Description of a Test Case: Gotein

Saison - France

Authors: M. Dewitte[1], D. Courret[2], S. Tomanova[2], F. Lemkecher[1], L. Chatellier[1], L. David[1]

[1] Institut Pprime – CNRS – Université de Poitiers
[2] AFB - Pole Ecohydraulique AFB-IMFT, Toulouse

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Figure 1 and Figure 2 allow locating the HPP of Gotein at different scales.

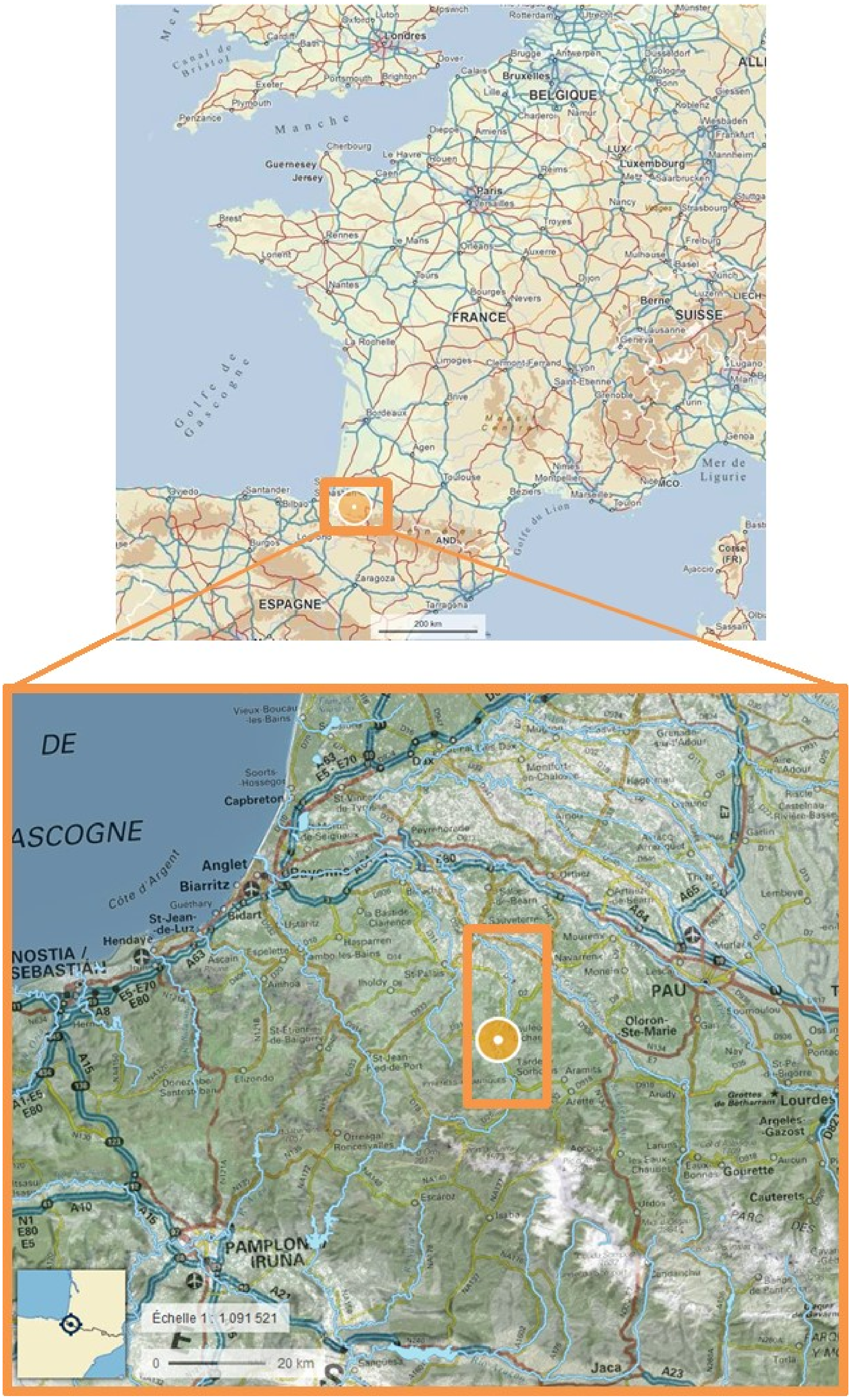


Figure 1: Location of the HPP of Gotein at national and regional scale

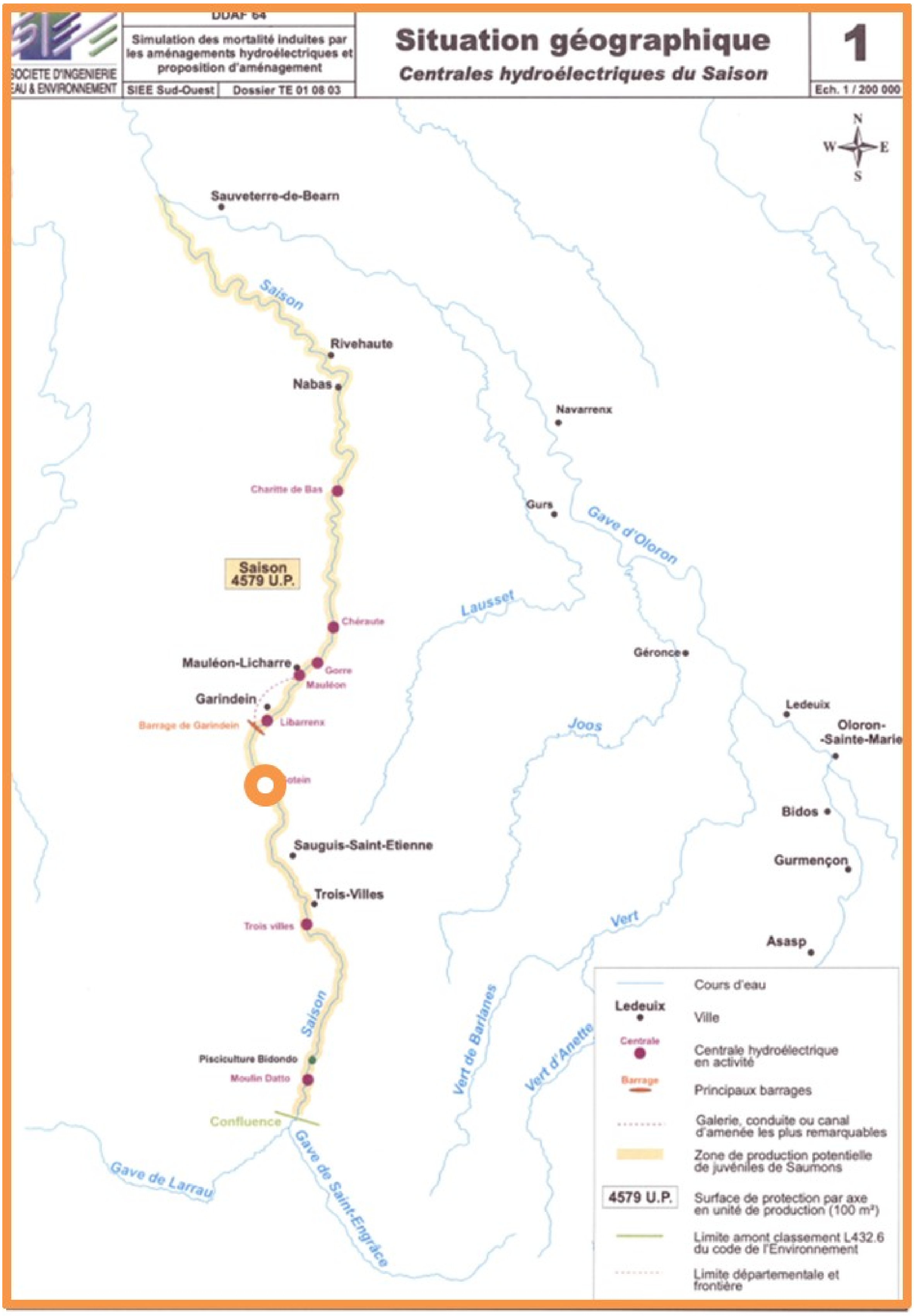


Figure 2: Location of Gotein at the scale of the river

1.1. Description of the water bodies related to the HPP

The HHP of Gotein is included in waterbody 262. Waterbody 262 (Saison) is connected with 3 other water bodies: 2 upstream 261 (Saison) and 434 (Gave de St Engrâce) and one downstream 263 (Saison)

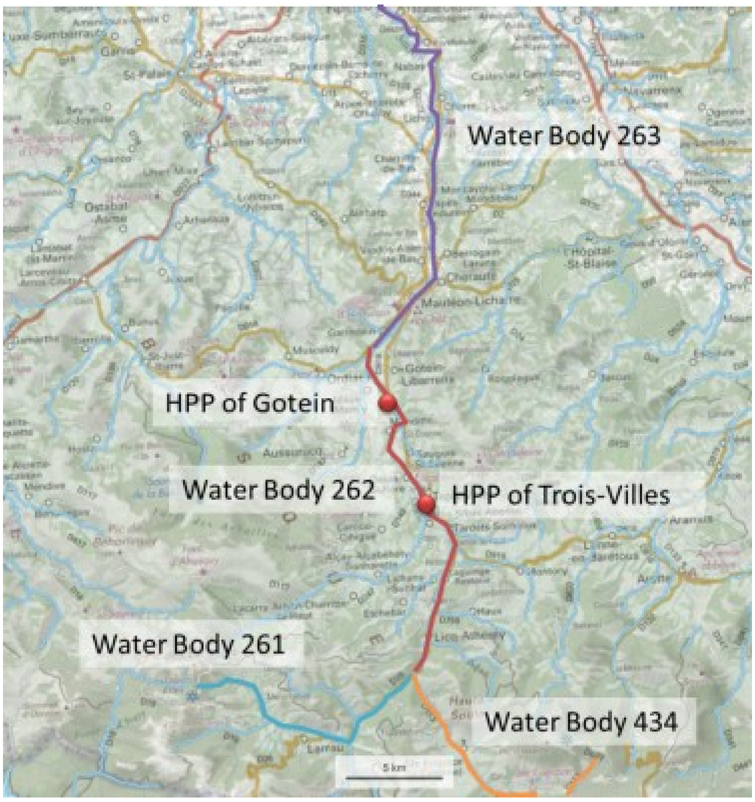


Figure 3: Water bodies related to the HPP of Gotein

1.1.1. Hydrology of the Saison at Mauléon-Licharre

The hydrology of the Saison is characterized by sustained flows in winter, high water levels in spring due to snow melting and low water period from August to October.

At Gotein the mean interannual discharge is estimated at 22.3 m^3/s.

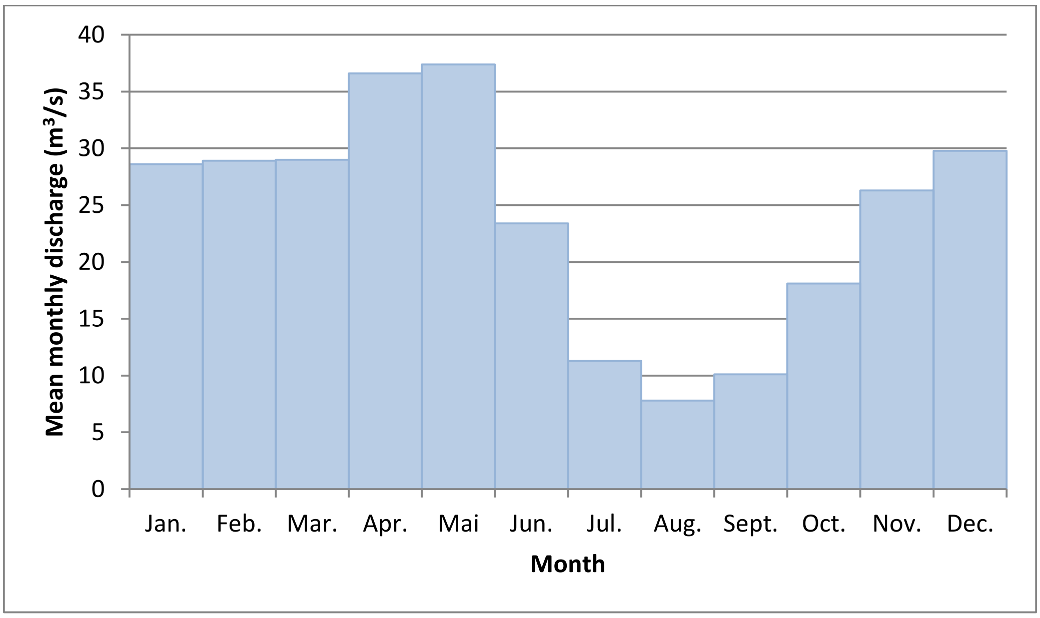


Figure 4: Mean monthly discharge of the Saison at Mauléon-Licharre (source: www.hydro.eaufrance.fr)

1.1.2. Main pressures

Several pressures are listed for the Saison near Gotein:

Table 1: Main pressures on the Saison

Water treatment plant effluents	no significant
Spillover of Stormwater overflows	no significant
Nitrogen derived from agriculture	no significant
Pesticides	no significant
Water supply	no significant
Continuity	Moderate due to the 3 HPPs
Hydrology	high due to hydropeaking management upstream
Morphology	minimal

A SDAGE (Schéma Directeur d'Aménagement et de Gestion des Eaux) is like a River Basin Management Plan and describes measures to be implemented. All the measures are not related to hydropower pressures.

Table 2: Measures to be implemented at the river basin scale of the Saison

Flow change	legislation: instream flow in bypassed reach since 2014: 1/10 from the minimum annual discharge
Fish migration measures	3 HPP: *Moulin Datto:* bar screen (bar clearance 2cm), fish ladder; *Bidondo's fish farming*: fish ladder; *Trois-Ville*: bar screen 2cm, fish ladder; *Gotein:* bar screen 2cm, fish ladder
Pollution control	implement a global study or a masterplan for reducing the pollution associated to industry, sanitation,

1.2. Fish Fauna of the Saison

General data on fish fauna in the Saison

The fish fauna of the Saison is composed of amphibiotic and holobiotic species.

The **amphibiotic species** identified are:

- The atlantic salmon (upstream migration mainly from Mai to November);
- The sea trout (upstream migration mainly from Mai to November);
- The eel (upstream migration from April to October and mainly from June to September);
- The shad (upstream migration from April to July);
- The sea lamprey (upstream migration from April to July);

The **holobiotic species** identified are:

- *Salmonidae* : brown trout (upstream migration mainly autumnal for the trout);
- *Cyprinidae*: bleak, barbell, common bream, roach, chub, dace…
- *Cobitidae*: stone loach…

The study of the production capacity in juveniles of salmon was realized during the 1980s by the Scientific council of fishery based on flow facies of Malavoi (1989), (S.I.E.E. & GHAAPPE, 2002). The habitats taken into account for the calculation were: riffles, rapids, runs, with a weighting coefficient of 1/5 for runs.

On this basis, the Saison have a production surface of 45.79 ha which corresponds to 22 439 eq. smolts.

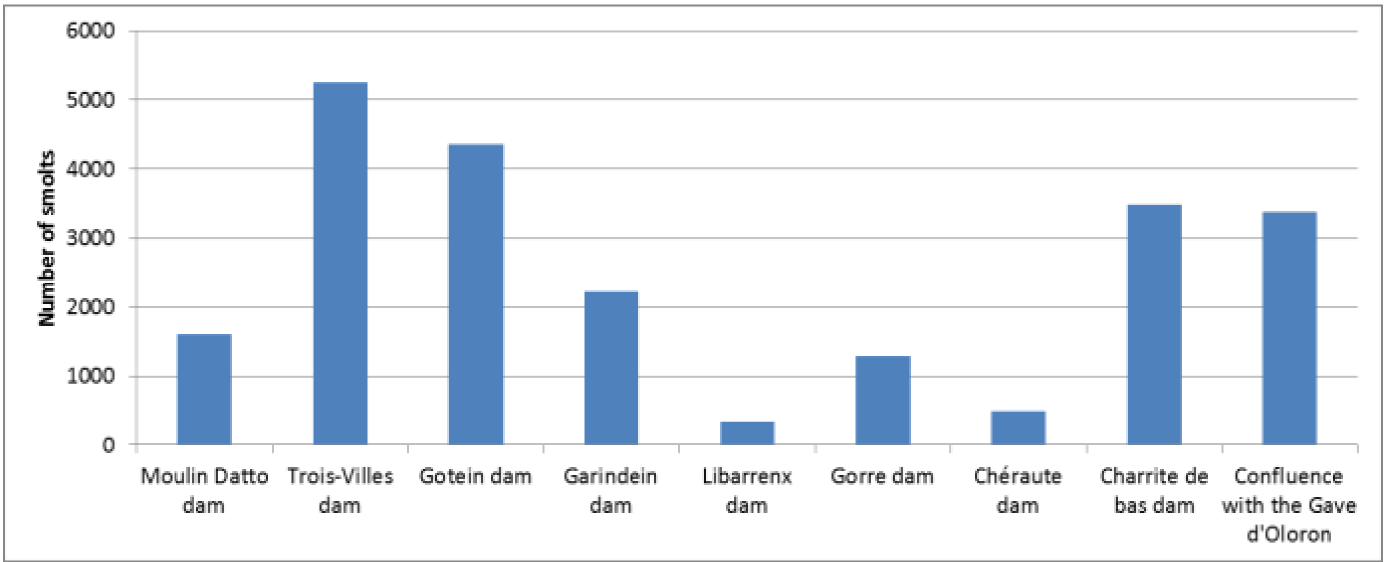


Figure 5: Potentialities between each facility (source : (S.I.E.E. & GHAAPPE, 2002))

In 2007, MIGRADOUR also published a study about potentiality of the Saison for the period 2002-2007. On its course, the Saison has a potential minimum production of 94 000 Atlantic salmons smolts and a potential maximum production of 135 000. These potential productions have been assessed thanks to a study on habitat availability.

In 2016, the mean production was around 60 150 Atlantic salmon smolts. The mean production is assessed thanks to control electrofishing on control station all along the river. These fishing allow calculating an abundance index per station; it corresponds to the number of smolts captured in 5 minutes. Then the density of smolts is calculated: the arithmetic average of the abundance index on the concerned station. Then the density is multiplied by the effective production area. This gives the production of smolts of a river stretch.

1.3. Presentation of the HPP

1.3.1. Main characteristic of the HPP of Gotein

Table 3: Main characteristics of the HPP of Gotein

Watercourse	Saison
Situation :	Commune de Gotein
Inter-annual discharge	22.3 m^3/s
Instream flow in the bypassed reach :	5 m^3/s
Function of the dam :	Hydropower
Length of headrace canal :	770 m
Length of bypass-reach:	2260 m
Maximum turbine discharge:	6.6 m^3/s
Species concerned :	Salmon, sea trout, lamprey, eel, brown trout
Capacity of HPP	0.32 MW

Figure 6: Upstream view of the HPP of Gotein

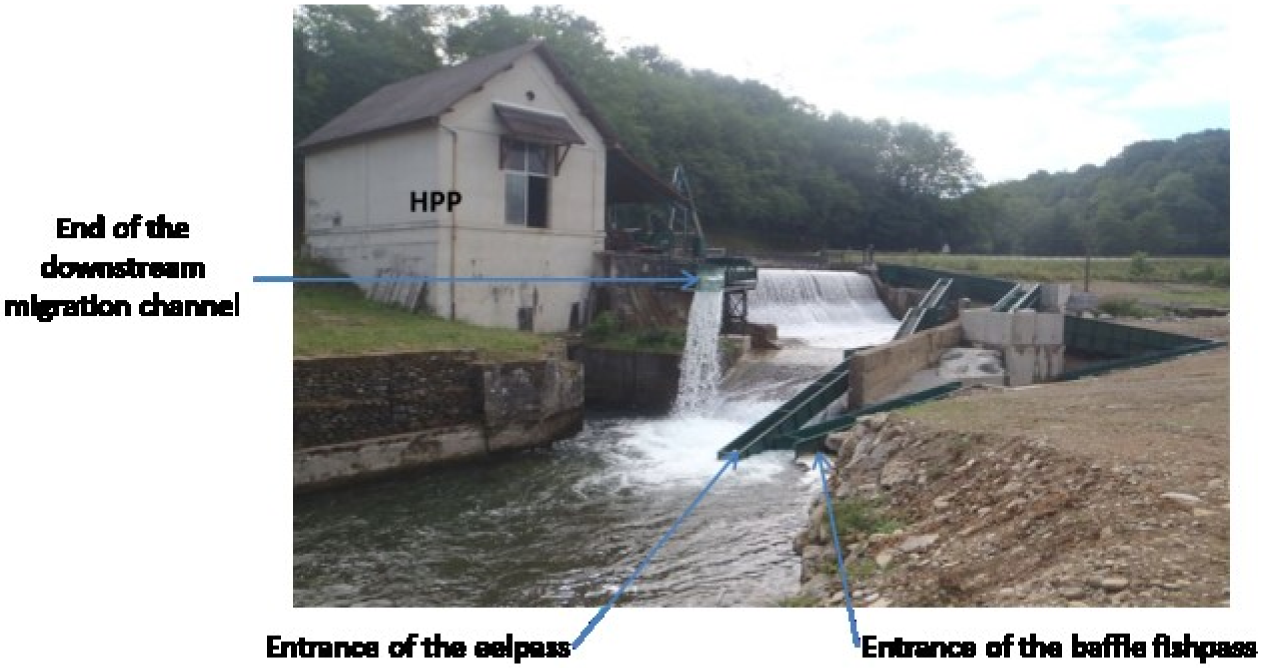


Figure 7: Downstream view of the HPP of Gotein

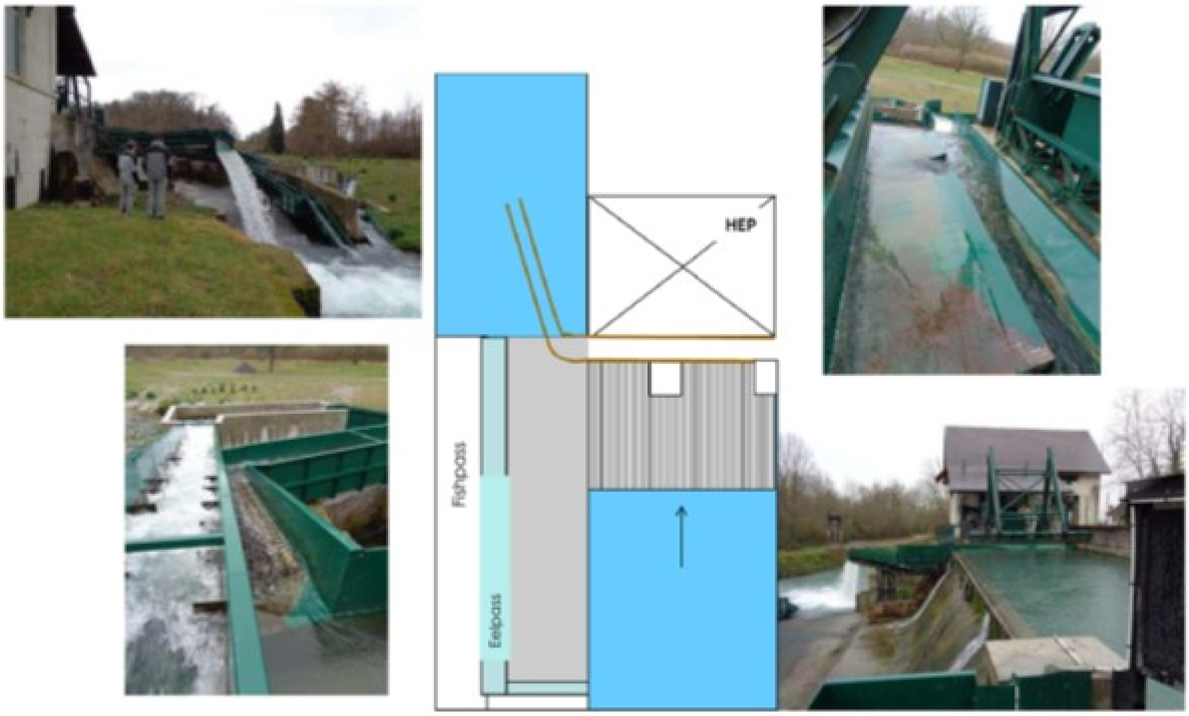


Figure 8: Devices for upstream and downstream migration at Gotein

Equipment:

1 Kaplan turbine at the power plant:

- Maximum turbined flow: 6.6 m^3/s
- Rated head: 5.81 m
- Number of blades : 4
- Diameter of the wheel: 1.2 m

- Rotation speed: 330 rpm

1.3.2. E-flow

In France, the law of 2006 (LEMA) imposes an environmental flow that permanently guarantee the life, circulation and reproduction of the species that inhabit the waters, and also defines a minimum value of 1/10 of the mean inter-annual discharge. This should be implemented before 1rst January 2014 at the latest. The definition of the environmental flow in bypassed sections is normally based on a detailed study of hydrology (natural low flow), hydromophology and habitat. In 2014, if such study was available, its results were considered to define the environmental flow, otherwise it was mostly set to the minimum value (1/10 of the mean inter-annual discharge).

At Gotein, the environmental flow is since a long time set at 5 m^3/s (20% of mean annual discharge).

1.3.3. Downstream migration devices

- Former bar-screen in front of the HPP (until 2014):
    - Width of the bar screen :
    - Clearance between the bars : 45 mm
    - 1 downstream migration outlet located at the top of the bar screen at the right bank, discharge in the outlet: about 0.15 m^3/s.

- Bar screen located at the hydropower plant (2014):
    - Length of the bar screen: 6.30 m
    - Clearance between the bars : 20 mm
    - Inclination ß of 26°
    - 2 downstream migration outlets located at the top of the bar screen, dimensions of each outlet: L = 0.80 m and h = 0.50 m
    - Flow for the downstream migration : 190 l/s in each outlet = 380 l/s = 5.4% of the max turbined flow
    - Maximum velocity in front of the rack: 0.47 m/s
    - Downstream migration duct whose section increase when getting closer to the downstream migration channel (from 0.45m to 0.90 m width); 7.16m long to the control weir.

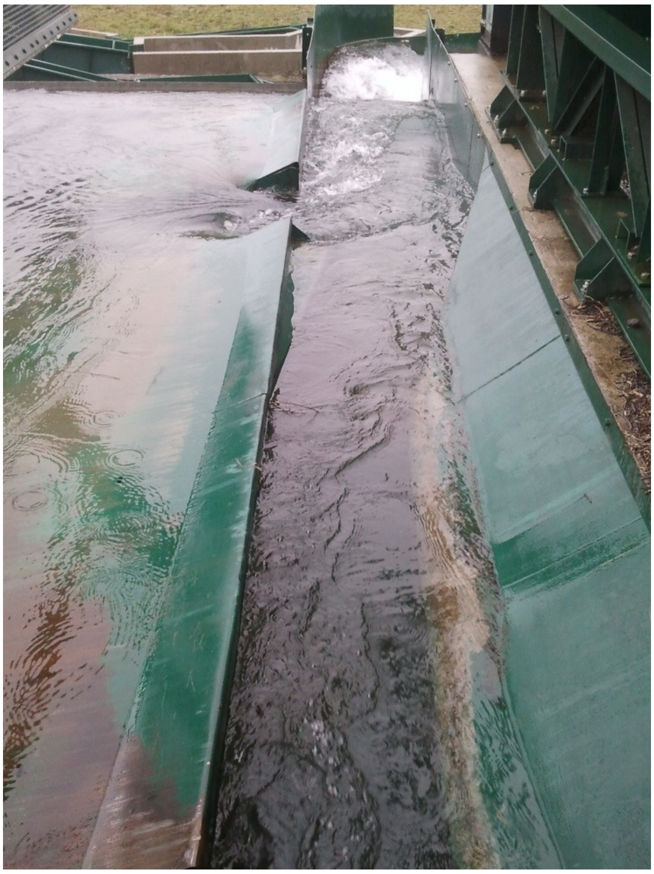


Figure 9: View of the migration duct with an enlargement at the entry of the second outlet

In the past, several studies have been conducted on the Saison axis. One of them concerned the induced mortality by the hydropower facilities during migration of Atlantic salmon smolts.

1.3.4. Previous study of the induced mortality by the hydropower facilities during downstream migration of Atlantic salmon smolts (2002)

(S.I.E.E. & GHAAPPE, 2002)

The area of the study is 55 km long and includes 8 HPPs and 1 fish farm (Bidondo).

Hydrology between 1991 and 2000

The year 1992 was a really wet year; on the contrary 1993 was really dry. The hydrology has a big role on the distribution of production on the section.

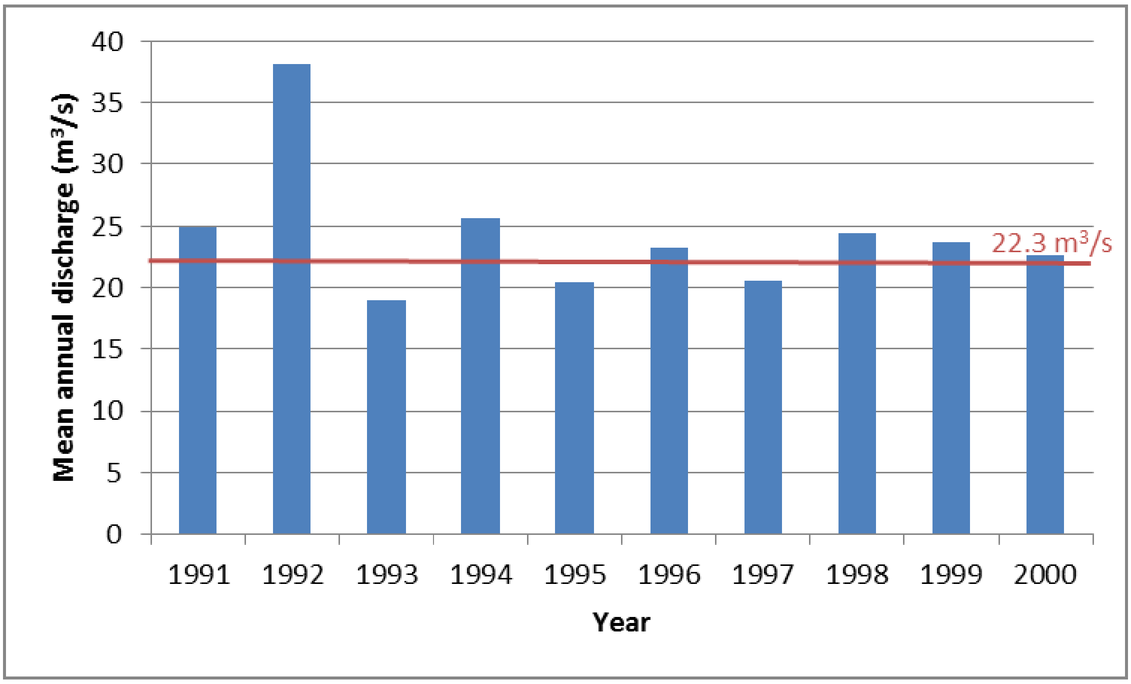


Figure 10: Mean annual discharges of the Saison between 1991 and 2001 at the station of Mauléon-Licharre (source: banque hydro France)

State of downstream migration facilities in 2002

According the characteristics of each facility the potential mortalities at each site are relatively high and bigger than 10%, except at Gorre HPP where the rate is about 8%.

At Gotein, according the bar spacing and the low downstream migration discharge, the efficiency of the former downstream migration device (bar-rack) is estimated at 15%.

The global mortalities were simulated for the years 1991 to 2000 at each site, see Table 4. The mean total mortality for the Saison until the confluence with the Gave d'Oloron is about 18.6% and varies from 10% to 25.9 %. The more important global mortalities are calculated for the HPP of moulin Datto and Mauléon. The HPP of Gotein induces a global mortality of 7.1% in average. These mortalities are theoretical and are calculated on a basis of 100 potential individuals going downstream at each HPP.

It's important to take into account the real number of fishes going downstream to evaluate the real impact of each facility. So, if we care about the percentage of dead fishes for one facility regarding the total number of fishes dead on the entire section, the HPPs of Mauléon, Gotein and Charitte de Bas are responsible of 65.3% of the total losses on the axis, see Table 5.

The HPP of Gotein induces 17.4 % of the total losses of the axis, which corresponds to 727 individuals among 4175.

Table 4: global mortalities at each facility taking into account the spill at the dam (source: (S.I.E.E. & GHAAPPE, 2002))

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Average
Moulin Datto	7.5%	6.3%	15.3%	5.7%	15.3%	15.3%	15.3%	11.0%	8.2%	11.3%	11.1%
Trois Villes	5.6%	6.6%	6.6%	4.6%	6.6%	6.6%	6.6%	6.6%	6.6%	6.6%	6.3%
Gotein	**4.3%**	**3.0%**	**9.4%**	**2.9%**	**9.4%**	**9.4%**	**9.4%**	**9.4%**	**4.4%**	**9.4%**	**7.1%**
Mauléon	7.1%	5.6%	16.2%	5.4%	16.2%	16.2%	16.2%	10.5%	7.9%	10.6%	11.2%
Libarrenx	4.0%	2.8%	8.5%	2.7%	8.5%	8.5%	8.5%	8.5%	5.2%	8.5%	6.6%
Gorre	0.6%	0.9%	1.4%	0.5%	2.6%	19.0%	3.8%	1.8%	1.2%	1.2%	3.3%
Chéraute	1.2%	2.1%	2.7%	1.1%	5.9%	4.7%	6.2%	4.2%	2.8%	2.7%	3.4%
Charitte de bas	2.4%	2.8%	4.7%	2.1%	6.8%	6.2%	7.4%	5.3%	3.9%	4.0%	4.6%

Table 5: distribution of losses due to each facility (source : (S.I.E.E. & GHAAPPE, 2002)

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Average
Moulin Datto	4.3%	3.8%	5.1%	4.1%	4.4%	4.7%	4.2%	3.7%	3.8%	4.2%	4.2%
Trois Villes	13.6%	16.6%	9.1%	14.0%	7.8%	8.3%	7.5%	9.3%	12.6%	10.2%	10.9%
Gotein	**16.7%**	**11.9%**	**20.5%**	**14.2%**	**17.7%**	**18.7%**	**16.9%**	**20.8%**	**13.2%**	**22.9%**	**17.4%**
Mauléon	31.8%	26.3%	39.8%	30.6%	34.2%	36.1%	32.8%	26.2%	27.8%	29.1%	31.5%
Libarrenx	10.6%	9.0%	0.6%	10.7%	0.5%	0.6%	0.5%	8.0%	9.9%	8.7%	5.9%
Gorre	2.6%	4.4%	3.3%	3.0%	5.4%	4.0%	7.5%	4.5%	4.5%	3.2%	4.2%
Chéraute	5.7%	10.5%	6.7%	7.1%	12.3%	10.5%	12.4%	10.7%	10.3%	7.5%	9.4%
Charitte de bas	14.7%	17.6%	14.8%	16.3%	17.6%	17.2%	18.2%	16.8%	17.9%	14.1%	16.5%

Simulations of the mortality on the section were also led with improvement of the downstream migration devices. Two hypothesis of efficiency of downstream migration devices were chosen: 50% and 70%.

Simulation of efficiency improvement to 50%

With an improvement of the efficiency of all downstream migration devices to 50%, the global mortality on the axis falls to 12.6% in average. The HPP of Mauléon is the more damaging, see Table 7.

The global mortality of Gotein is 2.7% which represents 15.2% of the global losses on the axis.

Table 6: global mortalities at each facility taking into account the spill at the dam for an improve efficiency of 50% for all downstream devices (source: (S.I.E.E. & GHAAPPE, 2002))

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Average
Moulin Datto	3.7%	3.1%	7.7%	2.9%	7.7%	7.7%	7.7%	5.5%	4.1%	5.6%	5.6%
Trois Villes	4.7%	5.5%	5.5%	3.9%	5.5%	5.5%	5.5%	5.5%	5.5%	5.5%	5.3%
Gotein	**2.5%**	**1.8%**	**5.5%**	**1.7%**	**5.5%**	**5.5%**	**5.5%**	**5.5%**	**2.6%**	**5.5%**	**4.2%**
Mauléon	3.9%	3.1%	9.0%	3.0%	9.0%	9.0%	9.0%	5.8%	4.4%	5.9%	6.2%
Libarrenx	4.0%	2.8%	8.5%	2.7%	8.5%	8.5%	8.5%	8.5%	5.2%	8.5%	6.6%
Gorre	0.6%	0.9%	1.4%	0.5%	2.6%	1.9%	3.8%	1.8%	1.2%	1.2%	1.6%
Chéraute	0.8%	1.5%	1.9%	0.8%	4.2%	3.4%	4.5%	3.0%	2.0%	1.9%	2.4%
Charitte de bas	1.4%	1.6%	2.8%	1.2%	4.0%	3.6%	4.3%	3.1%	2.3%	2.3%	2.7%

Table 7: distribution of losses due to each facility with an improvement of the efficiency of downstream migration devices up to 50% (source: (S.I.E.E. & GHAAPPE, 2002))

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Average
Moulin Datto	3.2%	2.7%	4.0%	3.0%	3.3%	3.5%	3.1%	2.7%	2.7%	3.1%	3.1%
Trois Villes	16.7%	19.9%	11.9%	17.1%	9.9%	10.6%	9.3%	11.3%	15.2%	12.6%	13.5%
Gotein	**14.5%**	**10.1%**	**18.9%**	**12.2%**	**15.7%**	**16.9%**	**14.9%**	**17.9%**	**11.2%**	**19.9%**	**15.2%**
Mauléon	26.4%	21.3%	35.7%	25.2%	29.7%	31.9%	28.0%	21.9%	22.7%	24.7%	26.8%
Libarrenx	15.8%	13.0%	0.9%	15.9%	0.8%	0.8%	0.7%	12.0%	14.5%	13.2%	8.8%
Gorre	4.0%	6.6%	5.8%	4.5%	9.0%	6.8%	12.3%	7.0%	6.8%	5.1%	6.8%
Chéraute	6.2%	11.1%	8.2%	7.6%	14.6%	12.6%	14.4%	11.9%	11.1%	8.5%	10.6%
Charitte de bas	13.2%	15.3%	14.6%	14.4%	17.0%	16.8%	17.2%	15.3%	15.8%	13.0%	15.3%

Simulation of efficiency improvement to 70%

With an improvement of the efficiency of all downstream migration devices to 50%, the global mortality on the axis falls to 7.9% in average. The HPP of Mauléon is the more damaging, see Table 9 and Table 7.

The global mortality of Gotein is 2.5% which represents 15.0% of the global losses on the axis (264 dead individuals at Gotein among 1760 dead overall the entire section.

Table 8: global mortalities at each facility taking into account the spill at the dam for an improve efficiency of 70% for all downstream devices (source: (S.I.E.E. & GHAAPPE, 2002))

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Average
Moulin Datto	2.2%	1.9%	4.6%	1.7%	4.6%	4.6%	4.6%	3.3%	2.5%	3.4%	3.3%
Trois Villes	2.8%	3.3%	3.3%	2.3%	3.3%	3.3%	3.3%	3.3%	3.3%	3.3%	3.2%
Gotein	**1.5%**	**1.1%**	**3.3%**	**1.0%**	**3.3%**	**3.3%**	**3.3%**	**3.3%**	**1.5%**	**3.3%**	**2.5%**
Mauléon	2.4%	1.9%	5.4%	1.8%	5.4%	5.4%	5.4%	3.5%	2.6%	3.5%	3.7%
Libarrenx	2.4%	1.7%	5.1%	1.6%	5.1%	5.1%	5.1%	5.1%	3.1%	5.1%	3.9%
Gorre	0.3%	0.5%	0.8%	0.3%	1.6%	1.1%	2.3%	1.1%	0.7%	0.7%	0.9%
Chéraute	0.5%	0.9%	1.2%	0.5%	2.5%	2.0%	2.7%	1.8%	1.2%	1.1%	1.4%
Charitte de bas	0.9%	1.0%	1.7%	0.7%	2.4%	2.2%	2.6%	1.9%	1.4%	1.4%	1.6%

Table 9: distribution of losses due to each facility with an improvement of the efficiency of downstream migration devices up to 70% (source: (S.I.E.E. & GHAAPPE, 2002))

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Average
Moulin Datto	3.1%	2.6%	3.8%	3.0%	3.2%	3.4%	3.0%	2.6%	2.6%	3.0%	3.0%
Trois Villes	16.5%	19.6%	11.6%	16.9%	9.6%	10.3%	9.0%	10.9%	14.9%	12.2%	13.2%
Gotein	**14.4%**	**10.0%**	**18.6%**	**12.2%**	**15.4%**	**16.5%**	**14.5%**	**17.5%**	**11.1%**	**19.6%**	**15.0%**
Mauléon	26.5%	21.2%	35.6%	25.2%	29.4%	31.7%	27.7%	21.8%	22.6%	24.7%	26.6%
Libarrenx	15.8%	13.0%	0.9%	15.9%	0.8%	0.8%	0.7%	12.0%	14.5%	13.1%	8.8%
Gorre	4.1%	6.7%	5.9%	4.6%	9.2%	7.0%	12.5%	7.2%	6.9%	5.3%	6.9%
Chéraute	6.4%	11.3%	8.5%	7.8%	15.0%	13.0%	14.9%	12.3%	11.3%	8.8%	10.9%
Charitte de bas	13.4%	15.5%	15.0%	14.6%	17.5%	17.3%	17.8%	15.7%	16.1%	13.3%	15.6%

Conclusion

The Saison got a good potential of production: 22 439 eq. smolts. The cumulative mortalities depend on the hydrology and vary between 10% and 25.9%. The more damageable facilities are Mauléon, Gotein and Charitte de bas. It appears to be essential to operate some changes at these HPP in order to decrease the total mortality on the section.

(S.I.E.E. & GHAAPPE, 2002) recommended to improve the efficiency of the downstream migration device to 70% at least. The bar spacing has to be reduced to at least 3 cm, and the downstream migration discharge has to represent minimum 5% of the turbined discharge (i.e. 0.3 m^3/s). This increase goes together with a resize of the existing outlets or by building a new device. Furthermore, the currentology at the dam is unfavourable to downstream migration. The velocities are very high approaching the pre-grids, these guide the fishes into the headrace channel. It would be very interesting to build a notch in the weir in order to facilitate the passage through the dam for downstream migration and to increase the attractiveness of the fishpasse for upstream migration.

1.3.5. Upstream migration devices

At the dam, the fishes can use a pre-barrage fish pass to go upstream (2014).

- Flow in the fish pass: 1 m^3/s
- 2 pools of 38 and 45 m^2

Table 10: Dimensions of the pre-barrage

	Pool 1		Pool 2		Downstream		
	Notch	weir/wall	Notch	weir/wall	Notch	weir/wall	weir/wall
Upstream	1.00	11.15		7.95			
	168.91	170.25		170.25			
Pool 1 (38 m²)			1.00	8.20			
			168.74	169.80			
Pool 2 (45 m²)					1.00	6.20	4.94
					168.42	169.46	169.90

Figure 11: Location of the fish pass at the dam

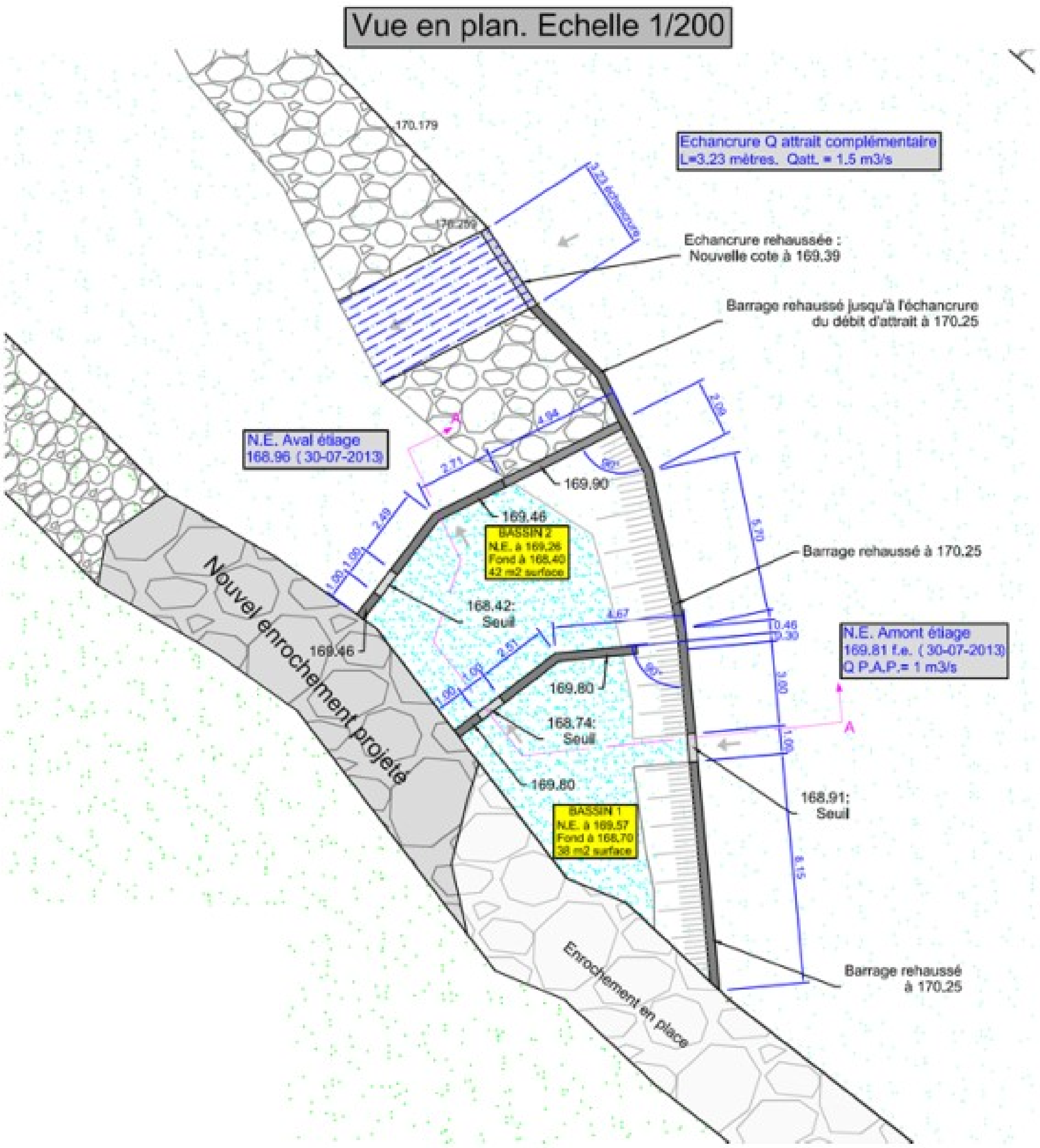


Figure 12: drawing of the pre-barrage fish pass at the dam (source : (Atesyn, 2014))

The dissipated energy in the pools is between 72 W/m^3 in low flow water periods and 196 W/m^3 when the discharge is 2 times the mean interannual discharge (≈44 m^3/s).

At the power plant:

At the hydropower plant the choice was made to consider only large migrating species like salmon, sea trout and eel. Indeed the dam is already equipped with a multispecific fishpass which is previous to the fishpasses at the HPP.

Baffle fish pass (2014):

- 16% slope
- 5 portions 0.5*7.5 m connected with pools 3.0*2.0*1.0 m
- Flow in the fish pass : 150 l/s

Figure 13: upstream view of the baffle fishway

Eelpass (2014):

- 4 portions of 4 to 6 m long
- 25-30% slope
- Resting pools 1.5*1.0*0.5 m
- Flow in the pass: a few l/s

Figure 14: eelpass at the HPP

2. Objectives on this Test Case

What we are planning?

In Gotein different activities are planned:

- Assessment of the efficiency of the fishfriendly water intake for smolt;
- Characterization by measurement of the flow repartition between the 2 bypass entrances
- Hydraulic modelling of the of the fishfriendly water intake in order to characterize the attractiveness of the bypasses;

Why are we planning this on this Test case?

The test case site of Gotein is a small HPP with a fish friendly water intake. Most of actual design recommendations are respected on this test case.

What are we expecting?

We expect from this test case to consolidate the design recommendation for fish friendly water intake.

Relevance in FIThydro?

We will respond to some objectives of the project and WP2 like applying the existing SMTDs on a test case, have feedback on their use and application range.

A study was led by the French Agency for Biodiversity in order to assess the efficiency of Gotein's downstream migration device for Atlantic salmon smolts (Tomanova, et al., 2018).

6 batches of 50 to 52 fishes were released between 18h and 00h 100m upstream the power plant, in the headrace channel

3. Presentation and results of activities in FIThydro

3.1. Efficiency of downstream migration devices

3.1.1. Methodology

In 2016, a study was led by the French Agency for Biodiversity in order to assess the efficiency of Gotein's downstream migration device for Atlantic salmon smolts (Tomanova, et al., 2018).

3.1.1.1. Technology

The fishes are tracked with the PIT-Tag technology and detected with RFID antennas.

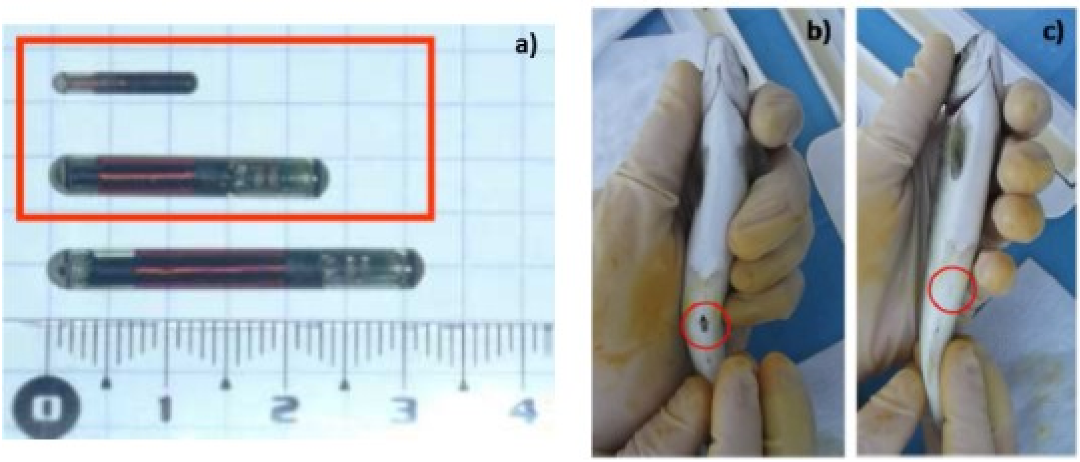


Figure 15: Tagging of fishes a) mark of 23 mm used b) and c) surgical insertion of the mark in the fish (source: (Tomanova, et al., 2018))

The fishes were marked the between the 29th and the 30th of March 2016 at the fish farm of Castels. The fishes were anaesthetized with eugenol for the surgery. The 11th of April they were moved to Trois-Ville and stabled in a pool with non-stop renewing of water.

6 batches of 50 to 52 fishes were released between 18h and 00h 100m upstream the power plant, in the headrace channel, see Table 11.

Table 11: Number of fishes and their size for each batch, date and time of release on Gotein's site (source : (Tomanova, et al., 2018))

Batches	Number of fishes	Date of release	Time of release		Size (mm)			
					Average	Standard deviation	Min	Max
GOT_L1	50	12/04/2016	19:45	evening	188.0	8.0	171	202
GOT_L2	50	12/04/2016	22:40	night	188.0	11.4	158	212
GOT_L3	50	13/04/2016	00:40	night	186.5	10.9	155	211
GOT_L4	50	13/04/2016	18:37	evening	186.8	12.6	152	209
GOT_L5	50	13/04/2016	22:38	night	185.0	11.9	150	213
GOT_L6	52	14/04/2016	00:17	night	186.1	11.6	165	220

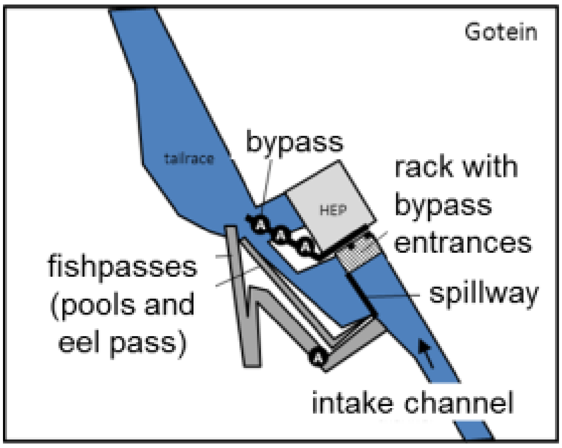
3.1.1.2. Set of detection antennas

Three antennas were installed in the downstream migration channel (metal) downstream the control weir and one in the resting pool of the fish pass, see Figure 16. The eel-pass was screened in order to avoid the smolts to enter it. If the fish is detected by an antenna in the downstream migration channel it means that it took this way of passage. The efficiency of the antennas in the channel was tested. 20 fishes were released one by one in the channel, than two groups of 5 fishes were released in the channel.

Table 12: Detection efficiency (%) of the antennas in the downstream migration channel (source: (Tomanova, et al., 2018))

	test ind20	test gr5-1	test gr5-2
EXU1	100	80	80
EXU2	100	80	60
EXU3	100	40	100
EXU1+2+3	100	80	100

The efficiency decrease when several fishes go through the channel at the same time because of the collision between marks but the result after aggregation of detection of the three antennas shows that it still satisfactory. We supposed that every fish going through the channel will be detected by the antennas.



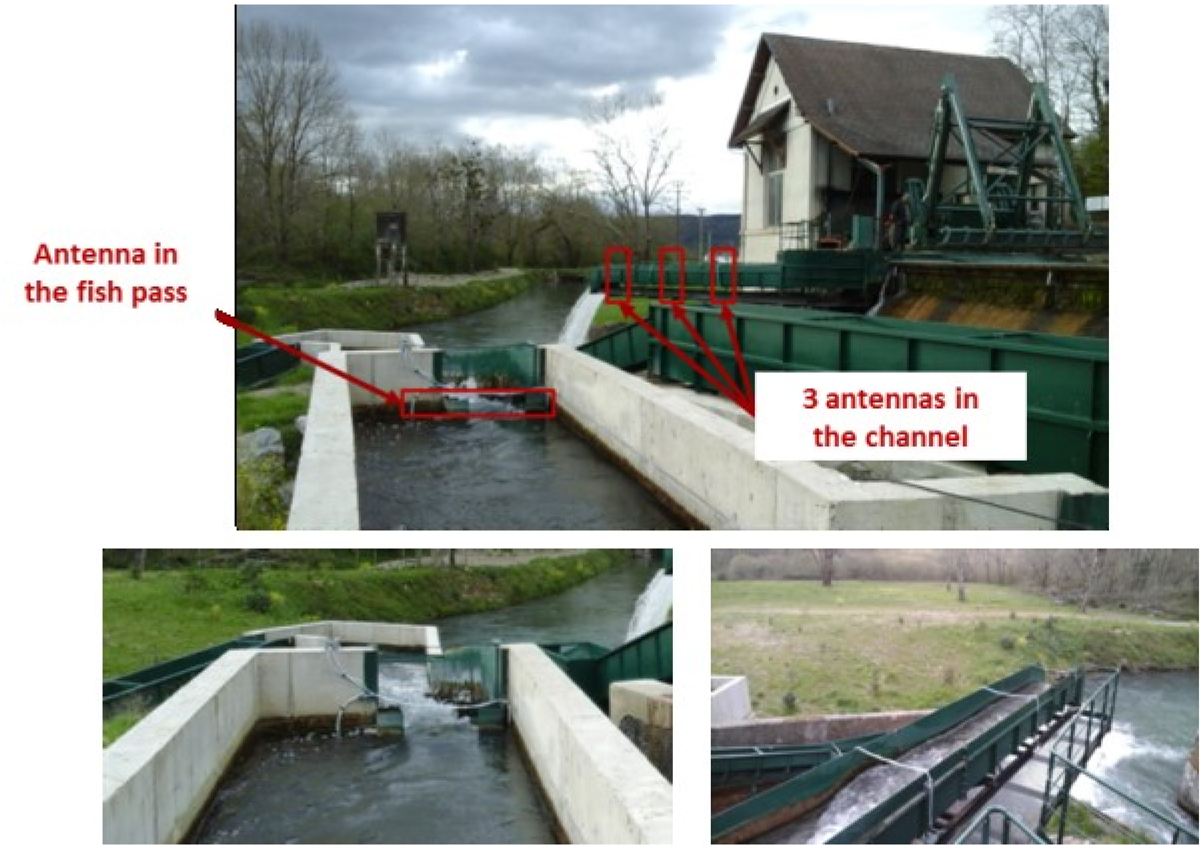


Figure 16: Pictures of the HPP and location of the antennas (source: (Tomanova, et al., 2018))

It is not possible to detect the fishes going through and the rack and therefor through the turbine. We will consider that non-detected fishes went through the turbine.

3.1.1.3. Hydrology of the Saison during the study

During the 5 days after the first release the discharge varied between 29 and 46 m^3/s. Most of fishes went downstream during this period. Goteins HPP worked stable, the discharge in the headrace channel is controlled at the dam. An ADCP measurement the 19^{th} of Mai revealed a discharge of 6.7 m^3/s in the headrace channel and 0.35 m^3/s in the downstream migration channel.

3.1.2. Results

In average 80.9% of the fishes went through the downstream migration device and 2% used the fish pass, see Table 13. The efficiency is bigger for the fishes released in the evening: the difference is between 13 and 22%.

Table 13: number and distribution of detected fishes or not in the different ways at Gotein (in blue: batches released in the evening) (source: (Tomanova, et al., 2018))

Batch	Total of released fishes	Number of non detected fishes	Number of fishes detected in		Percentage of fishes detected in		Total percentage of fishes gone
			bypasses	fish pass	bypasses	fish pass	
GOT_L1	50	0	50		100	0	100
GOT_L2	50	11	38	1	76	2	78
GOT_L3	50	10	39	1	78	2	80
GOT_L4	50	5	44	1	88	2	90
GOT_L5	50	14	36		72	0	72
GOT_L6	52	12	37	3	71.2	5.8	76.9

A Student test was run in order to detect an eventual difference of size between fishes taking the downstream migration device or non-detected. The mean size of fishes taking the downstream migration device (188 mm) is bigger than the one non-detected (180.1 mm). The student test revealed that this difference is significant, see Figure 17.

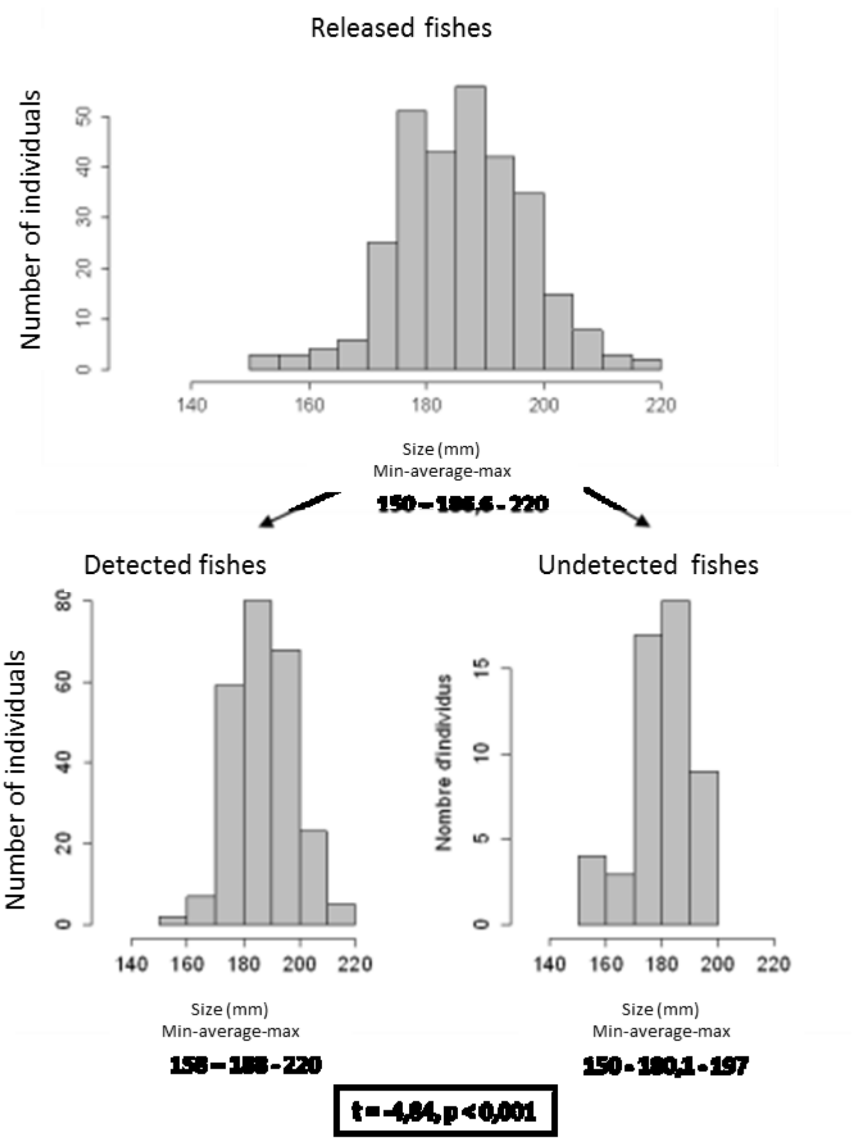


Figure 17: Distribution of released fishes' size, non-detected fishes' size and detected in the downstream migration channel fishes' size (source: (Tomanova, et al., 2018))

The timing was also studied. For all batches the first detections happened between 3 and 8 minutes after release. 50% of fishes take less than 20 minutes to circumvent the power plant through the downstream migration device, 75 % need less than 1h08, see Table 14. The timing passage is longer for the fishes released in the evening than at night.

Table 14: Timing of passage of smolts for the different batches, in grey the batches released in the evening (source: (Tomanova, et al., 2018))

	Nb d'ind.	min	Q25	mediane	Q75	max
LOT1	50	0:06:35	0:14:48	0:51:29	1:57:16	187:33:21
LOT2	38	0:08:17	0:13:51	0:20:32	0:41:12	6:05:32
LOT3	39	0:03:25	0:07:02	0:11:53	0:19:57	1:31:24
LOT4	44	0:05:31	0:18:17	0:37:19	1:25:03	44:48:44
LOT5	36	0:03:47	0:10:56	0:19:45	0:53:25	52:22:36
LOT6	37	0:05:55	0:13:00	0:18:27	0:35:38	108:06:54
Total	244	**0:03:25**	0:12:05	**0:19:59**	**1:08:13**	187:33:21

3.1.3. Conclusion

The efficiency of the downstream migration device at Goteins HPP is **80.9 %.**

Taking into account the new efficiency of the infrastructure, the global survival rate can be updated, see Table 15.

Table 15: Summary of the distribution of fishes among the different ways, passage rate through turbines (this study) and their mortality rates (according (Voegtlé, 2010)), and global passage efficiency taking into account passage over the spillway, the downstream migration device and survival after passage through turbines (Tomanova, et al., 2018)

Dam		Power plant			**Total survival rate at Gotein**
Proportion (%) of fish passing over the spillway of the dam	Proportion (%) of fish led to headrace channel	Proportion (%) of fish passing through the turbine	Mortality through the turbine (%)	Proportion (%) of fish assumed dead due to passage through the turbine	
32.4	67.6	11.61	11	1.28	**98.72**

The global survival rate of Gotein is 98.72% which is not perfect but is considered satisfactory.

3.2. Characterization of the flow repartition between the 2 bypass entrances

Thanks to the law of spillways and the DEVER tool, developed by the AFB, the discharge over the control weir was calculated (see Table 16). Two water levels upstream the control weir were measured, one before the measurements in the bypass and one after.

Table 16: Calculation of the discharge over the weir

Parameter	1rst value, before the measure in the bypass	2nd value, after the measure in the bypass	Unit
Water level upstream the control weir (under the gate)	0.550	0.580	m
Floor level upstream the control weir	0.080	0.080	m
Width of downstream migration channel	0.900	0.900	m
Width of control weir	0.900	0.900	m
Water height upstream the control weir (under the	0.470	0.500	m
Flow cross-section upstream the control weir (under	0.423	0.450	m²
Level of the control weir	0.230	0.230	m
Head on the weir	0.320	0.350	m
Discharge calculated by the DEVER tool	**0.326**	**0.376**	**m^3/s**
Mean value	**0.351**		**m^3/s**
Flow velocity upstream	0.771	0.836	m/s

The mean value allowed to downstream migration is 0.351 m^3/s.

Measurements in the bypass channel were also done downstream the first outlet thanks to a current meter. The discharge after the first outlet is 0.144 m^3/s. By subtraction, the discharge passing through the second outlet is 0.207 m^3/s.

Table 17: Distribution of discharge in the different outlets

		Value (m^3/s)	Proportion	Mean flow velocity in the outlet (considering H = 0.5 m and L = 0.8 m)
Discharge Outlet 1	Measure	**0.144**	**41.1%**	0.36
Discharge Outlet 2	Subtraction	**0.207**	**58.9%**	0.52
Total discharge	Spillway law	**0.351**	100.0%	

3.3. Hydraulic modelling of the fish friendly water intake

Methodology:

Numerical simulations have been performed using the multi-physics open-source library OpenFOAM (OpenField Operation And Manipulation), which provides solvers, meshing utilities and post-processing tools for various physics and mathematics problems. The code is written in C++ and solves partial differential equations (PDE) problems using the finite volume method. OpenFOAM is fully customizable and can address a number of fluid mechanics problems such as compressible and incompressible flows, multiphase flows, heat transfer, combustion, etc.

Free surface flow simulations of the laboratory bar-racks have been carried out using the interFOAM unsteady incompressible multiphase solver which solves the Navier-Stokes Equations (NSE) using the merged PISO-SIMPLE (PIMPLE) algorithm, and the phase concentrations using the VOF (Volume Of Fluid) method. The VOF method can be used to track free surfaces and fluid interfaces by considering the volume fractions of multiple fluids that are advected in the computational domain.

The full-scale simulations of the test-case HPP intakes have been conducted using the steady incompressible single phase simpleFoam solver, which solves the NSE using the SIMPLE algorithm.

Turbulence can be modelled using various approaches, and in particular the steady and Unsteady Reynolds-Averaged NSE (RANS and URANS) used in this study with the k-epsilon turbulence model.

Meshing

For all simulations, channels have initially been defined as cartesian blocks with base cell size set to 1 cm. Bar racks and bypass structures have been modelled as CAD elements which have then been subtracted for the initial blocks using mesh castellation and local surface adaptation. The openFOAM utilities blockMesh and snappyHexMesh have been used to perform these pre-processing operations.

Results

Single-phase numerical simulations have been carried out at full scale for the test-case HPP of Las Rives. The intake channel is 6.36 m wide with a water depth of 2.62 m. The 6.36 m wide bar rack is vertically inclined at 26° with respect to the river bed, comprising 8 mm thick bars with hydrodynamic profile, 20 mm free spacing between bars, and horizontal spacer lines of width 12 mm. The total inflow is nominally set at 6.7 m^3/s, from which 0.35 m^3/s discharges trough the bypass on the left bank of the intake channel. The bar rack and progressive width bypass are shown in the Figures.

The numerical simulations the free surface is represented as a fixed horizontal boundary with the slip condition at the nominal water height. Figures 18 to 21 show the bar rack with its supporting elements, terminated by the 2-entrance bypass channel of progressive width.

The resulting average approach velocities at 3 stations along the rack are represented in Figures 18 (longitudinal and vertical velocity components), 19 (transverse velocity component) and 20 (tangential and normal velocities). The tangential-to-normal velocity ratio is presented in Figure 21. The velocities are in agreement with the fish friendly criteria.

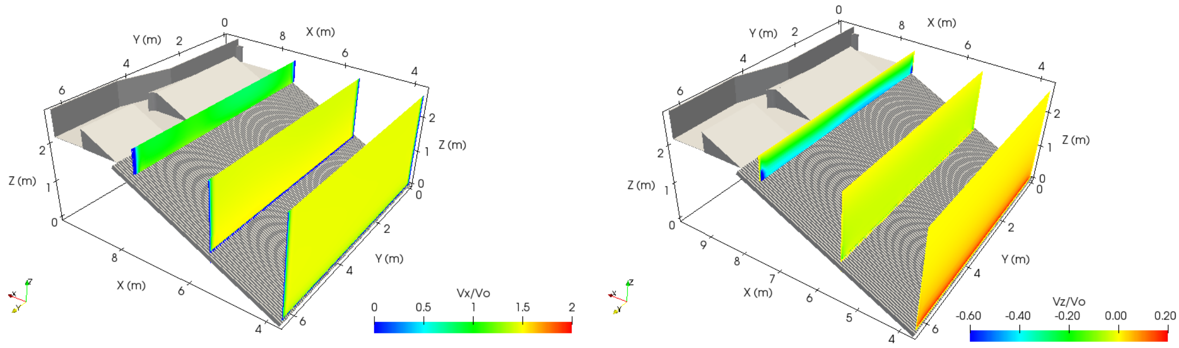


Figure 18: Cartographies of the normalised numerical velocities Vx/Vo and Vz/Vo with Vo=0.4m/s

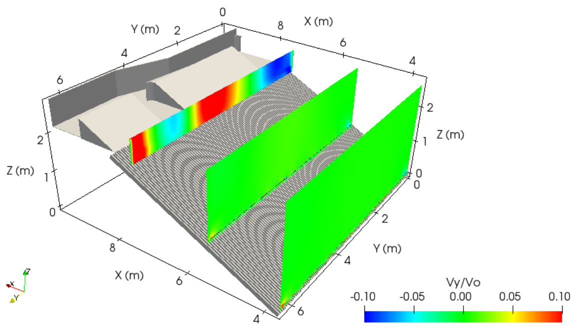


Figure 19: Cartographies of the normalised numerical velocities Vy/Vo with Vo=0.4m/s

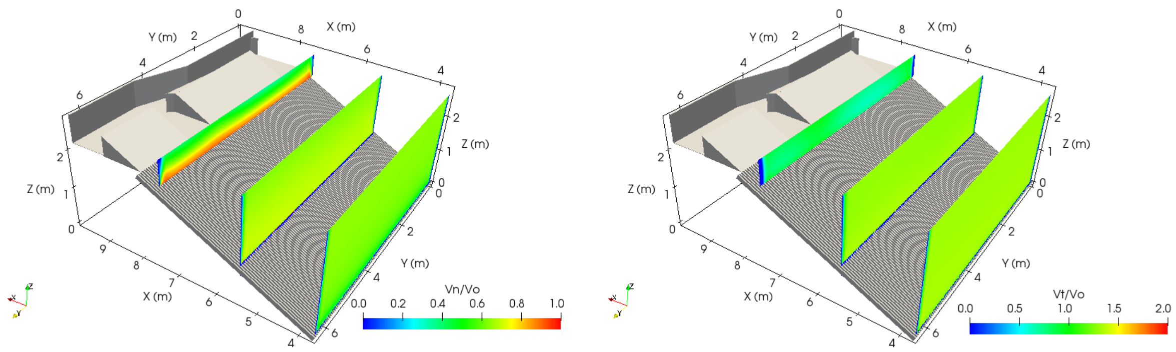


Figure 20: Cartographies of the normalised numerical velocities Vn/Vo and Vt/Vo with Vo=0.4m/s

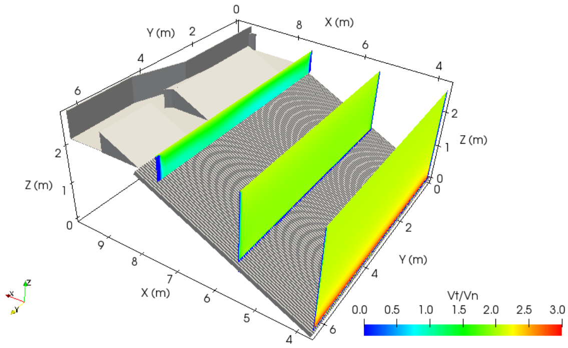


Figure 21: Cartographies of the ratio between normal and tangential velocities Vt /Vn

Figure 22 shows the velocity distribution and streamlines at free-surface level upstream of and across the bypass channel. The curvature of the streamlines evidences both the attractiveness of each of the bypass entrances and the homogenization effect of the enlargements along the bypass channel. Compared to field measurements, the numerical results tend to under-estimate the flow rate across the left bank entrance by 30% and the flow rate across the right bank entrance by 2% (Table 1). The distribution of flow rates is however acceptably reproduced in terms of flow.

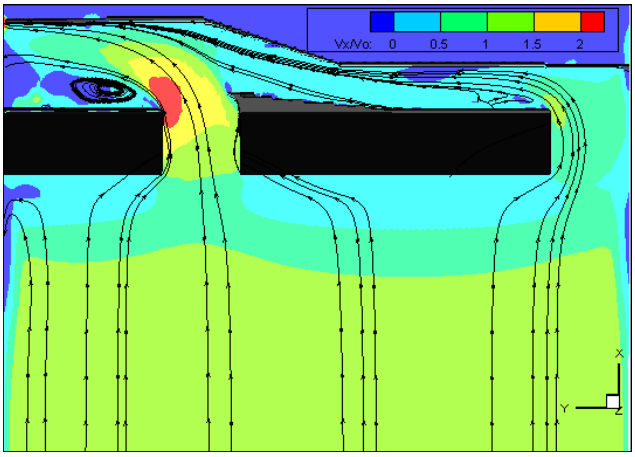


Figure 22: Top view of the slice at z=2.3m of the normalised axial velocity Vx/Vo with Vo=0.4m/s and the streamlines of the flow.

Table 1: Comparison between simulated and measured flow rates.

Bypass	1	2
Cumulated in-situ flow rate (m^3/s)	0.144	0.351
Percentage of flow rate by bypass (%)	41.03	100
Cumulated numerical flow rate (m^3/s)	0.1	0.345
Percentage of flow rate by bypass (%)	28.57	98.57

4. Conclusion of the activities on the test case

The Gotein test case consists in a small HPP with a fish friendly water intake. Most of current design recommendations are respected on this test case for both upstream and downstream migration. This test case is used for evaluating the efficiency of an inclined low bar spacing trashrack and for validating the discharge calculated using 3D modelling inside the bypasses. Pit-tag measurements have been carried out on six batches of 50 smolts over days during which the discharge varied. Fishes were released in the headrace channel and used a variety of paths to migrate downstream. A flowmeter was used to monitor the discharge in the two bypasses entrances of the bar rack. Some dissymmetry has been observed and confirmed with 3D numerical modelling. In average, 80.9% of the fishes went through the downstream migration device and 2% used the fish pass. A better efficiency is observed for fishes released in the evening, with increases in the range of 13% to 22%. The efficiency of the downstream migration device at the Gotein HPP is **80.9 %** and the global survival rate of Gotein is **98.72%**.

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