Optimizing the utilization of hydraulic resources: Calibration with dye dilution of the flow monitoring system in La Nouva intake

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Abstract

In the purpose of a more efficient use of hydraulic resources a monitoring of the water availability can be decisive in the choices for plant optimization and refurbishment strategies. The Grand Eyvia river was supposed to deliver much more flow than the amount exploited by Chavonne power plant.

A prominent cross wall on riverbed determines a load basin at el.1300 m which allows the flow of the adduction channel to reach the Chavonne power plant. The double intake to gallery is provided with grids and weirs (not respecting codes for measurements).
The adjustment of the load basin level is obtained via an automated cylindrical gate located in a side way on the river calibrated in order to have only 5 cm water over the cross wall level (so called environmental vital flow).

It was decided to monitor the flow rate all around the year by measurements of level in the basin and cylindrical gate opening.
The paper presents the tests performed in "La Nouva" intake having the extent to correlate the flow in the channel with the measurement of level before the weirs and the exceeding flow through the river with the cylindrical gate opening.

Dye dilution method by Rhodamine WT has been used. This method did not require any modification to the hydraulic system and had very small impact in unit operation. Despite some difficulties the measurements gave quite reliable results.
The flow correlation has given important technical data and sufficient information to evaluate the return of investment in the hypothesis of re-powering.

Plant description and scope of tests

The hydraulic system of the Chavonne Power Plant in Val d'Aosta allows the passage of a portion of the flow of Grand Eyvia stream through a dam on the river and an cylindrical gate that allows the outflow of water not diverted in the inlet gallery of the power plant where a weir is located , the gate is calibrated in order to have only 5 cm water over the cross wall level.
The total flow of the stream is then divided into three parts: the first direct to the inlet gallery of the Chavonne Power Plant, the second passing under the cylindrical gate and the third not considered in this study passing over the cross wall, in fact under normal conditions only the vital flow of about 1 m^3/s is maintained whereas it can dispose of several dozen cubic metres in the event of sudden flood.
Most of the year is supposed that the portion flow of the stream not used by the Chavonne Power Plant, is significantly higher than the amount of water needed for maintaining the minimum vital flow but for a proper cost-benefit analysis of a possible upgrading is necessary to have an estimate of the real discharge, accurate as much as possible and monitored in a wide period.
The water level at gallery entrance upstream the weir and the cylindrical gate opening were already transmitted to a control system and recorded all over the year, It was supposed to correlate the flow in the gallery with the water level upstream the weir and the flow passing through the gate with the gate opening.
The measurements, carried out to determine these correlations, were made using the dye dilution method; tests were conducted in accordance with standards IEC EN60041-Ed 11-1991 and subsequent updates and all arrangements arising from W.E.S.T. experience in this field.
The tests were preceded by normal control tests, zero checks and calibration of all instruments used.
Dedicated instrumentation that allows to perform the measure with tracer minimizing the environmental impact of this technique has been used.

Test Procedure

The tests were carried out under a constant flow : substantially with a balance between incoming and absorbed discharge without any change in levels. The duration of the release of dye for each test was 8 minutes each, in order to define with sufficient precision the plateau of concentration within the time required to measure the range. The methodology of plateau was flanked to integration methodology so that a mutual verification of the results is possible. The final flow was obtained as an average between these two methods of calculation.
The overall stream flow was calculated during all tests as detected by upstream level measurements.
The different points measured were obtained by changing the flow released in the channel: these changes of the flow in the channel were obtained by manually varying the position of the entrance gates to the channel in order to adequately reduce the section of passage. The flow in riverbed passing through the cylindrical gate did also change consequently (being the total flow fixed) and the gate position was changed in order to have only 5 cm water over the cross wall level. The Data Acquisition system measures in a first phase the flow in the channel and in the second phase the residual flow through the cylindrical gate.

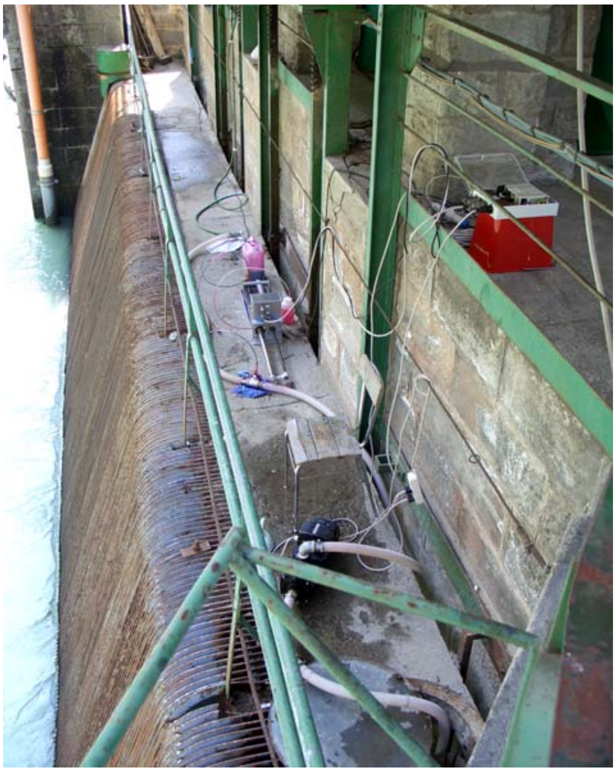
Flow Measurements

The flow was measured with tracer method, injecting Rhodamina WT through calibrated sprayers mounted on a metal structure, properly installed.

During measurements in the channel (flow to Power Plant) the injection was made downstream the entrance grid. The measuring section where the diluted mix is sampled to detect the concentration of dye in water, was installed immediately upstream of the weir (measures taken in preliminary tests downstream of weir have shown not reliable results).

The flow rate through the cylindrical gate (flow released in riverbed), the placing of tracer was carried out by installing the spraying structure just in front of the gate itself. The measuring section where the diluted mix is sampled to detect the concentration of tracer mix has been prepared in riverbed of the stream at appropriate distance from the point of release. Since the section drawing sufficiently far it is considered that the measured flow also includes the low flow passing above the cross wall (the level adjustment is such as to allow the minimum vital flow even with cylindrical gate fully closed).

The RhodamineWT was pre-diluted to approximately 4.75% for injection and the discharge of the release pump was selected so as to obtain the concentration level of dye after mixing at around 10-15 ppb (parts per billion) value as to be barely perceived at sight and over 3000 times below the threshold of environmental attention.




The photos show installations for measurements

The Flouri-meter Turner Designs 10 AU is able to measure concentrations of RhodamineWT starting from 100 ppt (parts per trillion) with a sensitivity of 10 ppt. Then with the measured concentration the level of sensitivity is ± 0.1%.
The instrument is also equipped with a cell that allows continuous measurement of concentration in real time with the possibility of setting of the main filter. In the present case 1 second filter was chosen. When the conditions of plateau is reached the concentration was obtained as average of about 480 values.

The continuous measuring cell was set to have the automatic removal of white obtained with the water passing through without Rhodamine and with automatic temperature compensation. The measurement system is calibrated and controlled through secondary samples in solid form. Before testing the system of measurement is used to determine the concentration of samples of Rhodamine used in the injection system, diluted with stream water in precise ratio at concentrations close to those of measurement. In this manner is eliminated the error related to uncertainty of concentration of injected Rhodamine and the error related to possible interference (fluorescence) of water flow on the measures.
The Flouri-meter Turner Designs 10 AU interfaced to the computer, transfers the data via RS 232 for calculating the flow with the various methods of integration envisaged by W.E.S.T.procedures. The Data acquisition internal electronics system also allows to discriminate against any inconsistent signals.
The computer provides a printing counts acquired in order to ensure consistency of the data provided from the display of the instrument with the data used by the computer for subsequent processing.

In each test were also taken 10 samples in the plateau in order to verify, in the laboratory and under controlled conditions, the reliability of the values obtained from the Flouri-meter in the field.

The photo show the cylindrical gate injection and the stream with mixed Rodhamine

Error in discharge measurements

The total error introduced in the flow measurement using the dye dilution method in constant injection derives from many factors.

The error due to calibration Flouri-meter is linked to the uncertainty of determination of sample solutions, adopting arrangements stipulated in the test procedure is normally contained in $f(C_T) = \pm 0{,}25\%$.

The error due to uncertainty pump calibrated for release on the basis of data design and functional periodic checks is certainly lower the value limit $f(P_T) = \pm 0{,}20\%$.

The error due to interference with the environmental conditions, characteristics of water, temperature and pH are normally known and have taken into account during the verification of calibration field and in determining the curve correlation fluorescence / concentration.

The uncertainty of that curve is not easy to estimate $f(V_T) = \pm 1.40\%$.

The error due to poor mixing of the tracer in the fluid is normally the one more difficult to assess. It is a function of distance between the section of release and the levy and scope of release.

The fluctuation of the value of fluorescence (concentration) is an indication of the goodness of mixing and then that error is mainly manifested physically as a random error and not systematic. In the specific case the results lead to $f(M_T) < \pm 1{,}40\%$.

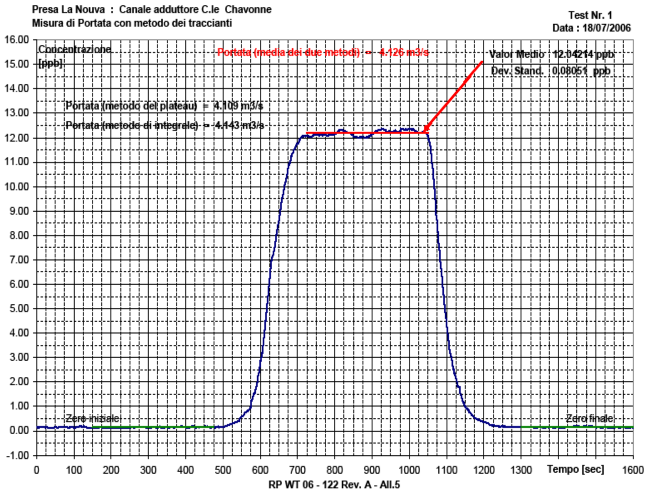
In this case (both installations) ,the error in determining the flow (error systematic and random) is contained within:

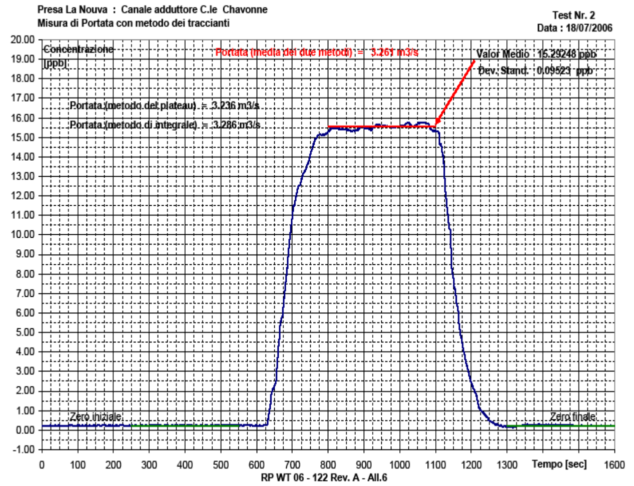
$$\mathbf{f(Q)} = \pm (f(C_T)^2 + f(P_T)^2 + f(V_T)^2 + f(M_T)^2)^{0,5} = \pm \mathbf{2.00\%}.$$

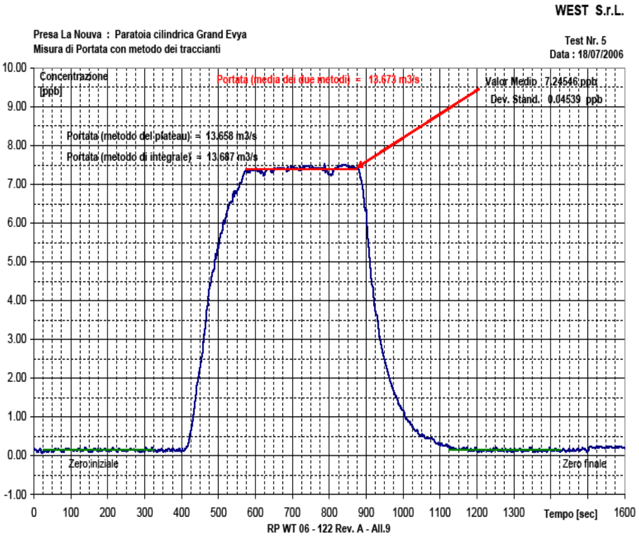
Results

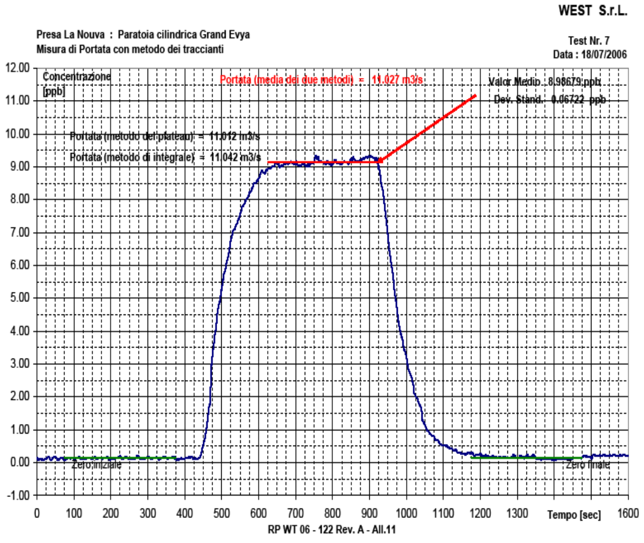
The following graphs represent some of the charts on the concentration of Rhodamine WT in water versus the measurement time. For each of the tests the plateau condition has been detected by means of a chart of the evolution of concentration.

Seven different tests were made, four with tracer measuring the flow in the channel (flow to Power Plant) and three measuring the flow rate through the cylindrical gate (flow released in riverbed).









The concentration of Plateau with the relative Dev.Standard are indicated and, as mentioned, it is ascertainable that the random error is always less than ± 1.40%. The difference between the concentration of plateau and the initial/final values determines the flow on the basis of the injection discharge of dye. The distance between the sections, where dye is injected and where the mixed water is sampled, determines a front going up and down quite steep and the plateau has a duration comparable to 8 minutes of release. The flow, obtained from the integration, is always fairly close to that obtained from the plateau analysis with discrepancies always contained in ± 0.50%. As already stated, the global analysis of the measure indicates that the error of measurement is less than the requested uncertainty of ± 2.00%

The following table shows the values of the level in the tank load, the opening of the channel inlet gates, the opening of the cylindrical gate ,the level in the channel of adduction, the flow measured with tracer and the flow in channel and through of the cylindrical gate obtained by theoretical laws of weirs and gate efflux law adequately corrected by parameters according to the dye test results.

La Nouva : Adduction Channl to Chavonne P.P. and Grand Eyvia stream Cylindrical Gate
Discharge measurements with dye dilution method

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Test Nr.	Sart hh.mm	Level Reservoir signal Volt	Level Reservoir m	Channel Gate Position mm		Channel Gate Opening mm	Level above Gate m	Opening Gr.Eyvia Cyl Gate %	Opening Gr.Eyvia Cyl Gate m	Discharge Gr.Eyvia Cyl Gate m3/s	Discharge from dye meas. m3/s	Level Chavonne Channel m	Heigh above Chavonne Weir m	Discharge Chavonne Channel m3/s	Sream Total Discharge m3/s	Probable Error %	Cyl Gate Flow section m^2
			reservoir lever in remote regulation								Dye measurement made in the Chavonne Channel Dye Injection at Chavonne channel main gates						
1	12.15	2.412	1300.049	0	0	520.0	1.549	10	0.140	4.474	4.126	2.606	0.646	4.125	8.599	0.02	5.3262
2	15.10	2.418	1300.053	-130	-131	389.5	1.553	19	0.266	8.124	3.261	2.512	0.552	3.258	11.382	0.08	5.0904
3	15.45	2.414	1300.05	-243	-241	278.0	1.550	24	0.336	9.967	2.574	2.433	0.473	2.584	12.551	-0.41	4.9439
4	16.20	2.421	1300.055	-325	-325	195.0	1.555	26	0.364	10.695	1.974	2.355	0.395	1.972	12.667	0.09	4.8968
											Dye measurement made in Grand Eyvia stream						
			reservoir lever in remote regulation								Dye Injection at Grand Eyvia cylindrical gates						
5	17.40	2.420	1300.055	-520	-520	0.0	1.555	35	0.490	13.614	13.673	1.960	0.00	0.000	13.614	0.43	4.6306
6	18.26	2.418	1300.053	0	0	520.0	1.553	21	0.294	8.881	8.956	2.610	0.650	4.178	13.059	0.84	5.0347
7	19.00	2.422	1300.057	-305	-305	215.0	1.557	27	0.378	11.050	11.027	2.362	0.402	2.032	13.082	-0.21	4.8721

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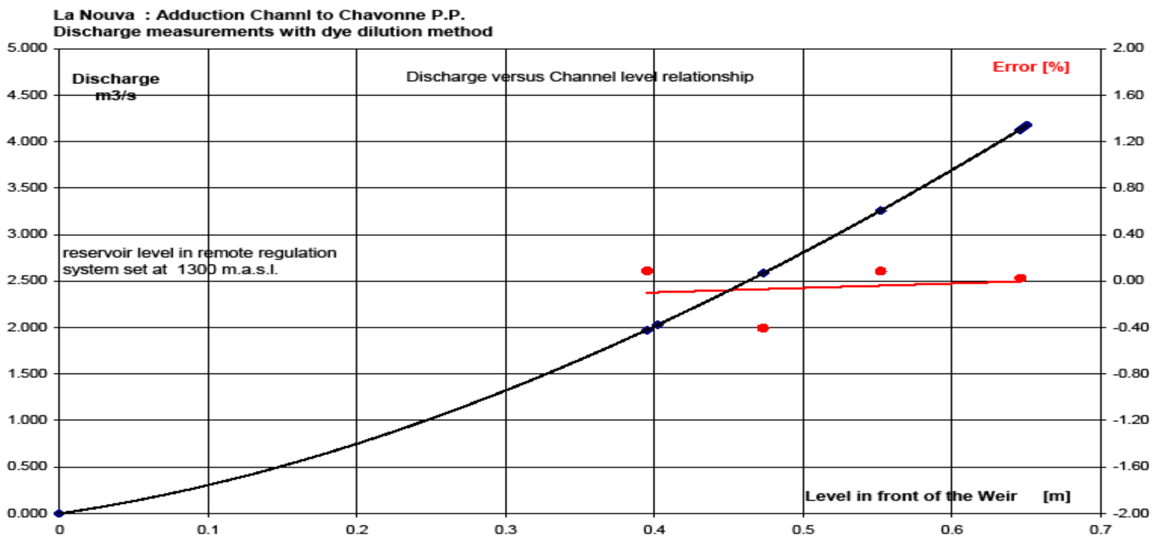
The following graph shows the behaviour of the channel according to the level in the channel itself.



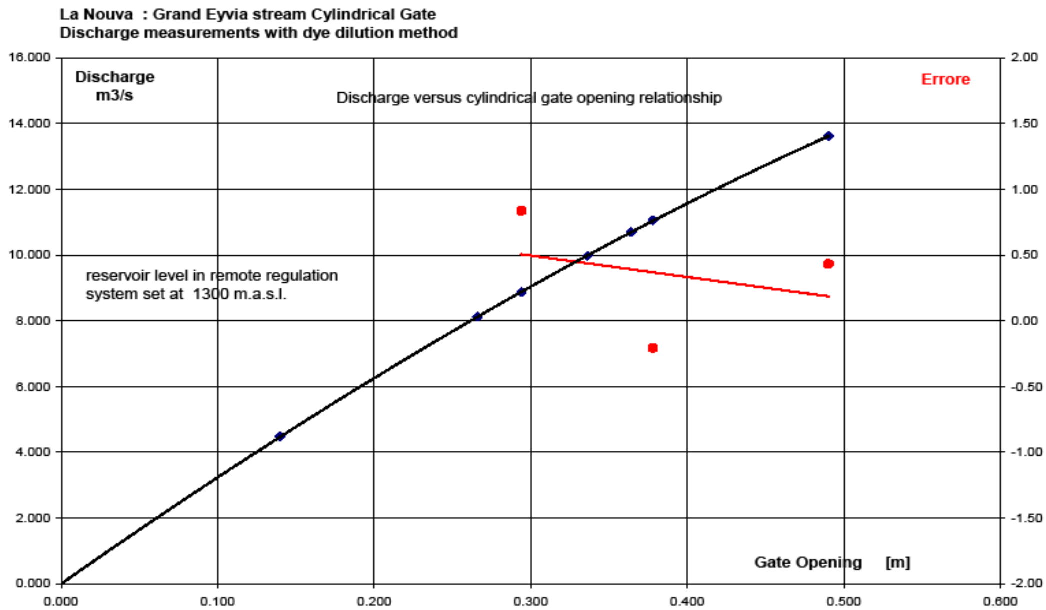
The flow is achievable through the weir typical equation:

$$Q = C \times B \times (2g)^{0.5} \times h^{1.5}$$

where being the weir not under codified conditions and in particular in lack of hair ventilation the upstream level is typically lower than the theoretical and therefore has good congruence with the test obtained with Rodhamine that gives C = 0,473 assuming the width of the blade B = 3.8 m.

The error of the theoretical curve compared to the measures with tracer is always less than 0.5% with light trend to overestimate the flow in the lower part of the scale.

The following graph shows the behaviour of the flow delivered to riverbed according to the opening of the cylindrical gate.



The flow is achievable through the typical efflux relationship

$$Q = K \times A \times (2gh)^{0.5}$$

where Section A is a function of opening and width assumed in 6 m while the height h is variable as effect of the change in the elevation of the centerline of the exhaust section. Therefore follows a the third order relationship with the experimental coefficient K = 1,013 higher than the theoretical in order to maintain consistency with the tests performed with Rodhamine WT.

The error compared to the measures with tracer is on average less than 0.5% .

CONCLUSIONS

The measured values were verified as a result of recalibration of the measuring instrument, checks on samples taken during the tests and measures concentration of the solution placed confirming what obtained

Tests have shown that the dye dilution method can be a valuable tool for the determination of parameters that allow the evaluation of flow even in conditions not favourable as in the case of measurement made directly into streams.

The uncertainty of the measures is such as to allow enough accurate analysis on the affordability of any re-powering.

In this case the monitor developments temporal scope of the torrent Grand Eyvia is still underway. The results achieved so far seem to validate the possibility of re-powering of Chavonne power plant giving significant results on design features of new groups

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