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TRACING THE PLUME OF TREATED WATER FROM TANCAT DE MILIA DISCHARGING INTO THE ALBUFERA LAKE, VALENCIA, SPAIN

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SUMMARY

Domestic, agricultural and industrial waters are discharged into the Albufera Lake, Valencia. These flows contain high concentrations of phosphorus, ammonia and nitrate which lead to poor water quality, habitat degradation, and a decline of biodiversity.

In order to reduce these interlinked environmental problems, the constructed wetland 'Tancat de Milia´ was created in the south part of the Albufera Lake. Its main goal is to filter the water and thereby improve the water quality of the lake. However, it is currently unknown how treated water from the Tancat de Milia is spatially distributed in the Albufera Lake. Therefore, the NGO Fundación Global Nature asked us, a group of students from Wageningen University, to investigate this topic.

The methodology of this research is based on literature review, fieldwork and data analysis using GIS and Excel. Based on literature review the initial parameters selected to trace the plume are: temperature, pH, electrical conductivity, dissolved oxygen, turbidity, nitrate, ammonia, orthophosphate and the depth. These parameters were measured in the Tancat water and in the lake water up to a distance of 90m approximately from the outflow point in order to choose the adequate tracer for the plume.

Vegetation patterns, wind data, tracer experiments and lake dynamics were used to create a sampling plan to assess the spatial distribution of the plume. The sampling plan was designed and adjusted during the fieldwork to come up with the final sampling plan which consists of six transects and six sampling points each.

To be more realistic as possible we stuck to the normal pumping hours of the system and thereby we took measurements after 7 hours pumping out water from the Tancat. The daily procedure consisted of taking samples in the lake using a boat after stopping the engine. Afterwards, all parameters were measured using probes and kit analysis in a working space. Few days after measuring all parameters, the electrical conductivity (EC) was found to be the most reliable tracer for the plume since it shows the biggest difference in values between the Lake (1860 mS/cm) and the Tancat (2560 mS/cm). The total duration of the fieldwork was 7 days and includes pumping and no pumping days to compare results.

The interpolation tool 'Natural Neighbour' of GIS was used to visualise the EC gradients each day and thus assess the plume. Results show no uniform pattern of spatial distribution of the treated water coming from the Tancat flowing into Albufera Lake. The spatial distribution is strongly influenced by weather conditions and hydrology of the lake. On day 1 and 3 the mixing was almost complete, caused by the wind intensity and other external factors. During day 2 no water was pumped out and the plume was not observable anymore. And finally, for day 4 and 5 a clear EC gradient could be observed since the weather conditions were good. To conclude, during the measurement days the treated water from the Tancat could be observed from 10 meters up to a maximum of 90 meters, which strongly dependent on the wind conditions and other external factors.

Our research has shown that mixing occurs fast. For this reason it is not recommendable to further study the spatial distribution of the Tancat water. It would be more interesting to investigate the Tancat sytem functioning since we measured some surprising values, such as high EC values.

WHO ARE WE?

We are five students from Wageningen University who have been commissioned by Antonio Guillem Avivar from Fundación Global Nature in order to investigate how the treated water from Tancat de Milia is spatially distributed in the Albufera Lake.

Flavia Cosoveanu (Flavia.cosoveanu@gmail.com)
I studied my Bachelor in Environmental Sciences at Alcalá Univeristy in Madrid. I had many courses related to water and project management. At the moment, during my International Land and Water Management Master, I attended a Water Treatment course and learn a lot about how to work in an international team.

Jessica van Grootveld (jessicavangrootveld@gmail.com)
I have completed the BSc International Land and Water Management and am currently in my final year of the MSc International Land and Water Management-Track: Irrigation and Water Management. I have followed a number of courses at Wageningen University and at the technical University of Delft related to water purification, water reuse and designing water treatment systems.

Jasper van den Heuvel (Jasper.vandenheuvel@wur.nl)
Before studying at Wageningen I did a bachelor International Land and Water Management at Van Hall Larenstein, where I did measurements on water quality. During a traineeship in Portugal I set up a research project, to identify the effects of pesticide use in viticulture on water quality in the Certima catchment. I made soil columns, did literature research and selected the research location.

Rosa Hueting (Rosahueting@hotmail.com)
In 2012 I finished my bachelor Future Planet Studies with a major in Earth Science. After my bachelor I started with a Master in Hydrology at Amsterdam University (NL), which I completed last summer. Currently I study International Land and Water management. I conducted fieldwork in the Netherlands, Spain and Portugal during my studies.

Sijmen Weesie (Sijmen.weesie@wur.nl)
I *examined during my bachelor thesis the shallow lake 'markermeer' (3-5 m depth), various problems were analysed, such as a sludge problem. Besides different alternatives to improve the water quality were submitted. I did for my current Master International Land and Water management an internship in Northeast Brazil whereby I researched the influence of external conditions (rain, evapotranspiration, reservoir operation) on the reservoir volume over time.*

THANKS TO

This study for Fundación Global Nature could not have been completed without the help of a number of people. We would therefore like to take this opportunity to express our gratitude to all those who have generously given their time and assistance.

First of all we would like to thank our commissioner, Antonio Guillem Avivar, for his supervision as well as for all the efforts he took to arrange all kinds of practicalities. Secondly, we would like to thank Javier Jiménez Romo for helping us understand Tancat de Milia better and for adjusting the pumping regime to fit our study. The both of you made us feel very welcome. Thank you.

Furthermore we would like to express our gratitude towards our WUR supervisors, Erik van Slobbe and Saskia Werners, for the useful comments and overall supervision that they have given us throughout the course of our research.

Of course we would also like to thank Boro –Salvador Ferrer San Canuto- our boat driver, for assisting us during our fieldwork. Without you, we would not have been able to carry out our research on the Albufera Lake.

Finally, we would like to thank Miguel Martin Monerris and Carmen Hernández for their feedback, help and practical support- arranging among others a spectrophotometer and sampling bottles- during the course of our research.

1. WHY SHOULD WE CARE?

The Albufera de Valencia is one of the most important wetlands in Europe (LifeAlbufera, 2015d). In 1986 it officially became a national park- *Parque Natural de l´Albufera de Valencia*- (GNF, 2015) and in 1990 it was declared a Ramsar site (J. Soria, 2006). Additionally it is also recognized as a bird protection area (since 1991) (J. Soria, 2006). The Albufera de Valencia is located approximately 15 km south of Valencia City (Boelens et al., 2015) and covers an area of 21000 hectares. Within the wetland three different ecosystems can be distinguished: the Albufera Lake, the marsh and the coastal forest (also called the Devesa). (LifeAlbufera, 2015d)

In the 1960s people used to drink the water from the Albufera Lake (Boro, 2015), but during the last couple of decades the water quality of the Albufera Lake has deteriorated drastically due to urban and industrial development (LifeAlbufera, 2015d) (J. Soria, 2006). In the Northern part, domestic and industrial waters discharge into the lake, which contain high concentrations of phosphorus and ammonia (Vicente & Miracle, 1992). Nitrate rich water that originate from the agricultural fields arrive mainly from the Southern part (Vicente & Miracle, 1992). Annex A elaborates more on all of the in- and outflows of the Albufera lake.

In order to address the interlinked environmental problems which the Albufera Lake is facing, the governmental organisations Confederación Hidrográfica del Júcar (CHJ) and Aguas de las Cuencas Mediterráneas (ACUAMED) converted rice fields into three constructed wetlands in 2006 (MedWet, 2015). In October 2013 the Albufera LIFE project was launched with the main objective to increase, in an integrative way, the efficiency of Tancat de la Pipa, Tancat de Milia and Tancat de L'illa in order to achieve an improved water quality of Lake Albufera and improve habitats and bird conservation (LifeAlbufera, 2013, 2015d). The project builds on the three European directives of Water, Birds and Habitats (Guillem Avivar, 2015a). Annex A contains more information about the Albufera LIFE project.

One of these constructed wetlands is Tancat de Milia (see Text Box A), which is located on the South shore of the Albufera lake and covers an area of 33.4 ha (see Figure 1). It is managed by the environmental NGO Fundación Global Nature and has been in operation since 2012. Its main goal is to improve the water quality of Lake Albufera, and at the same time enhance biodiversity and create habitats (LifeAlbufera, 2015a).

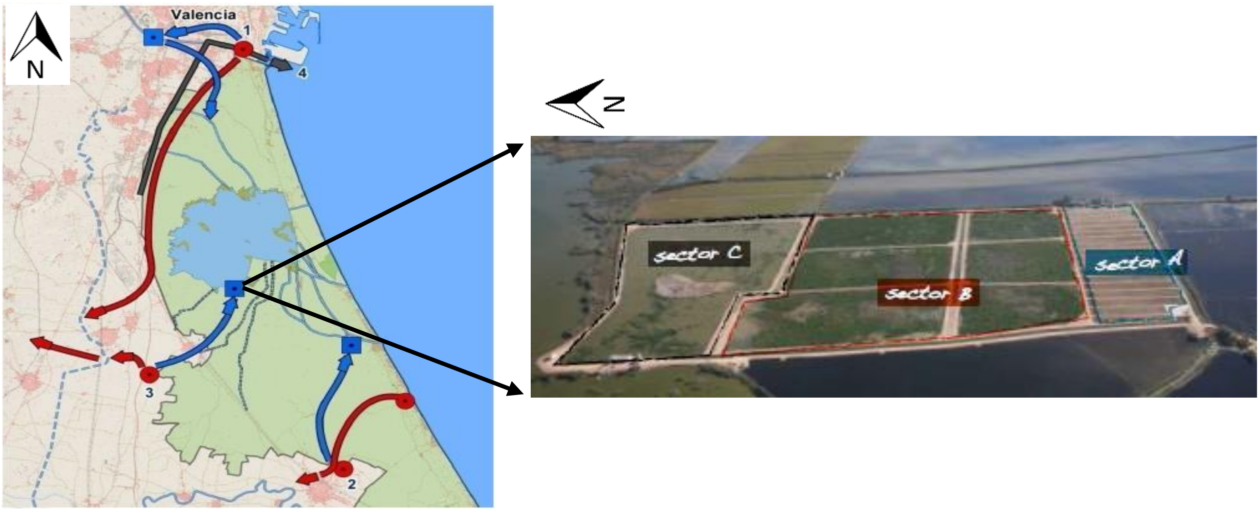


Figure 1: Location of Tancat de Milia (Ferruses, 2014)

OBJECTIVE & RESEARCH QUESTIONS

According to Fundación Global Nature, it is currently unknown how the treated water from the Tancat de Milia is spatially distributed in the Albufera lake and therefore this project sets out to investigate this. Once this is known, calculations can be made on the number of additional Tancats needed in order to treat all of the water of Lake Albufera sufficiently (Guillem Avivar, 2015b). This research can also be used by students/researchers in order to further investigate the plume (see Text Box B) of treated water originating from the Tancat de Milia. A detailed description of the assignment, formulated by our commissioner Antonio Guillem Avivar, can be found in Text Box C.

In this report we will answer the following question: *To which extent is the treated water from the Tancat de Milia spatially distributed in to the Albufera Lake?*

The main research question is operationalised with the following sub research questions:

- *Which water quality parameters are suitable to measure horizontal gradients of the treated water plume, which flows from Tancat de Milia into the Albufera Lake?*
- *What are the horizontal water quality gradients within the treated water plume, which flows from Tancat de Milia into Albufera Lake?*

Text Box A: Tancat de Milia, "Green Filter"
The basic principle of the Green Filters is to recirculate the water along areas with vegetation. The plants up-take the nutrients reducing their concentration leaving a cleaner water (LIFEAlbufera, 2015) See Annex A

Text Box B: Plume is "a visible or measurable discharge of a contaminant from a given point of origin" (MiMi, 2015) See Annex B

Text Box C: Antonio Guillem Avivar's assignment

Why?

The water quality of the Green Filter Tancat de Mlia is better than the water from the Albufera Lake. The continuous supply of clean water in a specific area can significantly improve the ecological conditions of the Lake.

Wat?

The outflow of the Tancat de Milia is discharged into the Albufera Lake with an approximate volume of 1180m^3 /h more or less every two days. The purpose of this study is to determine the extent of the discharge into the lake. Thus, this study will establish if the water flowing from the system remains in the outflow area and if the lake water volume would be improved by the filter.

How?

Two daily (morning and afternoon) samples will be done in 15 different points. Thus, there will be taken samples with different wind conditions and effluent discharge into the lake. The effluent of the Green Filter and a farther point in the lake will be analysed in order to know until where the characteristics of the effluent remain similar and therefore determine the extent of the area.

The sampling plan consist of measurements with a portable multiparameter probe for oxygen, conductivity, pH y temperature. Additionally, the parameters Pt, Nt BOD and NH_4 will be measured with an analysis kit. And finally, the turbidity will be measured with a Secchi disc and a spectrophotometer provided by the NGO Foundation Global Nature.

Future use of the results

Getting to know the extent of the area into the lake will be very useful for the future planning of improving the water quality in the Albufera. Therefore, if the extent of the area and the volume of the water that the Tancat discharges into the lake are known, the number of Tancats needed to improve the ecological conditions of the lake can be calculated. The results of the project can be a starting point for future students interested in study the same or different topic related to the functioning of the Green Filters.

El Palmar, 26/06/2015

2. HOW WE DID IT

In this section we elaborate on which parameters we have measured during our research. Furthermore, a schematic representation of our sampling grid is given. The sampling grid is optimised during the fieldwork (e.g. add extra sticks on order to be able to measure the entire plume). The steps to achieve this grid are described in the Section ‘Steps to get there’.

2.1 WHAT WE MEASURED

Multiple water quality parameters were selected to be measured in the Albufera Lake during the fieldwork as potential tracers for the outflow plume of the Tancat. We selected these parameters as our literature research suggested that these were the most feasible to show water quality differences between the Tancat and the lake. Parameters include nitrate caused by agricultural activities and ammonia and orthophosphate from domestic wastewater.

Water samples were collected and analysed for temperature, DO concentration, pH and EC with probes (more information about the sampling plan and procedure can be found in Chapter 2.2 and 2.3.). The turbidity was measured using a Merck SQ 118 Spectrophotometer. Nitrate (NO_3^-), orthophosphate (H_2PO_4-) and ammonia (NH_3) were measured using a Hach kit. The water samples were combined with in-situ (lake) depth and turbidity measurements. The former was measured using a bamboo stick with cm units and the latter using a Secchi disk. More information about why and how all parameters are measured can be found in the Annex C.

2.2 THÉ SAMPLING PLAN

The final sampling plan is constructed out over the first week of fieldwork out of field observations and literature. The steps we took in order to achieve at the final sampling are described in Subchapter Chapter 2.4.

The final sampling plan is schematically represented in Figure 2. In total there are six transects, labelled A, B, C, D, E and F. For each transact we measure six locations. The distance between the sticks is indicated in the figure (10 meters, 15 meters and 20 meters respectively). We estimated that the total distance of 90 meters would be enough to measure to the end of the plume. The red dots in Figure 2 display the measuring points marked by bamboo sticks on the water-transects and the black dots indicate the random measuring points.

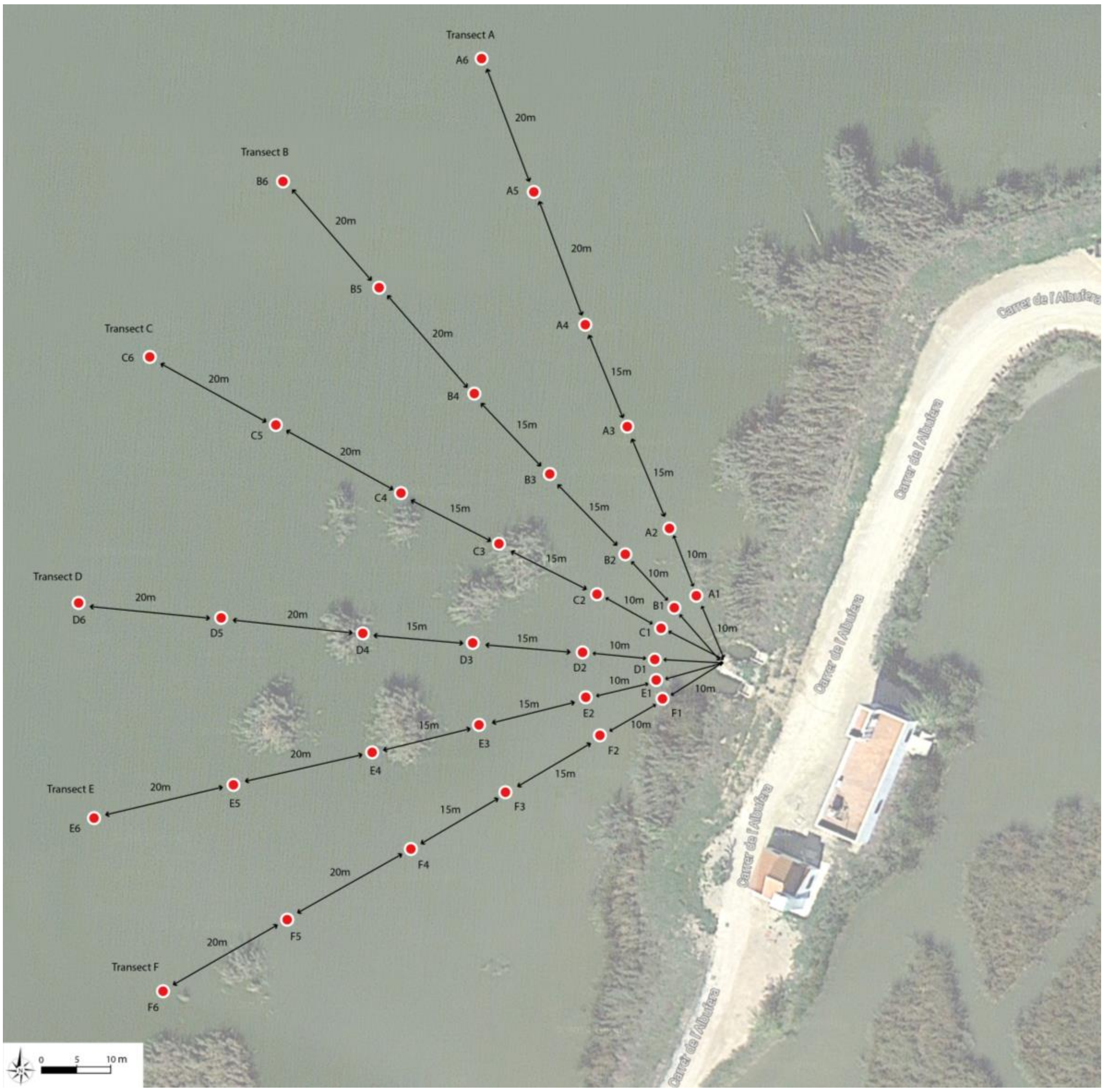


Figure 2: 'The' sampling plan

2.3 SAMPLING PROCEDURE

The sampling procedure to determine the spatial distribution of the water originating from the Tancat de Milia, after 7 hrs of pumping (see more details on pumping regime in Annex D), consists of five steps. Step 1 deals with calibrating the equipment and preparing the samples bottles deals with measuring the water quality of the Lake and the Tancat. In step 2, we measured both the water quality of the lake and the Tancat. Step 3, all the sample bottles were filled with water from the Lake according to the designed transects. Step 4 all the parameters were measured outside the lake with the equipment. Step 5 at the end the chemical parameters were measured using a kit. The steps are described in more detail in Text Box D.

The procedure of the fieldwork was more or less the same every day including small exceptions related to time and logistics constrains. The timeline from Annex E shows an overview of the daily activities during the fieldwork. The sampling procedure had to be adjusted some days because of changes in the sampling grid and the decisions about which parameters are the adequate tracers to define the plume in this research. The group members rotated every day for the different tasks necessary to be done. The results and the analysis of all the measurements will be discuss in the next chapter.

In addition, it was important to check the wind conditions for each measure day as it may influence the water stream direction of Tancat water into the lake. The wind direction and speed were checked every day in the morning before the fieldwork for the three closest stations to the Albufera: El Saler, El Pollo and El Perello on the following websites: http://www.windguru.cz/es/index.php and http://es.windfinder.com/. However, after few days we observed that the wind direction was not the same that the weather stations were showing. We will further elaborate on this when discussing the our measurement results (Chapter 3).

Text Box D: Sampling procedure

Step 1

Reference levels were taken during pumping time in front of the outflow point. Random samples were taken further away in the lake on a distance further then 50 meters from the outflow point. Thereby we could compare the difference between the parameters from the Tancat and the lake water.

Step 2

By starting to take samples from the lake water the equipment for EC, pH and T had to be calibrated beforehand. Additionally, the sampling bottles were labelled and placed into the cooler. All the materials were prepared on a table in the shadow close to the outflow point in the Lake. The tasks were divided between the group members every day: two people were calibrating the probes, and the other three were in charge of the bottles and installing the table outside.

Step 3

Every day two people had to go on the lake with the boat driver to fill the sampling bottles from the different sampling points. We did two transects per round which means starting at A1 (Figure 5) till the end of the water-transect (A6 or A4.), and coming back through B6 or B4 till B1. When the two people were finished to fill the bottles, the third person was waiting at the starting point with the bottles ready in the cooler for the second transect round (C and D). The same person had to write down the time of starting and stopping the sampling.

Step 4

Immediately after collecting the first samples, one person was doing the DO measurement and a second person could measure the EC, pH and T with another probe. A third person was in charge of ordering the bottles in the cooler for the second or third round and pick up the full ones. The turbidity measurements were done by someone who was already finished with other tacks or later in the afternoon.

Step 5

During the afternoon two people were doing the chemical analysis and the turbidity measurement if there was not enough time for it in the morning. The three remaining people could pass the data from the forms into the excel file for further analysis and making a map draft every day to interpret the results. At the end of the afternoon, all the equipment was cleaned and tidied up for the next day of measurement.

The procedure of the fieldwork was more or less the same every day including small exceptions related to time and logistics constrains. The timeline from Annex E shows a wider overview of all the activities daily during the fieldwork. The sampling plan had to be adjusted some days because of changes in the sampling grid and the decisions about which parameters are the adequate tracers to define the plume in this research. The group members rotated every day for the different tasks necessary to be done. The results and the analysis of all the measurements will be discuss in the next chapter.

2.4 Steps to get there

As discussed earlier, the sampling plan was develop and optimised during the first week of fieldwork, taking into account the outcomes of natural tracer experiments, vegetation patterns, wind direction, and lake dynamics. In this section we will elaborate on these different steps.

We used dried vegetation such as reed and grasses as a natural tracer in order to visualize the movement of the plume. The reed was placed in the water at the outlet of the Tancat, than the pump was turned on for 10 minutes. During this period we observed the movement of the plume by following the reed. We did this experiment three times on the 11th of June. More information about tracers is provided in Text Box E.

Text Box E: Tracer. They are commonly used in order to determine the time it takes for water to flow from point A to point B. Therefore, tracers are useful to monitor the spatial distribution of a plume.
See Annex F

Figure 3 demonstrates the result of a natural tracer experiment. The light blue plume visualises the movement of the reed tracers during the entire experiment over time. Light blue arrows indicate the location and flow direction of a small part of the tracers. Figure 3 displays that vegetation is important for the spatial distribution process of the treated water as it creates a junction of the water. The outcomes of the two other experiments can be found in Annex G.

Based on these experiments we have decided to place two bamboo sticks each at 10 m distance from each other starting from the outflow of the Tancat. This is schematically represented in 'the' sampling plan (See Figure 2).

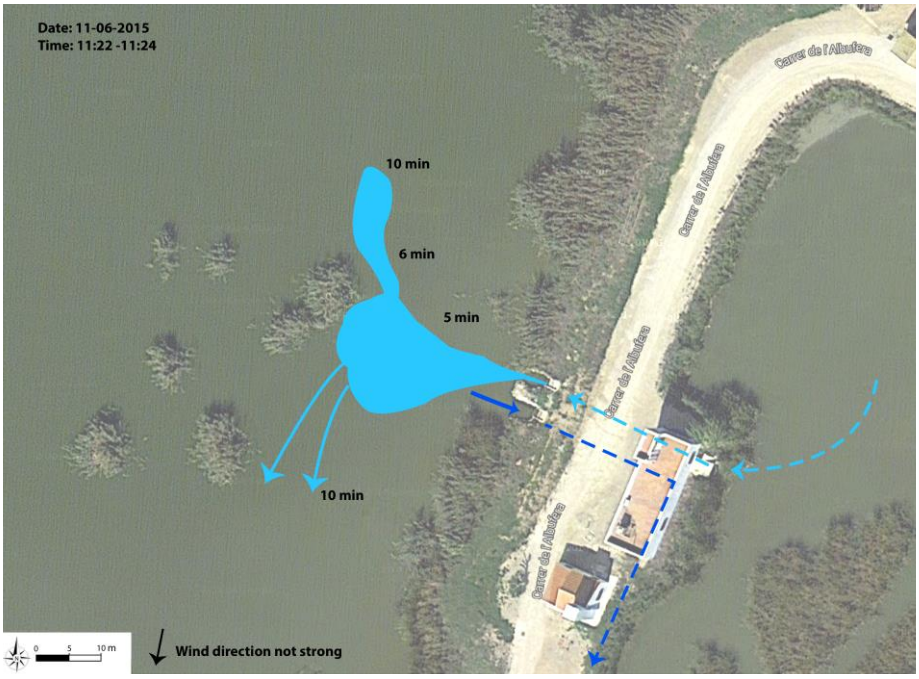


Figure 3: Natural tracer experiment conducted on 11-06-2015. Picture: edited version of Google maps (22-06-2015)

The presence of vegetation is further studied by using satellite images since vegetation influences the flow in which the water flows. In Figure 5 the vegetation patterns close to the outflow are illustrated. The green dotted lines indicate the areas that could possibly influence the flow of Tancat water. Therefore we decided to cover the locations close the reed, mainly the reed island, with sticks which is depicted in our final measurement plan (transect C, D, E and F).

Figure 5: Vegetation patterns

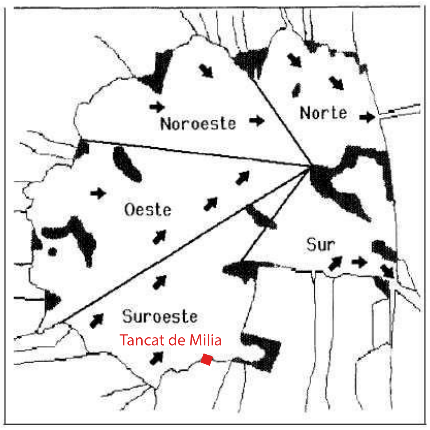


Figure 4: Outline of the Albufera Lake indicating the zonal distribution and directions of water circulation in each of the lake areas. Water flows towards two outlets called 'Gola del Pujol' and 'la Sequiota', which in turn flows toward the 'Golas del Perellon (J. M. Soria & Vicente, 2002)

Figure 4 shows the outflow of the Albufera Lake into the sea on the East side of the lake. In addition, it also demonstrates that water circulates from the surroundings of the Tancat de Milia towards the outlets (J. M. Soria & Vicente, 2002). Hence, measuring points have been placed in North Eastern direction from the outflow (transects A and B in Figure 2).

After the first three measure days we concluded we measured higher EC values than the days before as a response we added two extra sticks at the end of every transect (row 5 and 6) with a distance of 20 m.

The sampling plan changed over time due to the measurement results. Figure 2 shows the measure plan that we have used in the last two days. Table 1 is an overview of the different transects including the justification.

Table 1: Transects, graphical direction from the point of the outflow from the Tancat and reasons for placement

Transects	**Graphical direction from the point of outflow from the Tancat**	**Justification**
Transect A	North-eastern direction	Lake dynamics
Transect B	North-eastern direction	Lake dynamics, Tracer experiment
Transect C	Eastern direction	Tracer experiment
Transect D	South-western direction	Tracer experiment
Transect E	South-western direction	Tracer experiment
Transect F	South-western direction	Tracer experiment

3. What we found and how we can explain it

In this section we will present and discuss our findings. Firstly we will discuss why we selected EC as the most suitable water quality parameter to identify the plume of treated water and why the other measurements were disregarded. Secondly, we will use our EC values of the five measurement days in order to present and describe the plume of treated water originating from Tancat de Milia.

3.1 Tracer parameters

Before we can identify the plume of treated water flowing into the Albufera Lake, we have to identify the most suitable water quality parameters or tracers.

As explained previously, we initially started with measuring multiple water quality parameters, namely: temperature, pH, EC, DO, turbidity (using a Sechhi disk and a spectrometer), ammonia, nitrate and orthophosphate. The main goal of this study is to identify the spatial distribution of water coming from the Tancat de Milia, and not to do an extensive water quality study. During the fieldwork days we adjusted the parameters that we measured, based on the notion of whether they are a good tracer parameter or not. Comparing the lake reference levels with the Tancat levels (see Table 2) showed us whether there was a significant difference between the parameters in the lake and the Tancat. Only if there is a significant difference one can use them as a tracer.

Table 2: Comparison of water quality parameters of Albufera Lake and Tancat de Milia (based on fieldwork days 1 and 3)

Parameter	**Unit**	**Albufera Lake**	**Tancat de Milia outflow**	**Difference**
Temperature	(°C)	25,5	26,6	1,1
pH	(-)	8,7	8,0	0,7
Electrical conductivity	(µS/cm)	1860	2460	600
Dissolved oxygen	(mg/L)	12,1	7,9	4,2
Turbidity (Spectrophotometer)	(UNF)	67	44	23
Nitrate	(mg/L)	0-8,8[1]	0-8,8	0,0
Ammonia	(mg/L)	0,3	0,7	0,4
Orthophosphate	(mg/L)	0,1	0,1	0,0

Table 3 gives an overview of the parameters that we measured in each fieldwork day. The tables containing the results of our water quality measurements for each day can be found in Annex H.

[1] This range between 0 and 8,8 mg/l of nitrate has to do with the fact that the Hach water quality test kit was not so accurate. It was impossible to distinguish between some neighbouring colours on the colour disk, as it has probably been exposed to too much light in the past couple of years. Nitrate measurements with nitrate strips showed similar results: that there is no (significant) difference between the Tancat and the Lake nitrate levels.

Table 3: Parameters measured per fieldwork day

	Day 1 (17-6-2015)	**Day 2 (18-6-2015)**	**Day 3 (19-6-2015)**	**Day 4 (22-6-2015)**	**Day 5 (25-6-2015)**
Sampling points	24	33	36	43	51
Depth	X	X	X	X	X
Temperature	X	X	X	X	X
pH	X	X	X	X	X
Electrical conductivity	X	X	X	X	X
Dissolved oxygen	X	X			
Turbidity (Spectrophotometer)	X	X	X	X	
Secchi transparancy (m)	X	X	X	X	X
Nitrate (hach kit)	X		X		X
Ammonia (hach kit)	X		X		
Orthophosphate (hach kit)			X		
Nitrate (strips)				X	X

Temperature

In hydrological studies, temperature is often used to trace ground water movement (USGS, 2003) as there is frequently a large difference of heat between surface and ground water. The temperature difference between the lake water and the Tancat water also differs quite a bit. On average there is a difference of 1.6 degrees Celsius, whereby the Tancat water is colder than the Lake water. Based on this, temperature could be a useful tracer. However, in our case it is not a reliable parameter to use, as we did not perform the measurements in situ. The temperature of the samples will have increased during the transportation. Additionally, the measurements took around two hours, which will have had an effect on the temperature, and will not allow us to compare for instance A1 with F1.

pH

Table 2 shows that there is not a significant difference between the pH of the Tancat water and the pH of the Albufera Lake water. There are also a lot of natural and human factors that influence the pH of surface water (UtahStateUniversity, 2015). These two reasons have made use decide not to use pH as a parameter to trace the plume of treated water.

Electrical Conductivity (EC)

Salt- and thereby the electrical conductivity of water- is commonly used as a tracer. There is a large difference between the EC of the Tancat water and the Albufera water. On the first fieldwork day this difference was 600 µS/cm. Tancat de Milia is thus discharging water with a high salinity level into the Albufera Lake. Why the EC within the Tancat increases so much is outside of the scope of this research. What we can conclude is that EC is a suitable parameter to identify the plume as the difference in EC between the treated water and the Albufera water is so high.

To help us understand this difference in EC, we tried to look at the bigger picture. There are a lot of drainage channels discharging water into the Albufera Lake. This drainage water can either be a source of saltier water (a high EC) or a source with water with a lower EC value. On the rice fields surrounding the Albufera Lake, water- which is used for irrigation- is frequently pumped up and recycled. Evaporation causes this irrigation water- which eventually discharges into the ALbufera Lake- to become more and more salty. Of course it depends on the origin of the irrigation water (Jucar River water or Albufera Lake water) whether the drainage channels contribute to an increase or decrease of salinity (Vos, 2015). Only on our last fieldwork day we measured the outflow of a drainage channel located close to the in/outflow point of Tancat de Milia. The measured EC values were 1750 & 1760 compared to the lake reference of 1797.

Dissolved oxygen (DO)

After the second fieldwork day we decided to stop measuring the DO concentration of our water samples as the amount of dissolved oxygen within a water sample is easily disturbed. We came to this conclusion by performing the following test: We took some water samples, measured the DO, shook the sample bottles vigorously and measured the DO again. The results showed that the DO dropped with 4.2 mg/L. Dissolved oxygen is thus not a suitable parameter to trace the plume of treated water.

Turbidity

As Table 2 shows, the turbidity, a measure of cloudiness, of the Tancat water is in general much lower than the turbidity of the reference levels. Based on this, one could argue that turbidity is a useful parameter to identify the plume of treated water. Our results however show that turbidity can vary quite a lot within the different transects. This is probably a result of the fact that turbidity is susceptible to multiple external conditions. It can be caused by high concentrations of phytoplankton, sediments from erosion and re-suspended sediments from the bottom of the lake (stirred up by certain fish species) (Bruckner, 2015) (Lenntech, 1998). One can imagine that boats causing an up flow of the bottom sediment layer, also increase the turbidity. On the final sampling day there were researchers, cleaning their muddy crates in our sampling grid area (see Figure 6).

For this reason we decided not to measure the turbidity on this day. As turbidity is influenced by various external conditions we have decided to disregard it as a parameter to trace the plume of treated water. Another measure for turbidity which we used was the Secchi transparency. We used this method to cross check the trends in turbidity which we observed using the spectrophotometer. However, the secchi disk reading is subjective since it is merely an indication for transparency and because different people have different eyesight's and weather conditions can also influence the secchi disk reading process (Gillissen, 2015).

Figure 6: researchers disturbing the turbidity

Nutrients

We measured the values of nitrate, ammonia and orthophosphate for the Tancat water and the Lake reference levels on a number of days (for details see Annex H). Our results showed that for nitrate and orthophosphate there are no measurable differences between the Tancat and the Lake water. This is surprising, as another water quality study conducted from January 2014 until January 2015, shows a decrease of total nitrogen and total phosphorus (LifeAlbufera, 2015c). For ammonia we did measure a difference of 0.4 mg/l, yet as this difference is so little, this parameter has been discarded as a plume tracer.

Conclusion

We conclude that EC in our case is the most suitable to use to trace the plume of treated water coming from Tancat de Milia.

Representativeness of our measurements

Table 4 gives an overview of water quality parameters of the Albufera Lake and Tancat de Milia measured over a longer time period. Our measured values for the temperature, pH, EC and DO fall within the ranges which have been measured by Carmen Hernández. Similar to our results, also high EC values have been measured in the treated Tancat de Milia water (on average 2914 µS/cm compared to 2085 µS/cm in the Albufera Lake). Table 4 also shows relative low nitrate values for the Albufera Lake, considering it to be in a hypertrophic state. Carmen Hernández measurements show quite a difference in nitrate values between the Tancat and the Lake (on average 1,78 mg/L) which does not coincide with what we have measured (no difference).

Table 4: Tancat de Milia and the Albufera Lake Water quality indicators based on data from January 2014- May 2015 (Hernández, 2015)

Parameter	Unit	Albufera Lake range	Albufera Lake average	Tancat de Milia range	Tancat de Milia average
Temperature	(°C)	7,6-28,4	17,67	8-27,7	17,61
pH	(-)	7,15-8,88	8,09	7,05-8,31	7,65
Electrical conductivity	(µS/cm)	1602-2560	2085,19	2070-4120	2914,23
Dissolved oxygen	(mg/L)	5,38-13,37	9,94	1,92-11,13	6,22
Turbidity	(UNF)	14,45-70	34,81	8,31-51,6	19,89
Nitrate	(mg/L)	0,10-5,18	2,09	0,1-0,69	0,31
Ammonia	(mg/L)	No data	No data	No data	No data
Orthophosphate	(mg/L)	No data	No data	No data	No data

The following section will show and describe the plume of treated water- using EC as a tracer- on each of our fieldwork days.

3.2 TRACING THE PLUME OF TREATED WATER WITH EC

In this section a description is given of the observed EC patterns. Moreover, the results will be linked to the wind observations in the field. Wind is expected to be of importance for the mixing processes in the Lake (see Text Box E about mixing concept).

Day 1 (17-6-2015)

Figure 7 shows that the plume is only measurable from the outlet of the Tancat up to the first 10 meters. This gradient ranges from 2460 μS/cm to < 1900 μS/cm. Note that the gradient in the figure is a result of the interpolation tool 'Natural Neighbor' of GIS. See Annex I for the justification of using this specific interpolation tool. The result of this interpolation is a typical rainbow of lower EC values, which is not the case if you would measure smaller gradients yourself. This interpolation rainbow could be observed for day 4 and 5 as well.

After this relatively small gradient there is no effect of the treated water originating from the Tancat (EC values < 1900 μS/cm). The last measurement located at 50 meters point of gradient D shows a small increase in EC. However, it is doubtful whether this water originates from the Tancat water since all the other measurement points equal the lake EC value assuming complete mixing. Also in the transect E there is a small gradient visible of about 2015 μS/cm.

During this day a mirror could be observed. In this research the mirror is defined as a clear division between areas were the wind does not have an influence, which looks almost like a mirror and areas further away from the Tancat where the wind has free play causing little waves. However, we do not see this reflected in our results. The area where the wind has no influence (the mirror) also mixing occurred since the water quality of the entire measurement grid is quite homogeneous.

Day 2 (18-6-2015)

Figure 8 is a representation of a day without pumping. It clearly shows that the Tancat water is completely mixed with the lake water since we cannot distinguish a plume. The fact that all the Tancat water is well mixed and not measurable anymore can be considered positive because treated water is not flowing back into the Tancat system for treatment. In order words: the treated water is not recirculating between the Tancat and the lake. At the end of gradient A, B and C the EC slightly increases which probably does not originates from the Tancat since this was also not measured the day before, see also Figure 7.

Text Box E: Mixing enables the distribution of suspended and dissolved matter (Fabian& Budinski, 2013). In shallow lakes, vertical mixing is a less dominant process compared to horizontal mixing since there is not stratification (Peeters et al, 1996).
See Annex J

Day 3 (19-6-2015)

On the 19th of June (Figure 9) we measured higher EC values (>2200 μS/cm) within the plume compared the other measurement days. Moreover, also the lake reference level was higher (2055 μS/cm). The lake EC differs in orders of 200 μS/cm for this particular day compared to the other days. However, this value is not remarkably high since this EC value is still within the range (1602 μS/cm – 2560 μS/cm) that is often measured (Hernández, 2015). There is a plume of Tancat water moving towards North Eastern direction up to 50 meters and mixing is increasing towards the South Western direction since we measure lower EC values at those locations. The lowest EC value that we measured in the plume is 2220 μS/cm, E4 located 50 meters, which is still not the reference level of the lake indicating that complete mixing did not occurred yet.

During this measurement day we observed small waves. Waves enhance the mixing process however, we did not observe complete mixing yet. Nevertheless we can assume that after 24 hours the Tancat water is entirely mixed- and thus no effect of the Tancat water is measured- taking into account the non-pumping day.

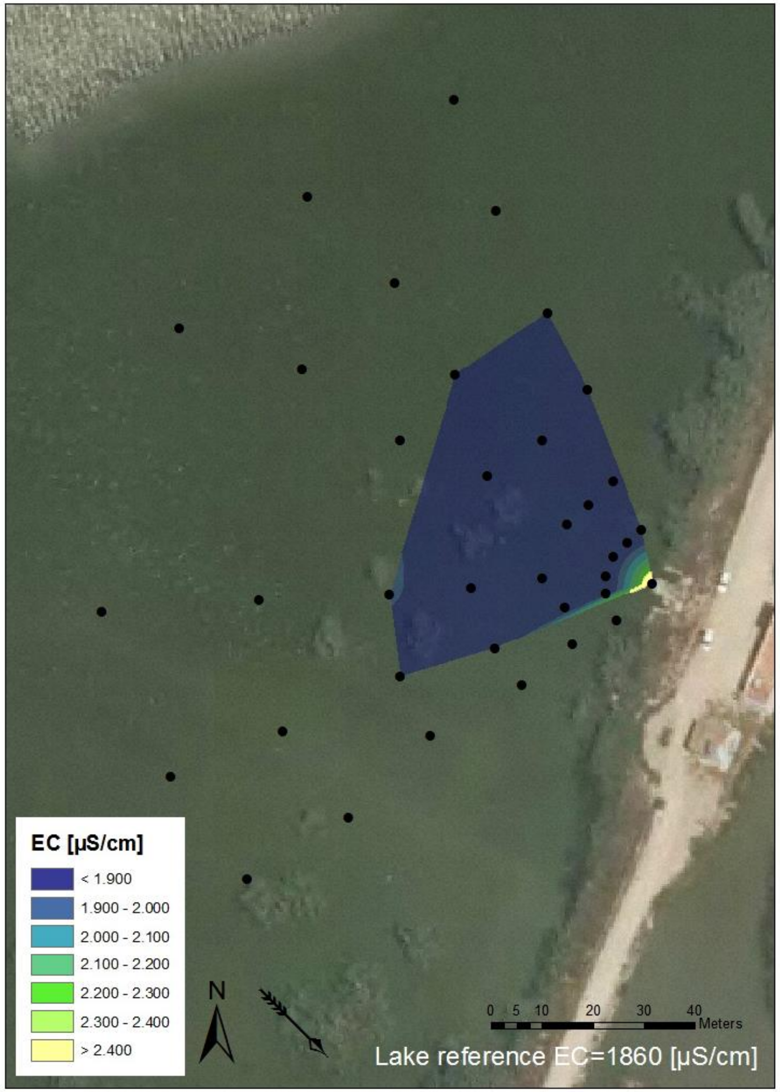


Figure 7: EC plume day 1

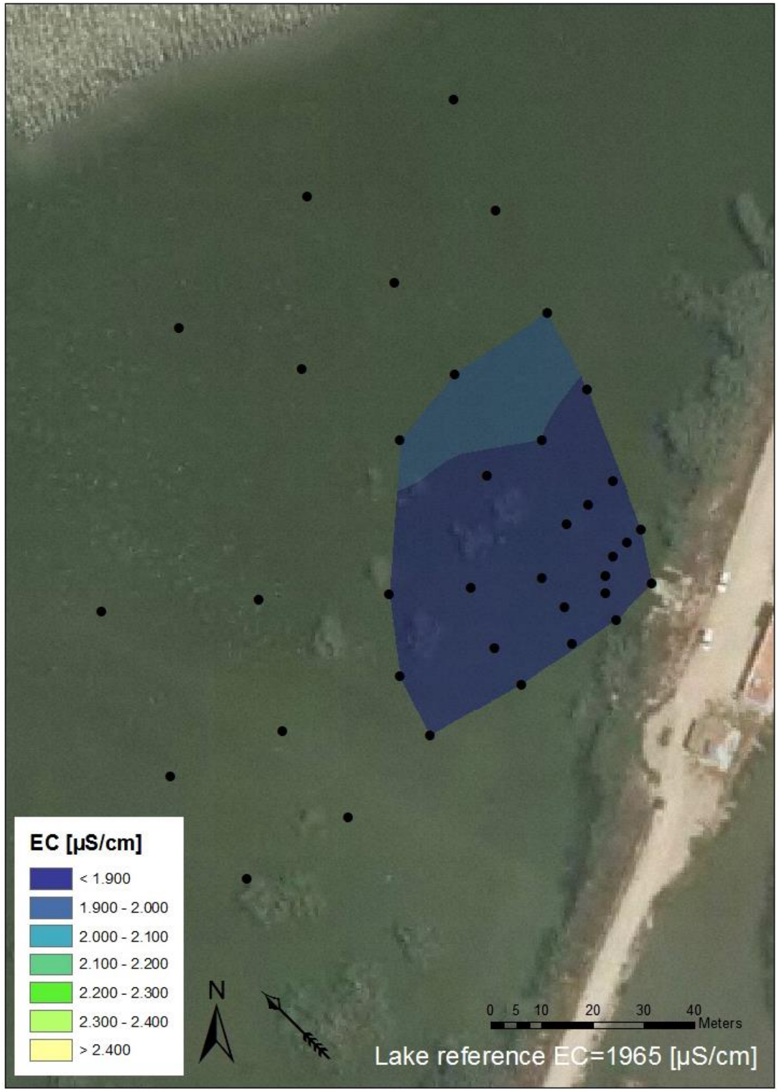


Figure 8: EC plume day 2

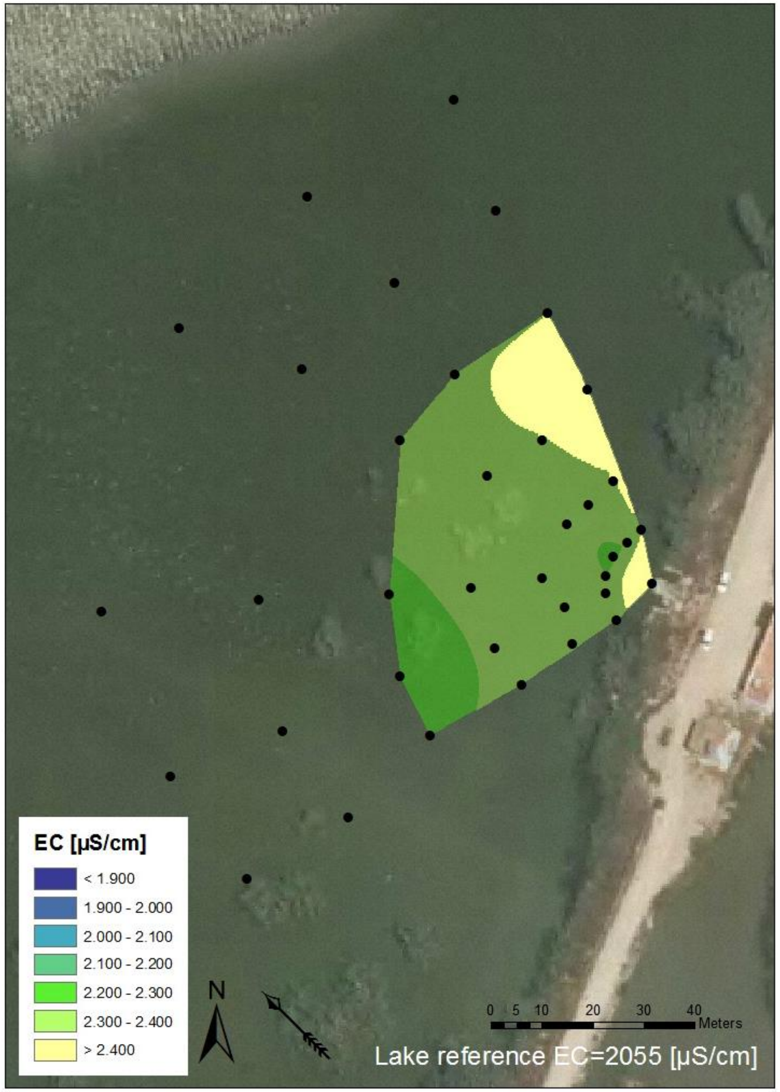


Figure 9: EC plume day 3

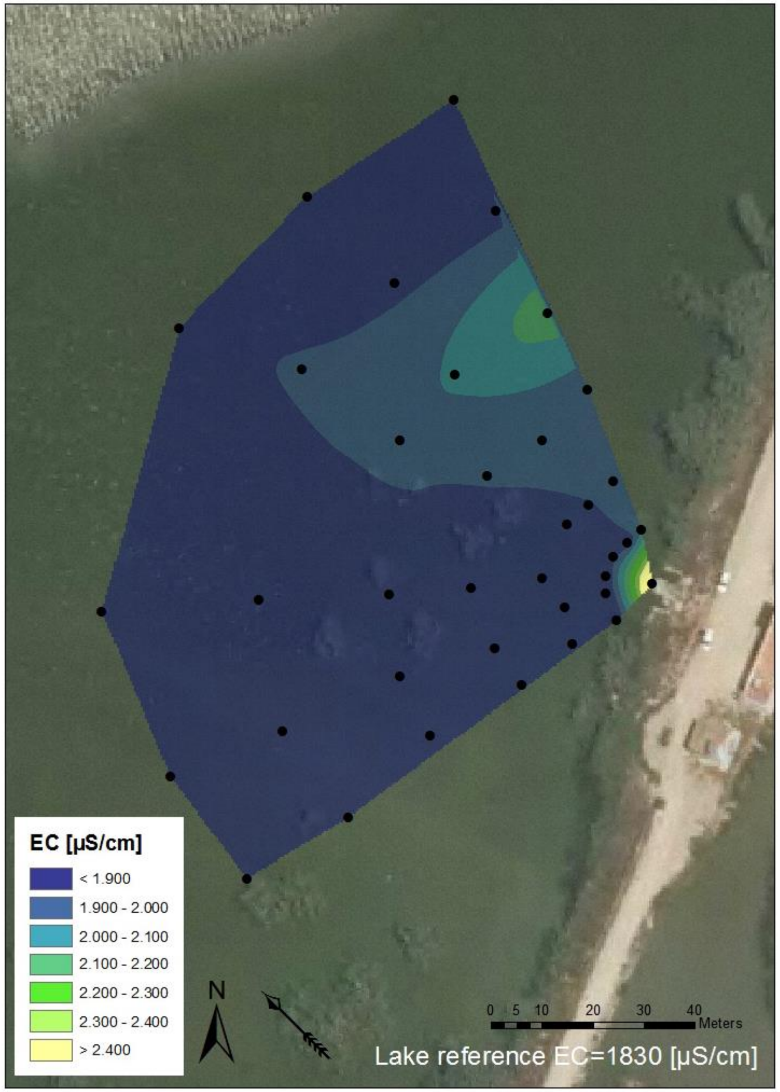


Figure 10: EC plume day 4

Day 4 (22-6-2015)

The gradient of the plume is visible from the outlet up to the first measurement point of our grid located 10 meters from the outflow, Figure 10. Moreover the plume is spatially distributed up to 50 meters towards to the North Eastern part of the lake as well as slightly towards the West. For the other measurement points of our grid we can observe EC values below 1900 μS/cm, which indicates complete mixing with the lake water.

During this day we observed the biggest waves (Figure 12). We also measured complete mixing on this day. There is only one plume of water that is still left but observing the last measurement points we can assume that this plume will quickly disappear within the Lake water due to the windy conditions.

Figure 11: Lake on the 22th of June in the morning showing the wave conditions generated by the wind

Day 5 (25-6-2015)

On this day (see Figure 13) a clear gradient can be observed from the outlet up to our first 10 meters of our grid. Furthermore, there is a plume of Tancat water measurable with the same EC value from the first measurement point till the fourth measurement point (located at 50 meters) for almost the whole width of our grid. Within this plume one island is measured with a slightly higher EC (2040 μS/cm). Possibly there is some stagnant Tancat water, which is not well mixed because of the reed. After 50 meters the Tancat water is almost entirely mixed with the lake water and therefore the treated water is hardly observed from point 4 onwards. On the Northern part of our measurement grid also a treated water plume could be observed with an EC of 1970 μS/cm stretching out over 90 meters.

On the fifth day of our measurement we observed a mirror approximately up to our fourth measurement point. This is also reflected into our result since we see a clear distinction of the EC between measurement point 4 and 5+6. Point 5 and 6 are subjected to wind creating waves. These waves are enhancing mixing and therefore we assume that mixing of Tancat and lake water lowered the EC in those points. We assume that the entire plume is fully mixed after 24h, since that is what we observed during the no pumping day. Furthermore, we observed that during the day, the mirror slowly moves towards the outlet of the Tancat, which also implies increased mixing conditions.

Importance of wind observations

The wind direction of the weather station El Perello is indicated with an arrow in all of the maps. However, during the last two days we observed the wind direction ourselves which differs from the weather station. It is therefore important to further analyse this since we expect that wind direction has a strong influence on the spatial distribution of the plume.

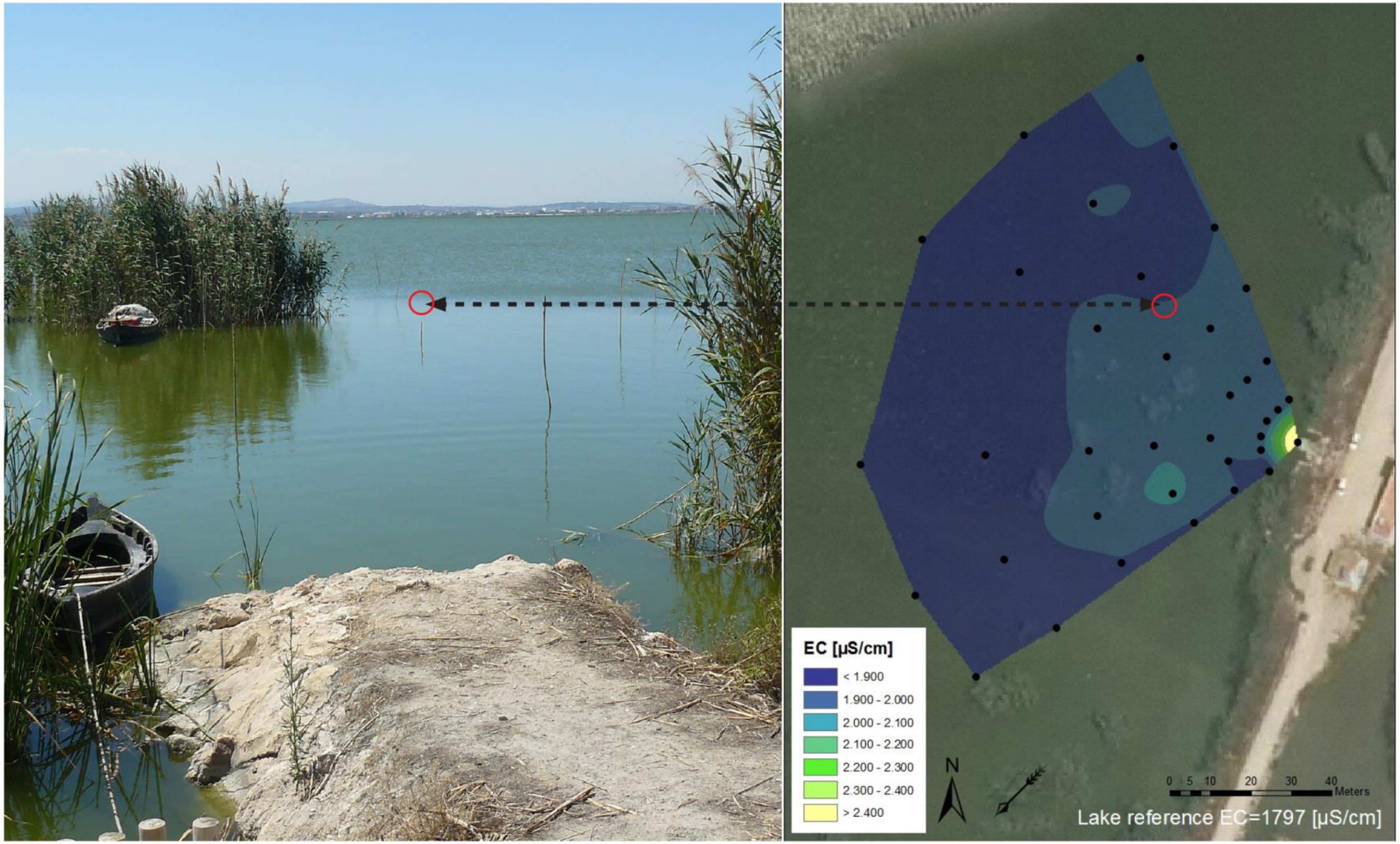


Figure 12: Mirror image and EC plume day 5

4. Reflection on methodology

In this chapter a critical reflection will be given on our methodology and more specifically on the parameters we used as tracers, the sampling plan, the fieldwork procedure and the results. We will reflect on what and how the research can be improve for future investigation.

Parameters as a tracer

In our research we have found EC to be 'the' tracer to identify the plume of treated water coming from Tancat de Milia. However we have selected it from a limited number of water quality parameters (see results chapter 3.1). Other parameters can possibly turn out to be useful tracers: such as ammonium, phosphate, alkalinity, chloride, chlorophyll a and total oxygen. Research should show whether this is the case. It could be interesting to measure these parameters with a multi meter since this gives more accurate results in comparison to the Hach kit.

Procedure of the sampling plan

We started every day taking the samples direct after stopping the pump. We observed that mixing occurs within 24 hours. We did not measured this mixing process at different time periods. It could therefore be interesting to take measurements while pumping, starting at different times (1h, 2h or 3h after starting pumping). This will help to better identify the mixing process. This could be of importance for our commissioner since he could start the pump start earlier with pumping lake water into the Tancat. We did not perform in situ measurements. This could possibly make it easier to identify the boundaries of the plume, since you are not stuck to a fixed measurement grid.

We measured five days, in the month June only. It could be that due to stronger winds in the winter the mixing process changes. An improvement of the sampling plan would be to take the same measurements regularly, for instance one day every week during a whole year. Thereby, we will have enough results from days with different weather conditions. In this way we will have different insights to compare results in order to study the extent of the plume and the gradients of the parameters.

Measuring wind direction and speed

We noticed that our wind observations in the field differ from the wind direction of the weather stations. Since we believe that wind direction is of importance it would have been interesting to observe the wind direction for all days. The wind conditions can easily be observed in the field by installing a basic wind station and also using the compass. Thus, we suggest that both wind speed and direction should be noted down every hour during the fieldwork because the projected wind data from weather stations are different from field observations and wind directions change rapidly. We observed during the first days that the projected wind data from weather stations seems very different from our own perception. This difference was key to increase the measurement grid in order to identify the full extent of the plume from Tancat de Milia into the Lake.

Moreover, keep in mind that we measured only in June; seasonal effects could also influence the distribution of the plume. Five measurement days were carried out during this month, a short amount of days to measure the plume or trends in mixing processes, especially considering that many processes (also unknown processes) can have a big influence on the plume distribution. For instance, wind characteristics and rainfall patterns can be different during other months of the year. Additionally, external discharge into the lake and flows out of the lake can differ throughout the year.

5. What we conclude

This research investigated the spatial distribution of the treated water coming from Tancat de Milia and flowing in to the Albufera Lake. In order to investigate this we designed a measurement campaign for which we selected EC as the parameter to distinguish the plume of treated water flowing into the lake water. Finally we constructed maps in which the EC values are schematically represented showing the spatial distribution of the plume.

Measurement campaign

We designed a measurement grid of 6 transects- containing 36 measuring points. Additionally, on each fieldwork day also the Tancat and the Lake reference levels were measured. EC turned out to be the most suitable parameter to trace the plume of water as there is a large difference between the Tancat de Milia and the Albufera Lake water- which ranges between 530 and 896 µS/cm.

Spatial distribution of the plume

Our results show no clear or uniform pattern of the spatial distribution of treated water coming from the Tancat and flowing into the Albufera Lake. The spatial distribution seems to be day dependent as the extent and the values of the EC within the plumes varied across the 5 measurement days. Wind is also an important factor to take into consideration when analysing the plume. We reason that the parts of the lake that are not influenced by the wind are less susceptible to mixing, which is well represented on the last measurement day (25^{th} of June). For this day the plume reaches up to 50 meters and is spatially distributed over the whole width of the measurement grid. Mixing is enhanced when the wind has free play, this is observable after measurement 4 since the plume is hardly measurable anymore. The plume is completely mixed on day 1 and 3 which is represented with a homogenous EC value for almost the whole grid. On these days, the treated water from the Tancat is only visible for the first 10 meters. The fact that mixing occurs can be considered as positive for the functioning of the green filter. This means basically that the untreated water is not pumped back into the Tancat system for treatment. In order words: the treated water is not recirculating between the Tancat and the Albufera Lake.

Final conclusion

The treated water is completely mixed before the water is again pumped back into the Tancat, which can be considered as positive. Moreover, wind induces mixing processes by creating waves, which has been observed for measurement days 1 and 3. Therefore we consider wind as an important factor for the distribution of the plume. More detailed research is needed before one can draw well-funded conclusions about this. All in all, we can conclude that during our measurement days the treated water from Tancat de Milia could be distributed from 10 meters up to a maximum of 50 meters.

6. What we recommend

The main conclusion of this research is that mixing occurs fast. For this reason it is not recommendable to further study the spatial distribution of the Tancat water. It would be more interesting to investigate the Tancat sytem functioning since we measured some surprising values. EC values are higher compared to the Lake and nutrient levels are hardly filtered out by the Tancat. At least this is what our results showed which are based on five measurement days. Therefore, we would like to give the following recommendations:

A. We propose a recommendation that is related to the values of EC from both the Lake and Tancat de Milia. The average EC measured in the Tancat is around 2500 µS/cm and in the Lake around 2100 µS/cm. Further research is required to identify why the EC value is higher in the Tancat and additionally we propose to study the cause of this increase. Also it could be interesting to know the different perspectives of farmers and fishermen regarding this increase in the Lake Albufera.

B. Nitrate, ammonia and orthophosphate levels in both Lake Albufera and Tancat de Milia are quite low. It might be worthwhile looking into the theory of alternative stable states from Scheffer (2008) as lakes can still be hypertrophic even with low nutrients levels.

ANNEXES

ANNEX A: BACKGROUND INFORMATION

A1: Inflow and outflow of the Albufera Lake

Five natural rivers flow into Lake Albufera which are Poyo-Torrent-Massanassa Gully, Picassent – Beniparrell Gully, Hondo – Tramusser Gully, Berenguera Gully and Agua - Alginet Gully, respectively (J. Soria, 2006). Only the Massanassa and Beniparrell directly discharge into the lagoon in the Northern part. Other running waters drain into several irrigation channels in the Southern part (Vicente & Miracle, 1992). Moreover, the lake is fed with groundwater springing from the surrounding marsh and from the bottom of the lagoon (Vicente & Miracle, 1992). Also precipitation could be considered as an important direct input.

In the Northern part, domestic and industrial waters discharge into the lake, which contains high concentrations of phosphorus and ammonia (Vicente & Miracle, 1992). Nitrate rich water that originate from the agricultural fields arrive mainly from the Southern part (Vicente & Miracle, 1992). Moreover, Lake Albufera is connected with the sea through three main channels, which are called Pujol Nou, Perellonet and Perelló. The outflow via these channels is controlled by sluice-gates (Vicente & Miracle, 1992). Nowadays, fresh water flows into the lake through 64 spots, of which 5 are mouths of its hydrographical basin and the rest are channels. These streams carry irrigation waters from the fields, as well as urban and industrial outflows (J. Soria, 2006). Tancat de Milia is constructed to improve the water quality by treating the water from the lake in order to reduce organic pollution and secondly it could serve as a second treatment step for waste water originating from the waste treatment plant of Valencia. An overview of all of the in- and outflows into Lake Albufera is given in Figure 13.

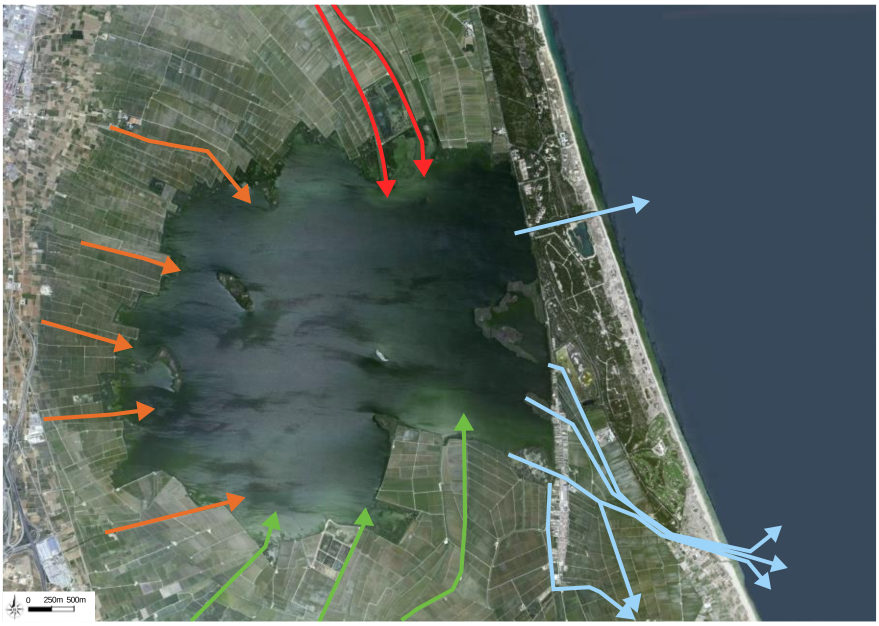


Figure 13: In and outflows Lake Albufera from Bing maps (02-06-2015) Blue arrows represent outflow cannels, red arrows represent inflow from waste water (Valencia), orange arrows represent inflow from industries, and green arrows inflow of agriculture water.

A2: Albufera LIFE project

In 2006, as a response to the degrading water quality of Lake Albufera, rice fields have been converted into three constructed wetlands by the governmental organisations Confederación Hidrográfica del Júcar (CHJ) and Aguas de las Cuencas Mediterráneas (ACUAMED). Both organisations belong to the Spanish Ministry of Agriculture and Environment (MAGRAMA). (MedWet, 2015) The locations of the three constructed wetlands Tancat de la Pipa, Tancat de Milia and Tancat de L'illa can be seen in Figure 14.

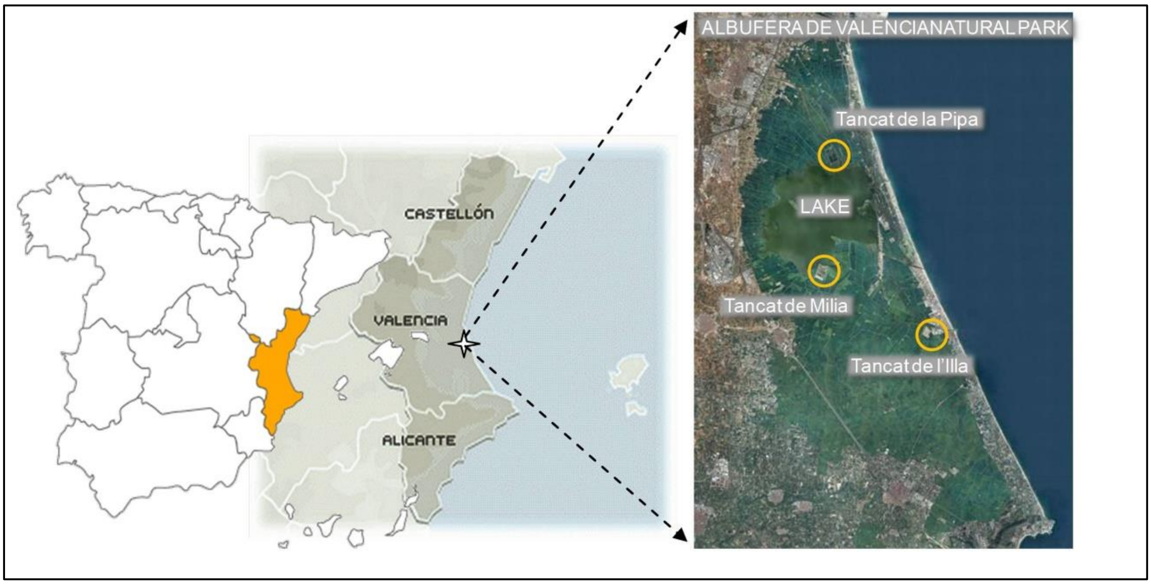


Figure 14: Locations of Tancat de la Pipa, Tancat de Milia and Tancat de L'illa in Albufera National Park (MedWet, 2015)

In October 2013 the Albufera LIFE project was launched. The project will continue until September 2016. (Guillem Avivar, 2015a) The research institute of water and environmental engineering (IIAMA which stands for Instituto de Ingeniería del Agua y Medio Ambiente) of the technical university of Valencia is the coordinator of the project (LIFEALbufera, 2015b). They are partnering with the following organisations: Acció Ecologista-Agró, SEO/BirdLife and Fundación Global Nature. The project is co-financed by ACUAMED and CHJ. Table 4 gives an overview of the different parties involved in the project and their share of financing. The budget of the project is 1.446.234 Euros (LIFEAlbufera, 2015e). As is evident from Table 5, a large part (50%) of the Albufera LIFE project is funded by the European commission through the LIFE + programme. LIFE is a European funding mechanism for projects related to nature conservation and climate action (EuropeanCommission, 2015).

Table 5: Project LIFE participants (based on information from (LIFEAlbufera, 2015e))

Organisation	Type of organisation	Contribution to budget of the project (%)
Research Institute of Water and Environmental Engineering (IIAMA)	University	22.7
Aquas de las Cuencas Mediterránas (ACUAMED)	Governmental organisation	8.6
CHJ	Governmental organisation	6.9
Fundación Global Nature (FGN)	Environmental NGO	5.5
SEO/Birdlife	NGO	5.2
AGRÓ	NGO	1
European Commission		50

The objectives of the Albufera LIFE project are to increase, in an integrative way, the efficiency of Tancat de la Pipa, Tancat de Milia and Tancat de L'illa in order to achieve an improved water quality of Lake Albufera and improve habitats and bird conservation (LifeAlbufera, 2013, 2015d). The project integrates the three European directives of Water, Birds and Habitats (Guillem Avivar, 2015a). The phases of the Albufera LIFE project are presented in Figure 15.

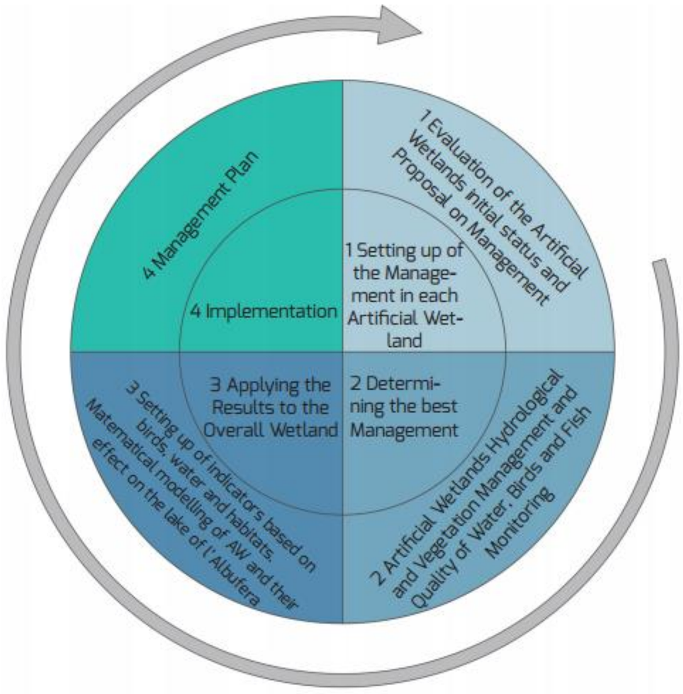


Figure 15: Project phases (LifeAlbufera, 2015c)

A3: Tancat de Milia

Tancat de Milia is a constructed wetland of 33.4 ha located on the South site of L'Albufera Lake in the municipality of Sollana (see Figure 16). The word "*Tancat*" comes from Valencian and means "closed". It is the word used for the rice plots which are characterized by having an independent management of the irrigation water part of a community of small landowners. Additionally, they are called "*tancat*" because the water level is below the Albufera Lake level (FGN, 2012).

It has as area of 33.4 ha promoted by the public company ACUAMED for the current Ministry of Agriculture, Food and Environment. ACUAMED has several activities planned in order to improve the water quality in the Albufera with the CW (FGN, 2012):

1. Redevelopment of hydraulic infrastructure ¨La Huerta¨ and sewerage.
2. Finishing the reuse of the wastewater from Pinedo
3. Reuse of Albufera South wastewater(only this the objective of this research project)
4. Reuse of wastewater from EDAR of Sueca

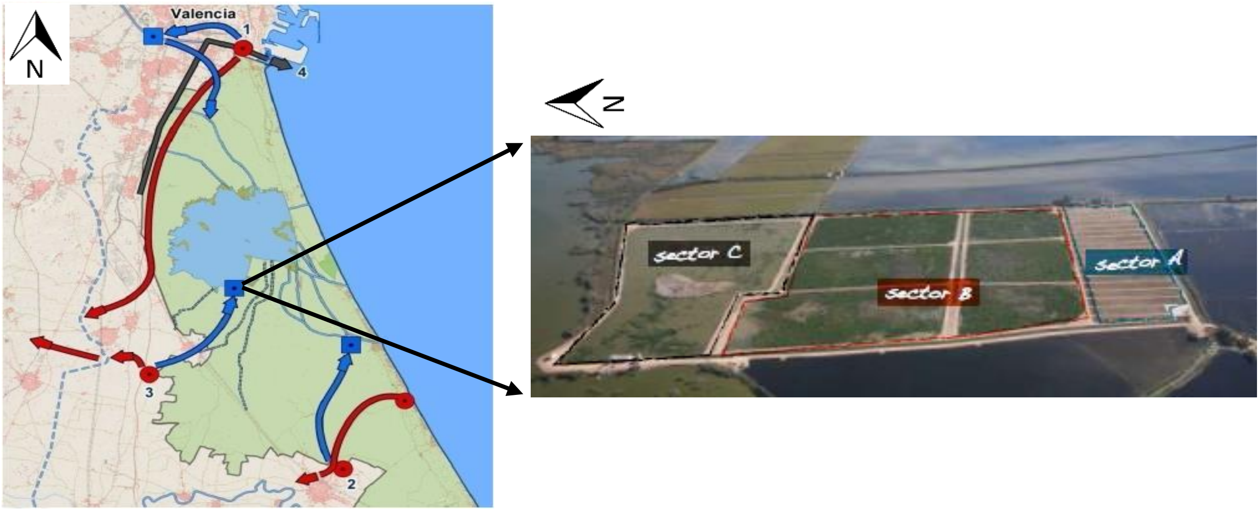


Figure 16: Location of Tancat de Milia (Ferruses, 2014)

The project "*Reuse of Albufera South wastewater*" is in the framework of the Immediate Action Plan, in the chapter "*Recovery of the quality of water inputs*" and within the subprogram "*Rehabilitation of the lakes and the wetlands*". On 25th of January 2008, ACUAMED contracted SEDESA and COMSA companies to implement the project (FGN, 2012).

ACUAMED plans to improve the water quality in the Albufera by reducing the nutrients and increasing the biological quality of the water. Therefore, ACUAMED aims to accomplish both goals. On one hand, with a tertiary treatment reduces the amount of nutrients (P<0.3mg/l and N) and the amount of suspended solids. On the other hand, with the green filters (or CW) the nutrients concentration can be decrease even more and improve the biological water quality (FGN, 2012).

The Tancat de MIlia started to operate in 2012 and it is managed by the NGO Global Nature Foundation. The system has the double possibility of inflow: water from the lake for treatment or receiving water discharged by the waste water treatment plant of Albufera South, which would provide one last refining treatment before the water reaches the lake. Nevertheless, the latter option is not currently operational.

The specific objectives of the Tancat de Milia are (FGN, 2012):

1. Improve the water quality of Albufera Lake and reducing the pollutants concentrations. Additionally, improve surrounding areas of the lake.
2. Development of grassland vegetation underwater because these plant community was dominant into the lake before the eutrophication.
3. Create a natural reservoir of native vegetation seeds.
4. Create permanent water habitats, not affected by the availability of irrigation water and seasonality of rice fields.
5. Create flora and fauna reserves.
6. To spread this kind of innovative and integrated system in natural areas, with specialized public visits and projects dissemination.

Flora and fauna are the most important components of the area. They are linked since many of the birds feed on the vegetation. Many birds that went past by on their annual migration, now they stop to rest, feed and breed in the area restored because of the permanent water habitat.

Tancat de Milia has three different sectors: sector A, B and C (see Figure 17), which will be described below:

SECTOR A.

Sector A has an area of 4.5 ha and it is the sub-flow system (SFS) to remove phytoplankton. The water runs through an underground gravel bed in which macrophytes plants are rooted. The purpose of this sector is to remove the phytoplankton.The outflow of this sector has a transparent water because the chlorophyll is eliminated. The section of this sector is formed by:

- A layer of clay (30cm) to enhance waterproofing.
- A layer of geotextile to separate the system´s water of the underground water.
- A gravel bed (50cm) where the water flows and plants are rooted.
- A layer of geotextile to prevent clogging of the gravel.
- A layer of topsoil (15cm)
- The vegetation of this sector is reed (*Phragmites australis*), cattail (*Typha latifolia*) and bulrush (*Scirpus lacustris)* which are native plants used to the climate of the area. The vegetation covers 50% of the area.

SECTOR B

This part of the wetland has an area of 18 ha and surface flows (SF). In this section, the superficial layer is aerobic while the deeper one is anaerobic. These conditions provide a very effective situation for removing nitrogen and phosphorus, elements that in a high concentration cause eutrophication. For an effective phosphorus removal, the retention times of the wetland needs to be increased. The vegetation is the same as in Sector A.

Within sector B there is diffusive flow from the rice fields underneath the dike towards sector B. This flow of water is entering sector B clean since the traveling through the sand layers serves as a filter treating the water. (Guillem Avivar & Jimenez Romo, 2015)

Besides this diffuse flow there is also a hydrologically connection between the tancat and the aquifer, meaning that water from the aquifer is recharging the tancat as well. There is a monitoring well located in sector B which is interesting to measure since we can use the results of the water quality analysis of the aquifer to explain the quality of the Tancat water.

SECTOR C

The third sector is situated at the north of the wetland. It is a lagoon of 10 ha of which 7.3 ha is vegetation and 2.7 ha two islands for birds nesting and resting. The objectives are diverse: final step of the water treatment from Sector B and a global integration in the natural environment. Moreover, it is used to enhance the development of underwater vegetation. These communities were typical in the lake when the water had good quality in the 60's. The overall objective of sector C is to model how the Albufera Lake should become or could be (Guillem Avivar & Jimenez Romo, 2015).

In this sector the vegetation distribution is heterogeneous, both in shores and underwater habitats. The emerged plants are: *Hydrocolylo vulgaris*, *Tamarix, Chara hispida and fragilis, Myrioplyllum* and the same that in the previous sectors. The sub-emerged plants are: *Myriophyllum, Potamogeton, Iris pseudacorus. (FGN, 2012)*

The water inflow and the outflow are situated on the same side (number 1 in figure 17). However, according to a recent interview with Antonio Guillem (Guillem Avivar, 2015b), environmental expert from the NGO Global Nature Foundation, the pipe of the outflow is broken. Due to this, the inflow and the outflow cannot operate at the same time: the former is open in the morning and the latter in the afternoon. From the inflow point the water is pumped until the Sector A of the wetland. From this point, the water flows down due to gravity through sector B until sector C. If the water does not have the required quality in the sector C, a gate can be open to recirculate the water back to sector A to repeat the filtration process.

The water quality is best after sector A and in the sectors B and C the water quality deteriorates a little, as in these sectors phytoplankton, nitrogen and phosphorus are released via soil/water interactions. Additionally fish and birds also contribute to an increased amount of nutrients. However the plants in sector B and C also take up N and P. It is important to note that the treated water which leaves Tancat de Milia is much cleaner than the Albufera Water. The following quote from Antonio Guillem illustrates the importance of balancing water quality goals with biodiversity objectives: “Would you rather have 0.5 mg/l less P in sector B or would you prefer 50 more Flamingo’s? “ (Guillem Avivar & Jimenez Romo, 2015). The increase of nutrients and phytoplankton in sectors B and C is thus not an issue.

Figure 17: Structure of Tancat de Milia (FGN, 2012)

Annex B: Plume concept

According the dictionary a plume is "a visible or measurable discharge of a contaminant from a given point of origin" (MiMi, 2015). A plume is a model used to assume steady state conditions and it does not take into account short or long term temporal or spatial changes in the density or water quality. The changes can be a result of seasonal warming and cooling, reservoir operation, inflow and outflow and the plume-lake interaction itself. The latter becomes more complex and more knowledge of this interaction is needed to correctly simulate plume dynamics (McGinnis, Lorke, Wüest, Stöckli, & Little, 2004). For this research a combination of field measurements and satellite images observation will be used to study the plume and the plume-lake interaction.

Annex C: Selection of water quality parameters

Temperature [°C]

Why is it important to measure?

Temperature influences biological activity and growth: the higher the temperature, the higher are the biological activity and growth. The temperature of a lake is also related to the types of organisms which will occur in the water. Most aquatic species have a preferred temperature spectrum. The temperature of water also influences the chemical characteristic of water. Generally, it can be said that the rate of chemical reactions goes up when the temperature increases. Therefore, warmer waters contain less oxygen than cooler waters as it becomes saturated more easily. (Michaud, 1991)

It is important to note that there is of course variability in the temperatures of lakes. Obviously the temperature changes in accordance with seasons but also daily variations can occur (cooling down at night time).

How are we going to measure it?

We will use a thermometer probe to measure the temperature of all the sampling points. Placing the thermometer directly into the lake is preferred above taking a water sample and subsequently measuring the temperature of the water sample. If one does decide to take a water sample and then measure different water characteristics it is important to measure the temperature immediately (Michaud, 1991). However, during the fieldwork we measured the temperature using water samples straight away after collecting the samples from the lake. A multi-parameter analyser with the brand Eijkelkamp 18.21 is used to measure temperature.

pH

Why is it important to measure?

The pH of water is a measure to indicate how acidic or alkaline the water is. Neutral water has a pH of 7, a lower pH is indicating that the water becomes acidic and when the pH is higher than 7 it is more basic. The pH is an indicator for the solubility and biological availability of nutrients (e.g. the amount that can be taken up by aquatic life) (Perlman, 2015). Solubility is strongly influenced by pH since it determines how much and in which form a particular substance is abundant in the water (Perlman, 2015).

How are we going to measure it?

Before using the pH device it is important to calibrate the probe. This is done with two liquid buffers of which the pH is known; mostly these buffers have a pH of 7 and 10. After the calibration, the probe needs to be rinsed with the sample. The next step is to fill a clean bottle with the sample and then place the probe in the water. Stir the probe and wait until the pH is stabilized. Write down the pH and clean the electrodes with demi water and wipe the whole probe with a clean tissue. Fill the protective case with demi water and place it on the electrode. This is of importance in order to prevent that the electrodes dry out. Note: the pH device is mostly combined with the temperature gauge. A multi-parameter analyser with the brand Eijkelkamp 18.21 is used to measure pH.

Electrical conductivity (EC)

Why is it important to measure?

EC is a measurement to determine dissolved material in water, which is related to the ability to conduct an electrical current through it. The higher the EC the more dissolved material is in the water. Moreover, the EC of the water can be used to estimate Total Dissolved Solids (TDS) with the following formula: TDS (mg/L) = EC (µS/cm at 25oC) x 0.6 (DEPI, 2015).

How are we going to measure it?

First, the EC meter should be calibrated with an EC buffer. Since we are going the measure EC directly in the treated water plume, the measurement probe can be put into the water immediately therefore, sampling bottles are not needed. After measuring the EC the probe should be cleaned with demi water and stored in the case. A multi-parameter analyser with the brand Eijkelkamp 18.21 is used to measure electrical conductivity.

Dissolved oxygen (DO) [mg/L]

Why is it important to measure?

A certain level of dissolved oxygen is needed for aquatic organisms to survive. On a daily basis there is a huge variation in the DO concentration of water bodies due to photosynthesis, respiration and decomposition. Photosynthesis, whereby oxygen is produced, only occurs during sunshine hours whereas respiration and decomposition, processes whereby oxygen is consumed, occur constantly.

Water is also enriched with oxygen via the air. This happens at the intersections between water and air- thus at the water surface. Air contains on average 21 % of oxygen whereas water generally contains around 1% of oxygen. Because of a difference in concentrations some of the air oxygen molecules will dissolve into the water. (Michaud, 1991) There is also a strong relationship between water temperature and oxygen saturation. As mentioned before warmer waters become saturated more easily than cooler waters.

In deep lakes there can be large differences in DO concentration at different depths. In the top layer there is a lot of oxygen production whereas at the bottom of the lake there is mainly oxygen consumption. In shallow lakes, such as Lake Albufera, these differences in DO are not common as the water is easily mixed.

How are we going to measure it?

Figure 18: Hach DO probe

We will measure DO in milligrams per litre using the DO probe depicted in Figure 18. The probe does not need to be calibrated as this has already been done during the production process.

Turbidity

Why is it important to measure?

Turbidity is defined as: "a liquid cloudy, opaque, or thick with suspended matter" (Oxford, 2015). It is related to the transparency or clearness of water. Waters with high concentrations of total suspended solids (TSS) are cloudy and turbid whereas waters which are clear and thus do not contain a lot of TSS are less turbid. (Bruckner, 2015) Turbidity can be caused by high concentrations of phytoplankton, sediments from erosion and re-suspended sediments from the bottom of the lake (stirred up by certain fish species). (Bruckner, 2015) (Lenntech, 1998) Turbidity affects light intensities through the water column, which can influence photosynthesis and the distribution of organisms and is therefore important for aquatic life. Highly turbid waters can even result in infilling of lakes. Overall it can be said that the more turbid a lake is, the less aquatic life it is able to support. (Bruckner, 2015)

How are we going to measure it?

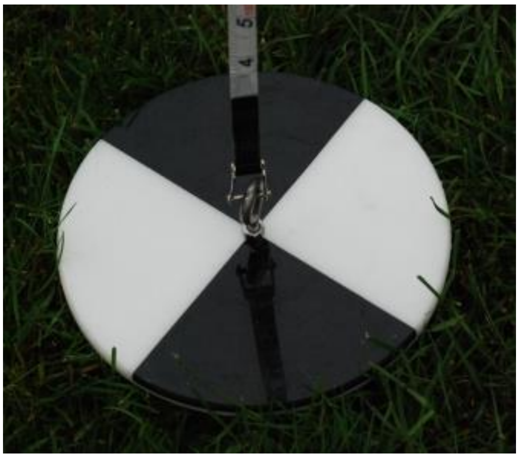


Figure 19: Secchi disk (Bledzki, 2013)

We will measure the turbidity of Lake Albufera using a Secchi disk (see Figure 19) in the lake and a spectrophotometer in the lab for the water samples.

The Secchi disk is a very common and cheap method in order to estimate the turbidity of lakes, give an indication of algae abundance and measure the general lake productivity (Michaud, 1991). The Secchi disk (attached to a rope) is lowered into the water until it can no longer be seen. This disappearance depth is a measure for the transparency of water. In order to estimate the turbidity you have to pull the Sechhi disk up until it reappears. (Bledzki, 2013) The average of these two depths is the turbidity depth. It is important to realize that Secchi disk reading is subjective. Different people have different eyesight's and weather conditions can also influence the Secchi disk reading process. It is therefore important to note down the weather conditions and do the secchi disk measurements under the same circumstances (wear no sunglasses or hat and done by the same person). (Gillissen, 2015)

Figure 20: Merck SQ 118 Spectophotometer

A spectrophotometer is able to measure the amount of light that a sample absorbs. A beam of light (stream of photons) is passed through a sample and measuring the intensity of light reaching a detector (Blauch, 2014). The spectrophotometer used during the measurement of the turbidity was the Merck SQ 118 (see Figure 20). This type of photometer measures the turbidity in UNF units.

The water sample is place in a glass cuvette. First we had to measure the intensity of light passing through the blank using demi water. And second, we measured the intensity of the light passing through the sample. For each sample, it is necessary to clean the cuvette with demi water.

Nutrients

Why is it important to measure?

Nutrients are essential for living organisms as nourishment (Walker, Younos, & Zipper, 2007). The main important nutrients in the Lake Albufera phosphorus and nitrogen. Phosphorus is used by organisms to form cell membranes and for energy generation (Walker et al., 2007). In general the main sources of phosphorus are point-source discharges, terrestrial runoff, faeces from waterfowl, decaying organisms, and rocks containing phosphorus (Walker et al., 2007). There is also an important input in Lake Albufera of phosphorus due to human activity such as industry, municipal effluents and irrigation channels transporting water with fertilizers. Nitrogen is an important building block for organisms to form proteins. These proteins act as enzymes and regulate cell activity furthermore, it is an important component for chlorophyll (Walker et al., 2007). Nitrogen mostly comes from human activities such as waste water and fertilizers. It sometimes originates from natural sources such as decomposing plants and animals (Walker et al., 2007).

Too much nutrients will increase the primary production (plant biomass), which consumes large amounts of oxygen. Lakes with a high plant biomass are called eutrophic or even hypertrophic, which is the case for Lake Albufera (Walker et al., 2007). The water quality of Lake Albufera is extremely low. (Vicente & Miracle, 1992) highlighted that the stress produced in the lake by these phosphorus and nitrogen inputs is seen by the strikingly high values of chlorophyll concentration and primary production. These values are only comparable with the most hypertrophic lakes in the world.

How are we going to measure it?

We will measure Nitrate NO_3^-, Ammonia NH_3, and Orthophosphate H_2PO_4- using the Hach Ten-Parameter Aquaculture Kit.

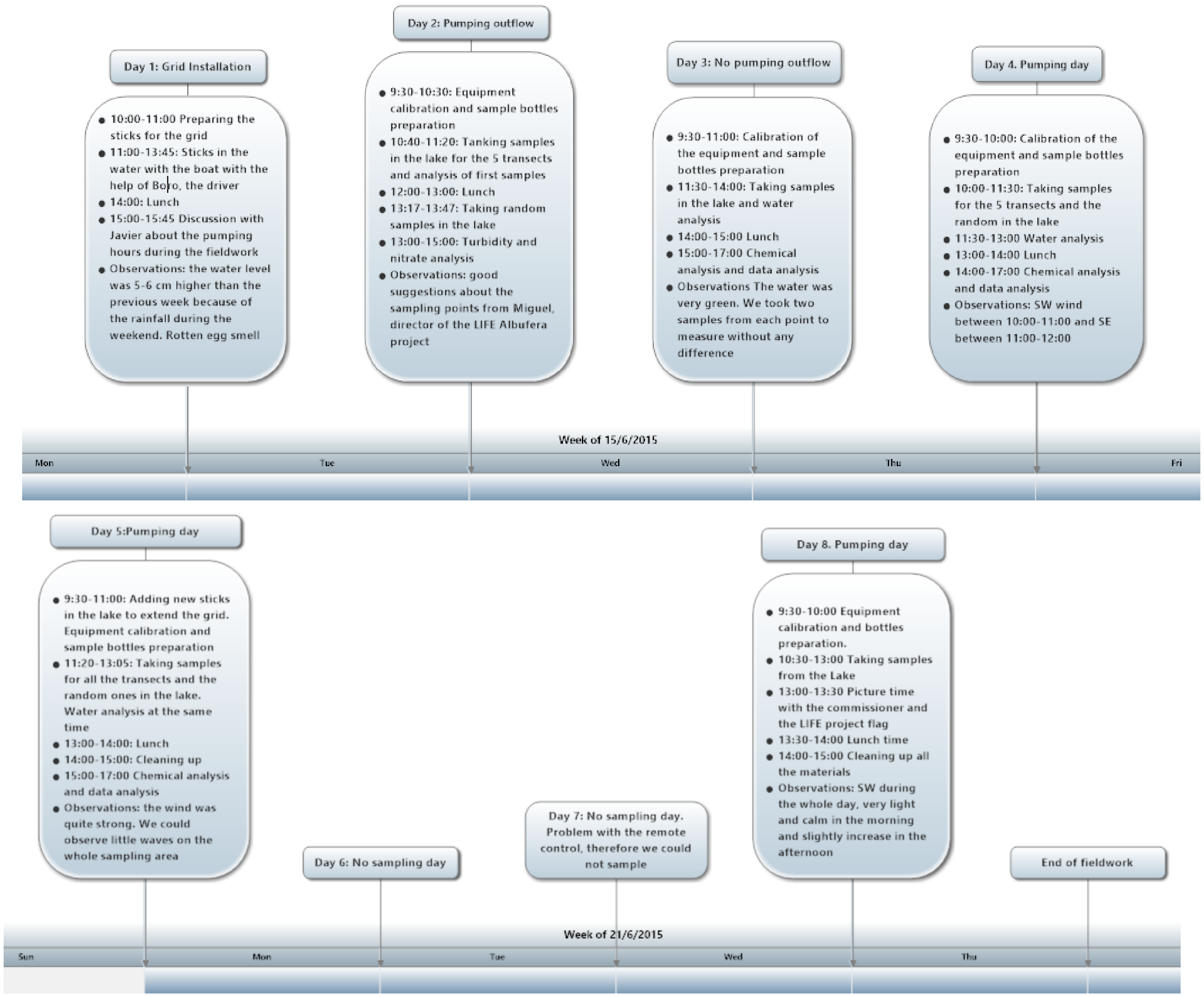
ANNEX D: PUMPING REGIME TANCAT DE MILIA

The water volume of the inflow is between 420-440 m^3/h and the outflow is a fixed amount of 1180m^3/h. normally, the water is pumped in from the Lake into the Tancat during the night (23:00) till the morning (10:00). After that the water is pumped out from the Tancat into the Lake for 7 hours, which happens only once every two days. In order to keep the normal functioning of the system during our measurements the system´s operator changed the pumping hours. Therefore, the outflow of Tancat water into the Albufera Lake changed to 03:00 in the morning till 10:00 in the morning on measuring days. Hence, we could take samples in the morning after 7 hours (normal manner) to measure the spatial distribution of Tancat water into the lake. Table 6 shows the hours that the water was pumped in and out of the Tancat during the fieldwork days.

Table 6: Pumping hours Tancat the Milia.

Date	**Pump out with 1180 m3/h (h:min)**	**Pump in with 420-440 m3/h (h:min)**
15/06/2015	-	09:45
16/06/2015	06:34	11:19
17/06/2015	07:38	11:02
18/06/2015	00:54	-
19/06/2015	05:38	06:24
20/06/2015	-	12:02
21/06/2015	02:31	11:12
22/06/2015	07:15	
23/06/2015	-	08:15
24/06/2015	-	-
25/06/2015	06:37	03.30

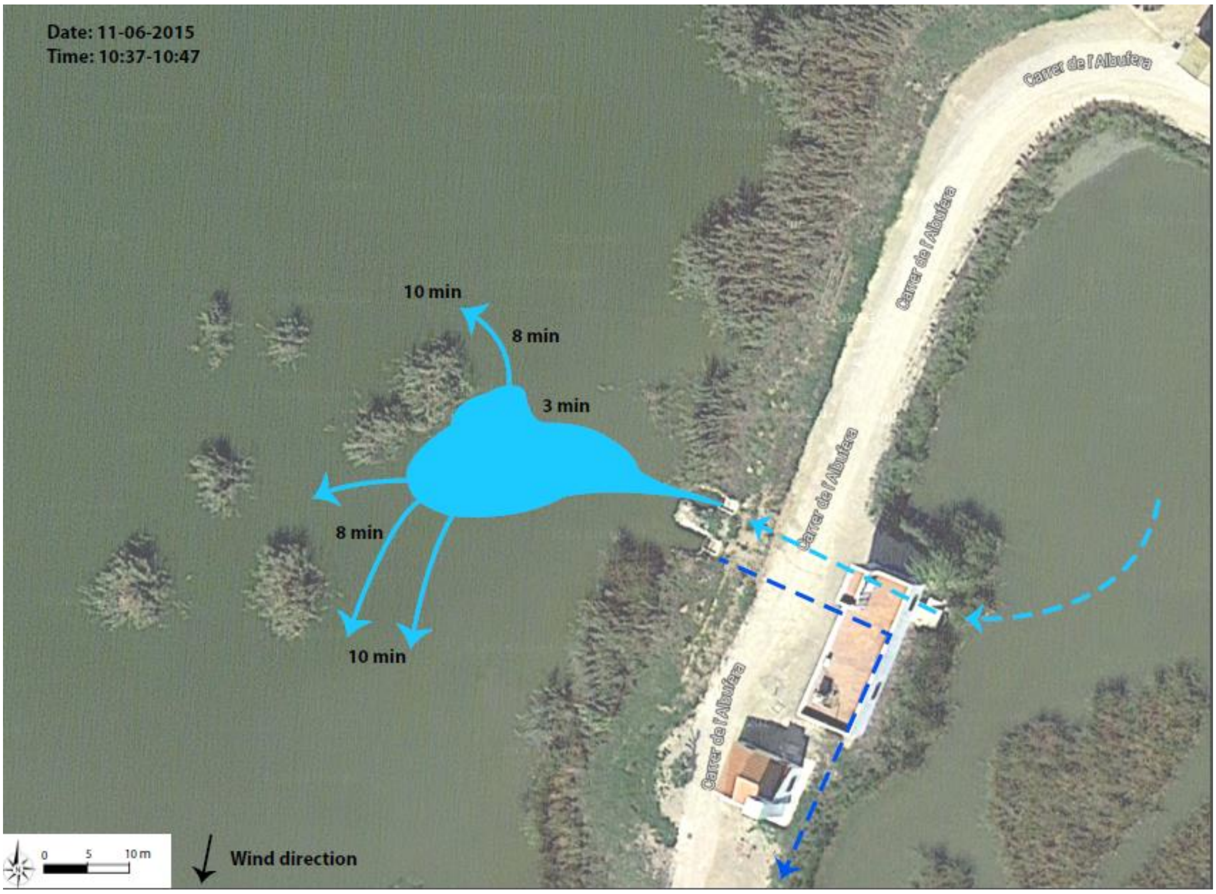
ANNEX E: TIMELINE



ANNEX F: TRACER CONCEPT

Tracers are commonly used in order to determine the time it takes for water to flow from point A to point B therefore, tracers are useful to monitor the spatial distribution of a plume. Translating this into our case study tracers can visualize the plume of the treated water from the Tancat de Milia into Lake Albufera which is important to set up a sampling plan. Different tracers can be used such as dye, salt and objects that float such as a reed or leaves. Salt concentrations can be detected by using an EC meter. Unfortunately, we are not allowed to use dye since Lake Albufera is located in a protected nature area. Still we can use natural tracers (reed, leaves or other natural material) in order to observe the plume of the treated Tancat water. Also differences between the EC of the Tancat and the lake water can be used as a tracer. In order to do so, it should be investigated if the EC difference of the two water types is large enough to distinguish the treated plume from the lake.

ANNEX G: OUTCOMES OF NATURAL TRACER EXPERIMENTS


Date: 11-06-2015
Time: 10:37-10:47
10 min
8 min
3 min
8 min
10 min
Carrer de l'Albufera
Carrer de l'Albufera
Carrer de l'Albufera
Carrer de l'Albufera
0
5
10 m
Wind direction

ANNEX H: DATA

Day 1 (17 – 06 – 2015)

Sample code	GPS coordinates		Temperature	pH	EC	DO	Depth	Secchi depth I	Secchi depth II	Secchi transparency	Turbidity	Nitrate	Ammonia
-	N	W	[°C]		[µS/cm]	[mg/l]	[m]	[m]	[m]	[m]	UNF	[mg/L]	[mg/L]
A001	727926	4354684	24.5	8.16	1690	10.36	0.95	0.34	0.32	0.56	54	No data	No data
A002	727924	4354693	24.5	8.35	1720	10.34	1	0.34	0.32	0.56	53	No data	No data
A003	727919	4354711	24.2	8.34	1720	10.27	1.03	0.34	0.32	0.56	49	No data	No data
A004	727911	4354726	23.8	8.39	1760	10.48	1.02	0.34	0.32	0.56	59	No data	No data
B001	727927	4354680	23.6	8.39	1750	10.58	1.11	0.34	0.32	0.56	48	No data	No data
B002	727918	4354687	23.8	8.33	1746	10.02	1.02	0.34	0.3	0.54	53	No data	No data
B003	727910	4354701	23.2	8.35	1770	10.08	1.05	0.34	0.32	0.56	50	No data	No data
B004	727893	4354714	23.5	8.37	1730	10.17	1.07	0.34	0.34	0.58	54	No data	No data
C001	727923	4354680	23.9	8.38	1760	10.29	1.13	0.34	0.32	0.56	53	No data	No data
C002	727919	4354683	23.5	8.36	1860	10.41	1.15	0.35	0.31	0.56	52	No data	No data
C003	727900	4354695	23.9	8.3	1680	10.18	1.05	0.34	0.3	0.54	48	No data	No data
C004	727883	4354702	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data
D001	727921	4354674	23.3	8.33	1730	10.33	0.97	0.35	0.31	0.56	46	No data	No data
D002	727910	4354674	23.7	8.35	1710	10.36	1	0.35	0.32	0.57	47	No data	No data
D003	727896	4354672	23.6	8.35	1690	10.3	0.98	0.4	0.35	0.64	47	No data	No data
D004	727884	4354670	23.8	8.26	1940	9.73	1.03	0.36	0.34	0.60	45	No data	No data
E001	727922	4354672	24.2	8.29	1730	10.74	1	0.35	0.32	0.57	41	No data	No data
E002	727918	4354668	23.7	8.34	1760	10.81	0.97	0.36	0.33	0.59	61	No data	No data
E003	727901	4354658	23.4	8.38	1780	10.8	0.93	0.36	0.35	0.60	56	No data	No data
E004	727879	4354654	23.6	8.27	1690	10.15	0.93	0.38	0.35	0.62	47	No data	No data
X	727894	4354705	23.5	8.37	1760	10.34	1.07	0.34	0.31	0.55	47	No data	No data
Y	727900	4354695	23.8	8.36	1720	10.25	1.1	0.35	0.37	0.61	49	No data	No data
Lake water	727829	4354808	25.5	8.65	1860	12.13	1.17	0.3	0.35	0.5525	67	0 - 8.8	0 - 0.3
Tancat water	727986	4354667	26.6	7.98	2460	7.92	0.5	0.4	0.35	0.6375	44	0 - 8.8	0 - 0.7

Day 2 (18 – 06 – 2015)

Sample code	GPS coordinates		Temperature (I)	Temperature (II)	pH (I)	pH (II)	EC (I)	EC (II)	DO (I)	DO (II)	Depth	Secchi depth (I)	Secchi depth (II)	Secchi transparancy	Turbidity	Nitrate	Ammonia
-	N	W	[°C]	[°C]			[µS/cm]	[µS/cm]	[mg/l]	[mg/l]	[m]	[m]	[m]	[m]	UNF	[mg/L]	[mg/L]
A001	727926	4354684	26.6	26	7.98	8.22	1810	1850	12.29	11.42	0.95	0.35	0.32	0.57	54	No data	No data
A002	727924	4354693	26.4	26	8.35	8.36	1810	1860	11.98	11.62	1	0.4	0.35	0.64	50	No data	No data
A003	727919	4354711	26	25.6	8.47	8.42	1890	1880	11.96	11.9	1.03	0.37	0.33	0.60	52	No data	No data
A004	727911	4354726	26	24.3	8.5	8.51	1950	1750	12.12	11.96	1.02	0.35	0.32	0.57	56	No data	No data
B001	727927	4354680	25.7	25.4	8.36	8.38	1850	1850	12.1	11.21	1.11	0.39	0.35	0.63	45	No data	No data
B002	727918	4354687	25.1	25.2	8.43	8.46	1880	1890	12.12	11.38	1.02	0.35	0.32	0.57	50	No data	No data
B003	727910	4354701	25.3	24.9	8.45	8.45	1900	1890	12.63	11.73	1.05	0.36	0.33	0.59	45	No data	No data
B004	727893	4354714	25.4	25	8.52	8.5	1930	1920	12.91	11.56	1.07	0.34	0.3	0.54	54	No data	No data
C001	727923	4354680	26.2	25.3	8.45	8.39	1880	1880	11.93	11.58	1.18	0.35	0.32	0.57	51	No data	No data
C002	727919	4354683	25.9	26	8.46	8.43	1870	1850	12.32	11.38	1.09	0.35	0.32	0.57	49	No data	No data
C003	727900	4354695	26.4	25.6	8.46	8.5	1890	1910	12.12	11.31	1.03	0.35	0.32	0.57	53	No data	No data
C004	727883	4354702	26.7	26.4	8.53	8.42	1910	1820	12.14	11.45	1.1	0.4	0.35	0.64	55	No data	No data
D001	727921	4354674	26.4	25.9	8.49	8.46	1900	1900	12.28	10.99	0.95	0.35	0.32	0.57	49	No data	No data
D002	727910	4354674	26.1	23.6	8.5	8.49	1900	1900	12.66	10.66	1.02	0.35	0.32	0.57	51	No data	No data
D003	727896	4354672	25.7	25.7	8.46	8.47	1900	1890	12.09	11.04	1	0.35	0.32	0.57	55	No data	No data
D004	727884	4354670	26.1	26	8.43	8.45	1880	1900	11.19	10.56	1.01	0.38	0.35	0.62	50	No data	No data
E001	727922	4354672	26.9	26.7	8.41	8.41	1890	1880	11.46	11.05	1	0.35	0.32	0.57	49	No data	No data
E002	727918	4354668	26.6	26.2	8.41	8.43	1900	1890	11.38	11.39	0.9	0.4	0.36	0.65	51	No data	No data
E003	727901	4354658	26.7	26.4	8.44	8.44	1900	1880	11.69	10.94	0.91	0.4	0.35	0.64	53	No data	No data
E004	727879	4354654	26.6	26.4	8.41	8.42	1860	1860	11.54	10.2	0.92	0.36	0.33	0.59	49	No data	No data
F001	727927	4354668	26	26.1	8.46	8.47	1880	1880	10.78	10.88	0.97	0.38	0.34	0.61	48	No data	No data
F002	727916	4354661	26.1	26.1	8.38	8.41	1900	1880	11.58	10.7	0.91	0.39	0.35	0.63	46	No data	No data
F003	727906	4354653	26.6	26.2	8.44	8.43	1880	1880	12.02	10.57	0.96	0.35	0.32	0.57	48	No data	No data
F004	727888	4354643	26.3	26.2	8.41	8.42	1880	1880	11.71	10.85	0.95	0.4	0.35	0.64	50	No data	No data
V	727927	4354694	26.1	25.7	8.5	8.5	1890	1890	11.92	10.93	1.08	0.36	0.33	0.59	53	No data	No data
W	727912	4354677	28.3	27.2	8.44	8.43	1860	1850	11.85	10.9	1.02	0.35	0.32	0.57	51	No data	No data
X	727894	4354705	26.2	26.2	8.52	8.53	1920	1910	12.79	10.73	1.04	0.35	0.32	0.57	55	No data	No data
Y	727900	4354695	26.2	25.7	8.5	8.44	1900	1890	12.24	10.52	1.02	0.35	0.32	0.57	56	No data	No data
LakeI	727859	4354818	26.6	No data	8.61	No data	2000	2000	13.57	No data	1.1	0.35	0.32	0.57	59	No data	No data
LakeII	727821	4354779	26.4	No data	8.61	No data	1980	1980	13.32	No data	1.07	0.35	0.32	0.57	53	11	0.1
LakeIII	727785	4354735	26.1	No data	8.55	No data	1950	1950	12.52	No data	1.08	0.35	0.32	0.57	54	No data	No data
LakeIV	727742	4354690	26.4	No data	8.53	No data	1930	1930	10.36	No data	1.07	0.35	0.32	0.57	54	16.5	0.1
Tancat water	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data

Day 3 (19 – 06 – 2015)

Sample code	GPS coordinates		Temperature	pH	EC	Depth	Secchi depth (I)	Secchi depth (II)	Secchi transparancy	Turbidity	Nitrate	Ammonia	Orthophosphate
-	N	W	[°C]		[µS/cm]	[m]	[m]	[m]	[m]	UNF	[mg/L]	[mg/L]	[mg/L]
A001	727926	4354684	24	8.97	2380	0.95	30	25	46.75	109	No data	No data	No data
A002	727924	4354693	24	9	2370	1	25	20	38.25	106	No data	No data	No data
A003	727919	4354711	24	9.11	2630	1.03	20	15	29.75	110	No data	No data	No data
A004	727911	4354726	23.6	9.13	2390	1.02	20	15	29.75	112	No data	No data	No data
B001	727927	4354680	23.8	8.8	2310	1.11	25	20	38.25	92	No data	No data	No data
B002	727918	4354687	23.7	8.88	2330	1.02	25	20	38.25	102	No data	No data	No data
B003	727910	4354701	23.7	9.17	2380	1.05	22	18	34	111	No data	No data	No data
B004	727893	4354714	23.9	9.21	2390	1.07	20	15	29.75	111	No data	No data	No data
C001	727923	4354680	24.7	8.69	2280	1.18	25	22	39.95	84	No data	No data	No data
C002	727919	4354683	24.5	8.83	2320	1.09	25	20	38.25	92	No data	No data	No data
C003	727900	4354695	24.3	9.08	2390	1.03	25	20	38.25	110	No data	No data	No data
C004	727883	4354702	24.2	9.25	2390	1.1	25	20	38.25	113	No data	No data	No data
D001	727921	4354674	24.7	8.73	2300	0.95	25	22	39.95	94	No data	No data	No data
D002	727910	4354674	24.5	9.05	2360	1.02	25	20	38.25	112	No data	No data	No data
D003	727896	4354672	24.5	8.83	2330	1	25	20	38.25	92	No data	No data	No data
D004	727884	4354670	24.6	8.16	2270	1.01	25	20	38.25	78	No data	No data	No data
E001	727922	4354672	25	8.8	2310	1	25	22	39.95	97	No data	No data	No data
E002	727918	4354668	24.4	8.96	2340	0.9	25	20	38.25	104	No data	No data	No data
E003	727901	4354658	24.5	8.81	2320	0.91	25	20	38.25	91	No data	No data	No data
E004	727879	4354654	24.8	8.51	2220	0.92	25	20	38.25	78	No data	No data	No data
F001	727927	4354668	24.5	8.87	2320	0.97	25	22	39.95	98	No data	No data	No data
F002	727916	4354661	24.7	8.92	2340	0.91	25	22	39.95	104	No data	No data	No data
F003	727906	4354653	24.9	8.71	2310	0.96	25	20	38.25	97	No data	No data	No data
F004	727888	4354643	24.9	8.61	2290	0.95	25	20	38.25	82	No data	No data	No data
V	727927	4354694	24.3	9.04	2350	1.08	25	20	38.25	116	No data	No data	No data
W	727912	4354677	24.6	9.07	2370	1.02	25	20	38.25	108	No data	No data	No data
X	727894	4354705	24.3	9.2	2390	1.04	22	18	34	112	No data	No data	No data
Y	727900	4354695	24.3	9.24	2380	1.02	25	20	38.25	118	No data	No data	No data
LakeI	727859	4354818	25.5	8.85	2100	1.1	30	25	46.75	85	0 - 8.8	0 - 0.1	0 - 0.06
LakeII	727821	4354779	25.3	8.8	2100	1.07	30	25	46.75	76	0 - 8.8	0 - 0.1	0 - 0.06
LakeIII	727785	4354735	24.7	8.69	2010	1.08	30	25	46.75	102	No data	No data	No data
LakeIV	727742	4354690	29	8.73	2010	1.07	30	25	46.75	102	No data	No data	No data
TancatI	727933	4354674	22.8	7.31	2540	No data	No data	No data	No data	63	0 - 4.4	0 - 0.5	0 - 0.8
TancatII	727933	4354674	23.2	7.57	2570	No data	No data	No data	No data	63	0 - 4.4	0 - 0.44	0 - 0.06
TancatIII	727933	4354674	22.6	7.65	2550	No data	No data	No data	No data	62	No data	No data	No data
TancatIV	727933	4354674	22.3	7.77	2680	No data	No data	No data	No data	62	No data	No data	No data

Day 4 (22 – 06 – 2015)

Sample code	GPS coordinates		Temperature	pH	EC	Depth	Secchi depth (I)	Secchi depth (II)	Secchi transparancy	Turbidity	Nitrate (strip)
-	N	W	[°C]		[µS/cm]	[m]	[m]	[m]	[m]	UNF	[mg/L]
A001	727926	4354684	26.9	7.53	1990	0.95	35	30	55.25	47	0 - 10.0
A002	727924	4354693	26.7	7.79	1970	1	40	35	63.75	44	No data
A003	727919	4354711	26.8	8.03	1930	1.03	40	35	63.75	43	No data
A004	727911	4354726	26.6	7.95	2180	1.02	40	35	63.75	50	No data
A005	727901	4354746	26.6	8.33	1850	1.05	40	37	65.45	42	No data
A006	727892	4354770	26.5	8.42	1810	1.1	40	36	64.6	44	0 - 1
B001	727927	4354680	26.7	8.1	1830	1.11	40	35	63.75	35	No data
B002	727918	4354687	26.5	8.12	1890	1.02	40	35	63.75	38	No data
B003	727910	4354701	26.6	8.17	1930	1.05	40	35	63.75	41	No data
B004	727893	4354714	26.6	8.12	2030	1.07	40	35	63.75	44	No data
B005	727881	4354732	26.6	8.32	1870	1.1	40	37	65.45	41	No data
B006	727856	4354756	26.9	8.48	1710	1.2	40	37	65.45	43	No data
C001	727923	4354680	26.8	8.05	1880	1.18	40	35	63.75	33	No data
C002	727919	4354683	26.8	8.24	1880	1.09	40	35	63.75	41	No data
C003	727900	4354695	26.9	8.24	1910	1.03	40	35	63.75	40	No data
C004	727883	4354702	27	8.25	1910	1.1	40	35	63.75	46	No data
C005	727856	4354712	27	8.22	1920	1.18	38	35	62.05	43	No data
C006	727833	4354725	26.9	8.4	1840	1.18	38	35	62.05	41	No data
D001	727921	4354674	26.9	8.15	1810	0.95	40	35	63.75	34	No data
D002	727910	4354674	26.6	8.12	1780	1.02	40	35	63.75	37	No data
D003	727896	4354672	27	8.19	1810	1	40	35	63.75	36	No data
D004	727884	4354670	27	8.26	1890	1.01	40	35	63.75	35	No data
D005	727850	4354669	26.9	8.31	1840	1.1	40	35	63.75	39	No data
D006	727814	4354666	26.6	8.35	1860	1.2	40	35	63.75	42	No data
E001	727922	4354672	27.9	7.99	1770	1	40	35	63.75	33	No data
E002	727918	4354668	27.2	8.07	1770	0.9	40	35	63.75	36	No data
E003	727901	4354658	27.1	8.11	1820	0.91	40	35	63.75	36	No data
E004	727879	4354654	27.6	8.2	1780	0.92	40	35	63.75	34	No data
E005	727859	4354644	27.2	8.25	1770	1.2	40	35	63.75	37	No data
E006	727837	4354635	27.2	8.3	1770	1.2	40	35	63.75	33	No data
F001	727927	4354668	27.2	8.07	1780	0.97	40	35	63.75	30	No data
F002	727916	4354661	27	8.1	1780	0.91	40	35	63.75	34	No data
F003	727906	4354653	27.1	8.17	1770	0.96	40	35	63.75	37	No data
F004	727888	4354643	27.3	8.2	1770	0.95	40	35	63.75	35	No data
F005	727872	4354627	27.2	8.2	1760	1.1	40	35	63.75	38	No data
F006	727852	4354615	27	8.23	1760	1.1	40	35	63.75	34	No data
LakeI	727819	4354963	27.7	8.77	1870	1.12	35	30	55.25	53	0 - 10.0
LakeII	727734	4354869	27.7	8.77	1860	1.08	35	30	55.25	51	No data
LakeIII	727668	4354803	27.6	8.77	1820	1.08	35	30	55.25	50	0 - 10.0
LakeIV	727643	4354648	27.9	8.66	1770	1.08	35	30	55.25	49	No data
TancatI	727933	4354674	24.6	7.35	2610	No data	No data	No data	No data	62	0 - 10.0
TancatII	727933	4354674	24.5	7.38	2690	No data	No data	No data	No data	57	0 - 10.0
TancatIII	727933	4354674	24.4	7.48	2660	No data	No data	No data	No data	60	No data
TancatIV	727933	4354674	24	7.56	2650	No data	No data	No data	No data	59	No data

Day 5 (25-06-15)

Sample code	GPS coordinates		Temperature	pH	EC	Depth	Secchi depth (I)	Secchi depth (II)	Secchi transparancy	Turbidity	Nitrate	Ammonia	Orthophosphate	Nitrate (strip)
-	N	W	[°C]		[µS/cm]	[m]	[m]	[m]	[m]	UNF	[mg/L]	[mg/L]	[mg/L]	[mg/L]
A001	727926	4354684	26.5	7.73	1900	0.95	35	30	55.25	No data	No data	No data	No data	No data
A002	727924	4354693	26.1	8.12	1900	1	35	30	55.25	No data	No data	No data	No data	No data
A003	727919	4354711	26.4	8.25	1920	1.03	35	30	55.25	No data	No data	No data	No data	No data
A004	727911	4354726	26.2	8.36	1900	1.02	35	30	55.25	No data	No data	No data	No data	No data
A005	727901	4354746	26.2	8.53	1890	1.05	35	30	55.25	No data	No data	No data	No data	No data
A006	727892	4354770	25.7	8.62	1970	1.1	35	30	55.25	No data	No data	No data	No data	No data
B001	727927	4354680	26	8.25	1920	1.11	40	35	63.75	No data	No data	No data	No data	No data
B002	727918	4354687	25.9	8.27	1910	1.02	38	33	60.35	No data	No data	No data	No data	No data
B003	727910	4354701	26	8.42	1920	1.05	35	30	55.25	No data	No data	No data	No data	No data
B004	727893	4354714	26	8.4	1870	1.07	35	30	55.25	No data	No data	No data	No data	No data
B005	727881	4354732	26	8.58	1910	1.1	35	30	55.25	No data	No data	No data	No data	No data
B006	727856	4354756	24	8.35	1810	1.2	35	30	55.25	No data	No data	No data	No data	No data
C001	727923	4354680	26.8	8.26	1910	1.18	38	33	60.35	No data	No data	No data	No data	No data
C002	727919	4354683	26.6	8.33	1960	1.09	35	30	55.25	No data	No data	No data	No data	No data
C003	727900	4354695	26.9	8.44	1960	1.03	35	30	55.25	No data	No data	No data	No data	No data
C004	727883	4354702	26.5	8.54	1950	1.1	35	30	55.25	No data	No data	No data	No data	No data
C005	727856	4354712	26.7	8.39	1800	1.18	35	30	55.25	No data	No data	No data	No data	No data
C006	727833	4354725	26.7	8.31	1770	1.18	40	35	63.75	No data	No data	No data	No data	No data
D001	727921	4354674	26.6	8.27	1930	0.95	38	34	61.2	No data	No data	No data	No data	No data
D002	727910	4354674	26.6	8.14	1970	1.02	35	30	55.25	No data	No data	No data	No data	No data
D003	727896	4354672	26.4	8.39	1980	1	35	30	55.25	No data	No data	No data	No data	No data
D004	727884	4354670	26.4	8.43	1910	1.01	35	30	55.25	No data	No data	No data	No data	No data
D005	727850	4354669	26.9	8.41	1830	1.1	35	30	55.25	No data	No data	No data	No data	No data
D006	727814	4354666	26.2	8.48	1850	1.2	35	30	55.25	No data	No data	No data	No data	No data
E001	727922	4354672	27.3	8.09	1950	1	35	30	55.25	No data	No data	No data	No data	No data
E002	727918	4354668	27.1	8.31	1890	0.9	35	30	55.25	No data	No data	No data	No data	No data
E003	727901	4354658	27	8.17	2040	0.91	35	30	55.25	No data	No data	No data	No data	No data
E004	727879	4354654	1.97	8.19	1970	0.92	35	30	55.25	No data	No data	No data	No data	No data
E005	727859	4354644	26.8	8.3	1860	1.2	35	30	55.25	No data	No data	No data	No data	No data
E006	727837	4354635	26.7	8.39	1800	1.2	35	30	55.25	No data	No data	No data	No data	No data
F001	727927	4354668	26.6	8.06	1810	0.97	35	30	55.25	No data	No data	No data	No data	No data
F002	727916	4354661	26.6	8.14	1910	0.91	35	30	55.25	No data	No data	No data	No data	No data
F003	727906	4354653	27	8.17	1890	0.96	35	30	55.25	No data	No data	No data	No data	No data
F004	727888	4354643	26.6	8.22	1890	0.95	35	30	55.25	No data	No data	No data	No data	No data
F005	727872	4354627	26.7	8.26	1720	1.1	35	30	55.25	No data	No data	No data	No data	No data
F006	727852	4354615	26.4	8.09	1740	1.1	35	30	55.25	No data	No data	No data	No data	No data
Lake1	727819	4354963	27.5	8.46	1870	1.12	35	30	55.25	No data	0 - 8.8	No data	No data	0 - 10
Lake2	727734	4354869	27.2	8.53	1820	1.08	35	30	55.25	No data	No data	No data	No data	No data
Lake3	727668	4354803	27	8.44	1730	1.08	35	30	55.25	No data	No data	No data	No data	No data
Lake4	727643	4354648	26.6	8.33	1730	1.08	35	30	55.25	No data	No data	No data	No data	No data
Lake5	727924	4354730	26.9	8.43	1800	No data	35	30	55.25	No data	13.2 - 17.6	No data	No data	0 - 10
Lake6	727915	4354758	26.7	8.67	1860	No data	35	30	55.25	No data	No data	No data	No data	No data
Lake7	727811	4354608	26.7	8.3	1720	No data	35	30	55.25	No data	No data	No data	No data	No data
Lake8	727847	4354599	26.5	7.84	1780	No data	30	25	46.75	No data	No data	No data	No data	No data
Lake9	727885	4354618	27.5	8.22	1860	No data	30	25	46.75	No data	No data	No data	No data	0 - 10
TancatI	727933	4354674	26.4	7.43	2680	No data	35	30	55.25	No data	0 - 4.4	No data	No data	0 - 10
TancatII	727933	4354674	25.6	7.7	2700	No data	35	30	55.25	No data	0 - 6.6	No data	No data	0 - 10
TancatIII	727933	4354674	26.1	7.71	2700	No data	35	30	55.25	No data	0 - 6.6	No data	No data	0 - 10
TancatIV	727933	4354674	25.7	7.7	2690	No data	35	30	55.25	No data	0 - 8.8	No data	No data	No data
Inlet1	727867	4354560	28.2	7.86	1750	No data	No data	No data	No data	No data	0 - 8.8	No data	No data	0 - 10
Inlet2	727867	4354560	28.6	7.79	1760	No data	No data	No data	No data	No data	0 - 8.8	No data	No data	0 - 10

ANNEX I: JUSTIFICATION GIS TOOL

For interpolation the method of Natural neighbor is chosen because of the following reasons: Automatically the excess area outside the measurement grid is cut, Thiessen Polygons are used for the Interpolation and weights are applied according the overlap. (ArcGIS, 2015). This results in smooth maps and no strange peaks, pits or ridges.

ANNEX J: MIXING CONCEPT

Mixing plays a substantial role in sustaining life-supporting processes by enabling the distribution of suspended and dissolved matter (Fabian & Budinski, 2013). In lakes, fluid motion is extremely complex since every lake behaves differently which strongly depends on the size, shape, and depth of the lake causing different boundary effects (Imboden & Wüest, 1995).

Mixing is largely controlled by stratification this is especially of importance for deeper lakes with long residence times. Stratification arises from temperature variations, which in turn is a function of the overall energy balance and the internal mixing processes of a lake (Socolofsky & Jirka, 2004). In stratified lakes, mixing is commonly faster horizontally than vertically since stratification slows down vertical mixing and it enhances horizontal mixing by channelling (Imboden & Wüest, 1995). In shallow lakes, vertical mixing is a less dominant process compared to horizontal mixing. This could be explained by the fact that there is hardly any stratification in shallow lakes or in other words there is no vertical density gradient (e.g. temperature differences), which induce transport (Peeters, Wüest, Piepke, & Imboden, 1996). Moreover, the inflow of the treated water into Lake Albufera is causing turbulence and therefore there is not adequate time for stratification to develop (Socolofsky & Jirka, 2004). Still field measurements need to be taken in order to investigate whether this is truly the case.

Taken the above into consideration, mixing in the Albufera Lake is mainly dominated by physical processes such as diffusion, advection, dispersion, and wind forcing which play important roles in determining the movement and change in concentration of contaminants and nutrients (Ho, Schlosser, & Caplow, 2002). Also inflows and outflows create mixing in lakes because of their own kinetic energy (Socolofsky & Jirka, 2004).

Diffusion, advection and dispersive transport

In this research the term 'mixing' is used for the combined effect of diffusion, dispersion and advection (Fabian & Budinski, 2013). Diffusion is described as the motion of particles down along the concentration gradient (Imboden & Wüest, 1995). The net transport is small since the particles do not maintain the same direction. Advection is a transport mechanism of a substance carried by fluid flow (Meerschaert & Tadjeran, 2004). Advection and diffusion are independent transport processes. Consider for instance a spot of dye in a river: advection moves the centre of mass of the dye downstream, diffusion spreads out the concentrated spot of dye to a larger, less concentrated region (Honrath, 1995).

Another transport process is mechanical dispersion. Dispersion has to do with variations in the movement of water, which carries compounds. These variations are caused by variations in the flow path and variations in velocity. For instance variations in flow paths could be caused by aquatic plants, which disperse water of a particular quality in different directs. Variations in velocity are caused by shear stresses: at the bottom of a lake shear stresses will slow down the velocity and therefore will hinder the spread in the longitudinal direction, in the direction of flow. In the middle of a lake shear stresses are minor causing water to be transported further.

Wind
Wind forcing is the major external factor responsible for mixing (Socolofsky & Jirka, 2004). Wind generates kinetic energy creating lake currents. Even though these currents have a low intensity, still they are of major importance in transport processes of suspended and dissolved matter (Fabian & Budinski, 2013). Wind affects the lake through the shear it imparts on the water surface. 'Shear drags the water in the downwind direction, adding kinetic energy and causing surface currents, surface waves, and a so-called surface set up: the mean lake surface downwind is tilted upward compared to the upwind side of the lake. This set up results in a basin-scale circulation: bottom-water return currents compliment the surface-water motion' [6, p. 162]. The wind-induced currents at the water surface are responsible for horizontal mixing. Imboden and Wüest (1995) highlight that the exposure of the lake to the wind may cause very extraordinary mixing patterns. In the research area, the dominant wind direction in June is from East to West. This dry wind is getting warmer when it travels inland which is caused by the Foehn effect. More specific information about the wind characteristics is provided in appendix D.

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