfall created by this difference in height can generate noise pollution. The higher the head, the greater the acoustic impact. However, it is estimated in this study that the potential noise generated by this waterfall is relatively low and is covered by the noise of the water eddies in the vicinity of the power plant.

6. AIR AND ENERGY

6.1 INTRODUCTION

6.1.1 Difficulties encountered

None.

6.1.2 Detailed impact assessment methodology

The purpose of the Air and Energy chapter is to assess the project's impact on air and on the production and distribution of electricity.

In terms of energy, after a theoretical presentation of the existing situation in the Walloon Region, and the integration of hydroelectric power plants into the energy context, the Project Manager presents an assessment of the energy consumption of the planned measures.

To assess the impact of the project, the consultant will carry out quantitative and qualitative assessments of the electricity production and loss of producibility induced by the implementation of the various measures.

In view of the measures taken for downstream fish at the various power plants, no atmospheric emissions are generated. These measures do not involve the use of installations that emit combustion gases, dust or other pollutants. Consequently, the characterization of the ambient air in the existing situation will not be presented in the first part of this chapter, and the environmental impacts in terms of atmospheric emissions will not be assessed as they do not exist.

6.2 ANALYSIS OF THE EXISTING SITUATION

6.2.1 Walloon energy context

According to the IWEPS, Wallonia's total final energy consumption (including non-energy uses) will reach 123.4 TWh in 2020, a fall of 4.8% on the previous year (-13.5% on 2010)[19] .

On February 19, 2014, a climate decree setting targets for reducing greenhouse gas emissions by 2030 and then 2050 in Wallonia was adopted. In order to implement this decree and gradually achieve the targets set for reducing greenhouse gas emissions and ambient air quality, a Plan Air Climat Energie (PACE) is drawn up every 5 years by the Walloon Government.

The first Air Climate Energy Plan draft was adopted in 2016 and covered the period up to 2022 (PACE 2016-2022). The PACE 2021-2030 was adopted by the Walloon Government on April 4, 2019, and the final Walloon contribution to Belgium's National Energy Climate Plan was approved by the Walloon Government on November, 28 2019.

The PACE has been updated to take account of the European Commission's recommendations. The updated PACE was adopted on first reading by the Walloon Government on December 16, 2022 and is currently being put out to stakeholder consultation with a view to final adoption in March 2023.

The plan includes 255 actions covering 10 themes, the aim being to mobilize all sectors and areas of society by anticipating and planning the necessary transformations, informing all players of the deadlines, supporting businesses and households and investing in sustainable alternatives. The themes are as follows:

- Moving away from fossil fuels;
- Massive deployment of renewable energies;
- Improving access to energy and supporting the energy transition;
- Accelerating and massifying building renovation;

[19]https://www.iweps.be/indicateur-statistique/consommation-denergie-secteur-vecteur/#:~:text=The%20total%20consumption%20of%C3%A9energy,%25%20by%20report%20%C3%A0%202010).

- Improving the energy and climate transition of businesses and industries;
- Ensuring the sustainability of agriculture, soils and forests;
- Transforming territories and mobility;
- Ensuring the acceptability of CAPC measures ;
- Supporting local energy and climate policy;
- Improving air quality.

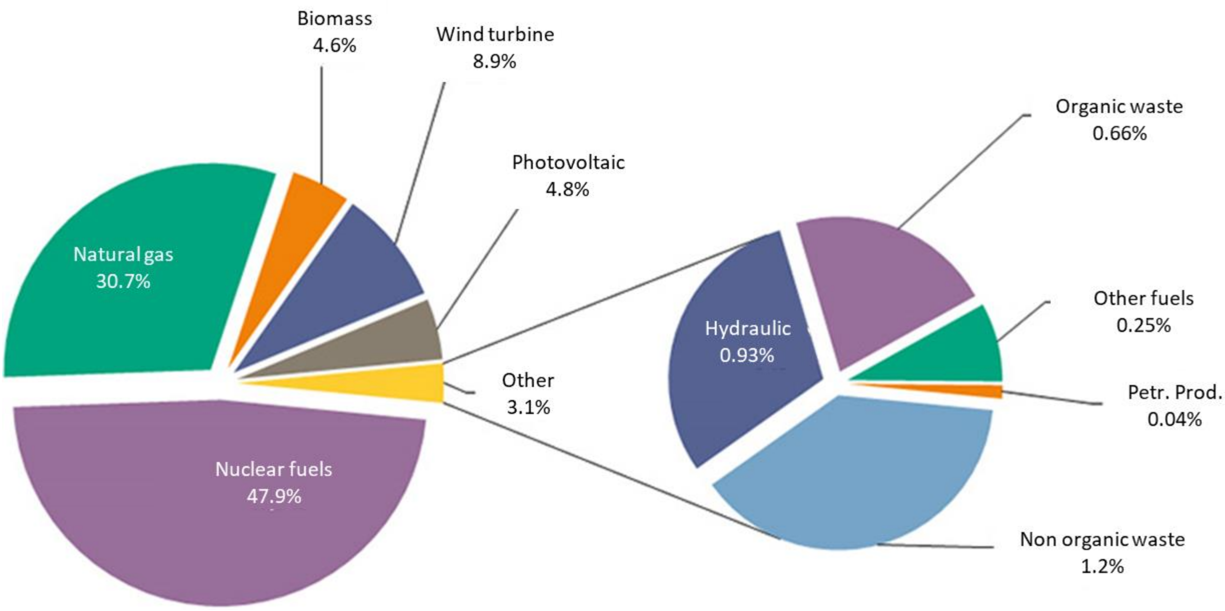
Renewable energies (wind, solar, hydroelectric, marine, geothermal and biomass, as well as biofuels) are all alternatives to fossil fuels that help to reduce greenhouse gas emissions, by diversifying energy supplies and reducing dependence on fossil fuel markets.

In 2009, the EU set itself the target of increasing the share of renewable energy in its energy consumption to 20% by 2020 (Directive 2009/28/EC)[20] . In 2018, this target was raised to 32% by 2030 and, since July 2021, there have even been proposals to increase it to 40%. Following Russia's invasion of Ukraine and the resulting energy crisis, the EU agreed to rapidly reduce its dependence on Russian fossil fuels before 2030 by accelerating the transition to clean energy. The updated Renewable Energy Policy Framework for 2030 and beyond is currently being negotiated.

Belgium missed its 13% target for 2020, but is now investing in green energy with renewed vigour. Its new target: by 2030, 40-50% of its energy supply should come from renewable sources[21] .

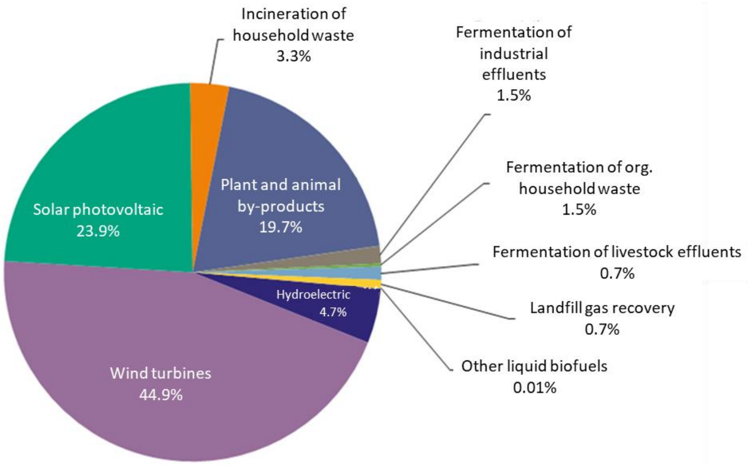
In 2020, net electricity production, i.e. useful electricity after consumption by plant auxiliaries and before self-consumption and/or grid connection, stood at 27.9 TWh in Wallonia (28.8 TWh including production by pumped storage plants), a drop of 17% compared with 2019.

In 2020, nuclear power alone, with a production of 13.4 TWh (-35% compared with 2019), provided 48% of Wallonia's electricity production (60%/2019). The other main source of electricity is natural gas, burned mainly in gas-steam turbine power plants (25.8%, +12%/2019).



Net renewable electricity production, which in 2020 will be 5,574 GWh (+4.7% on 2019 and double since 2010), accounts for 19.9% of total net electricity production, thanks to biomass, hydroelectricity, wind power and photovoltaics, with all sources progressing except hydro and biomass.

[20] https://www.europarl.europa.eu/factsheets/fr/sheet/70/energies-renouvelables
[21] https://lumiworld.luminus.be/fr/up-to-date-fr/comment-fonctionne-une-centrale-hydroelectrique/



6.2.2 Position of hydroelectric power plants

Hydropower is the world's third largest source of electricity production (16%), behind coal (41%) and gas (21%)[22]. It is the largest renewable electricity sector in the EU and already contributes for 40% of all renewable electricity production in Europe[23]. It can contribute to achieving the Energy Union's objectives, in particular to provide 20% of final energy consumption from renewable sources by 2020 and at least 27% by 2030.[23].

Belgium currently has 135 hydroelectric power plants, 118 of which are located in Wallonia, supplying energy to hundreds of thousands of people every day[21]. Annual electricity production by hydroelectric power plants varies from year to year and depends on rainfall. The graph below shows this production variability from 2009 to 2022 for Wallonia[24].

The 7 Luminus hydroelectric power plants supply some 60,000 Belgian households with green electricity. They produce around 227 GWh of electricity every year (ten-year reference), and their operation saves 101,250 tonnes of CO2 every year.[21].

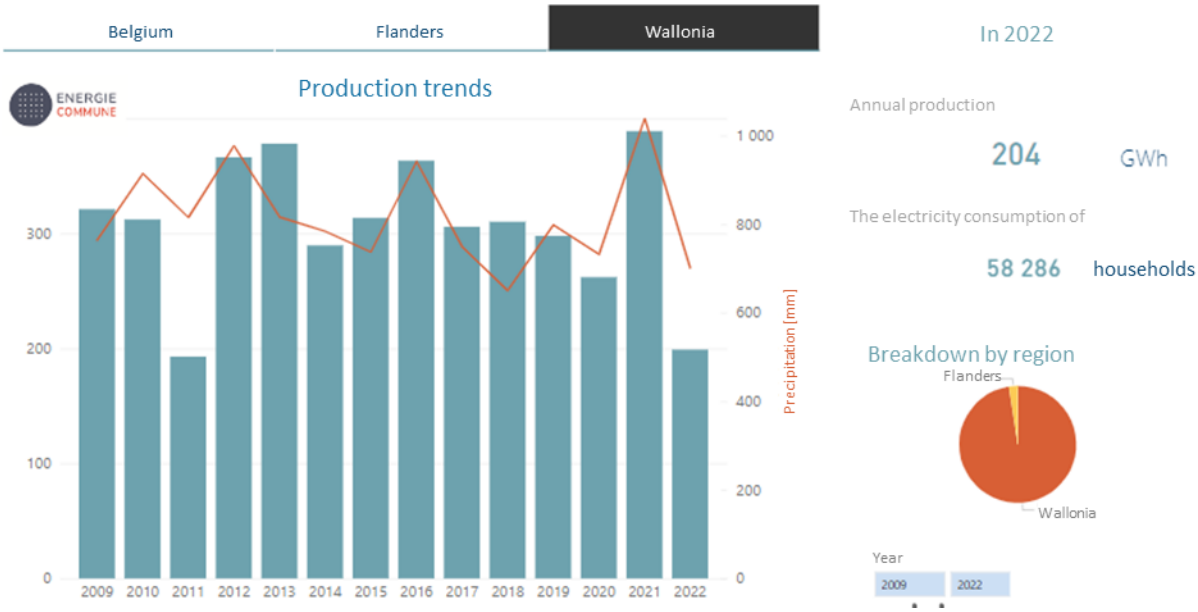


Figure IV-27: Electricity production by Walloon hydroelectric power plants from 2009 to 2022

[22] https://www.ern.org/fr/hydroelectricite/
[23] https://ec.europa.eu/commission/presscorner/detail/fr/IP_19_1477
[24] https://energiecommune.be/statistique/observatoire-hydroelectricite/

Let's compare three types of energy in terms of their production based on hours of operation and power. We'll take the case of a wind turbine, a nuclear reactor and a hydroelectric power plant[25] :

Power generation plant	Equivalent hours of operation at full power (avg/year)	Installed power	Productible = Average production	Equivalent number of wind turbines
Wind turbine (1 wind turbine)	2000 hours/year	2 MW	4 GWh	1
Nuclear (1 reactor)	7000 hours/year	1000 MW	7000 GWh	1790
Small run-of-river hydropower plant	4000 hours/year	2 MW	8 GWh	2
Large lake power plant	2000 hours/year	226 MW	300 GWh	75

An onshore wind turbine operates for around 2,000 hours a year with a rated output of 2 MW. It would therefore take 1,750 wind turbines to produce the average output of a nuclear reactor, and 75 wind turbines to produce the average output of a lake power plant[26]. On the other hand, there is little difference in production between a wind turbine and a small run-of-river hydroelectric power plant.

Luminus classifies hydroelectric power plants into 4 power levels:

- **Large power plants with a** capacity of more than 10 MW ;
- **Small power plants with an** output of less than 10 MW;
- **Mini-power plants with a** capacity of less than 1 MW ;
- **Micro-power plants with an** output of less than 100 kW.

The hydroelectric power plants operated by Luminus in Wallonia are either large (Monsin - 20 MW and Lixhe - 16 MW) or small (Grands-Malades - 5 MW, Andenne - 7 MW, Ampsin - 10 MW and Ivoz-Ramet - 10 MW). In terms of capacity and deliverability, we are therefore a long way from the "large lake power plant" considered in the table above, but rather a "small power plant".

6.2.3 Hydroelectric generation

The average annual output of each power plant is shown in the table below.

Table IV-24: Installed capacity and average annual output of power plants

Central stations	Installed capacity	Average electricity production
Grands Malades (CHG)	5 MWe	22 GWh/year
Andenne (CHA)	7 MWe	33 GWh/year
Ampsin (CHN)	10 MWe	35 GWh/year
Ivoz-Ramet (CHR)	10 MWe	39 GWh/year
Monsin (CHM)	20 MWe	60 GWh/year
Lixhe (CHL)	16 MWe	63 GWh/year

[25] L'hydroélectricité, Mieux comprendre les enjeux et les impacts sur les cours d'eaux, France Nature Environnement, 2019

[26] Lake power plant: pumped storage power plant

The annual electricity production of the six Luminus hydroelectric power plants from 2011 to 2023 is shown in the figure below. From this graph, we can see that there is a certain annual variability in the amount of electricity produced by the different power plants. This is because deliverability depends on a number of factors, including environmental factors.

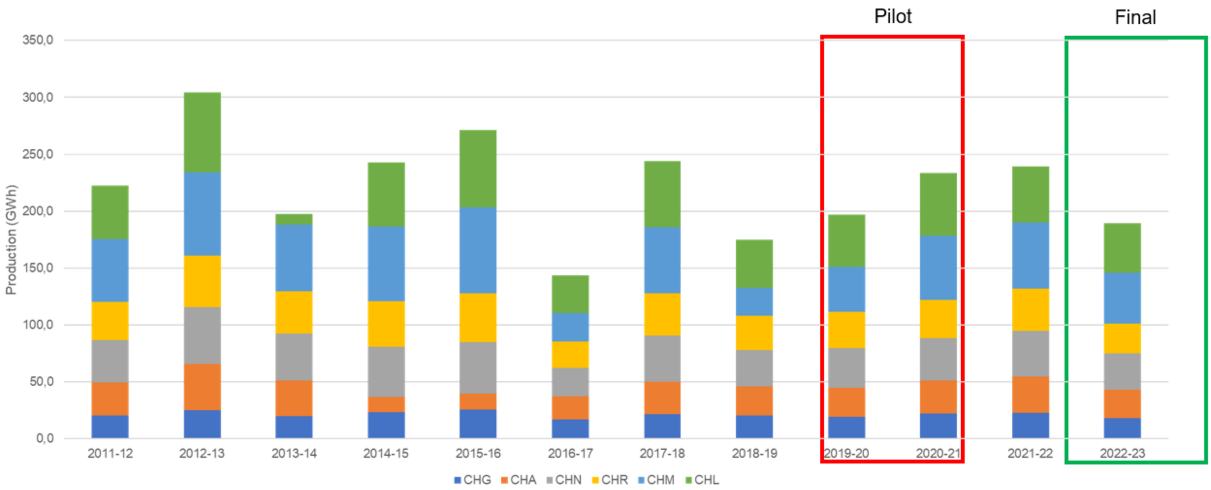


Figure IV-28: Annual electricity production at the six Luminus hydroelectric power plants from 2011 to 2023, taking into account losses in deliverability associated with the project

6.3 IMPACT ASSESSMENT

Among the measures taken, several sources of loss of producibility have been identified:

- Turbine management, which involves shutting down the turbines for a given period and therefore stopping electricity production;
- Water level management, which defines the flow of water to be turbined. The lower the water level, the lower the flow and the lower the amount of electricity generated;
- the installation of an outlet which also reduces the flow of water to be turbined;
- as well as, to a lesser extent, electricity consumption for the operation of electric barriers and bubble barriers (compressor).

The loss of producibility associated with the installation of an outlet has not been specifically measured by the Applicant. In the absence of figures, the consultant was unable to assess the impact of this measure on the deliverability of the hydroelectric plants.

Luminus has set a target of limiting the loss of electricity production to 5% for all 6 sites. Turbining must therefore be adapted to achieve this objective, which is in addition to the objectives of limiting the loss of salmon and eel individuals.

Average annual electricity production with the implementation of turbine management, assuming a maximum loss of cumulative producibility of 5% for all the sites concerned. The results obtained are presented in the table below.

Table IV-25: Estimated electricity production for each power plant with the measures in place

Central stations	Average electricity production	Loss of producibility	Electricity generation with L4F
Grands Malades (CHG)	22 GWh/year	5%	20.9 GWh/year
Andenne (CHA)	33 GWh/year		31.35 GWh/year
Ampsin (CHN)	35 GWh/year		33.25 GWh/year

Central stations	Average electricity production	Loss of producibility	Electricity generation with L4F
Ivoz-Ramet (CHR)	39 GWh/year		37.05 GWh/year
Monsin (CHM)	60 GWh/year		57 GWh/year
Lixhe (CHL)	63 GWh/year		59.85 GWh/year
TOTAL	**156 GWh/year**	-	**239.4 GWh/year**

The table shows that the setup of the measures would result in a maximum loss of 12.6 GWh/year.

6.3.1 Turbine management

As a reminder, this measure is being implemented at the **Grands-Malades, Ampsin, Ramet and Monsin** power plants.

According to Luminus data, the shutdown for downstream eels took place from 22/12/2022 10:00 to 25/12/2022 11:00. During this period, the 4 power plants mentioned above were shut down at the same time. This shutdown resulted in an estimated loss of 2.148 GWh of generating capacity, all plants combined. This represents a loss of approximately 1.5% of deliverable. It should be noted that, after analyzing the results, Luminus found that the general shutdown for the 4 power plants was not effective. The schedule will therefore have to be reviewed at a later date so that the sites can be shut down according to the number of individuals passing through each reach.

6.3.2 Water level management

With regard to salmon, as explained above, the methodological note recommends that the Monsin and Lixhe power plants be switched to "Fish Mode" from August 15 to May 31, and that a 50 cm spillway be opened in the channel closest to the Monsin and Lixhe power plants.

As recommended, the Monsin power plant was put into "Fish Mode", with the water level reduced to 50 cm on 22/03/2023 at 10:21 and to 20 cm on 09/05/2023 at 10:21. This operation resulted in an estimated loss of production of 1.393 GWh.

6.3.3 Bubble barrier

The loss of producibility linked to the installation of a bubble barrier is mainly due to the electricity consumption of the compressor used to create the air bubbles. As a reminder, this measure only concerns the **Ivoz-Ramet** hydroelectric power plant.

According to Luminus, this is a 55 kW compressor feeding a 3,000 l tank of compressed air at 11.5 bar. Assuming continuous operation during migration periods (from late August to February for eels and from March to June for salmon), i.e. the equivalent of 5,376 hours of operation, this would give an annual electricity consumption of around 296 MW. As a reminder, this measure had been implemented at the Ivoz-Ramet hydroelectric power plant and then withdrawn. Considering an average annual electricity production of 39 GWh for this power plant, the electricity consumption linked to the operation of the bubble barrier would represent around 0.76% of electricity production, which is negligible.

6.3.4 Electric barriers

The same logic can be applied to the electric barriers installed at the **Grands-Malades and Ampsin** hydroelectric power plants. According to the supplier, the energy consumption of a barrier varies between 500 and 700 kWh per month, depending on the conductivity of the water. If the water has a high conductivity, electricity consumption will also be higher; if the water has a low conductivity, electricity consumption will be lower. Assuming continuous operation of the electric barrier during migration periods, annual electricity consumption would be 8.4 MWh, equivalent to around 0.04% of annual electricity production at the Grands-Malades power plant, where the barrier is installed.

6.3.5 Conclusions

As the losses in producible following the implementation of the various Life4Fish measures have been estimated for each power plant concerned by these measures, it is now possible to determine the loss in producible for all the Luminus power plants (Table below). It should be noted that the loss of producible due to turbine management has been estimated for all the power plants and not for each power plant. An estimate of the loss of producibility linked to each power plant for this measure has been determined on a pro rata basis, according to their electricity production.

Table IV-26: Estimated losses in producibility with L4F measures at Luminus hydroelectric power plants

Central stations	Average electricity production	Unit	Loss of producibility				Electricity generation with L4F
			Turbine management	Water level	Bubble barrier	Electric barrier	
Grands Malades (CHG)	22	GWh/year	0,30	-	-	0,0084	**21,69**
Andenne (CHA)	33	GWh/year	-	-	-	-	**33,00**
Ampsin (CHN)	35	GWh/year	0,48	-	-	-	**34,52**
Ivoz-Ramet (CHR)	39	GWh/year	0,54	-	0,296	-	**38,17**
Monsin (CHM)	60	GWh/year	1,83	1,39	-	-	**57,78**
Lixhe (CHL)	63	GWh/year	-	n.d.	-	-	**63,00**
TOTAL	**252**	GWh/year	**2,148**	**1,39**	**0,296**	**0,0084**	**248,15**

According to this table, the implementation of Life4Fish measures would result in an estimated loss of 3.84 GWh/year. As a reminder, net electricity production in Wallonia in 2020 was 27.9 TWh, of which 0.93% was produced by hydroelectric power plants, equivalent to 259.47 GWh. Assuming a loss of producible electricity of 3.84 GWh from all Luminus power plants, this would represent a loss of 1.48% of hydroelectricity production and 0.013% of net electricity production in Wallonia from all sources combined. As a reminder, Luminus had set itself a maximum 5% loss of producibility, equivalent to 12.6 GWh. Based on this maximalist assumption, the loss in hydroelectricity production would be 4.86% and the loss in net electricity production in Wallonia to 0.0452%. Even considering the maximalist hypothesis of a 5% loss of producibility, it is considered that the loss of producibility engendered by the implementation of Life4Fish measures is insignificant on the scale of Wallonia and therefore of Belgium. Nevertheless, these measures are not likely to jeopardize the electricity supply of the various consumers.

V GENERAL CONCLUSIONS

Luminus and its partners (UNamur, Uliège, Profish technologies, EDF R&D) are involved in a project funded by the European Commission called "Life4Fish", which aims to implement and test various solutions to protect two species of migratory fish in the Meuse, the European eel and the Atlantic salmon during their downstream migration.

The solutions tested are :

- For eels
  - Turbine management using a predictive model ;
  - Installation of an electric barrier ;
  - Installation of a bubble barrier.
- For smolts
  - Turbine management using a predictive model ;
  - Installation of an electric barrier with an outlet, if necessary;
  - Installation of a bubble barrier ;
  - Management of water levels through a dedicated opening for smolt passage.

The impact assessment of the various solutions showed that there would be no negative impact on the physical environment, landscape and heritage, human beings, noise or air.

The evaluation also highlighted the effectiveness of the following solutions:

- Turbine management using a predictive model for both eels and salmon;
- Installation of an electric barrier for the downstream migration of eels;
- Installation of an outlet for the downstream migration of salmon (depending on the site) ;
- Increase in water level at one of the dam's openings.

The loss of producible power was difficult to assess due to the lack of figures for most of the measures implemented. However, if we assume that the implementation of the measures would result in a 5% loss of producibility for all the power plants (the target set by Luminus), this would represent a loss of 4.86% of hydroelectricity production and 0.0452% of net electricity production in Wallonia from all sources combined. It is therefore considered that the loss of producibility caused by the implementation of Life4Fish measures is insignificant on the scale of Wallonia and therefore of Belgium. However, these measures are not likely to jeopardize the electricity supply of the various consumers.

Five indicators were defined as part of the project, along with their objectives. These are shown in the table below.

	Objective	Initial situation	Final situation
Impact of the sites on eels	20%	20%	12,7%
Impact of the sites on salmon	10%	40,9%	22,5%
Green energy conserved	237.5 GWh	243.8 GWh	189.3 GWh
Turbine shutdown	900 h	0 h	446 h
Power plants equipped with a predictive model	6	0	5

In the light of the results, the solutions planned for the various sites are set out in the table below.

Hydroelectric power plants	Eels	Salmon
Grands Malades (CHG)	Electric barrier + predictive model with turbine management	Installation of an outlet
Andenne (CHA)	(if necessary)	-
Ampsin (CHN)	Predictive model with turbine management + electric barrier	Outfall managed by SPW (excluding Life project)
Ivoz-Ramet (CHR)	predictive model with turbine management	
Monsin (CHM)	Predictive model with turbine management + eco-sustainable turbines	50 cm water level during peak periods + eco-sustainable turbines
Lixhe (CHL)		20 cm blade then increased to 50 cm during peaks

LEXICON

CHA: Andenne hydroelectric power plant

CHG: Grands-Malades hydroelectric power plant

CHR: Monsin hydroelectric power plant

CHN: Ampsin-Neuville hydroelectric power plant

CHR: Ivoz-Ramet hydroelectric power plant

CSIS: underground cavity of scientific interest

RF: forest reserve

RNA: approved nature reserve

RND: national nature reserve

SGIB: site of great biological interest

ZHIB: wetland of biological interest