Connecting Hørning and Jeksen through water supply network

Final Dissertation

Master in European Construction Engineering

HUGO GISBERT GARCÍA

Horsens, August 2014

VIA UNIVERSITY COLLEGE

UC UNIVERSIDAD DE CANTABRIA

Connecting Hørning and Jeksen through water supply network

Master in European Construction Engineering

Academic Year 2014-2015

Author: Hugo Gisbert García

Supervisor: Henrik Bjørn

Moderator: Elena Blanco Fernández

ABSTRACT

Water supply networks need continuous refurbishment to ensure quality of supply and also save of money. This report analyses and defines the best way to connect the water supply networks between Hørning and Jeksen, this last with problems of supply. To achieve this goal the author will search on literature, take field measurements and also contact directly with manufacturers or local entities. Therefore the objectives of this report are: review of the current status of Hørning and Jeksen network, design the best pipe connection and how to install it, as well as the sizing of the booster pump in charge of provide the right pressure to Jeksen consumers. This report states the feasibility of the project besides some recommendations to the current supply system of Hørning.

RESEARCH STATEMENT

This Dissertation is an individual work performed as part of the Master in European Construction Engineering organized by the University of Cantabria.

The Dissertation herein is a project based report. The data from this project is going to be gathered from different sources such as literature to understand the theory related with this project since the basic hydraulics concepts until the detailed methods of pipe installation. Furthermore during this project has been taken field measurements in order to compare the computer based model to the real situation in the water supply network.

Thanks to the great database from Danish government, some information such as maps, information about pipes, master plans and so on have been utilised to obtain useful information relevant to this projects.

Regarding personal information, it was fundamental to the writing of this project because some data has to be asked directly to the board of water supply network to know general characteristics of the network to create the model. Also some specific costs has to be asked directly to providers for the reason that it was too specific to appear in general price books of construction.

Other source of information was a project from a Bachelor student that carried out a study of the network of one of the towns that are going to be connected in the project herein, so this model was taken as starting point.

ACKNOWLEDGEMENTS

To begin with I would like to express my gratitude to my supervisor for his assistance and his willingness to help me, not only in the Dissertation matters but also trying to introduce me into the Danish market.

Furthermore I am extremely grateful to my family for their support, showing me always their smile in the distance and the opportunity they give me to join this Master programme.

In addition I would like to thanks my girlfriend her love and patience with me in the distance and show me her optimism in the hard moments.

Last but definitely not least thanks to the eighteen people that form this year this Master for making it so special.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

CAD=Computer-aided design

GIS = Geographical Information Systems

mWC= meters water column

PVC= Polyvinyl chloride

PE= Polyethylene

HDD= Horizontal Directional Drilling

HDPE=High density Polyethylene

SDR= Standard Dimension Ratio

1. INTRODUCTION

1.1. Background

In our days the problem of scarcity of water is significant in most developed countries, not so in Denmark but is still a problem that the municipalities has to deal with. Developed countries are especially well concerned about new ways of sustainability and every time more and more people know the path that we have to follow to take care of environment.

Water savings has been promoted through all the sectors, in particular in the water supply network were the leakages through the network means not only the loss of water as a natural resource but also a waste of money for the municipalities.

Mainly due to this economic point of view, public bodies are increasingly convinced about keeping in optimal conditions their water supply network. The report herein is motivated mainly to optimize the water supply network of Jeksen, a town located in Skanderborg municipality. This little town has problems of supply, mainly due to the obsolescence on its waterworks.

The solution suggested is the idea of connecting Jeksen with the middle-size town Hørning, close to Jeksen. Hørning have an updated water supply network, and also its urban development is going in that direction. Hence, the connection of Jeksen to the water supply of Hørning makes a lot of sense.

Therefore a careful study is strictly necessary to choose the best alternatives to connect the water supply network of both towns as well as the modelling of existing networks to evaluate the possible weaknesses of the systems and verify if these weaknesses are going to affect our connection.

1.2. Aim and Objectives

The principal aim of this project is to include the existing area of a small village, Jeksen, into the water supply system of the nearby town, Hørning, which has a better waterworks than the out-dated one from Jeksen, therefore a water pipe connection between both towns should be designed.

Therefore the objective for this report is to review the pipe network model of Hørning and create the model of Jeksen to determine the best position of the connecting pipe, as well as the procedure to install it.

Furthermore in order to ensure the right pressure in Jeksen, located in a higher elevation than Hørning, the dimensioning of a booster pump should be carried out, as well as a recommended market pump.

Once that our model has been created, it is going to analyse the system as a whole and suggest which could be the improvements and recommendations that we could do to the network affected by this new connection.

Considering that this report wants to be used as starting point for a real project, a roughly cost estimation is going to be developed to guide the municipality to understand the amount of money this project could be cost.

1.3. Methodology

This project concerns a real supply area, so that it is going to carry out the following steps taking into account the practical facet of the project:

1. Figure out whether Hørning will be able to hold the new demand of water by means of analysis of an updated Hørning model.
2. Create a model of Jeksen in Epanet with data taken from databases and also information supplied from the waterworks from Hørning and review in this model if it is possible to keep the current network or if it needs any replacements. Also taking into account the possible growth of the town or the areas that are not included in the water supply yet by searching in municipality Master Plans.
3. Analyse how should be the connection between both towns:
    a. Study the best path that should be follow the pipe connection taking into account hydraulic and economic point of views.
    b. Study which kind of procedure is going to carry out during the installation of the connection pipe, analysing them in terms of time and costs by literature search.
4. Selection of a pump that fits in our model requirements:
    a. Design the theoretical water pump based on elevation, flow and other hydraulics variables.
    b. Look for an existing water pump in the Danish market that combine all the requirements, searching in manufacturers' webpages and personal contact if it was necessary.
5. Cost estimation based on Danish price books and manufacturers' information.
6. Conclusions and recommendations taken from the report.

1.4. Limitations and scope

This report has been constrained by several limitations in some points during its development, these are the followings:

- The time has been our main limitation, although the objectives of the projects were covered, a deeper study in some points could be performed in order to make more accurate the final data. As well as the period provided for the execution of this project from April to August does not match with the host University calendar which has July as period of vacations, therefore problems arose during this month has to be delayed until August to consult to the supervisor.
- Overcome the linguistic barrier with Danish databases was a problem especially during the search of Danish prices of construction.
- Since this report is for student purpose, it was difficult and sometimes unsuccessful obtain prices from manufacturers. As well as get the real consumption from every house.
- To create the models it has been used Epanet software that is commonly used although it is obsolete. Its hydraulic engine is really impressive after so many years, but there are in the market more advanced tools that overcome Epanet in all the aspects, particularly the way of manage the information introduced in the programme, although the other alternatives are payment programmes.

This report wanted to be as similar as possible to a full report made by a consultancy, therefore all the technical and economic details should be defined. However due to the limitations described above, it was not possible to achieve the data accuracy desired, consequently the scope of this report aspires to be as a reference to Skanderborg Kommune to check the feasibility of the project of connection of water supply network of both towns.

1.5. Dissertation Report Outline

The report herein is the Final Dissertation for the degree of Master in Science in European Construction Engineering, with a value of 20 ECTS credits which makes a total amount of 60 ECTS for the whole Master. Different parts have been performed to understand and design the connection of water supply systems of both towns:

- Analysis of existing network and preparation of the models to ensure the technical feasibility of this project.
- Definition of the connection pipe between Jeksen and Hørning, this includes material used, the path where is going to be installed our connection pipe as well as the construction method chosen for its installation.
- Pump design in terms of hydraulic matters together with a recommendation of a real pump taken from a Danish supplier.
- Data verification in order to ensure the similarity between our models and the reality, check possible conflicts between them and analyse their importance.
- Approximate cost estimation to be taken as a reference for deeper project.
- Interpretation of our final model adding the conclusions and recommendations suggested by the author.

2. ANALYSIS OF EXISTING NETWORK AND PREPARATION OF THE MODELS

2.1. Review Hørning model

The model from a Bachelor dissertation has been taken as a starting point, Hørning model was analysed in that project. Anyway a careful investigation is going to carry out by reviewing the existing network of Hørning in relation with the new demands that come from Jeksen, in addition to the review of hour pattern from Hørning and the analysis of the information that we have from Jeksen.

The main points that we are going to evaluate from the Bachelor Dissertation model are pressures along the network and head losses in regards to friction in pipes, in the next subchapter we will analyse the time patter common to Hørning and Jeksen.

Pressures

The main problem of Hørning in relation to Jeksen will be the low pressures. As we can see in the model, there are problems of pressure because of the elevation is higher in this part than the others (Figure 1), there are some point with values below 20 mWC. Exactly for this area is where the connection with Jeksen should be designed, so that a review of possible solutions to avoid those problems is necessary, although these solutions only are going to be taken if the supply of Jeksen affects dramatically the quality of supply in Hørning because of the decrease of pressure consequence of increment of flow in the existing pipes of Hørning.

In the past the waterworks from Hørning provided a pressure of 2.5 bars between 12 am and 5 am, and 3 bars the rest of the day. But now this night pattern has changed, now is between 12 and 7 am (Appendix 6).

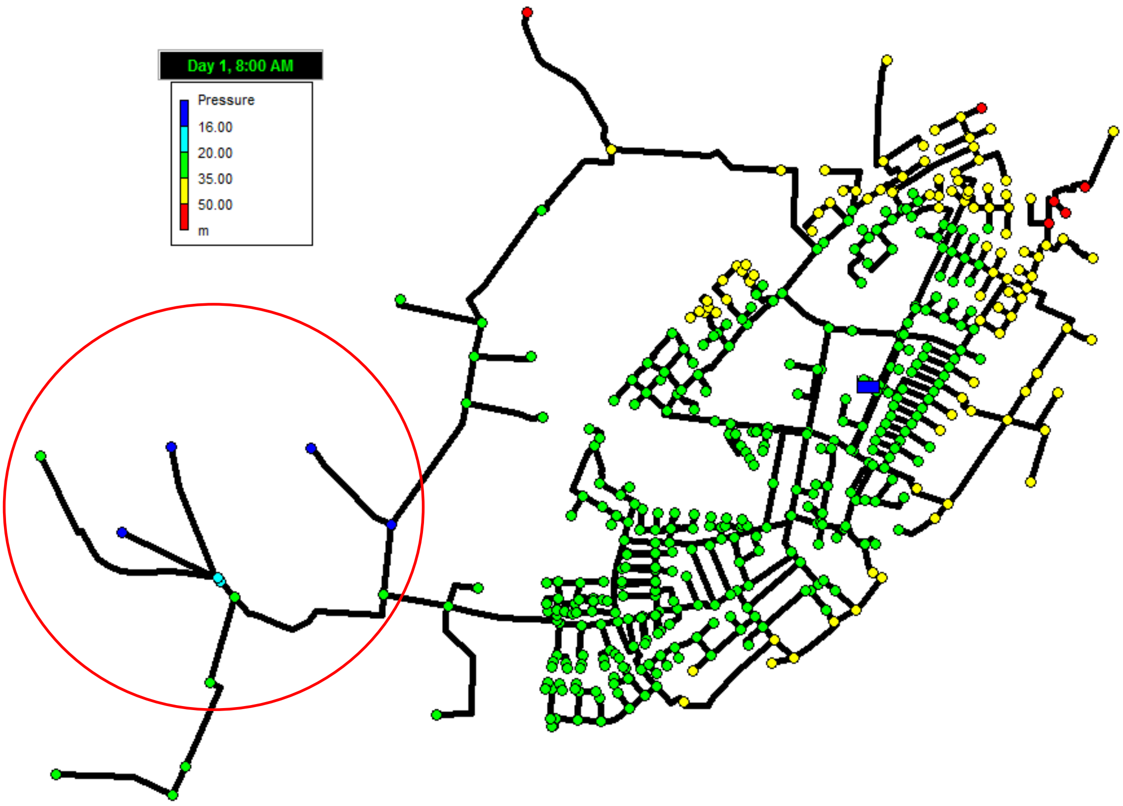


Figure 1. Epanet model of Hørning

Friction losses

For the calculation of friction losses was used the Darcy-Weisbach equation. The value of the Darcy friction factor for PVC/PE is around 0.0025 mm, but it was used a value of 0.01 mm in the previous model, maybe adding an extra value because of the local head loss, although this value is excessive. The point 2.4.2. is going to analyse which value is more suitable for the whole model including Hørning, and what extra value should be added to the regular value.

2.2. Jeksen demand

2.2.1. Volume of water along the year

In order to figure out the demand of Jeksen, we have to look back to check if the demand of the last years was steady, if it is not, it is needed to figure out why was in that way, and if the factors that made those changes in the past, they will continue in the future.

First of all, taking the table from the Geological Survey of Denmark and Greenland (Appendix 1) we can see how the decrease of volume of water since 2009, we have a little increase between 2012 and 2013, but this is justified by a big leakage (Appendix 2) that it was repaired.

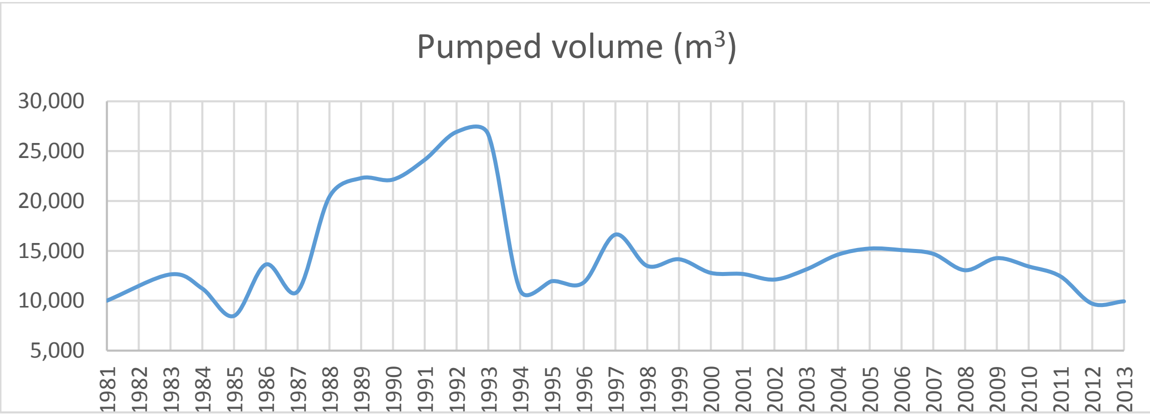


Figure 2. Chart of pumped water

Other important factor that may increase the demand is population, but in the case of Jeksen, being a small town, there is not any planned urban development, according to the Master Plan of community (Skanderborg Kommune, 2011).

In that way, we can make an average from the data in Appendix 1 of the last 5 years, this means an average value of 11 963.8 m^3 of water pumped per year.

2.2.2. Analysis of consumers

Taking into consideration the Appendix 2, the volume of water will be divided among the different consumers: household, farms without animals, farms with animals and industries.

The consumption in 2013 are the followings: (Appendix 2) Household volume 4177 m^3 (47%), Farm without animals 1355 m^3 (15%), Farm with animals 3214 m^3 (36%), Industry 94 m^3 (1%).

Applying these percentages to our estimated volume per year we have the next volumes per consumer: Household volume 5653.03 m^3, Farm without animals 1833.82 m^3, Farm with animals 4349.73 m^3, Industries 127.22 m^3.

2.2.3. Daily and Hourly consumption in Jeksen

In order to calculate the daily consumption of Jeksen we have to take into account separately all the volumes. Because the days per year of use in households are 365, nevertheless it is not the same for the rest of consumers considering that the working days are 250 approximately. Regarding the daily factor it will be considered 2.5. In that way we have the following hourly consumptions: Household 1.61 m^3/h, Farm without animals 0.76 m^3/h, Farm with animals 1.81 m^3/h, Industries 0.05 m^3/h, thereby we have a total value of 4.24 m^3/h.

All those values are the mean hourly consumption values, to make it more real, it is needed factors regarding the specific hour of the day. This is why an analysis of the existing hour patter of Hørning was carried out, since we do not have hour pattern for Jeksen we are going to use the same as Hørning.

2.3. Time pattern

From the graph of flow of Hørning waterworks (Appendix 3), we can obtain the current hourly factors, we are going to use the same pattern in Jeksen model since we do not have this information about Jeksen waterworks.

Those factors of time pattern were obtained from the total flow supplied by Hørning waterworks. This is not enough accurate, because it does not reflect the real pattern depending of the kind of user, however it is the only source of information during the preparation of this report. The hour patter is the following:

HOUR	FACTOR	HOUR	FACTOR	HOUR	FACTOR
1	0.50	**9**	2.26	**17**	2.01
2	0.35	**10**	2.01	**18**	2.51
3	0.35	**11**	1.76	**19**	2.26
4	0.35	**12**	1.51	**20**	1.76
5	0.50	**13**	1.51	**21**	1.51
6	2.01	**14**	1.51	**22**	1.26
7	3.01	**15**	1.51	**23**	1.26
8	2.26	**16**	1.76	**24**	0.75

Table 1. Hourly factors

2.4. Jeksen model

2.4.1. Information systems management

Before starting with the management of data we have to be sure of the interoperability between different software. For new-built water supply systems it will be more accurate to work in GIS than work in CAD, knowing that GIS software is better to have this kind of information as a database. But in our case we have to work with an existing model, this model is represented in Epanet and AutoCAD, in addition both files are with a geographic coordinate system different from the supplied from the Geodata Agency of Denmark, so that changing from one coordinate system to another is easier with AutoCAD and also create new lines.

We are going to work with AutoCAD and Epanet mainly, using EpaCAD as exchange program between them. This program allows to export not only geometry, but also elevations of the joints.

2.4.2. General considerations of the model

The model of Jeksen is going to be created from two sources of data. The first one is from a web application provided from waterworks (Appendix 4), which appears the location, diameter and material of every pipe in Jeksen. There are some problems, it is not so easy to know the exact length of every pipe and then introduced to AutoCAD, and this is why a second source of information is needed. Furthermore it is not possible to know information about some service pipes which connect the main pipelines with private houses, this is especially important in the detached houses in the outskirts of Jeksen, where these service pipes are longer than the main pipes in the downtown, the best possible solution to this problem is underestimate the service pipes to be sure that we are in the worst supposition, and we are not going to have problems in the real network.

The second source of information is from the Geodata Agency of Denmark (http://kortforsyningen.dk/), this webpage will provide maps of Denmark in .DWG format. We are going to use this file to draw the pipes, in this way we are going to have an accurate length of the pipes and also the elevation. We will be able to join this map with the existing map of Hørning also in .DWG format if it was necessary.

2.4.3. Creation of the model

Startup with Epanet model

All the pipes have been drawn in AutoCAD with polyline 3D in order to preserve not only the geometry but also the elevations. The polylines are going to be drawn in the ground level, this simplification allows us to draw them easier in AutoCAD without a significant change compared with the real model, because the pipes are going to be a maximum of 4 meters approximately below the ground level (AWWA, 2006, p. 128) to avoid frost penetration and other problems, so we are taking into consideration the same zero level for all the pipes in Jeksen. Anyway supposing that our modelled pipes are higher than reality, it only affects the booster pump design which could be slightly overestimated, in that way, we are not going to have problems of low pressure in Jeksen.

The Epanet model is going to be generated from the AutoCAD model through the program EpaCAD. It is important to say that the model of Jeksen and the existing model of Hørning have to be in the same geographical coordination system, in our case the model of Hørning provided by the supervisor of this dissertation was in a different system so that the new model of Jeksen has to be adapted to this system.

Adding characteristics to Epanet model

Once that the first sketch is done in Epanet, all the characteristics of the model should be added. These are the followings:

- Consumption: the consumption of every point will be taken from the total volume in the subchapter 2.2.3., and then divided into the number of houses, farms or industries. It would be more accurate to know the exactly consumption of every user but in regards to time and availability, this solution was dismissed.

  The total amount of farms without animals, farms with animals and industries is going to consider as a whole. Thanks to the data from Appendix 2, 17 farms/industries has been considered, this is enough accurate to our model. So that, we are going to consider that every farm/industry node demand as 0.155 m^3/h.

Regarding the detached houses there are a total of 52, but it only has been consider a total of 51. Maybe there is a house in Jeksen that does not appear yet in the data of Appendix 2, but it exists regarding the data from the waterworks, anyway it is not significant. We are going to consider that every detached house node demand as 0.032 m^3/h.

- Diameter of the pipes: information taken from Appendix 4.
- Fittings: some of the fittings appears on Appendix 4 but it is not possible to know technical properties of them regarding head loss. In that way it is going to simplify the model by the increase of head loss along the pipes.
- Material of the pipes: information taken also from Appendix 4. All the pipes from Hørning and also from Jeksen are made of PVC or PEL. This factor affects directly in the Epanet model, because of the roughness of the pipe. As it was said in the review of the Hørning model, the value of roughness in the previous model is 0.01 which is excessive. In our model we are going to use a total value of 0.00275, this values comes from adding to the roughness of PVC/PEL pipes an extra value of 10% (Kay 2007) because of the local head loss in fittings (pipe bends, reducers, valves and so on). This local head loss will be insignificant in almost all the network except for the pumping station, this is why a minimum value of 10% has been applied in all the model. Anyway, after the calibration, it is going to reconsider whether this supposed value is right.

3. CONNECTION PIPE BETWEEN JEKSEN AND HØRNING

3.1. Material

This report analyses the different materials utilized in water supply networks nowadays, these are the followings:

- Steel pipes are used when there is high pressure in a pipe (Kay, 2008). Steel pipes have corrosion problems in that way, they have to be protected with bituminous materials or galvanising. If the pipe is buried we can protect it by using a cathodic protection. This problem can represent not only an increasing in the cost of installation but also an increasing in the cost of maintenance. In regard to these problems, this material has been dismissed even for the outlet of the pump despite the high pressures that our connection pipe has to withstand.
- Thermoplastic pipes. Polyvinyl Chloride (PVC) pipes and Polyethylene pipes are thermoplastic pipes. The main difference between them, making a functional comparison with pipes with the same dimension ratio (relation between outside diameter and wall thickness), it is that in terms of cyclic changes in pressure or speed of water, high density polyethylene (HDPE) pipes are able to withstand much better those changes which appears during water hammers or pumps turning on and off (McElroy Manufacturing, Inc., 2013), which is our case. Besides the advantages already detailed, they are very flexible, therefore they allow methods of installation without open-cut as we are going to see in the subchapter 3.3.

3.2. Location

As it has been defined in Appendix 5, the path of the connection pipe between Jeksen and Hørning is going to start from a water main of 110 mm in Hørning water supply network, and it is going to continue through Jeksen Dalvej until the road curve, we are not going to continue more through the road because this might mean the replacement of the existing road and also a longer connection pipe.

When the forest starts we are going to take the shortest path through the forest to avoid the damage of it until the top of the hill.

Once the pipe arrives until the top of the hill, we are going to trace a line between this point and joint in Jeksen network as straight as possible. This joint has been chosen because of its position in the middle of Jeksen, and also because it is one of the biggest pipes in Jeksen, in that way, we are going to avoid the replacement of pipes in Jeksen because of the need of an increment in the diameter.

3.3. Installation procedures

We are going to analyse the most suitable procedures for the installation of our connection pipe. Once that we choose a specific material for the pipe, in our case HDPE we have different methods of installation (AWWA, 2006, p. 99-143):

- Open-cut: is the most common and easiest way of installing a pipe. First of all by trenching in the soil, dewatering if it was needed, then spreading the bedding, the placing of the pipe, a leak testing could be undertaken and the last step would be the trench backfill. As it can see, this method requires a lot of time-consuming tasks.

- Horizontal boring: is commonly used to install a pipe under a road to avoid the cost of replacing an existing infrastructure. This system consist on using a rotating drill with a steel casing. The pipe could be placed through a casing or directly in the borehole.
- Pipe bursting: This method employs a pulling head that fractures the original pipe and then pulls a new pipe of the same or larger size into the fractured old pipe. A sleeve pipe can be installed inside the fractured pipe before installing the new pipe. The sleeve pipe protects the PE pipe from the sharp pieces of the old pipe. We can use this method for the replacement of the pipes under the roads not only because of the save money but also for the social cost. This procedure is much more cost effective than trenching method, could be two or three times cheaper than trenching (Lee et al., 2007), although we are going to an economic study later on.
- Horizontal directional drilling (HDD): this technique consists on using a steel string with a cutting head. The cutting head is replaced by a backreamer. The pipe cable is joint together with the backreamer. The backreamer enlarges the borehole and the pipe is pulled back in. Compared with trenching method, we can decrease disturbance in people and traffic and it is more sustainable because we do not have to bring imported granular soil for the bedding (Young & Creelman, 2007). The use of this procedure in combination with PE pipes must include HDPE pipes such as PE100 in order to resist properly the pulling forces during the installation (Gong, et al., 2009).

Economic study

Since we cannot do a real economic study of our possibilities due to the lack of information, we are going to base our results in *Trenchless technology: Planning, Equipment, and Methods* (Najafi, 2013). This book includes regression equations base on empirical results. Although this book contains regression equations that combine length and diameter, it has been decided to use the regression equation for diameter and length separately considering that it is going to be more accurate in terms of relative values and we do not want an exact costs which is provided in US Dollars, we only want to compare costs between one method and the others to decide which is more cost-effective.

The results are based in US dollars, the diameter is in inches and the length in feet:

- Pipe bursting
    - Cost(Diameter) = 12,484 · Diameter+7,3133
    - Cost (Length) = 141,56 · $e^{-0.00001,Lenght}$
- Horizontal Directional Drilling
    - Cost(Diameter) = 3,9566 · $Diameter^{1,3916}$
    - Cost (Length) = =185,43 · $e^{-0,0005 \cdot Length}$
- Open-Cut
    - Cost (Diameter) = 91,637 · $e^{0,0653 \cdot Diameter}$
    - Cost (Length) = 3836,7 · $Length^{-0,409}$

We have supposed an exterior diameter of 100 mm.

Drawings in appendix 5.

Sector A; Length 245 m. Existing pipe of 75 mm.

	Cost (Diameter)	**Cost (Length)**
Pipe bursting	56 $	140 $
HDD	27 $	124 $
Open-Cut	119 $	249 $

Sector B; Length 633 m. New pipe installation.

	Cost (Diameter)	**Cost (Length)**
HDD	27 $	66 $
Open-Cut	119 $	169 $

Sector C; Length 954 m. Existing pipe of 50 mm.

	Cost (Diameter)	**Cost (Length)**
Pipe bursting	56 $	137 $
HDD	27 $	39 $
Open-Cut	119 $	143 $

Sector D; Length 1260 m. New pipe installation.

	Cost (Diameter)	**Cost (Length)**
HDD	27 $	39 $
Open-Cut	119 $	143 $

Table 2. Costs comparison between different installation methods

As we can see in all sectors is cheaper the installation of a new pipe using HDD, instead of using pipe bursting or doing an open-cut that is why it has been decided to include a new pipe using HDD. Apart from the cost supposed doing this method and comparing one by one, at the end it is going to be higher savings because of less cost of rented machinery.

In hydraulic terms, it is going to be also savings although they are going to be lower, the head loss will be lower in consequence of less fittings, more direct connection and also if it was any problem in the future it would be easier to detect problems.

3.4. Other specifications

The pipe is going to be located 1,2 meters below the ground level to avoid frost penetration, according to the Danish Standards.

Our connection pipe as well as the other replaced pipes has to be approximately between 80 and 100 mm inside diameter in order to bear with the new demand. But the most important fact to take into account is not the pressure of the water inside the pipe or the traffic loads, but the tensile stress that has to withstand the pipe during the installation using trenchless methods.

According to the Handbook of Polyethylene Pipe (The Plastic Pipe Institute, 2012), a deeper calculation should be taken. It is needed to figure out the maximum outer fibre tensile stress of the pipe, this value is the sum of the tensile stress during the pullback force, the hydrokinetic pulling force and the tensile bending stress due to the pipe curvature. The first two addend are unknown, they depend on total pulling force applied by the machine, the time that the pipe is under this tensile forces, the hydrokinetic pressure of the drilling slurry and the borehole diameter. Finally the Maximum outer fibre tensile stress of the pipe should be lower than the tensile stress of the pipe to verify the pipe characteristics, this allowable tensile stress of the pipe not only depends on the specifications of the pipe but also depend on the temperature during the installation and the type of soil. All those values could varying from one contractor to another, and the site. We are going to assume a pipe of 90 mm with a standard dimension ratio (SDR) of 17 which is a PE 100 class.

4. PUMP DESIGN

4.1. Location

Regarding the location of the pump station we have many variables to take into consideration. Between the Southwest of Hørning and Southeast of Jeksen, where it is going to be the connection, we have an increment in height of 37 meters approximately. The problem will be to install the pump station in a place that was not too high to avoid cavitation, but not too low in order to avoid high pressures in the supply pipe, which means more energy needed in the pump to lift the water.

The problem arises when the optimal point to avoid the highest pressures and cavitation, is located in a forest where a part from the high density of trees, there is a big slope, which could difficult the labours of installation and maintenance of the pump station (Appendix 5).

After study all the possible solution the most suitable solution is to install the pump just before the hill starts, in that way, our pressure will be higher with the subsequent negative effects of high pressure and highest energy consumption, but it is the only way to avoid cavitation and to have an easy access to the pump station.

4.2. Hydraulic requirements

We are going to look for a pump with the requirements that the model demands. Our pump station has to provide enough flow and pressure to ensure the right supply in the whole network of Jeksen.

Pressure and flow

In our case our pump station is going to deal with a maximum demand at 6 AM and minimum demand between 2 and 4 AM. So that, our pump has to be able to cope with these two situations. According to our model these situations are one with 12,8 m^3/h and other with 1,5 m^3/h. Our pump has to ensure a constant pressure of 77 mWC, in our model we have simplified the pump as a reservoir.

The pressure in the inlet of the pump is going to be around 44 mWC depending on the hour but we are going to consider the rush hour (maximum flow) when the pressure is the lowest, 30 mWC. Therefore our pump has to add to this value 47 mWC more to ensure the supply in the Jeksen network, this means ensure a minimum pressure of 15 mWC in the weakest point of Jeksen.

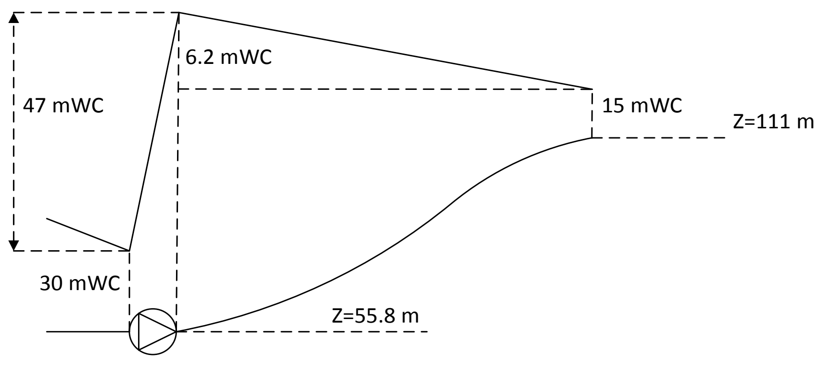


Figure 3. Hydraulic diagram of the pump

Mechanical fittings

Our pump station has to be composed of one suction manifold where the water is drawn out, after that a pressure transmitter should be installed in the inlet to assure that pressure never drops below 1 bar to avoid the dry-running which can damage the pump.

Our pumps are going to be installed in parallel, one of them is in standby to assure always the pressure and flow needed in Jeksen, if the main pump fails. Every pump has two isolating valves to make easy the replacement and maintenance works and also one non-return valve in the outlet to avoid water hammer and one in the inlet to avoid dry-running, if the pressure transmitter fails.

We are going to install in addition a diaphragm tank in the discharge manifold to avoid water hammer (subchapter 4.3.2) as well as a sensor which is going to assure the pressure required and a pressure gauge and a flowmeter to record and show the patterns from Jeksen.

All these elements are included in the pressure system that we have chosen in the following subchapter although some are optional as the diaphragm tank, the flowmeter and the check valves in the inlet.

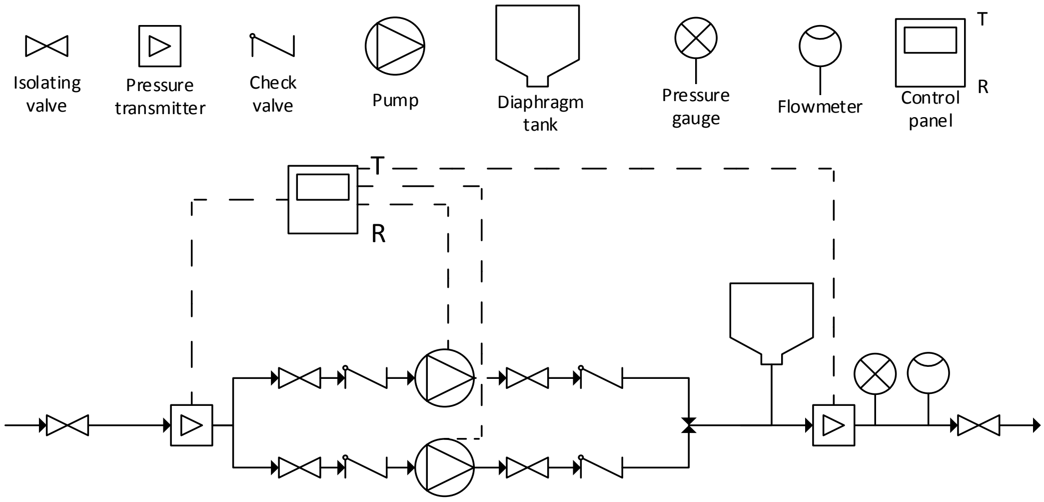


Figure 4. Pump station diagram

4.3. Market pump

There are a lot of different ways to solve this issue, for example using a reservoir together with a vertical turbine pump. However one of the objectives of this report is using a booster pump the reason is the low cost of installation compared with the construction of a reservoir and the high level of electronic devices which can be guarantee a better use of energy consumption.

4.3.1. Chosen model

The recommended pump in this report is the pressure booster system Hydro MPC-E 2 CRIE10-6 of Grundfos (Appendix 9). The booster systems Hydro MPC-E is designed for pressure boosting of clean water in waterworks. It is composed of two identical electronically speed-controlled pumps, the model CRIE 10-6 in our case. This booster system allow us to achieve the demand needed for Jeksen in terms of pressure and flow.

Other important characteristic of this model is the function called proportional pressure which allows compensate the head loss by adapting the pressure of the pump to the pressure required and not more by setting the pump in advance making a relation between the flow and the head loss with this flow. This is a more accurate way of work than a usual pump station which fixes two values of pressure, one for the whole day and one for the early morning hours.

4.3.2. Pump requirements

Building

Our pump has to be installed in a ventilated room to ensure sufficient cooling of the pump system. Our pressure system has an indoor use, it cannot be exposed directly to the sun. According to the guidelines of installation the booster system should be place with one meter distance in front and two meters in the sides for inspections or removal. Although it does not appear on the guidelines of the pump should be recommendable to install automated heating, turning on when the temperature inside the building drop below 0ºC.

Diaphragm tank

In spite of not being strictly necessary the installation of a diaphragm tank because of long pipes in water supply systems could hold the water hammer thanks to its elasticity. Our pump is located after a hill where the drop in height happens in a short distance, to avoid future problems and following the guidelines of the manufacturer a diaphragm tank of 18 litres is going to be installed.

5. DATA VERIFICATION

During this project some field measurements were taken in order to compare some nodes of our model to real points in the water supply network of Jeksen and Hørning. The measurements of comparison will be the pressure in the network, but only in the fire hydrants, not in the household consumer taps because these data are not accurate enough because when there is any flow in the tap the pressure data is falsified, because the pressure drops.

We have taken three points of comparison, two in Hørning and one in Jeksen (Appendix 6):

- Bodil Møllevej (Hørning): pressure between 50-37 mWC. Although we have a mean value of 46* mWC during days and 41* mWC during nights.
- Fire Station (Hørning): pressure between 47-33 mWC. Although we have a mean value of 43* mWC during days and 38.5* mWC during nights.
- Jeksen: pressure between 42-30 mWC. We have a mean value of 37.2** mWC.

* To these values we have to add an extra value of 1.2 meters to compare with the same reference elevation, this is the height between the outlet of the fire hydrant, where it was the manometer until the pipe underneath, which is the ground level in the model.

** To this value we have to add an extra value of 0.5 meters to compare with the same reference elevation, this is the height between the outlet of the fire hydrant, where it was the manometer until the pipe underneath, which is the surface level in the model.

So that, comparing with equal reference elevation, we have the following data:

	Reality		Model	
	Day	Night	Day	Night
Bodil Møllevej	47.2	42.2	42.5	38.5
Fire Station	44.2	39.7	40.5	36.5
Jeksen	37.7		39.4	

Table 3. Data comparison of reality and model

As we can see, in Bodil Møllevej logger we have about 4.2 mWC more of pressure in reality than the model. In Fire station logger we have about 3.5 mWC more of pressure in reality than the model. In Jeksen logger we have about 1.7 mWC less of pressure in reality than the model.

In Jeksen as it is normal, the pressure in reality is slightly lower than the model, justify by minor losses or ageing of the pipes. The problem arises in the measurements taken in Hørning, this measurements are extremely higher comparing with the model, this issue requires a better understanding of the variables that maybe affected by this disparity.

These are the variables that maybe contribute to this disparity between model and reality in Hørning:

- **Manometers.** Although Jeksen manometer match approximately with its model, and all the manometers where calibrated in the same way, a laboratory test was carried out (Appendix 7) to check the proper functioning of the manometers.
- **Valves.** The opening or closing of the valves could change the path through the water flows, and maybe cause this disparity.
- **Consumption.** A decrease in the consumption could mean this increase in the pressure because the head loss would be lower. It could not be possible to check

the consumption of every user in Hørning, due to reticence of public authorities in the past to collaborate with a university report, because this means the violability of privacy of the consumers. But it is a point that should be reviewed in the future.

- **Pressure booster.** Although the installation of a pressure booster is not reasonable because these areas are located one far from the other, and they did not have problems of pressure in the past. However it is a possible justification of the increment of pressure that should be reviewed.
- **Model characteristics.** Some details in Hørning model have been reviewed to assure the similarity between the model and reality:
    - Elevation of the model. The elevation of the model in comparison with the reality have been checked and it was not any mistake.
    - New pipes (Length and diameter). There are not new pipes that could make vary the results so drastically.
    - Roughness. A higher roughness because of the ageing would mean lower pressure, which is the opposite of our results.

6. COST ESTIMATION

An estimated budget should be done to guide Skanderborg municipality to know the approximately final cost of this project.

No	Item	Unit	Quantity	Unit price [DKK]	Total value [DKK]
1.	Replacements				
1.1.	*Hørning*				
1.1.1.	Water supply pipe PVC 110 mm	m	100	93	9300
1.1.2.	Tee for PVC pipe 110/90 with reduction	pcs	1	188	188
1.2.	*Jeksen*				
1.2.1.	Water supply pipe PVC 90 mm	m	100	67	6700
1.2.2.	Tee for PVC pipe 90	pcs	1	114	114
2.	Pipe connection				
2.1.	Horizontal Directional Drilling installation pipe not included	m	3139	270	847530
2.2.	Water supply pipe PE 90 mm	m	3139	204	640356
3.	Pump station				
3.1.	*Building expenses*				
3.1.1.	Building, all included. Foundation, easy removable roof. One metallic door.	pcs	1	43000	43000
3.2.	*Booster system*				
3.2.1.	Hydro MPC-E 2 CRIE10-6 with optional accessories	pcs	1	79741	79741
3.2.2.	Booster system installation	pcs	1	3500	3500
Total value with safety factor of 20 %					1956378

Table 4. Bill of quantities

Our total budget will be around two million Danish krone excluding taxes. It has been included a safety factor of 20% because of the ignorance in most technical aspects due to the limitations defined in the beginning of this report.

All the prices were taken from Danish suppliers such as Agrotech A/S, Munck Forsyningsledninger A/S, Grundfos Holding A/S and Rotek A/S detailed in the references, except for the price of the building that was taken from the cost of a similar building located in Hørning and built recently for a borehole in charge of extracting water.

7. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Although this report has been done with limited resources, the conclusions extracted are clear enough. The cost estimation shows high costs although it is necessary for the proper functioning of the water supply system in Jeksen, in addition the planned site works and solutions have been thinking to ensure the lowest disturbance to the inhabitants from Hørning and Jeksen.

From the model we can ensure the feasibility of the project in hydraulic terms. Despite low pressure values in the West of Hørning, with the solution in this report, this issue is not going to affect the supply in Jeksen or the quality of supply in Hørning due to the increase of flow.

Field measurements showed higher pressures in reality than the model in Hørning, but this inequality will not affect the technical feasibility of our project. This discrepancy means that maybe our pressure booster might be overestimated and therefore it has designed with slightly more powerful engines than required which means a higher energy consumption, but the water supply in Jeksen is not affected.

Recommendations

The author is going to make some recommendations about Hørning network, even though it does not affect directly the aim of this project, it is necessary for a better understanding of the supply in Hørning. First of all, it is absolutely necessary to ensure the similarity between model and reality, higher pressure in the system than necessary implicates higher head losses of water and more probabilities of leakages or cracking in the pipes, the list of possible variable that could contribute to this disparity and should be reviewed appear on chapter 5 of this report.

Secondly, after the analysis of values taken from pressure gauges, it is clear that the consumption started to be really high at 6:30, especially significant during working days, so the pattern from Hørning waterworks should adapted to this demand by changing the day pressure starting from 7:00 to 6:00 in order to ensure enough pressure in its network.

If the municipality makes this project reality, regarding the connection between Jeksen and Hørning, the booster pump recommended has the ability to adapt its pressure to the head loss in the network, so it is required a precise set up of the pump to ensure a better adjustment to the needs of the network, which means savings in energy consumption.

Also it is highly recommendable to check the pressure in the highest point of Jeksen. With the new point of supply, the distribution of flow changes, so this point is the weakest in terms of low pressure. The pump has been dimensioned to ensure a pressure of 13 mWC in this point (Appendix 8) during highest demand period, so it is below the required minimum pressure. The recommended booster pump could increase its speed without affecting its reliability, if it was any complain of the consumer because of low pressure.

REFERENCES

American Water Works Association, 2006. *PE Pipe—Design and Installation*. Denver: Glacier Publishing Services, Inc.

Gong A., Wang Z., Walton D. & Wang C., 2009. Trenchless renovation & installation of municipal pipelines in China using PE pipes. In: *International Conference on Pipelines and Trenchless Technology*. Shanghai, China. 18-21 October 2009. American Society of Civil Engineers: Reston.

Kay, M., 2008. Energy loss at pipe fittings. In: Kay, M. 2nd ed. 2008. *Practical Hydraulics*. UK: Taylor & Francis. 4.6.

Kay, M., 2008. Materials. In: Kay, M. 2nd ed. 2008. *Practical Hydraulics*. UK: Taylor & Francis. 4.12.1.

Lee H., Najafi M., & Matthys, J., 2007. Cost Comparison of Pipeline Asset Replacement: Open-Cut and Pipe-Bursting. *Pipelines 2007: Advances and Experiences with Trenchless Pipeline Projects,* pp. 192-202.

McElroy Manufacturing, Inc., 2013. *Pressure Class Comparison for PVC and HDPE Pipes as a Function of Flow Velocity of Water*. [Online] Available at: http://www.mcelroy.com/pdf/HDPEvsPVC.pdf [Accessed 1 June 2014]

Najafi, M., 2013. *Trenchless Technology: Planning, Equipment, and Methods*. 1st ed. New York: McGraw-Hill.

The Plastic Pipe Institute, 2012. *Handbook of Polyethylene Pipe*. 2nd ed. Irving: The Plastic Pipe Institute

Skanderborg Kommune, 2011. *Master Plan of Skanderborg Kommune 2011-2030*. [Online] (Updated 1 May 2012) Available at: http://www.skanderborg.dk/Borger/Kommuneplan-og-Lokalplaner/Planstrategi.aspx [Accessed 15 May 2012]

Young J., & Creelman P., 2007. Horizontal directional drilling installation of segmented PVC watermain pipe in Richmond, Canada. *Pipelines 2007: Advances and Experiences with Trenchless Pipeline Projects,* pp. 343-352.

Personal references

Gl. Hørning waterworks - Kim Søe Jensen

Grundfos Holding A/S - René Smed Nielsen

Munck Forsyningsledninger A/S - Svend Blichfeld

Skanderborg Kommune - Carsten Vigen Hansen

Other references

Agrometer A/S, 2014. *PVC lime- og gevindfittings* [Online] Grindsted: Agrometer A/S. Available at: http://www.agrometer.dk/documents/00139.pdf [Accessed 23 August 2014]

Governmental webpages from Environmental Ministry of Denmark.

Geodatastyrelsen – Geodata Agency

Geocenter Denmark.

Notes of the subject Water Supply given by Henrik Bjørn.

Rotek A/S, 2014. *Produkter* [Online] Felding: Rotek A/S. Available at: http://www.rotek.dk/produkter.aspx [Accessed 23 August 2014]

V&S Datapris (Danish database for costs in construction).

APPENDICES

Appendix 1. Pumped water of Jeksen in m^3

Data taken from the Geological Survey of Denmark and Greenland (geus.dk).

Year	Pumped volume (m^3)	Year	Pumped volume (m^3)
2013	9.942	1997	16.637
2012	9.712	1996	11.826
2011	12.450	1995	11.963
2010	13.441	1994	11.063
2009	14.274	1993	26.675
2008	13.061	1992	26.932
2007	14.706	1991	24.137
2006	15.081	1990	22.154
2005	15.234	1989	22.302
2004	14.628	1988	20.415
2003	13.137	1987	10.929
2002	12.124	1986	13.634
2001	12.686	1985	8.481
2000	12.795	1984	11.226
1999	14.162	1983	12.642
1998	13.494	1981	10.010

Table 5. Water pumped in Jeksen sorted by year

Appendix 2. Jeksen consumption in 2013

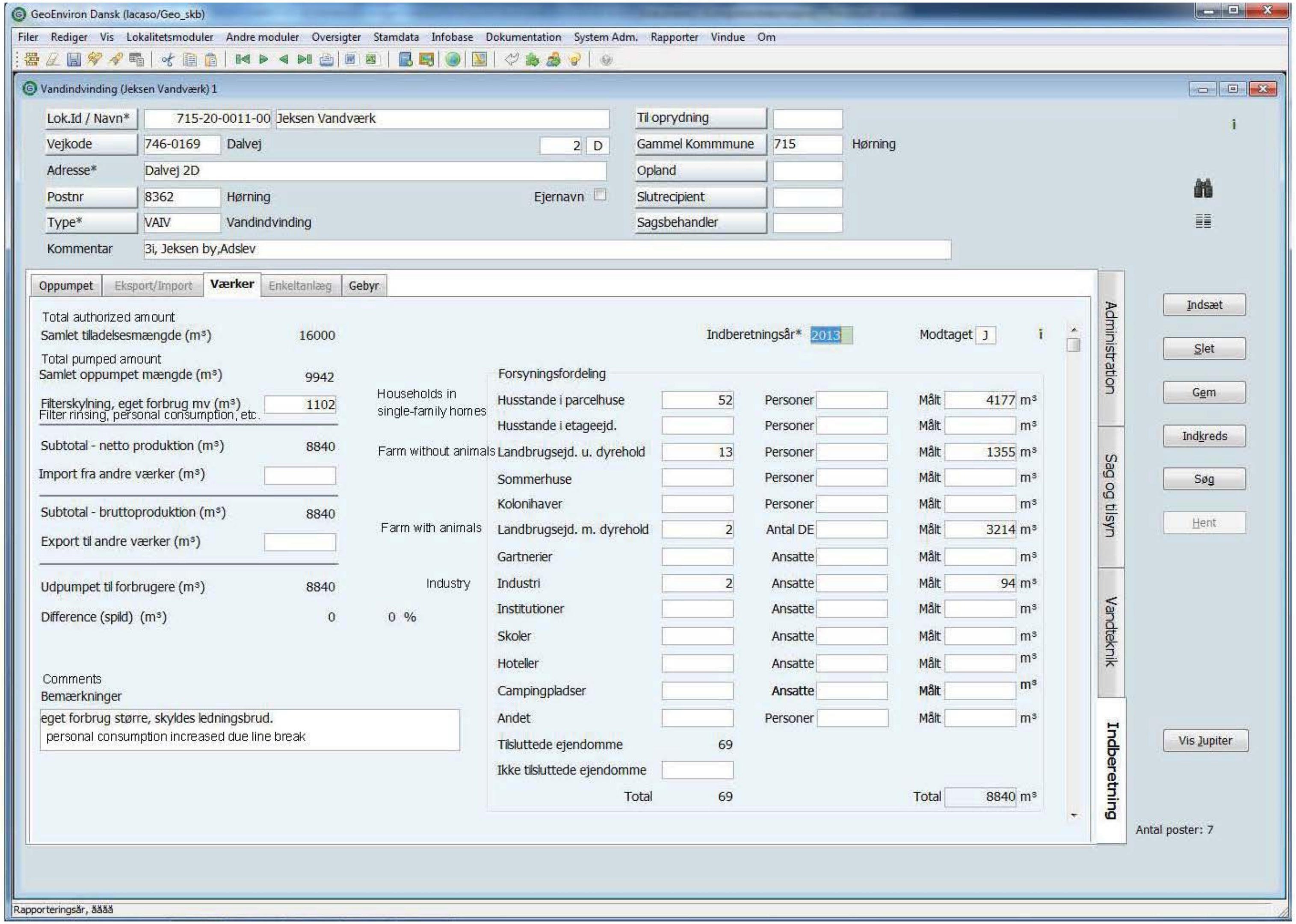


Figure 5. Jeksen consumption in 2013 sorted by type of user

Appendix 3. Flow output from Hørning waterworks

Data taken from Hørning waterworks.

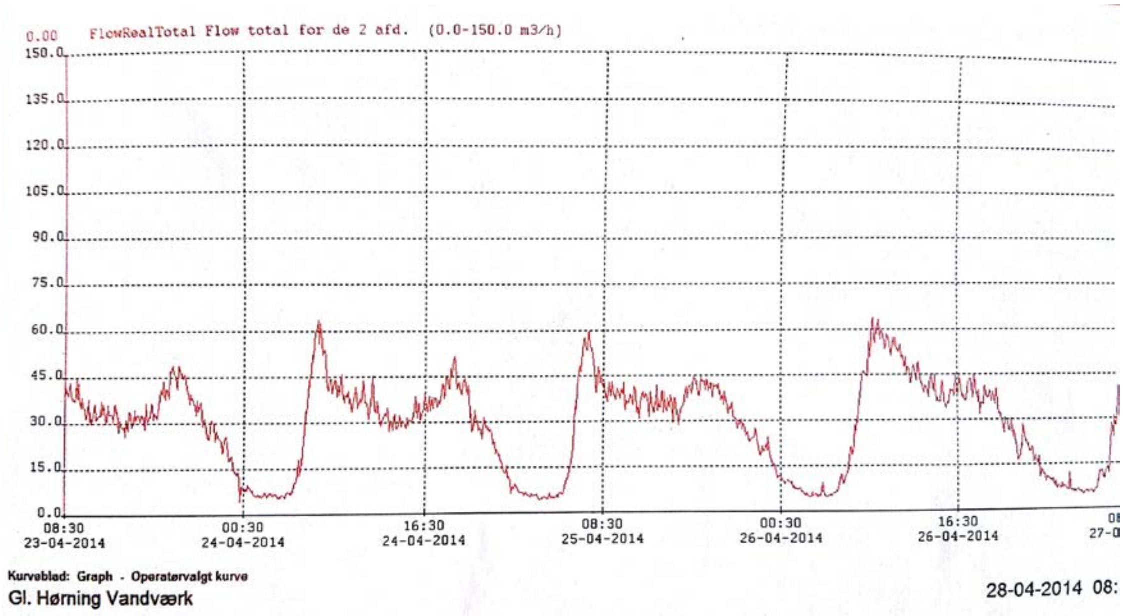


Figure 6. Flow output from Hørning waterworks (1)

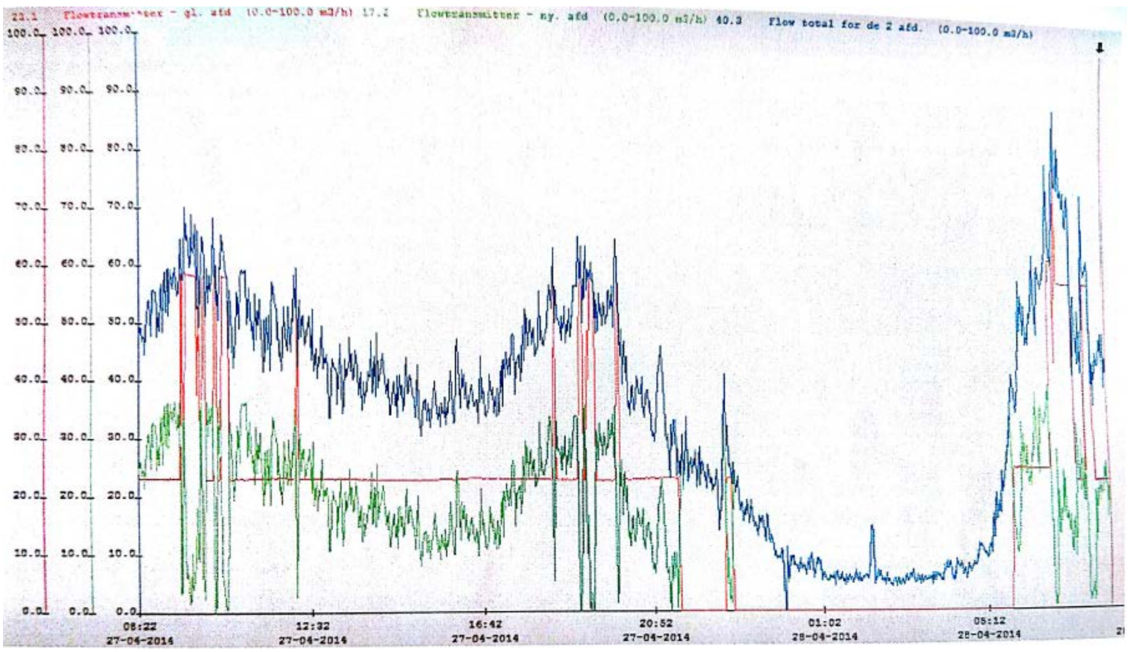
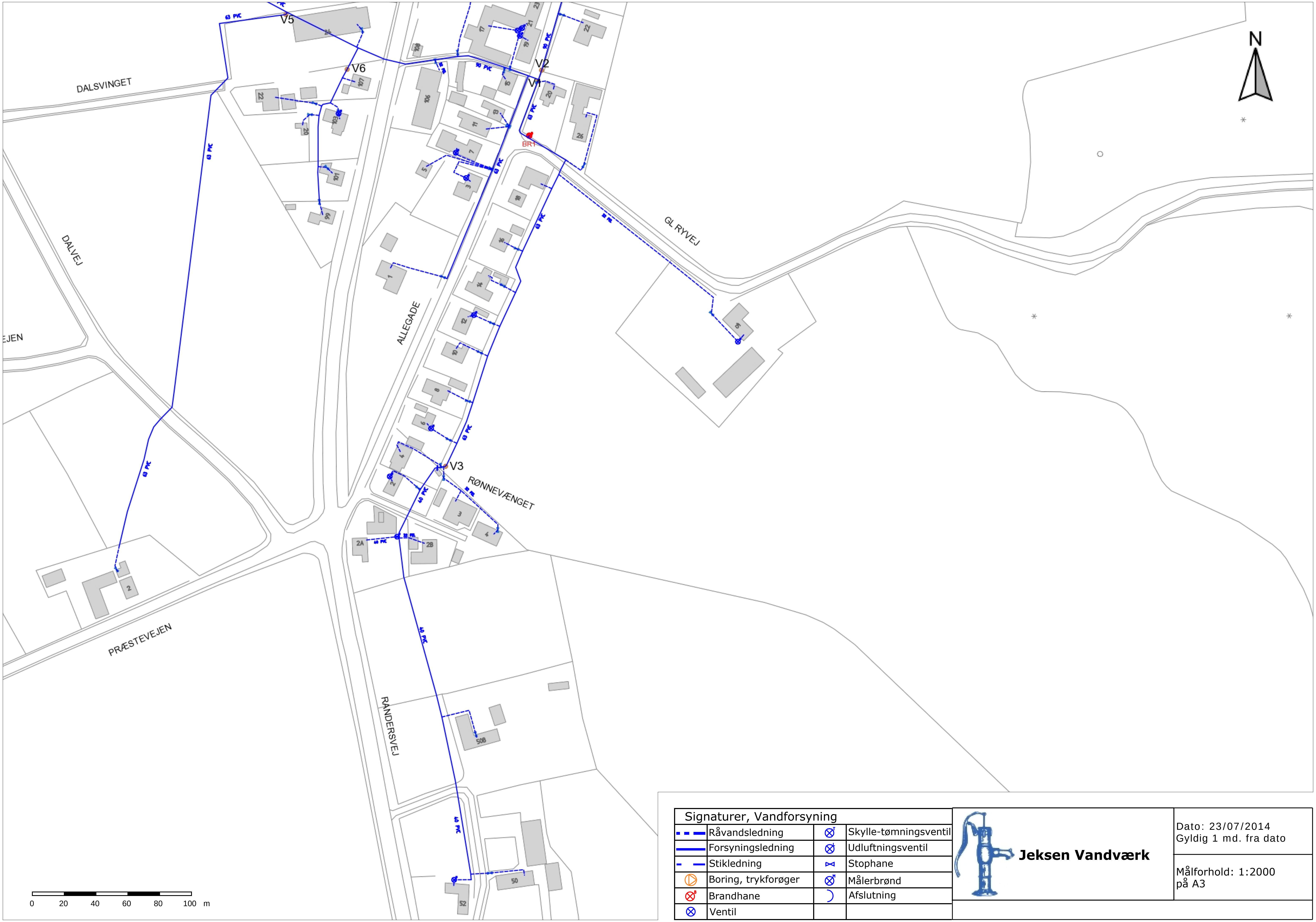


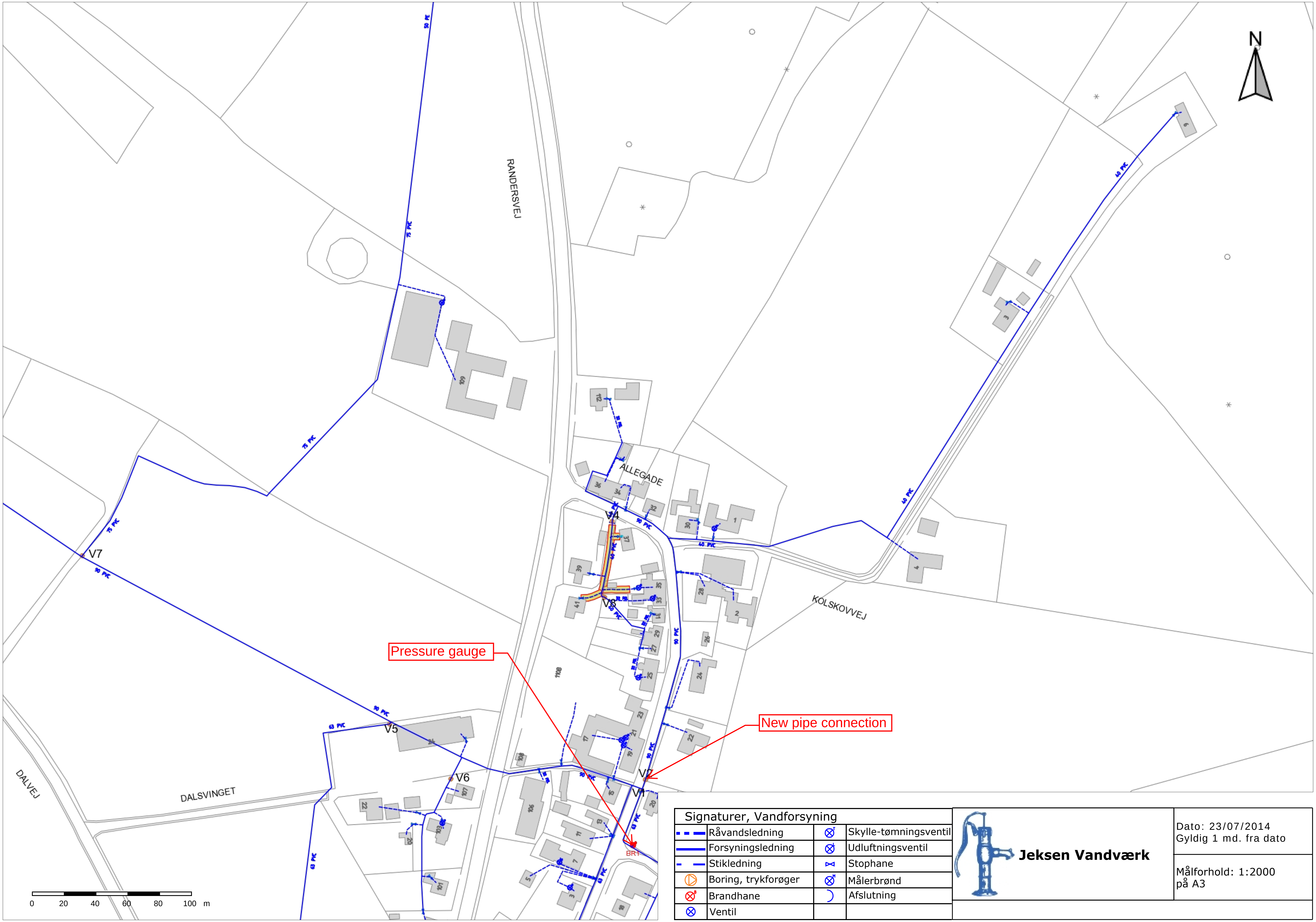
Figure 7. Flow output from Hørning waterworks (2)

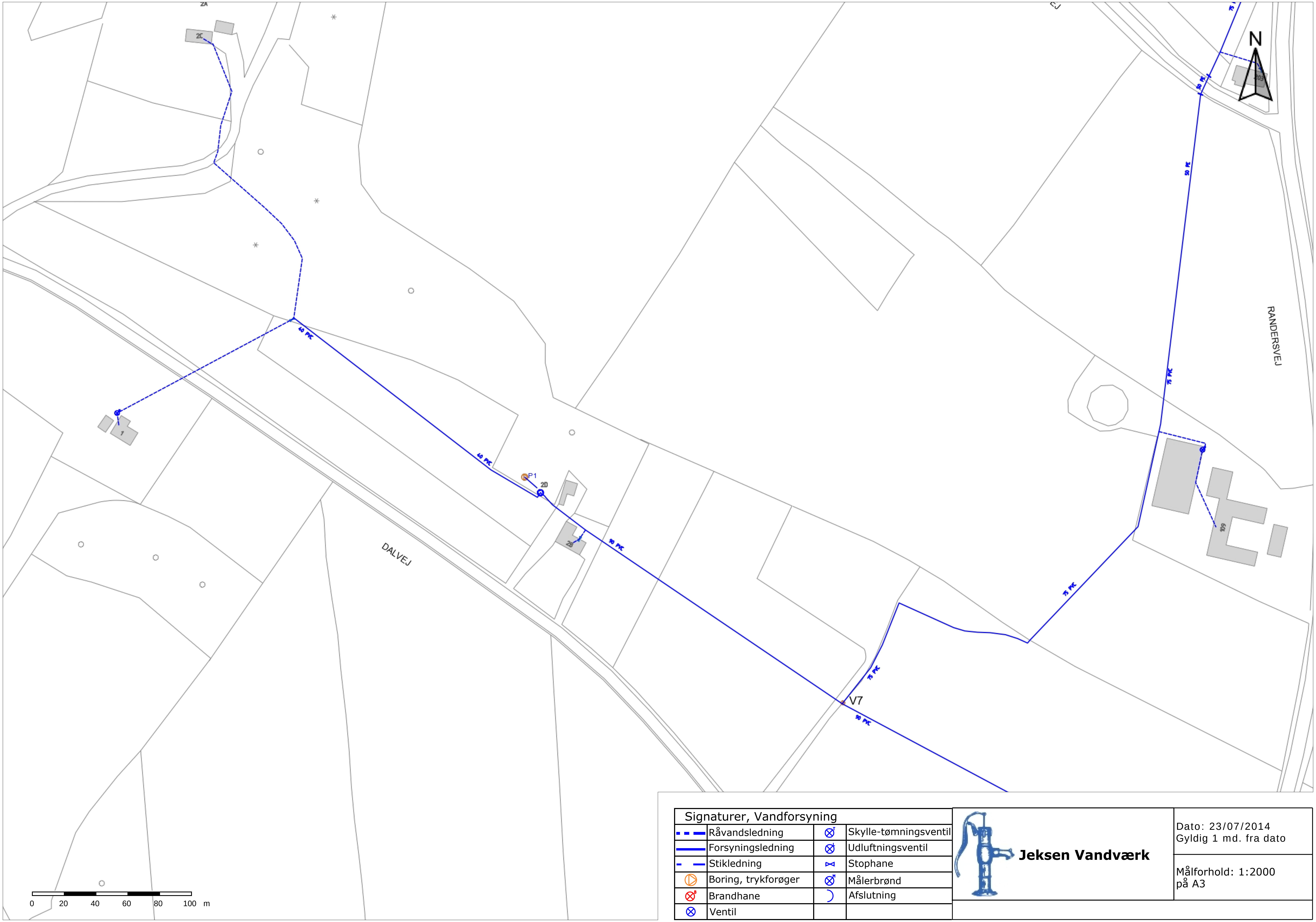
Appendix 4. Water supply network of Jeksen

Drawings downloaded from http://jeksen.vandforsyning.net/.



N
DALSVINGET
DALVEJ
EJEN
ALLEGADE
GL RYVEJ
RØNNEVÆNGET
PRÆSTEVEJEN
RANDERSVEJ
V1
V2
V3
V5
V6
BR1
0 20 40 60 80 100 m
Signaturer, Vandforsyning
Råvandsledning
Forsyningsledning
Stikledning
Boring, trykforøger
Brandhane
Ventil
Skylle-tømningsventil
Udluftningsventil
Stophane
Målerbrønd
Afslutning
Jeksen Vandværk
Dato: 23/07/2014
Gyldig 1 md. fra dato
Målforhold: 1:2000
på A3


N
RANDERSVEJ
ALLEGADE
KOLSKOVVEJ
DALVEJ
DALSVINGET
V1
V2
V3
V4
V5
V6
V7
BR1
Pressure gauge
New pipe connection
0 20 40 60 80 100 m
Signaturer, Vandforsyning
Råvandsledning
Forsyningsledning
Stikledning
Boring, trykforøger
Brandhane
Ventil
Skylle-tømningsventil
Udluftningsventil
Stophane
Målerbrønd
Afslutning
Jeksen Vandværk
Dato: 23/07/2014
Gyldig 1 md. fra dato
Målforhold: 1:2000
på A3

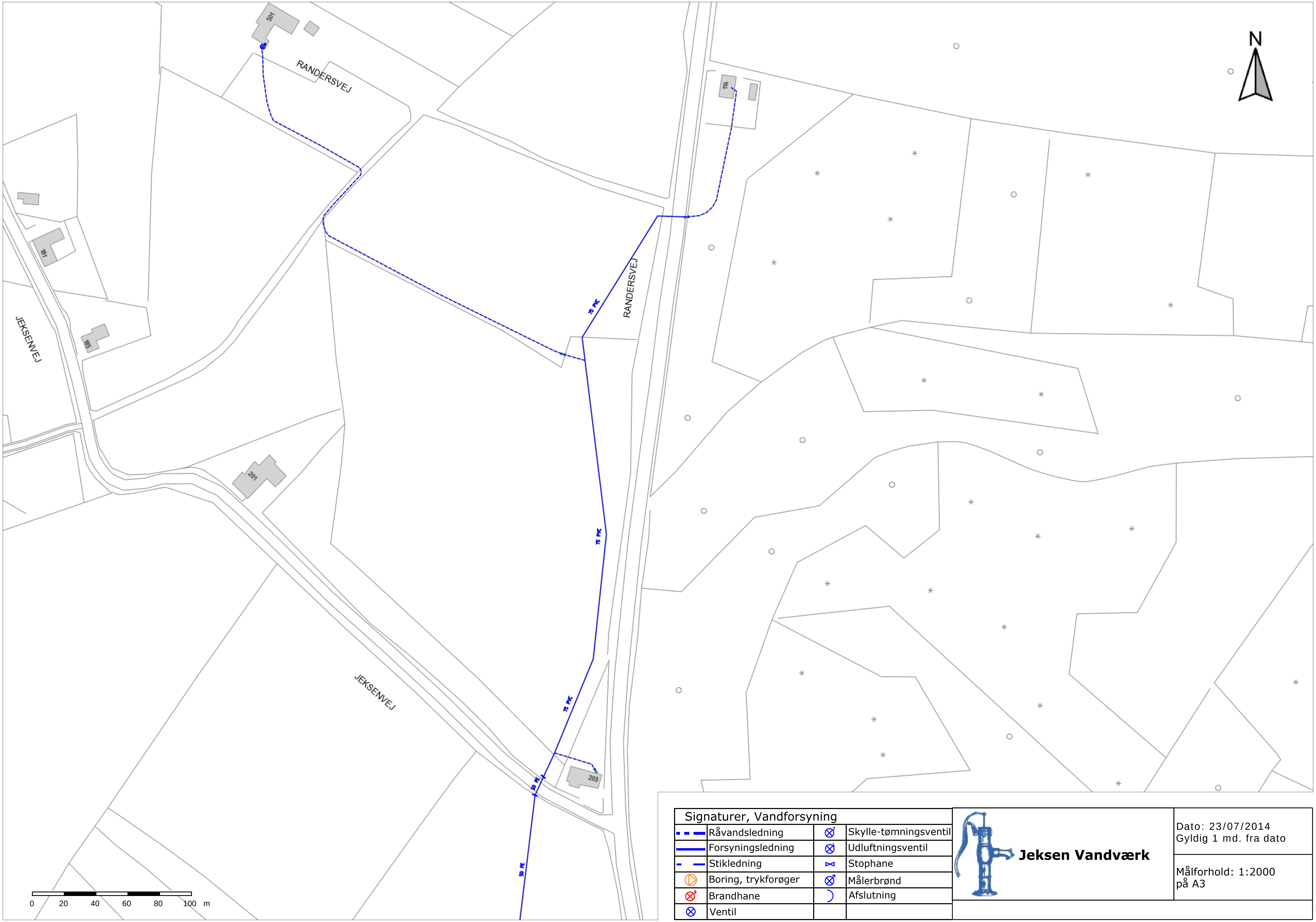


Signaturer, Vandforsyning		
Råvandsledning		Skylle-tømningsventil
Forsyningsledning		Udluftningsventil
Stikledning		Stophane
Boring, trykforøger		Målerbrønd
Brandhane		Afslutning
Ventil		

Jeksen Vandværk

Dato: 23/07/2014
Gyldig 1 md. fra dato

Målforhold: 1:2000
på A3



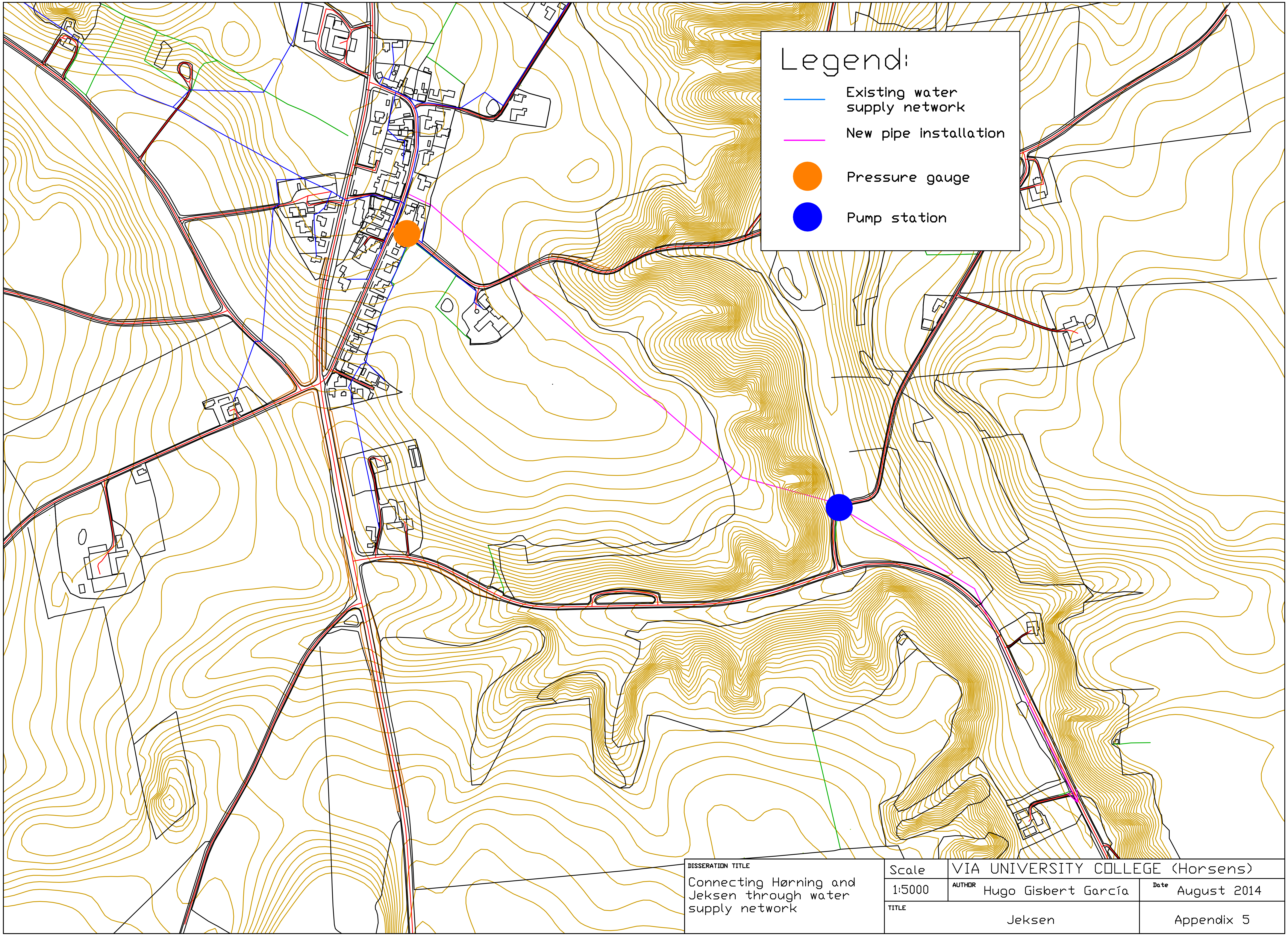
Signaturer, Vandforsyning			
	Råvandsledning		Skylle-tømningsventil
	Forsyningsledning		Udluftningsventil
	Stikledning		Stophane
	Boring, trykforøger		Målerbrønd
	Brandhane		Afslutning
	Ventil		

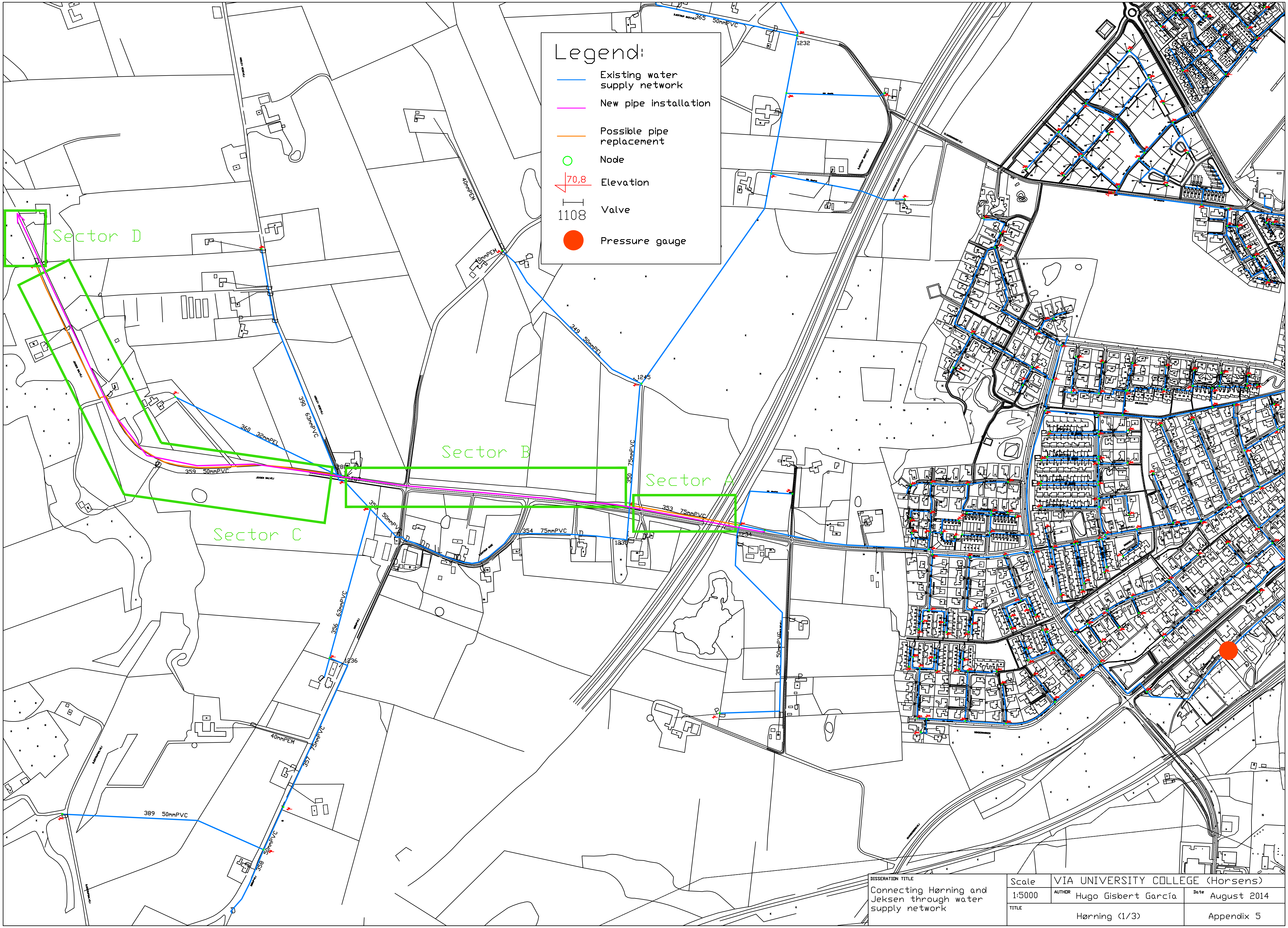
Jeksen Vandværk

Dato: 23/07/2014
Gyldig 1 md. fra dato

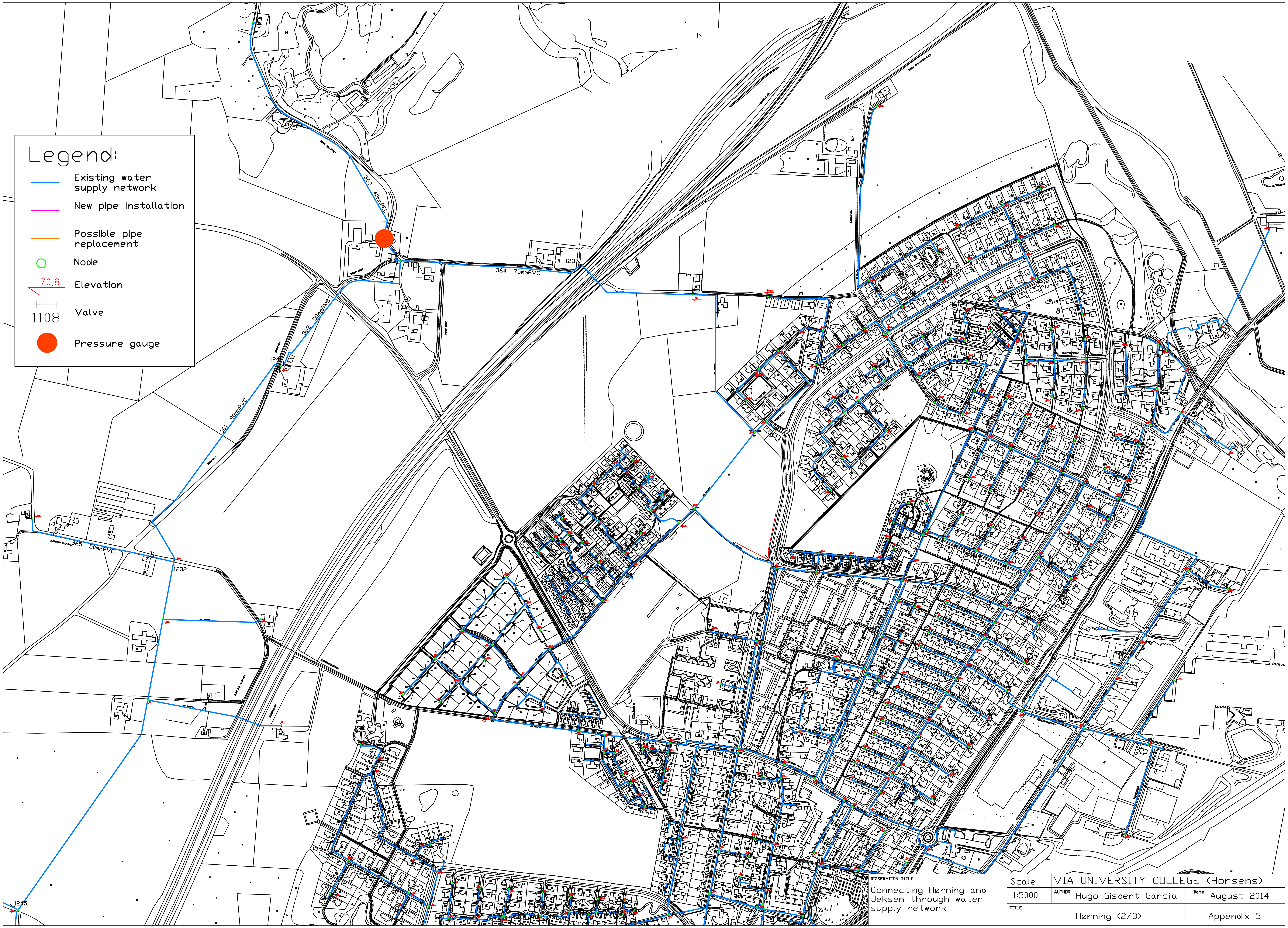
Målforhold: 1:2000
på A3

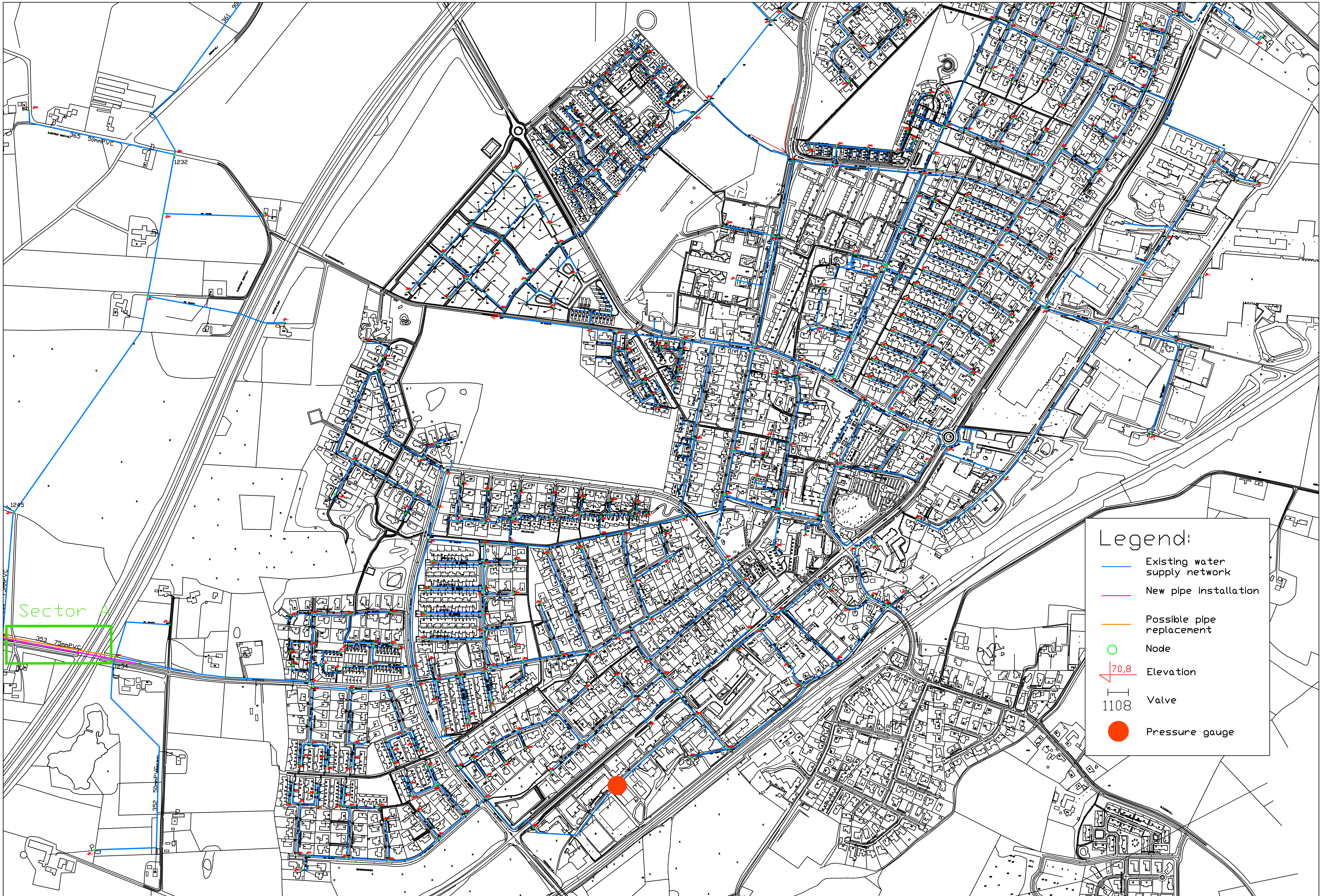
Appendix 5. Top view plans


Legend:
Existing water supply network
New pipe installation
Pressure gauge
Pump station
DISSERATION TITLE
Connecting Hørning and Jeksen through water supply network
Scale
1:5000
VIA UNIVERSITY COLLEGE (Horsens)
AUTHOR
Hugo Gisbert García
Date
August 2014
TITLE
Jeksen
Appendix 5



Legend:
Existing water supply network
New pipe installation
Possible pipe replacement
Node
70,8
Elevation
1108
Valve
Pressure gauge
Sector A
Sector B
Sector C
Sector D
365 50mmPVC
1232
40mmPEM
349 50mmPEL
1245
390 63mmPVC
360 32mmPEL
359 50mmPVC
350 75mmPVC
353 75mmPVC
354 75mmPVC
1230
1234
356 63mmPVC
1236
352 50mmPVC
357 75mmPVC
389 50mmPVC
358 50mmPVC
DISSERATION TITLE
Connecting Hørning and Jeksen through water supply network
Scale
1:5000
VIA UNIVERSITY COLLEGE (Horsens)
AUTHOR
Hugo Gisbert García
Date
August 2014
TITLE
Hørning (1/3)
Appendix 5


Legend:
Existing water supply network
New pipe installation
Possible pipe replacement
Node
70,8
Elevation
1108
Valve
Pressure gauge
363 40mmPEL
364 75mmPVC
362 50mmPVC
361 90mmPVC
365 50mmPVC
1237
1241
1232
1245
DISSERATION TITLE
Connecting Hørning and Jeksen through water supply network
Scale
1:5000
VIA UNIVERSITY COLLEGE (Horsens)
AUTHOR
Hugo Gisbert García
Date
August 2014
TITLE
Hørning (2/3)
Appendix 5



DISSERATION TITLE	Scale	VIA UNIVERSITY COLLEGE (Horsens)	
Connecting Hørning and Jeksen through water supply network	1:5000	AUTHOR Hugo Gisbert García	Date August 2014
	TITLE	Hørning (3/3)	Appendix 5

Appendix 6. Field measurements

Data gathered from 25/04/2014 to 29/04/2014.

These values are gauge pressure. We have deducted atmospheric pressure (1013.25 mbar) from absolute pressure. As it can be seen the time pattern from Hørning waterworks has different pressure between 12 and 7 am.

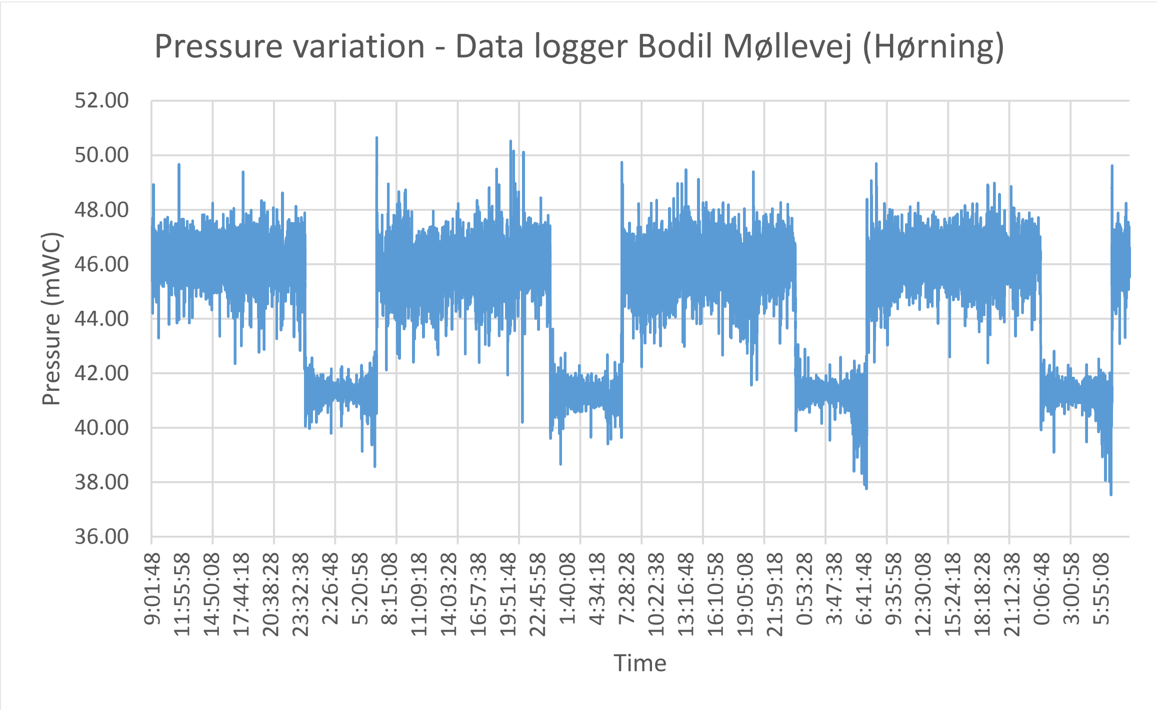


Figure 8. Data collected from pressure gauge in Bodil Møllevej (Hørning)

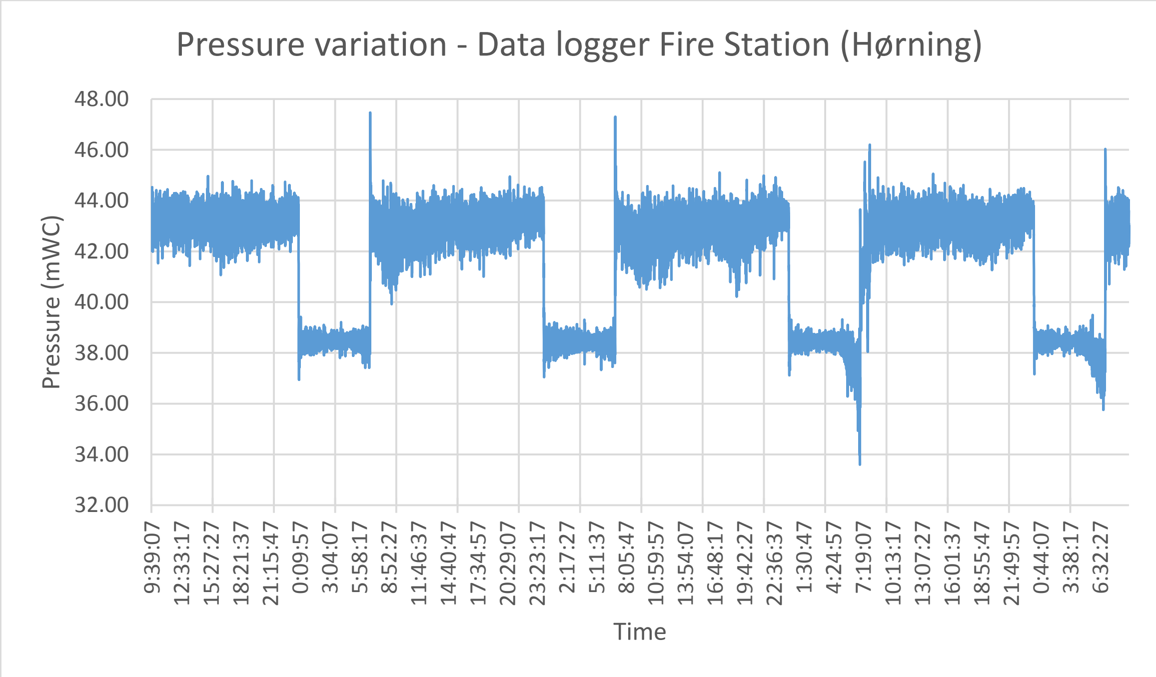


Figure 9. Data collected from pressure gauge in Fire Station surroundings (Hørning)

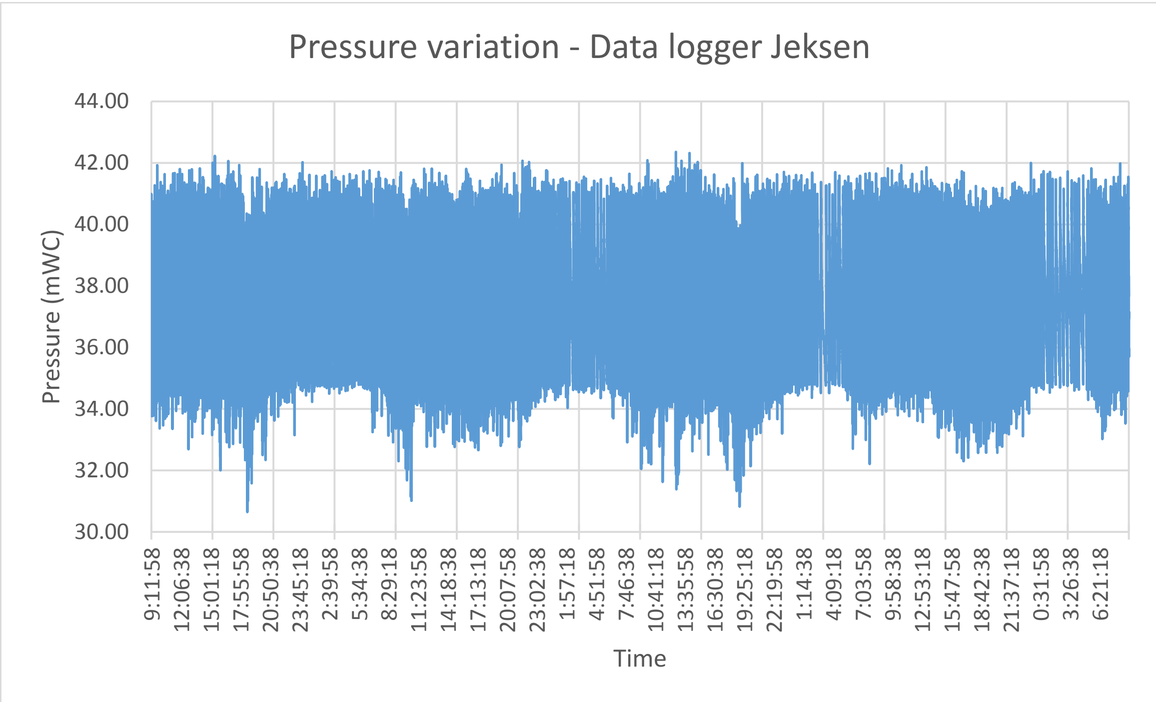


Figure 10. Data collected from pressure gauge in Jeksen

Appendix 7. Manometers verification

Due to the disparity in the results from Hørning model and manometers. A laboratory test was carried out to analyse whether all the manometers work properly. In this test we have been applied a constant pressure of 4 bar in the manometers adding the atmospheric pressure, which is the variable in our test.

The important thing is that the manometers measure the same value of pressure, which determine that all the manometers work properly and therefore the manometers are not the variable that fail in the data verification.

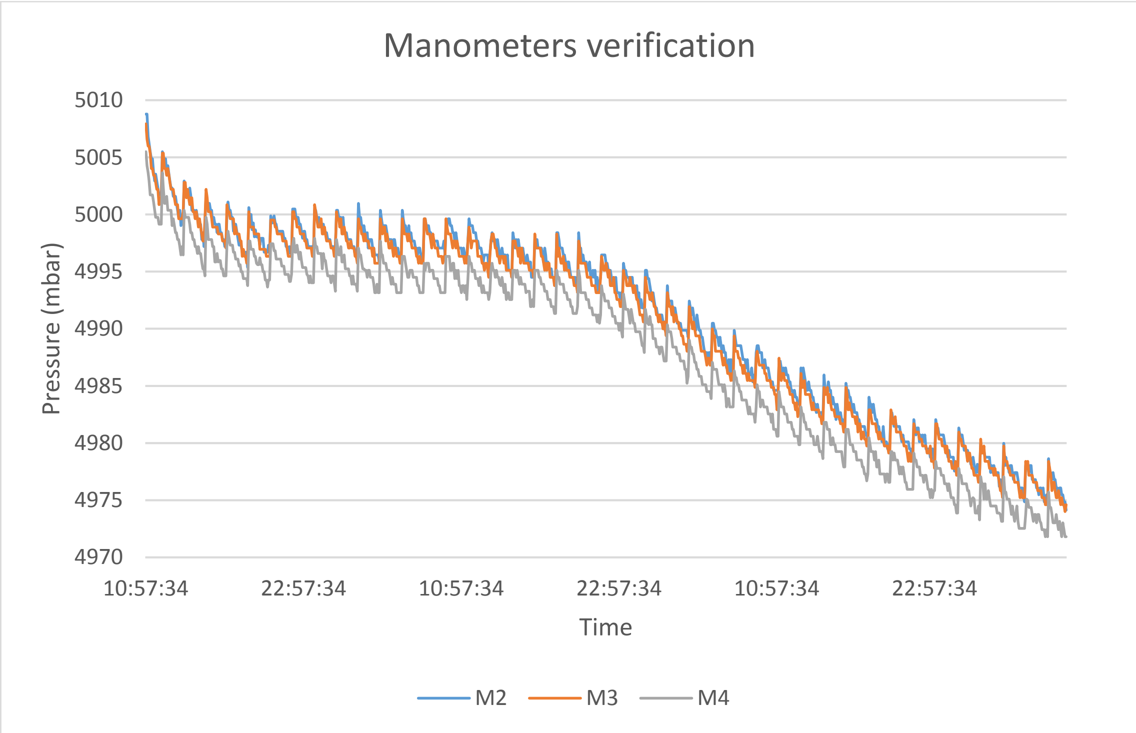


Figure 11. Laboratory test of pressure gauges

Appendix 8. Final model

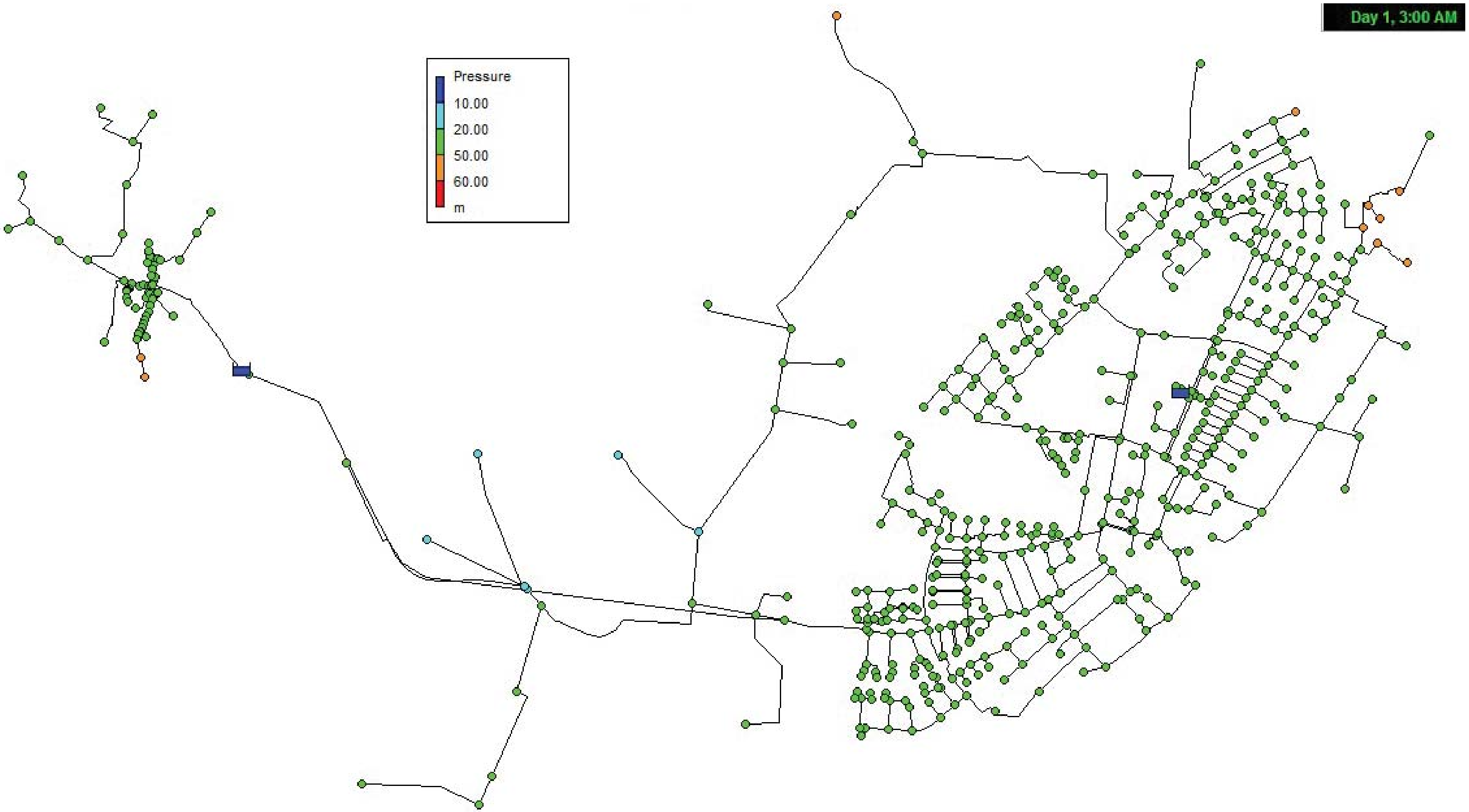


Figure 12. Final Epanet model, lowest demand

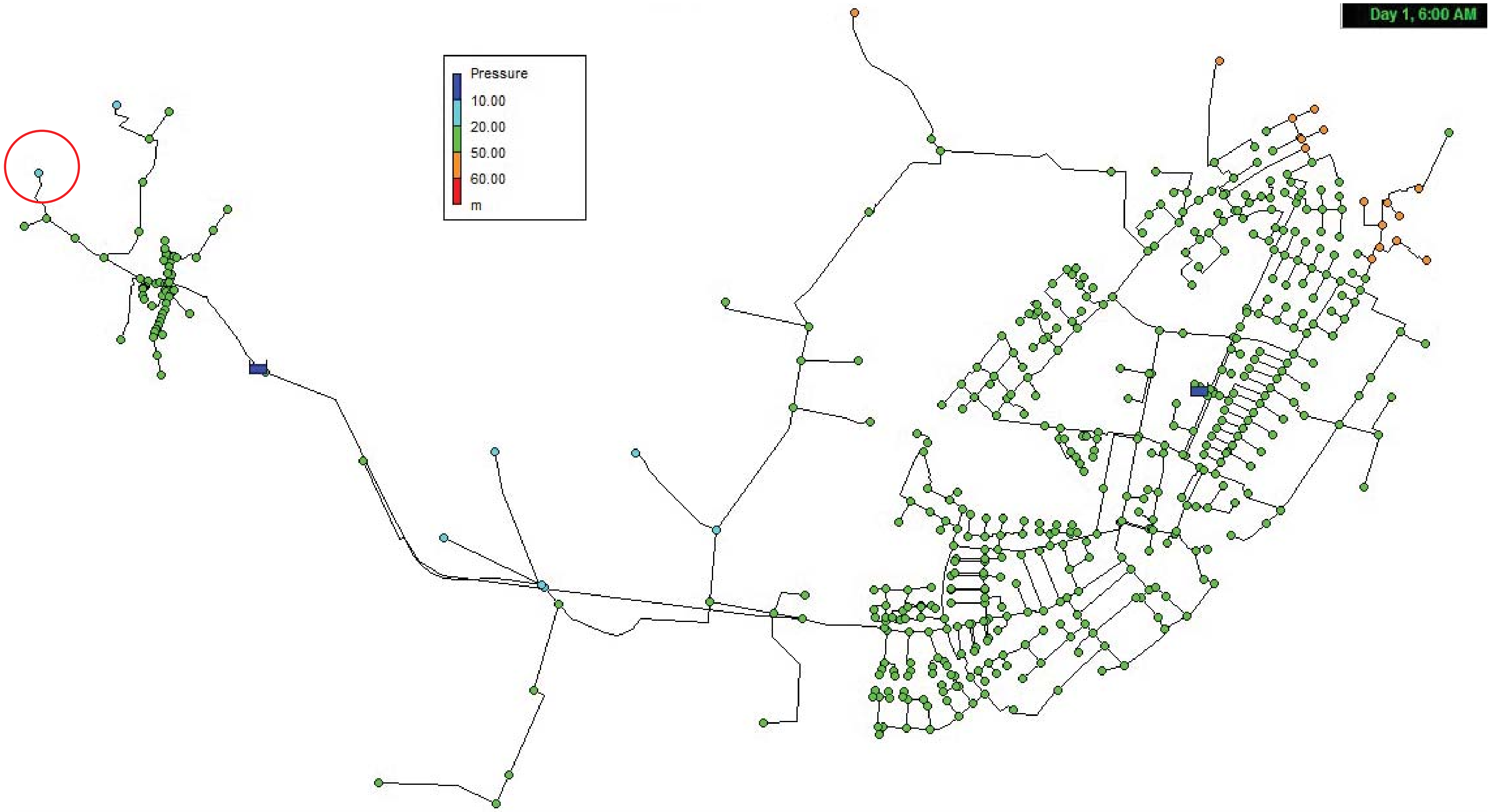
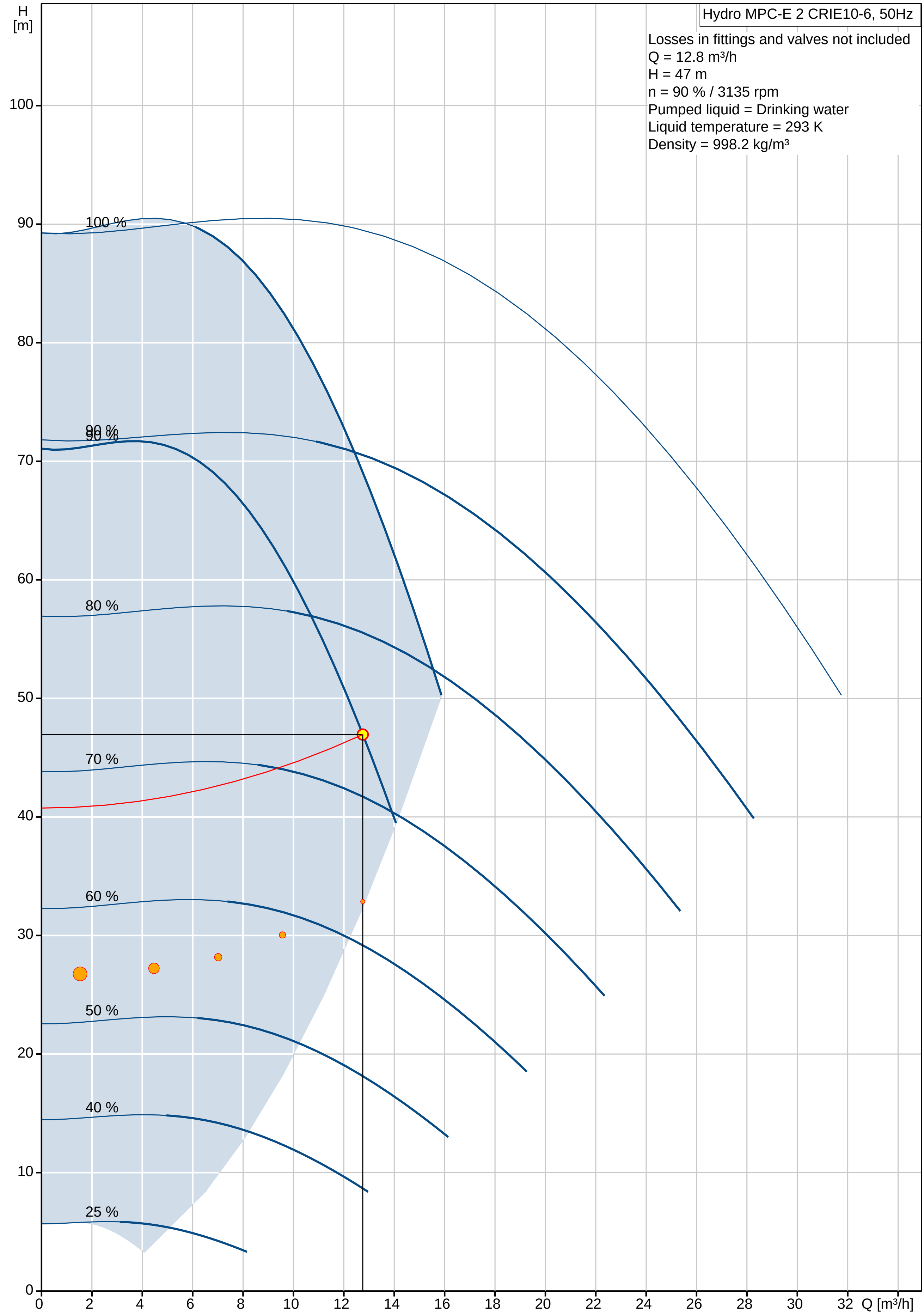


Figure 13. Final Epanet model, highest demand

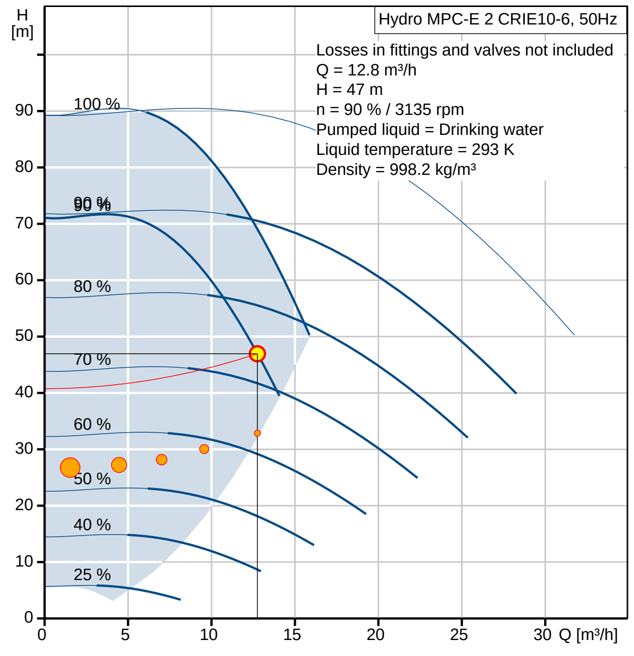
The highlighted point is the highest point in Jeksen and the point that is going to set the minimum pressure required in our booster pump.

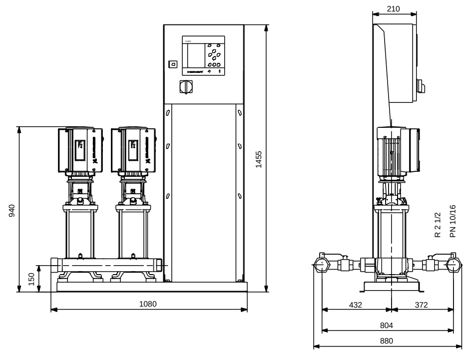
Appendix 9. Recommended pump details

95009106 Hydro MPC-E 2 CRIE10-6 50 Hz

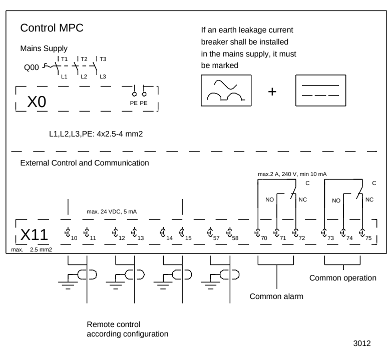


Description	Value
Product name:	Hydro MPC-E 2 CRIE10-6
Product No:	95009106
EAN number:	5700835167279
Technical:	
Actual calculated flow:	12.8 m³/h
Min flow system:	1.2 m³/h
Max flow:	31 m³/h
Max flow system:	15.7 m³/h
Resulting head of the pump:	47 m
Head max:	88.8 m
Impellers main:	6
Main pump name:	CRIE10-6
Main pump No:	96747798
Number of pumps:	2
Non-ret. valve:	at discharge side
Installation:	
Maximum operating pressure:	1600 kPa
Maximum inlet pressure:	710 kPa
Manifold inlet:	R 2 1/2
Manifold outlet:	R 2 1/2
Pressure stage:	PN 10/16
Liquid:	
Pumped liquid:	Drinking water
Liquid temperature range:	278 .. 333 K
Liquid temp:	293 K
Density:	998.2 kg/m³
Kinematic viscosity:	1 mm2/s
Electrical data:	
Power (P2) main pump:	4 kW
Mains frequency:	50 Hz
Rated voltage:	3 x 380 - 415 V, 50 - 60 Hz, PE
Rated voltage main pump:	3 x 380 V
Start. method:	electronically
Starting main:	electronically
Rated current of system:	16 A
Enclosure class (IEC 34-5):	IP54
Mains cable size:	L1,L2,L3,PE: 4x2.5-4 mm2
Radio interference supression:	EMC Certificate - Hydro MPC 1 [2007]
Controls:	
Control type:	E
Speed control:	Grundfos MGE 3 phase
Tank:	
Diaphragm tank:	No
Others:	
Net weight:	216 kg
Gross weight:	286 kg
Product range:	International
Config.file Control MPC:	98271946
Config.file Hydro MPC:	98272018
Epstan version:	V5.1347





Field Wiring



95009106 Hydro MPC-E 2 CRIE10-6 50 Hz

Input

Select Application

Overview mode	Yes Pressure boosting

Input overview:

Selected Area	Municipal water supply
Installation Type	Booster pump in mains
Flow (Q)	12.8 m³/h
Geodetic height	55.8 m
Friction losses	6.2 m
Discharge pressure (consumer)	150 kPa
More	Yes
Min. inlet pressure	297 kPa
Average inlet pressure	437 kPa
Max. inlet pressure	387 kPa
Evaluation criterion	Preference index
Include cheapest solution	Yes
Discharge pressure (pump)	500 kPa
Total Head	47 m
All control modes	Yes
Allow fixed speed	No
Frequency	50 Hz
Phase	1 or 3
Min. power limit for SD start	5.5 kW
Voltage	1 x 230 or 3 x 400 V
Ambient temperature	293 K
Max. operation pressure	All kPa
Pump operating time	8760.00 h/a
Energy price	1.33 DKK/kWh
Increase of energy price	6 %
Calculation period	15 years
Total number of pumps	2
Of these: number of standby pumps	1
Tank required on the discharge side	Yes
Membrane tank size	(to be calculated)
ON/OFF-band	20 %
Max. hits per product group	2
Max. hits total	8
Preferred design	Booster sets
Inline Multistage	Yes

Load Profile

	1	2	3	4	5	
Flow	100	75	55	35	12	%
Head	70	64	60	58	57	%
P1	2.24	1.45	1.02	0.707	0.433	kW
Eta total	50.7	53.7	52.9	46.8	25.6	%
Time	398	796	1195	2389	3982	h/a
Energy consumption	891	1159	1223	1689	1726	kWh/Year
Quantity	1	1	1	1	1	

Sizing result

Type	Hydro MPC-E 2 CRIE10-6
Quantity * Motor	2 * 4 kW
Flow	12.8 m³/h
H total	47 m
Power P1	2.95 kW
Power P2	2.43 kW
Eta pump	67.0 %
Eta motor	82.6 %
Eta pump+motor	55.3 % =Eta pump * Eta motor
Eta total	55.3 %
Flow total	37822 m³/year
Energy consumption	6687 kWh/Year
Price	On request
Price + energy costs	On request /15Years