Introducing criteria and initial process of evaluating sites suitability for Intelligent Buffer Zones using GIS data. A case study in the Sillerup catchment in Denmark.

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Photo of an IBZ in Lillerup taken by F. Bondgaard (SEGES), illustrating the elevation difference required from the water table in IBZ to the water table in stream.

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1. Introduction

In 2015 the Danish government agreed to implement the so called *agricultural package* (The European Commission (2016). The new legislation allows farmers to apply more N fertilizer, up to the amount that is economically optimal for the yield. Before this new paradigm in agricultural and environmental legislation, since 2nd Action Plan of the Environment in 1998, the farmers had to use 10% less nitrogen (N) in fertilizer and manure than the economically optimal application rate to reduce N emissions to groundwater and surface waters (Danish Nitrate Action Programme 2008-2015, 2012). Due to several other regulations during the period 1998-2015, the under-fertilization had reached nearly 20% below economic optimum. One of the main arguments for the recent change in regulation was that the protein content value in crops over time had been diminished. The protein content in cereals for fodder is very important for farm animals as well as for humans when the cereals are used in bread production, etc. Danish farmers claimed that they could not effectively compete with farmers from other European countries where there is no such regulations on under-fertilization.

Change in regulations regarding nitrogen emission raise environmental concerns. It has been estimated that under the current conditions, changed fertilizer regulations can result in an increase in nitrogen emissions by more than 3.500 tonnes per year (The European Commission, 2016). This is in conflict with obligations under The EU Nitrates Directive, the aim of the Nitrate Directive being to protect the quality of ground and surface waters in the EU by preventing nitrate loading from agricultural sources (The European Commission, 2016).

With the aim to fulfil the obligations of the EU Nitrate Directive, the adopted Action Plans include N reducing collective measures starting from 2017, such as afforestation, restauration of wetlands (Environmental Protection Agency, 2017). Also, there is a plan to establish 1,000 constructed so-called mini-wetlands until 2021 (Environmental Protection Agency, 2017). A new targeted environmental regulation starting from August 2019 introduces restrictions on individual farms' leaching of N (Environmental Protection Agency, 2017). Leaching permits will be appointed and a farmer will have flexibility to choose an instrument. Among various measures, the IBZ will be included on condition that it is proven scientifically to have a significant effect of reducing N (Kronvang B., 2017 personal communication). It has been calculated that the targeted regulation of nitrogen leaching at farm level will reduce the load of N into Danish coastal waters by approx. 3.500 tonnes per year by 2021 (Environmental Protection Agency, 2017).

Deciding on a right measure in the agricultural landscape can be a challenge for farmers and agricultural advisers (Bondgaard F. 2017, personal communication).

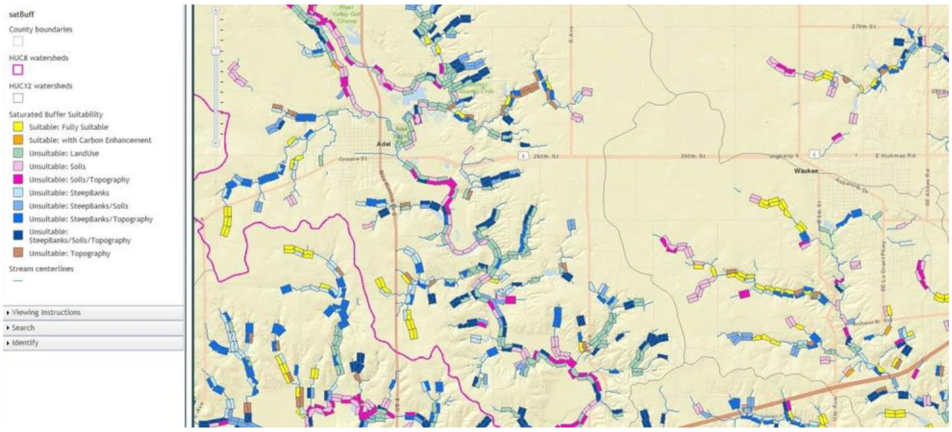
Landscape characteristics such as topography, soil type, drainage area and land use must be carefully considered to choose the most cost-effective measure that gives the best effect for reducing nutrients loading into the environment. This is because the landscape characteristics can affect the nutrient reduction processes within a mitigation structure, e.g. soil texture and structure have an effect on water flow through the soil. Moreover, when placed in a wrong landscape, a mitigation measure can cause problems e.g. in case the constructed wetlands or IBZs water can flood nearby areas (Bondgaard F. 2017, pers. comm). This problem will be further discussed in this report. For this reason, there is high demand for innovation and new environmental measures that can be suitable for various landscapes and soil types (Bondgaard F. 2017, pers. comm, BufferTech). BufferTech is an interdisciplinary project that is carrying out research on new environmental measures called *Intelligent Buffer Zones* (IBZs). The IBZs has a potential to be more effective in reducing nutrients than 9m buffer strips required by law by the streams and lakes in Denmark (BufferTech). The important conditions for an IBZ to reach the optimum efficiency are discussed in this paper and are based on experiences from the pilot IBZs.

In short, the IBZ can be described as a combination of a water basin and vegetation buffer zone along the stream or a lake (BufferTech). The water from the fields that carries sediment, nutrients and other pollutants enters a basin via a tile drainage pipe (BufferTech). The excess of water is directed into the stream, but part of the water entering the open basin is intended to infiltrate through the soil and later reaching the stream via groundwater.
The nutrients, such as N and phosphorus (P), are reduced by microbial transformations (in case of N denitrification) and physical processes such as sedimentation, chemical sorption and plant uptake (BufferTech).

Conducting field investigations in order to find out where an IBZ can be built can be a long and costly process. Hence, in the first stage of finding suitable sites, GIS data can be a valuable screening tool.

This report is inspired by the work conducted in Iowa, in the US; Geographic Information System toolbox called Agricultural Conservation Planning Framework (ACPF) that can be used within an ArcGIS and has been developed by USDA/ ARS to create maps that help to identify candidate places for conservation practises such as the riparian buffers (Tomer *et al*., 2005, Porter *et al*., 2017). A map created in ACPF is shown in fig 1.

Fig. 1 Map with potential places for saturated buffer zones created in the Agricultural Conservation Planning Framework GIS toolbox.



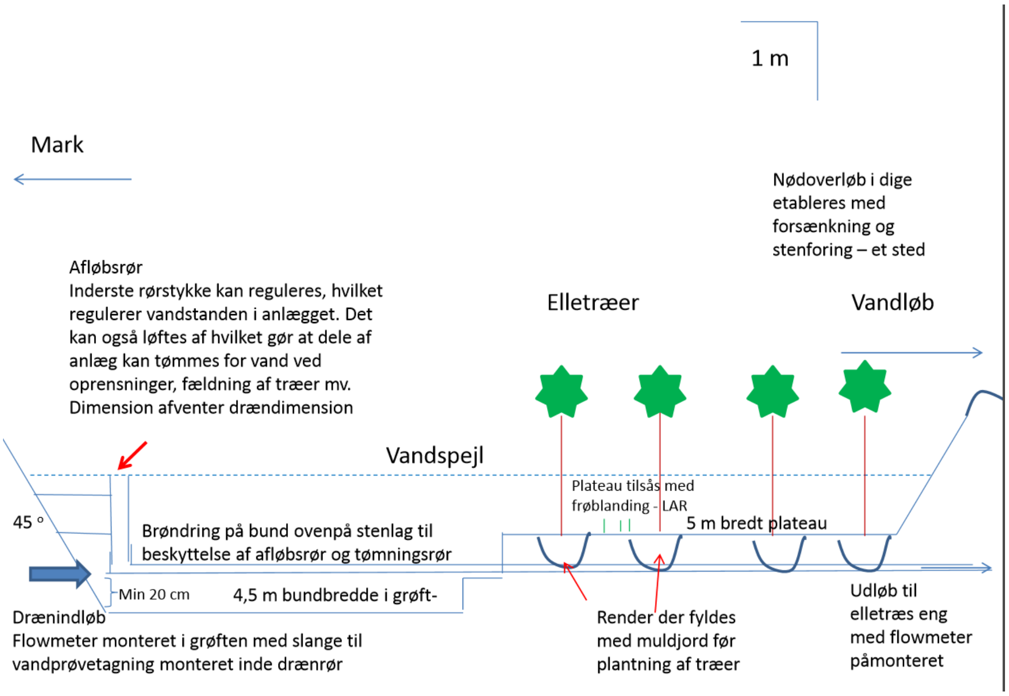
The aim of this report represents the initial stage towards creating such a Danish screening system for placement of IBZs in the landscape. The main purpose of this study is to present a simple classification system that can be used as a guideline to assess the suitability of the site using available GIS data. The classification system is applied for the agricultural land in the Sillerup catchment, southern Jutland, Denmark. Sites with high, medium and low potential for the IBZ placement were identified using information obtained from SCALGO Live and QGIS programme. In the final stage of my work, I had a field visit to some selected sites with an expert from SEGES to see how the data I found and classification I applied reflects conditions in reality.

2. Intelligent Buffer Zones (IBZs): design and function

2.1 Design of the Intelligent Buffer Zones

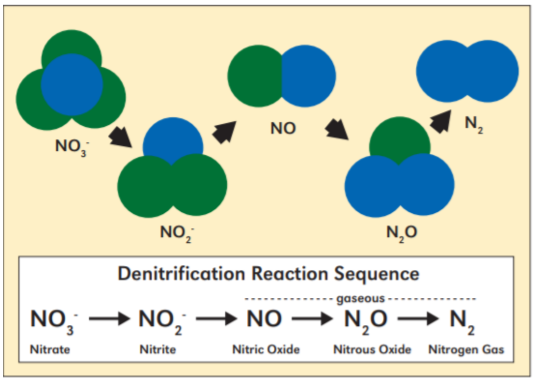
The IBZs are a novel mitigation measure that can be placed on drained agricultural fields along the streams (BufferTech). The IBZ consist of a water basin and vegetation plateau as illustrated in figure 2. Subterranean tiles that lower water tables in fields were installed so the land can be easier cultivated, these have been built in the last century and are present in majority of Danish agricultural landscape (Bondgaard F. 2017, pers. comm.). Through these pipes, water with pollutants and nutrients is rapidly and directly discharged into the surface waters (BufferTech). The water from the drainage pipes discharged is into the IBZ basin that is placed along the stream reduces the N and P in the water (BufferTech).

Figure 2. Intelligent Buffer Zone design (from BufferTech, IBZ Dimensioner mv).



The width of the IBZ is about 10m, however, the width can be adapted to the landscape (BufferTech). Research is underway, but current results indicate that for the IBZ to be effective a length of 7.5m is required for 1 ha of drained land (Kronvang B., pers. comm.). Tile drain leading to the stream is cut off at the IBZ, so drainage water from the agricultural fields is discharged into the IBZ water basin, and therefore not directly into the stream. On many sites tile drains are located at a depth of 1.1 - 1.2m. The bottom of the IBZ basin should ideally be 20cm below the pipe outlet (BufferTech, IBZ Dimensioner). This is done to prevent the clogging of the pipe with accumulation of sediment near the inlet. Therefore, an IBZ water basin is approx. 1.4m deep. The water basin is about 5m wide and so has a large surface area when compared to its volume. The bottom area of the basin and aquatic plants provide a substratum that is beneficial for microorganisms, being crucial for the denitrification process. Denitrification is essential for reduction of nitrates. Denitrification occurs as soil microorganisms use nitrate for the respiration and reduce nitrate to atmospheric nitrogen (N_2). Denitrification reaction sequence is shown in fig. 3.

Fig. 3 Dentification reaction sequence



Denitrification occurs at anaerobic conditions; the highest rate of denitrification has been observed at 60% water filled pore space (Torbert *et al.* 1992). Therefore, wet and saturated conditions on the plateau of the IBZ must be maintained for an IBZ to be effective. Subsurface layer where the basins are placed must allow sufficient time for denitrification and retention processes in sediments and soil. But contrary to the constructed wetlands, the layer must allow water infiltration into the vegetation plateau.

The IBZ vegetation plateau is approximately 5m wide; alder trees are planted in rows filled with soil that contains organic matter. The plateau is a vegetation zone being planted with fast growing vegetation that takes up nutrients and in return provides carbon as a food source for denitrifying microorganisms. Furthermore, vegetation roots can facilitate water infiltration in the soil. Common alder (*Alnus vulgaris*) grows well in saturated soil and is planted in the existing IBZs.

The IBZ also consists of wells that control water level (fig 4.). Controlling the water level in the IBZs is important for research purposes, this can shed light on how the water level affects N and P reduction. In the US, advisors look into opportunities for farmers to manage the measures such as saturated buffer zones themselves (Bondgaard F. 2017, pers. comm.). The possibility of managing the water level in the IBZs can give farmer more control in case problems such as backwater occur. This is important since it reduces some uncertainties for this novel mitigation measure (Bondgaard F. 2017, pers. comm.).

Fig 4. Wells that control the water level in IBZ.

2.2 IBZs as filters for nutrients in the landscape

Retention of nutrients is dependent on the IBZ design and characteristics of the terrain where it is placed. It has been calculated that in two basins of an experimental IBZ, retention of total P amounted to 43% and 50% for a period of 17 months (Kronvang *et al*., 2017). Nitrate (NO_{-3}) constitutes the largest part of total N in drainage water. Nitrate leaching is most prevalent in the autumn and winter with high net precipitation (precipitation – evaporation) In an experimental IBZ, the minimum retention of N was recorded in March (10%) and the biggest in the summer time (62% in June). The two basins of an IBZ in Fillerup retained 26% and 32% of N in a period of 17 months, which corresponds to 1,310 and 2,270 kg N ha^{-1} per year (Kronvang *et al*., 2017).

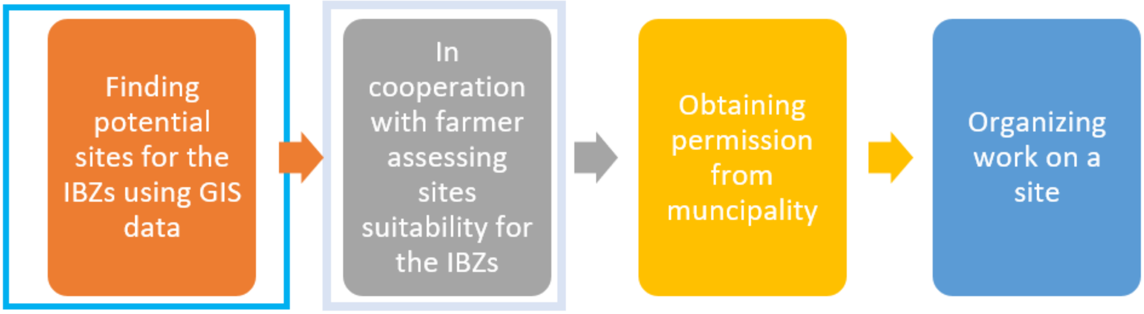
In addition to nutrients, the IBZ will retain sediments and might also retain some of the pesticides applied and lost from the fields. This, however, is to be further investigated, the current research focus on N and P reduction effectiveness.
Moreover, sediment loss via tile drains such as sand, silt and clay can affect physical conditions in especially small streams where excess inputs can destroy spawning grounds for trout and salmon (Kronvang *et al*., 2014).

The IBZs in Denmark are aimed to be established along smaller streams which often provide important habitat to trout (Kronvang B., pers. comm). Improved water quality of streams can result in improved habitat conditions for fish and macroinvertebrates in the stream. This can result in higher number of desired fish species and macroinvertebrates that are beneficial for obtaining good ecological conditions as required from the Water Framework Directive. Additionally, the water basin of an IBZ can attract water birds (Kronvang *et al*., 2014).

3. An overview of the process for implementing IBZs

Establishing an IBZ can be a long process. When funding for a project is available and the initial cost assessments are done, the process of establishing the IBZ can be divided in the basic stages showed in fig. 5.

Fig 5. Process of establishing an IBZ.



The first stage consists of finding suitable sites for establishing IBZs using GIS programmes, collecting terrain data, performing simple calculations and making decisions about the suitability of sites for establishing IBZs. This report focuses on this stage, a simple classification system was introduced to support decision making, and as an example the method was applied and tested in the Sillerup catchment, southern Jutland, Denmark. After sites with good potential are identified in GIS, owners are contacted to get permission to access and evaluate the sites of interest as a field survey.

The next stage consists of a survey of the possible sites in the field: finding the drain outlets and checking if the collected data about terrain topography and soil type is accurate. An important part of this stage is also assessing the extent of drained areas, many field owners have this information kept as old maps. Soil type assessment at the possible IBZ site of upper and deeper soil horizons is crucial, as water infiltration is a design factor for the IBZ. At this stage, it is also important to gain information about the groundwater flow and its depth on a site of interest. The groundwater and changing level through the year can affect the functioning of an IBZ (Bondgaard F., pers. comm). Groundwater contains less N and P than the water from the drainage pipes. Therefore, the groundwater in the IBZ basin decreases the IBZ potential to retain and reduce these nutrients.

The assessment can also involve taking samples for more detailed analysis to gain information about drainage flow, the N and P concentration in the tile drainage waters, the soil carbon content, and soil permeability. A further assessment could be cooperating with the farmer to collect information about crop cultivation in the drained field and the possible risk it imposes regarding nutrient load into the environment. This report contains some basic elements of the second stage. I visited some IBZ sites in the Sillerup catchment to see how the classification system for an IBZ site suitability reflects the field conditions in reality.

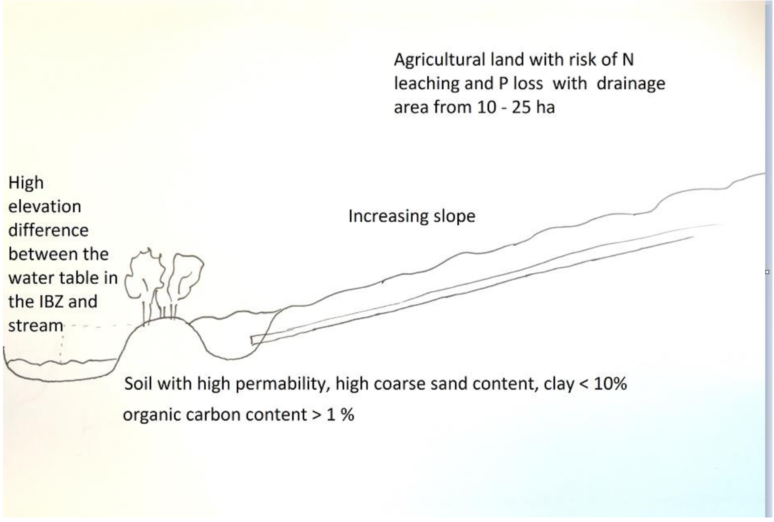
If the site is suitable and it is decided together with a farmer that an IBZ is the best mitigation measure for the landscape, the municipality must be informed to obtain a permission. The municipality has information about restrictions in the area and legal procedures. In the final stage clear guidance and information about the IBZ design to a company that constructs it must be provided.

Good communication, discussion with land owner, or even an offer of compensation in this process is important to obtain relevant information about the area and to gain owners consent for this novel voluntary IBZ measure.

4. Site characteristics, parameters and their ranking for a site suitable for the IBZ.

Fig. 6 summarises the main characteristics of sites suitable for IBZs. These characteristics and their effect will be explained, and finally a simple classification system for potential IBZ sites will be presented.

Fig. 6 Main characteristics of sites suitable for IBZs.



4.1 Land use, stream and subsurface drainage system- prerequisites for establishing the IBZ

The IBZ are applied at the edges of the cultivated fields by the streams. The IBZ design requires water inflow from tile drains. In Denmark for many fields there is no precise information about the exact location of tile drains. For some areas, drainage maps are available in archives, and these can be of great benefit for the initial site screening.

However, many drains have been changed through the years and it is expected that in most of cases information from the land owners is the most accurate.

Using SCALGO Live, the watershed area can be estimated. The calculations are based on land topography. It has been recommended that a watershed should be from 5 -20 ha to be suitable for an IBZ (Kronvang B., pers comm). For bigger watersheds it might often be better to use other mitigation measures such as constructed wetlands.

The drainage area can be determined using SCALGO Live to assist in finding sites suitable for an IBZ placement. However, in few cases for the Sillerup catchment it can be seen that the drainage system extends the borders of the watershed displayed and it is therefore likely to drain water from larger areas. In other cases, the displayed watershed area is large and there may be several tile drains draining this area.

4.2 Watershed area suitable for an IBZ

As a principle, a 7.5m long and 10m wide IBZ is applied for 1 ha of a drained land (Kronvang, pers. comm.). A large tile drained area therefore requires a very long IBZ along the stream. This may be difficult to implement in practise as terrain topography and the use of terrain is likely to vary along such a long area. The IBZ would have to run across a few fields and this adds legal complications as it requires approval of all the land owners. For this reason, the maximum area of a drained land for an IBZ is about 20-25 ha. The size of an IBZ can be adjusted depending on the precipitation in the area. Central Jutland is the most rainy part of Denmark with approx. 900 mm of rainfall a year, the least amount of rainfall is recorded in Kattegat and the Bornholm island with 500 mm a year (DMI, DK). Smaller watershed areas can be adopted for the rainy terrain. Western Jutland receives more net precipitation than in eastern Jutland, therefore a smaller catchment area of about 10 ha was proposed for establishing an IBZ in Western Jutland (Brian Kronvang).

4.3 Topography

4.3.1 Height difference from water table in an IBZ basin to the water table in a stream to ensure water flow through the soil: Darcys´ law

Darcys` equation defines the ability of water to flow through a porous media such as soil (Crites *et al.* 2006):

$$q = Q/A = K(\Delta H/\Delta L)$$

where:
q = Flux of water (the flow per unit cross-sectional area (in./hr; cm/hr).
Q = Volume of flow per unit time (in.3/hr; cm3/hr).
A = Unit cross-sectional area (in.2; cm2).
K = Permeability (hydraulic conductivity) (in./hr; cm/hr).
H = Total head (ft; m) (the sum of the soil water pressure head and the head due to gravity)

L = Hydraulic flow path (ft; m).
∆H/∆L = Hydraulic gradient (ft/ft; m/m). (Crites *et al.* 2006)

The equation describes the factors essential for water flow in a soil from an IBZ basin into the stream.

Permeability of the media, synonymous with hydraulic conductivity, is a measure of the ability of soil to allow liquids and gases to pass through.

The difference between the water table in the IBZ and water table in the stream has an impact on the water pressure. The water from the site with higher water table will be driven to the site with lower water table. The higher the difference, the higher water pressure which is the driving force behind the water flow. The driving force is called **hydraulic gradient**, which is shown in Fig 7.

Fig. 7 Hydraulic gradient between an IBZ basin and stream.

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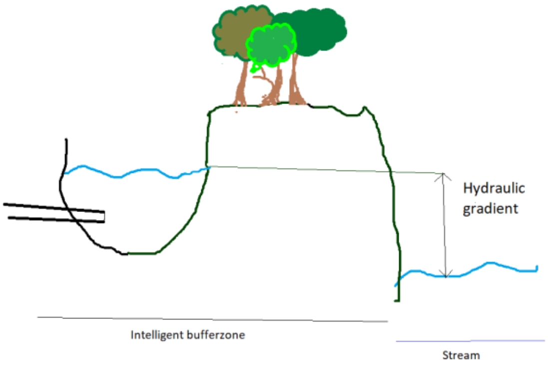


∆L refers to the length of the path the water flows through; the longer the path, the larger water pressure is required. Gravitation forces determines the direction of water flow, however, over time non-degradable particles accumulate within soil pore spaces. The blockage of the pore spaces can with time cease the flow of water through the buffer zone from the IBZ surface water basin.

4.3.2 Ranking of sites according to the elevation difference from the stream water table to 10 and 20 m distance.

When choosing a location for an IBZ in Scalgo Live, elevation difference from the stream water table (stream water surface) to a place **10m** and **20m** upwards from the stream (ideally along the pipe line) must be considered. Reason for this being that an IBZ water basin is usually placed from 5 to 10 m from the stream bank. With the aim of not taking too much land out of agricultural production, an IBZ should be placed as close to the stream bank as possible. Also, considering Darcys´ equation, the further an IBZ is located from the stream, the longer water flow path is needed through the soil, which results in reduced flow.

In some cases, it may not be possible to place an IBZ directly next to the stream bank as there may be already an existing buffer zone with old trees or a terrain may be not appropriate, hence elevation data at **20m** distance was collected and difference from this point to the stream water surface was calculated. Thus, in some cases this data can be more relevant than for 10m. This is important especially for sites with wide streams. From the water surface in SCALGO Live there can still be a distance of a couple of meters or more to the stream bank.

In table 1. the classification of sites potential are shown based on the elevation difference between the water surface in the stream and the place 10m and 20 m upward from the stream. Elevation difference required for a site to fall into a class is based on the data collected from the existing IBZs in Scalgo Live and discussions with experts who work with the existing IBZs.

Data on nutrient reductions has been collected from the experimental sites in Fillerup in Odder and Sillerup. These sites reduce and retain N and P and there is an evidence of water infiltration through the soil. Therefore, I used these sites first and foremost as a guidance to create a high and very high classification system. The data obtained in SCALGO Live for these sites is attached in Appendix A.

I suggest that when working with Scalgo Live, sites with a very high status should have at least 1.4m difference in elevation at both 10m and 20m distance. Elevation of 1.4m at 10m and 1.9m at 20m distance is present at an existing IBZ site in Odder. The site in Odder also contains loamy soil (BufferTech) that is not optimal for the water flow through the soil. And 1.4m difference at 10m in elevation is sufficient for this well-functioning IBZ. Also, for this exercise, 1.4m is set as minimum for the high status because this number was obtained for a site in Sillerup.

Water level in the stream changes through the year and as hydraulic gradient decreases. Moreover, the water level in the existing basins of the existing IBZs can be about 30 - 50cm below the terrain surface. Elevation difference of 1.4m seems to be sufficient for these existing IBZs.

For the high status I classify sites above 1m for 10m distance and 1.1m for 20m. For High status, first I looked at the minimum value for a well-functioning site in Sillerup which was 0.7m. One can argue that a 0.7m elevation difference at 10m distance from the stream is too small, especially in the rainy seasons when the water level in the stream rises. In the field the recorded difference was > 1 m. Work in Scalgo is the first initial screening only and this elevation difference can indicate potential sites for an IBZ. Therefore, I rated this value as medium potential, a rising slope from this point is sufficient for a good functioning of the IBZ. The IBZ in Sillerup is also placed at least a couple of meters further from the stream, next to an existing buffer zone (site visit).

Values below the 0.7m (lowest elevation difference at 10m found from the existing sites) I classified as of poor potential. Also, another argument for this classification is that a poorly functioning IBZ in Spjald near Kildesig Røjkum Creek has only around 50 cm difference from the stream to the IBZ basin (personal communication with Brian Kronvang).

Table 1. Rating of difference in elevation for potential sites for IBZs placement, from **10m and 20m** to the lowest point in a stream. Very High, High and Medium classes indicate potential suitable sites for IBZs. Low status at both **10m and 20m** disqualifies the site as being suitable for an IBZ.

Elevation difference from the lowest point in the stream to:	**Classification**										
		Poor			**Medium**			**High**		**Excellent**	
10 m from the strean	< 0.7 r	<7 %	4°	0.7- 1 m	7- 10	4° - 6°	> 1 m	> 10%	> 6°	> 14%	8°
20 m from the strean	< 0.8 r	<4 %	2°	0.8- 1.1 m	4- 5%	2° - 3	>1.1 m	> 5.5%	> 3°	> 7%	4°

For an IBZ in Sillerup the slope is rising as seen in appendix A and the difference increases till around 1.3 m at 20 m distance.

4.3.3 Terrain topography and backwater risk on sites with the IBZ.

Another important factor that must be considered when choosing a suitable location for an IBZ is the risk of backwater. “Backwater” refers to the flooding of the nearby area, a problem has occurred on a site with experimental IBZ in Vills and Mors. The backwater can result in higher proportion of land taken out of agricultural production, therefore it can reduce the cost effectiveness of this mitigation measure. Landowners may decide to cease an IBZ during part of the year (growing season) if the backwater causes production losses, make it difficult to use heavy machines on fields or results in flooding of the neighbouring fields.

The backwater can be a persistent problem or occur only in seasons with high rainfall. High water level in an IBZ can be beneficial for nutrient reduction and retention processes. This high-water level can be regulated and a high water level purposely maintained. However, if the terrain next to an IBZ is too flat it can cause flooding, this situation is shown in Fig. 6.

Fig 8. Flat terrain next to an IBZ can cause flooding (area with flood risk marked with red)

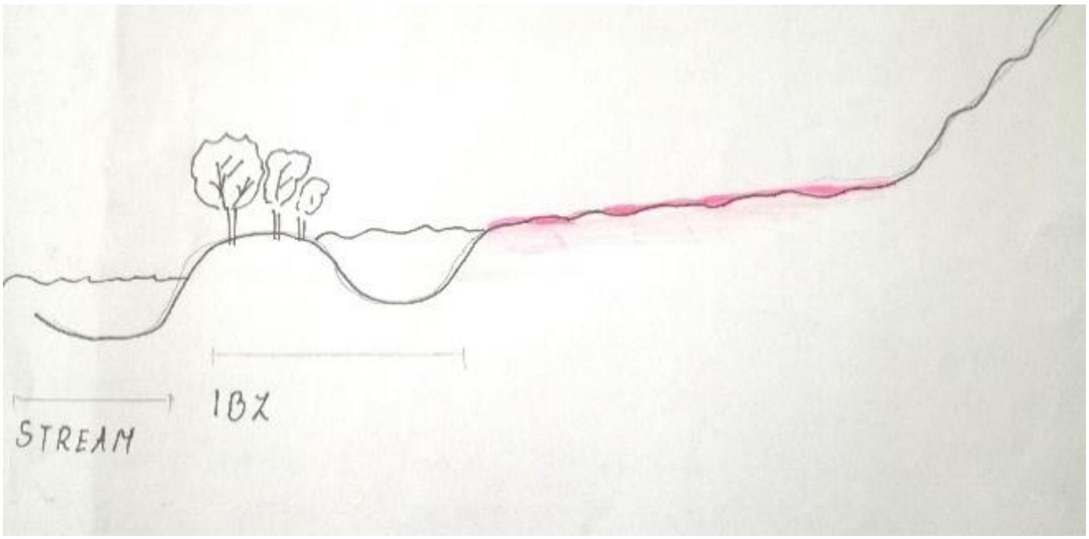
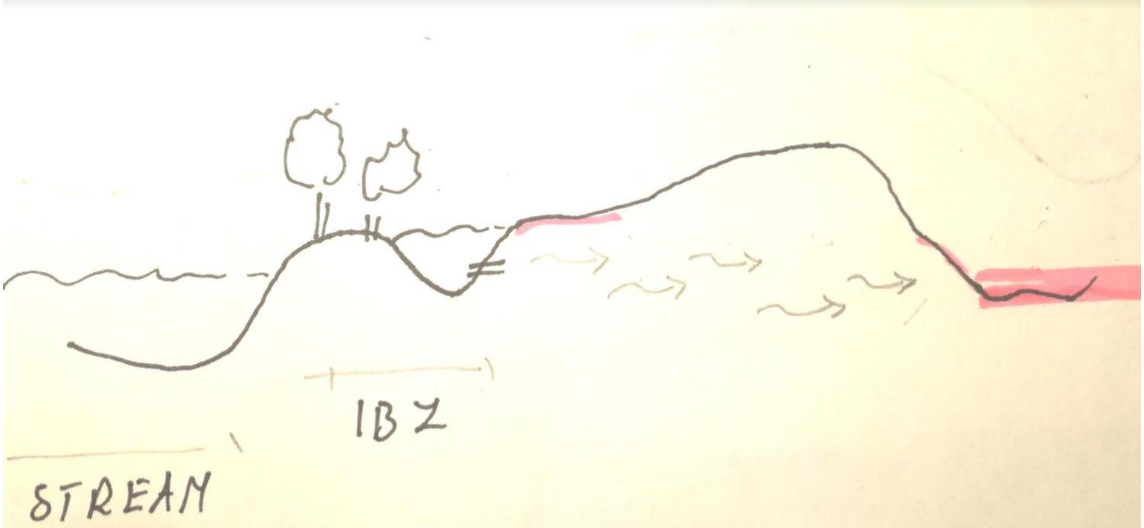


Figure 8. illustrates a different hypothetical scenario with the backwater problem: the slope increases and reduces the chances of surface water flow in the nearby area on the field. However, there is still a chance that an underground water flow from an IBZ basin causes the backwater or wet soil behind the hill. The IBZ is designed so the water seeps through the vegetation zone and reaches the stream, however the infiltration can occur also in other directions.

Water level in the stream changes through the year, so does the hydraulic gradient (Darcys´ law). In seasons with heavy rainfall, high water level in a stream can result in a smaller hydraulic gradient between the IBZ basin and the stream. With lesser hydraulic gradient, water infiltrating in other directions can result in wet areas on a field.

Fig. 9 Low laying areas after rain in the proximity of an IBZ can result in high quantities of water infiltrating towards it, instead of towards the stream, resulting in wet areas or standing water for longer time (hypothetical illustration).



In the next situation, shown in Fig. 10 the flooding can occur as a result of water flowing through the soil and on the surface. The water can accumulate in terrain dents.

Fig.10 Backwater risk in low lying area near an IBZ

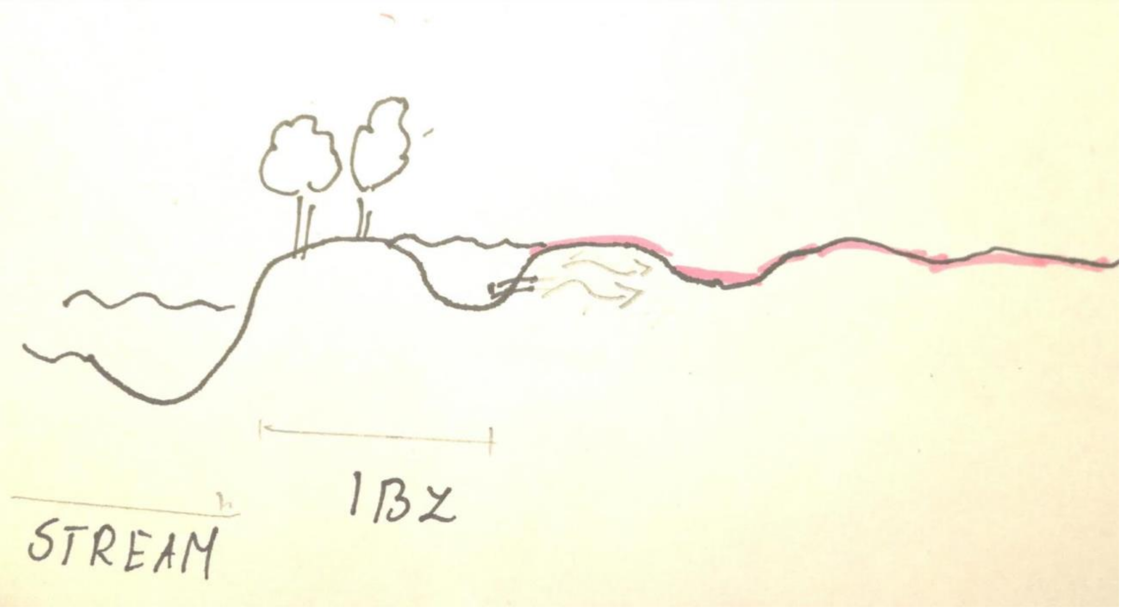
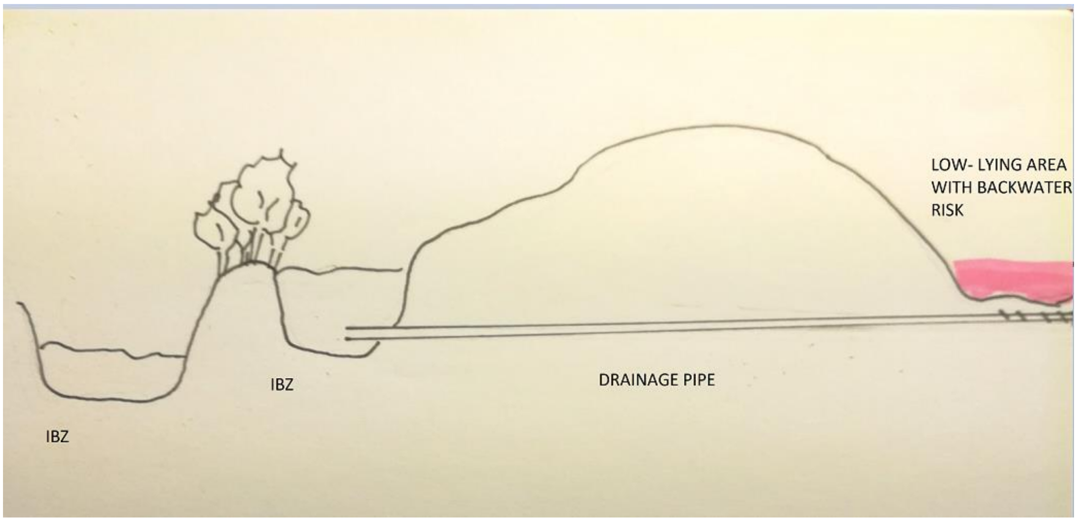


Fig. 11 shows an area with backwater risk some distance from an IBZ, behind a rising slope. The IBZ and the drained areas are connected by the drainage pipe and hydraulic gradient can result in the backwater. Moreover, because of the terrain the farmer did not dig the pipe in the sufficient angle and the water may not flow well into the IBZ basin.

Fig. 11 Backwater risk in a low-lying area

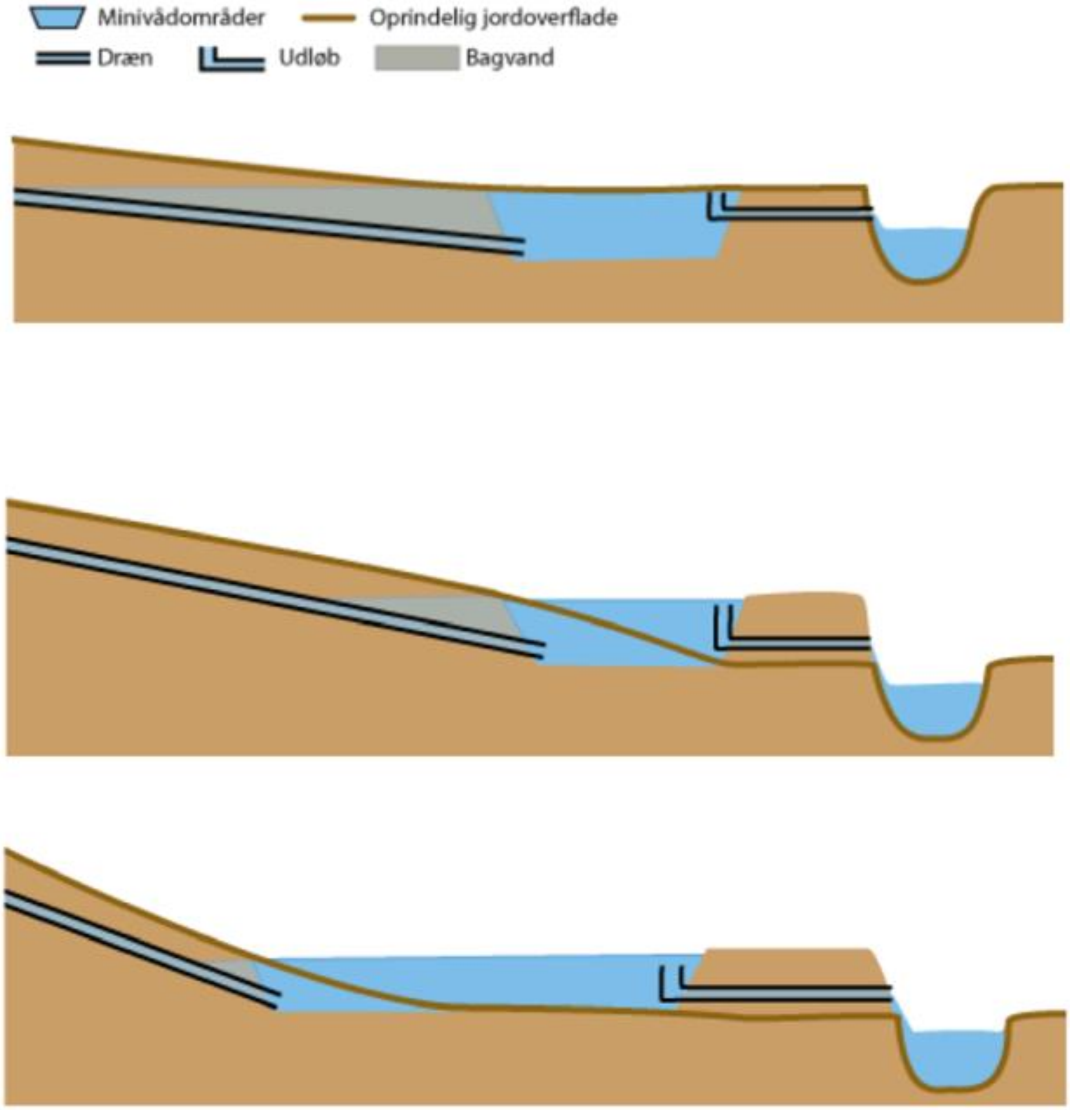


Other notes:

The flow of water in the ground from a basin can occur not only towards the stream but also in other directions.

The main drainage pipes are usually placed at around 1m – 1.2m depth, however, in some cases they may be placed at different depths. The depth of the pipe should be at least 1m to prevent backwater problems. If a pipe is placed shallower, higher slope gradient is required next to the basin. This is illustrated on an example of constructed wetlands in fig. 12.

Fig 12. Backwater problem in constructed wetlands (Frank Bondgaard, SEGES)



The shape of the graph in Scalgo Live can provide important information about slope increase and decrease. For example, we can see that an IBZ in Vills and Mors has backwater problems (Fig. 13). The slope on the site is not increasing. From the site in Odder we can see that a slope is rising (Fig. 14).

Fig.13 Elevation at a site with an experimental IBZ in Spjald. There is a backwater problem in the area.

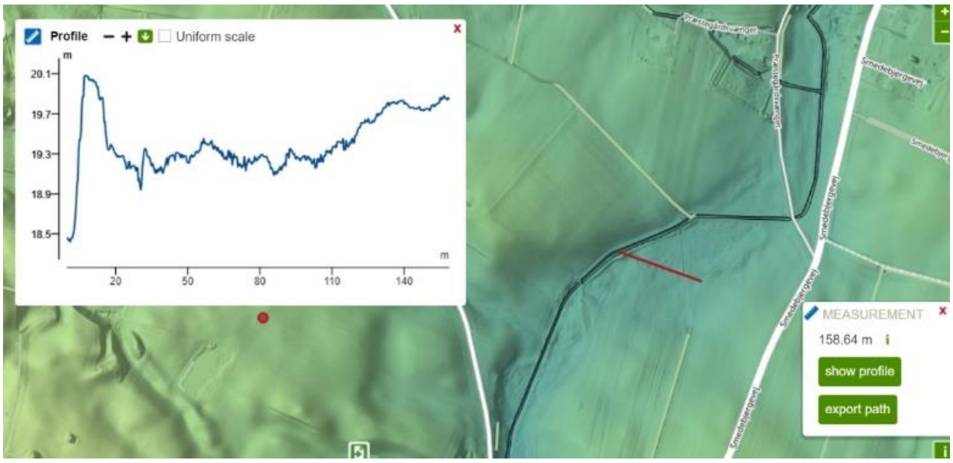
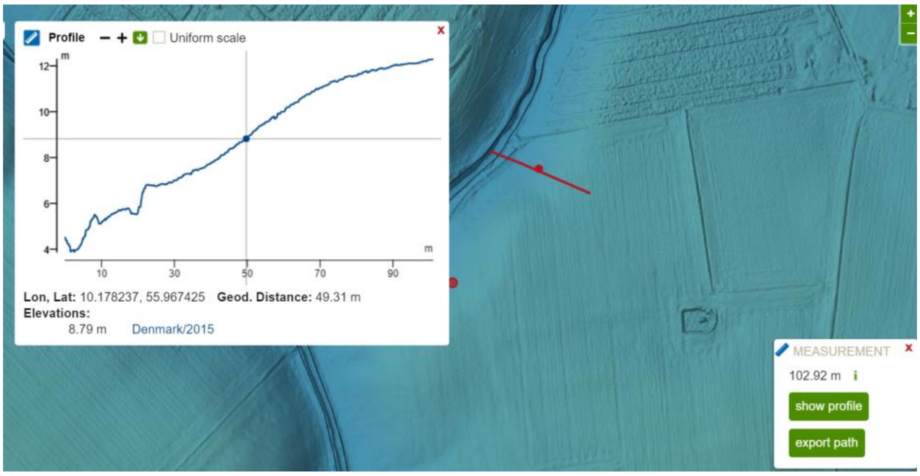


Fig. 14 Elevation at a site with experimental IBZ in Odder



Lon, Lat: 10.178237, 55.967425 **Geod. Distance:** 49.31 m
Elevations:
8.79 m Denmark/2015

4.3.4 Classification of the terrain 50 and 100 m distance from the stream water table.

Elevation difference from a site 50m and 100m upwards from the stream to 20 m were taken to assess if the slope is increasing sufficiently. The measurements were taken to follow the tile drain lines.

The terrain in an IBZ in Spjald resulted in backwater problems, now this IBZ will be reconstructed and another environmental measure will be put in its place, an IBZ in Vills and Mors also causes back water (Frank Bondgaard). Therefore, I eliminate the sites with no slope increase up to 50 m, and classify them as poor. If there is a sufficient elevation at 50m and the slope is not decreasing, then an IBZ site can be accepted. For sites with high elevation difference at 50m, e.g more than 3m, we can consider accepting a small decrease up to about 0.5m because this elevation still would be sufficient - well above a water surface in a basin of a potential IBZ.

In an IBZ in Lillerup there is a small backwater risk (Frank Bondgaard). Based on data from this site I classified 0.9m difference in elevation to be of medium potential. Very well-functioning sites in Lillerup and Odder have above 3m elevation difference from 50m to 20m. For high classification I decided on the middle value of 2m.

Table 2. Classification of elevation difference from 20 m to 50 m distance.

Elevation difference from 20 -50 m		
Poor < 0.9 m	Medium 0.9- 2 m	High > 2 m

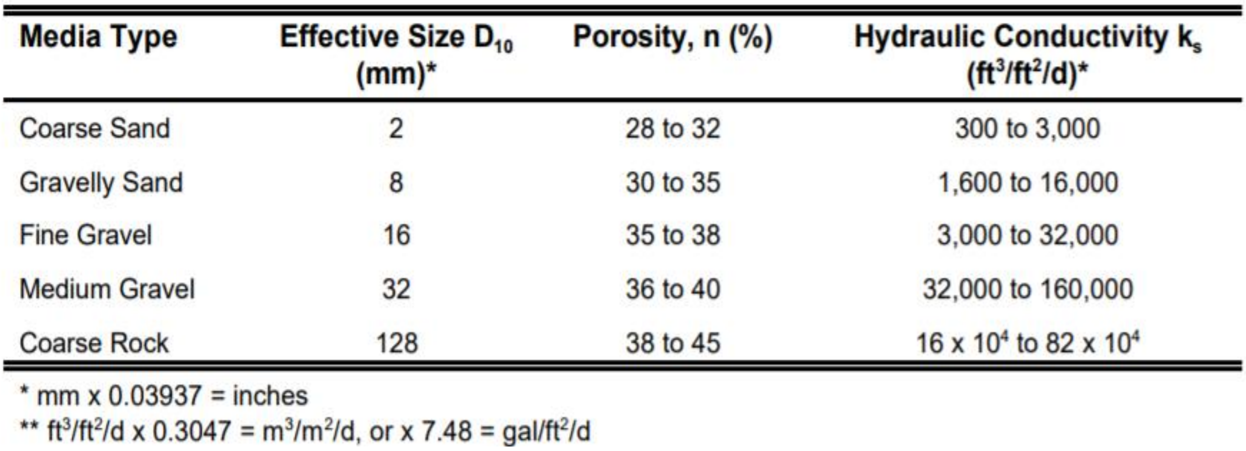
4.4 Soil types suitable for the IBZs.

4.4.1 Importance of textural composition and structure of soils for hydraulic conductivity

For the IBZs soils with high hydraulic conductivity are suitable. High hydraulic conductivity allows water to flow through the plateau from the IBZ basin towards the stream. The water mostly flows through the plateau of the IBZ from the open basin until it reaches the stream. As water is flowing into the saturated zone denitrification might occur.

The textural composition of the soil is therefore very important for an optimal functioning IBZ. Soils that contain higher percentage of coarse material have higher porosity and higher hydraulic conductivity hence allowing a higher water flow through the IBZ plateau (Table 3). Higher permeability in the IBZ results in increased water flux: the higher amount of water containing nutrients and pollutants passing through the plateau within a given time.

Table 3. Effective size of soil media, its effect on porosity and hydraulic conductivity (Reed *et al*. 1995).



Media Type	Effective Size D_{10} (mm)*	Porosity, n (%)	Hydraulic Conductivity k_s ($ft^3/ft^2/d$)*
Coarse Sand	2	28 to 32	300 to 3,000
Gravelly Sand	8	30 to 35	1,600 to 16,000
Fine Gravel	16	35 to 38	3,000 to 32,000
Medium Gravel	32	36 to 40	32,000 to 160,000
Coarse Rock	128	38 to 45	16×10^4 to 82×10^4

* mm x 0.03937 = inches

** $ft^3/ft^2/d \times 0.3047 = m^3/m^2/d$, or x 7.48 = $gal/ft^2/d$

For optimal soil conditions for an IBZ design, a certain unknown mixture of a little fine and coarse material may be required. A question remains about the adequate proportions. Due to the complexity of O_2 dynamics (Parkin & Tiedje, 1984) and other factors such as temperature (Parkin & Tiedje, 1984), C content (Torbert *et al.* 1992) and composition of micro fauna that have an impact on denitrification, it can be a challenge to assess the optimal soil composition for denitrification processes. Research shows that content of fine material in soil is important for sufficient residence time of subsurface flow in soil media. Moreover, natural clay particles that contain reactive iron and aluminium hydroxides have a high capacity for absorbing phosphate (Froelich, 1988). However, to allow water flow via the soil matrix, the soil material should not content more that 10% of clay (Kronvang B., pers. comm). Reed *et al*. 1994 also excludes sites >10% clay content for soil aquifer treatment systems where permeability is important.

Soil structure also influences permeability and nutrient retention. Soil structure refers to the arrangements of soil aggregates. Aggregates are comprised of solid particles and spaces. Good soil structure for the IBZ consists of a network of soil pores, cracks that allow a good water infiltration. Fine textures soils that are well structured can also allow good water flow. However, soil structure of fine soils can be easier damaged by the excavation, and over time can deteriorate as constant flow of water carries organic and mineral fine particles from the basin (VegetableSOILpak). Available GIS data does not provide such specific information on soil structure, hence I focus on the soil type in my classification.

So first of all in classification, when finding a suitable site for an IBZ, we look for soil types classified with a high amount of coarse soil material and a small content of medium size particles.

Soil content was analysed on the vegetation plateau on an experimental IBZ site in Lillerup. Results show that the soil there consists mainly of sand, and also some humus is present. Results showed that there are variations in relation to clay content on the site. On one location out of nine sampled, humus holding clay soil with >20% of clay was found at 32-60cm depth. This was the site with the highest clay content found at this depth. Also in one location, soil at 75-92cm depth contained 10-15% clay. On all other sampled places, clay at this depth and below is < 5% or absent. This layer is composed mainly of coarse white sand and gravel (private correspondence with Niels Bering Ovesen).

4.4.2 Importance of Soil Organic Matter (SOM) content for microbial transformations and trees establishment.

Organically enriched soils have higher potential of denitrification.
Rates of denitrification in riparian zones follow carbon distribution (Hill *et al*. 2000; Kellog *et al*. 2005). Carbon (C) is the most important electron donor for denitrifying microbes, it is essential for generating energy and growth (Hill *et al*. 2000). Organic C distribution in the soil can substantially affect denitrification of N in the water in an IBZ basin and seeping through the vegetation plateau. Studies have shown that denitrification in hydric soils in riparian setting occurred 3m down within 10m of the stream in alluvial and glacial outwash (Kellog *et al*. 2005). In situ studies revealed that denitrification may not effectively reduce NO_3^- as water passes through permeable sediments unless there are sites with organic matter (Hill *et al*. 2000). Denitrification can occur in localized zones with high Dissolved Organic Carbon (DOC) (Hill *et al*. 2000). Many of these “hotspots” where found near interfaces between sands and peats or C rich river channel deposits (Hill *et al*. 2000). The higher groundwater denitrification was close to the stream due to the increased C content.

In the US report for classification of the potential sites for saturated buffer zones the following criteria for SOM were taken: To promote denitrification, soil organic matter (SOM) content must exceed 1.7% from 0-100cm depth (Porter *et al.* 2017). The percent of soil organic matter is an average percent of soil organic matter across the soil depth. The 1.7–5.1% SOM is equivalent to a minimum mass concentration of soil organic carbon between 1-3% (Porter *et al*. 2017).

Although, the C content in Danish soils, especially in deeper layers is often low, fast-growing roots of trees can result in accumulation of carbon in deeper soil layer and creation of “hotspots” for denitrification (Rotkin-Ellman, 2004). There are also possibilities of C enhancement e.g. through addition of wood chips and some DOC will be imported to the IBZ via the tile drainage water that can also enhance denitrification.

Soil organic matter should be checked for the upper soil horizon of the IBZ plateau because it is important for trees establishment. This problem occurred in the IBZ in Odder, the difference in trees growth can be seen in fig. 15 (Bondgaard F., pers. comm). The trees near the stream bank grew much better than the trees in the first row, many of the trees had to be planted again. This difference can be explained by the higher organic matter content in soil near the stream bank.

Fig 15. Alder trees in an IBZ site in Odder

During the IBZ basin excavation it is advised to move the upper soil horizon (to 25 cm depth) onto the IBZ plateau where trees will be planted (Bondgaard, F. pers. comm). However, for the first screening of sites for simplicity I looked at the deepest soil horizon mapped for Denmark – C horizon. This is also because the problem was recognised and during the IBZ excavation the upper soil horizon with higher SOM from the place where an IBZ basin is excavated is shifted into the area where trees are planted.

4.4.3 Ranking of soil types according to their suitability for the IBZ placement

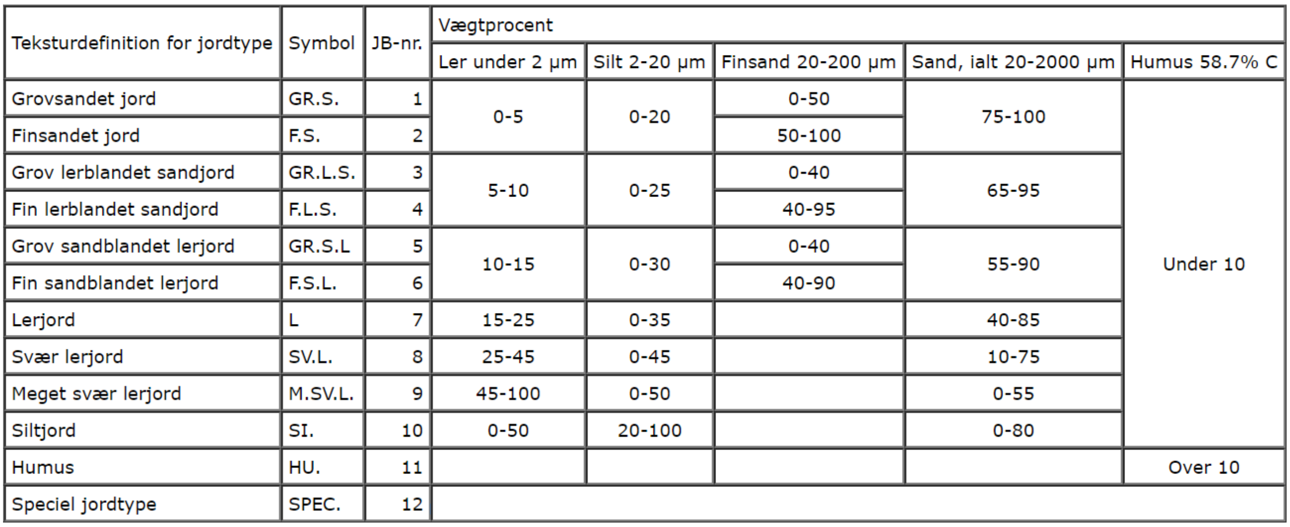
Classification of soil type in C soil horizon for the potential IBZ sites is shown in tab. 4. This is based on Danish soil classification shown in tab 5. In SCALGO there is no information about the soil C content and detailed composition but only JB soil number. In the next stage for assessing sites suitability that is out of scope for this project: C content (required above 10%) and clay content (< 10%), high sand content should be checked.

JB 11 has been classified as high as this soil is found on an experimental site in Odder using QGIS.

Table 4. Classification of soil type in C soil horizon for the potential IBZ sites.

Soil type	Classes
JB11 **JB1** **JB2**	**High**
JB3 **JB4** **JB5** **JB6**	**Moderate**
JB 7 **JB 8** **JB 9** **JB 10**	**Poor**

Table 5. Danish classification of soil types (from Jordbundsdata)



Teksturdefinition for jordtype	Symbol	JB-nr.	Vægtprocent				
			Ler under 2 μm	Silt 2-20 μm	Finsand 20-200 μm	Sand, ialt 20-2000 μm	Humus 58.7% C
Grovsandet jord	GR.S.	1	0-5	0-20	0-50	75-100	Under 10
Finsandet jord	F.S.	2			50-100		
Grov lerblandet sandjord	GR.L.S.	3	5-10	0-25	0-40	65-95	
Fin lerblandet sandjord	F.L.S.	4			40-95		
Grov sandblandet lerjord	GR.S.L	5	10-15	0-30	0-40	55-90	
Fin sandblandet lerjord	F.S.L.	6			40-90		
Lerjord	L	7	15-25	0-35		40-85	
Svær lerjord	SV.L.	8	25-45	0-45		10-75	
Meget svær lerjord	M.SV.L.	9	45-100	0-50		0-55	
Siltjord	SI.	10	0-50	20-100		0-80	
Humus	HU.	11					Over 10
Speciel jordtype	SPEC.	12					

5. Cross- ranking- combining parameters to assess suitable sites for the IBZs placement.

Sites with medium and high status should be further investigated as these can be potentially good sites for IBZs. Poor soil type or poor status for slope disqualify sites.

Based on the ranking (High, Medium, Low) for elevation differences at 10m, 20m and 50m distances upwards from the stream following the drainage pipe line (if available) I decided on the slope status for each site.

Only sites with all high rankings and conditions fulfilled for 100m obtained high status. All sites with poor ranking at 10m, 20m or 50m or unfulfilled conditions at 100m received Poor status.

Table 6. Slope status for IBZ sites based on ranking at 10m, 20m and 50 m if conditions for 100m are fulfilled (no decreasing slope).

Ranking at 10 m	**Ranking at 20 m**	**Ranking at 50 m**	**Slope status**
High	**High**	**High**	**High**
High	**High**	**Medium**	**Medium**
Medium	**High**	**Medium/High**	**Medium**
High	**Medium**	**Medium/High**	**Medium**
Medium	**Medium**	**Medium**	**Medium**
Medium	**Medium**	**High**	**Medium**
Poor	**Medium**	**Medium/High**	**Medium**
Medium	**Poor**	**High/Medium/Poor**	**Poor**
High	**High**	**Poor**	**Poor**
Medium	**Medium**	**Poor**	**Poor**
Poor	**High**	**Medium /High**	**Poor**

Soil type is as important as the slope for the IBZ to be effective, therefore in the overall classification for a site one can classify sites of high potential if both soil and slope conditions are high. Medium classification is ascribed to a site if either soil or slope conditions are Medium. Sites received poor classification if soil and/or slope conditions are poor.

Table 7. Overall sites classification for an IBZ based on slope and soil status.

Soil status	Slope status	Overall classification
High	High	High
High	Medium	Medium
Medium	High	Medium
Poor	Medium/High	Poor
Medium/ High	Poor	Poor

6. Methods

6.1 The Sillerup catchment description

Sillerup catchment is located in southern Jutland, it covers an area of 3.464 ha. and has been shaped during and after the last ice age (Weichsel). In many areas, soil is sandy, and sand has been deposited by the rivers running from the melting glaciers. Glaciers has shaped a hilly topography of the catchment (Hansen & Adamsen, 2011).

6.2 Methods – work with GIS data

I gathered the data shown in table 8 to assess the sites suitability for the IBZs

Table 8. Data obtained for initial assessment of sites suitable for the Intelligent Buffer Zones.

	Tools	**Data retrieved**
1.	QGIS	Soil type in C horizon
2.	QGIS	Nature Protected Areas
3.	SCALGO Live	Drainage systems and land use
4.	SCALGO Live	Elevation difference approx.10, 20, 50 and 100 m from the lowest point in the stream (the stream water table) along the main tile. Graph showing elevation data
5.	SCALGO Live	Watershed area

6.	SCALGO Live	For sites with acceptable conditions (Medium or High status), elevation change along the stream illustrated on a graph
7.	QGIS	CVR number of land owners for sites of interest
8.	https://datacvr.virk.dk/data/	Contacts to land owners

SCALGO Live is a browser based, digital tool that was used to check elevation, stream network and terrain use. Files were uploaded to visualize tile drain tiles and find their outlets. It can be accessed at: http://scalgo.com/live

QGIS is an Open Source Geographic Information System (GIS), that can be downloaded at: https://www.qgis.org/en/site/forusers/download

Files with a digital map of tile drains in Sillerup catchment were received from Haderslev municipality. A map is also available on website: http://kort.haderslev.dk/spatialmap?profile=konsulent

For this task it was taken into consideration that these drainage maps are based on old maps, it can be seen that the maps are not complete and may not be very accurate: the drainage system may have been changed and some pipes may have been connected or disconnected. SCALGO Live was used to check the gradient difference between the water surface in streams and the area where the IBZ could be set.
The data about soil types was obtained from SEGES, and QGIS programme was used.

Slope is the ratio of the vertical and horizontal change between two points on a surface. The vertical change between two points is called the rise, and the horizontal change is called the run. The percent slope is calculated: Rise/Run * 100

Slope angle was calculated using following function in Excel:
DEGREES (ATAN (elevation difference / distance))

For the assessment of suitable sites, a watershed area in a point of interest can be used, however this may have been changed through a drainage system.

7. GIS Results

Table 9. shows the data collected for slope and calculation for sites to status for their suitability for the IBZ placement. 12% of sites, 4 out of 33, have high status.

The results show that 9 out of 33 sites listed in the table, which corresponds to 27%, have medium or high status and can be investigated further. 58% of sites have poor status and are disqualified from further investigation.

Most of the sites in the Sillerup catchment had an acceptable elevation difference at 10m and 20m distance from the stream, The sites were mainly disqualified because of not sufficient elevation at 50m distance from the stream.

Table 9. Slope data and classification of potential IBZ sites in the Sillerup catchment. The colours indicate status, green- high, yellow- medium, red- poor. The sites in **bold** are the sites I visited.

Area/ sites		Elevation , gradient status	Elevation at the edge of stream bank (m)	Water table in the stream (m)	Elevation 10 m upward from the stream surface (m)	Difference in elevation from 10m distance to stream surface (m)	Percent slope	Slope angle (°)	Elevation 20 m from the stream water table (m)	Difference in elevation 20 m upwards from the stream	Slope angle (°)	Slope percent from water surface to 20 m	Elevation at 50 m distance from the lowest point in the stream	Difference in elevation 50 - 20 m	Difference in elevation from 50 m to the stream surface	Slope angle (°)	Elevation at 100m (m)	Difference in elevation from 100 to the stream table	Slope percent (from stream water table to 100m)	Slope angle (°)	Difference from the edge of the stream to the water surface
Area 1 / site 11		High	7.31	7.0	8.06	1.1	11%	6.3	8.23	1.3	3.7	6%	11.45	3.22	4.5	5.1	13.66	6.71	7%	3.8	0.4
Area 5/ site 1		High	3.96	3.5	5.07	1.5	15%	8.8	7.56	4.03	11.4	20%	10.46	2.9	6.9	7.9	12.55	9.02	9%	5.2	0.4
Area 6/ site 38		High	24.7	24.4	25.5	1.1	11%	6.3	26.2	1.8	5.1	9%	28.2	2	3.8	4.3	29.9	5.5	6%	3.1	0.3
Area 2/site 13		High	10.4	9.4	11.65	2.3	23%	12.7	12.1	2.7	7.7	14%	13.3	1.2	3.9	4.5	15.5	6.1	6%	3.5	1.0
site 21		Medium	25.52	25.4	27.91	2.5	25%	13.9	29.24	3.8	10.8	19%	30.04	0.8	4.6	5.3	31.6	6.16	6%	3.5	0.1
Area 6/ site 25		Medium	19.3	18.6	19.6	1.0	10%	5.8	19.7	1.11	3.2	6%	20.69	1.03	2.1	2.5	21.92	3.37	3%	1.9	0.8
Area 1/ site 14		Medium	10.3	9.9	10.6	**0.7**	7%	4.0	11.4	1.52	4.3	8%	13.56	2.14	3.7	4.2	13.9	4	4%	2.3	0.4
Area 3 site 19		Medium	18.9	18.6	19.4	0.8	8%	4.3	19.8	1.18	3.4	6%	20.79	1.02	2.2	2.5	22.15	3.56	4%	2.0	0.3
Area 4/ site 21		Medium	25.5	25.4	27.9	2.5	25%	13.9	29.2	3.8	10.8	19%	30.04	0.8	4.6	5.3	31.6	6.16	6%	3.5	0.1
site 19		Medium	18.9	18.6	19.35	0.8	8%	4.3	19.77	1.18	3.4	6%	20.79	1.02	2.2	2.5	22.15	3.56	4%	2.0	0.3
Area 1/ site 10		Low	6.7	6.5	7.4	1.0	10%	5.5	7.3	0.85	2.4	4%	7.92	0.61	1.5	1.7	13.48	7.02	7%	4.0	0.3
Area 5/ site 6		Medium	5.5	5.3	6.2	1.0	10%	5.5	6.4	1.13	3.2	6%	7.2	0.8	1.9	2.2	13.7	8.43	8%	4.8	0.2
Area 5 site 25		High	19.3	18.6	19.6	1.0	10%	5.8	19.7	1.11	3.2	6%	20.69	1.03	2.1	2.5	21.92	3.37	3%	1.9	0.8
Area 6 /site 26		Medium	17.7	16.9	17.71	0.9	9%	4.9	17.96	1.11	3.2	6%	19.1	1.14	2.3	2.6	20	3.15	3%	1.8	0.8
Area 6/site 30		Medium	20.5	19.9	20.7	0.8	8%	4.6	21.2	1.3	3.7	7%	22.4	1.2	2.5	2.9	22.2	2.3	2%	1.3	0.6
Area 1/ site 7		Low	5.91	5.6	6.39	0.8	8%	4.3	6.41	0.78	2.2	4%	6.66	0.25	1.0	1.2	8.8	3.17	3%	1.8	0.3
Area 2/site 12			9.2	8.6	9.3	0.7	7%	4.0	9.3	0.7	2.0	4%	10.18	0.88	1.6	1.8	12.4	3.8	4%	2.2	0.6
Area 1/site 9		Low	6.38	6.3	7.08	0.7	7%	4.2	7.08	0.74	2.1	4%	9.39	2.31	3.1	3.5	13.99	7.65	8%	4.4	0.0
Area 1/ site 10		Low	6.73	6.5	7.43	1.0	10%	5.5	7.31	0.85	2.4	4%	7.92	0.61	1.5	1.7	13.48	7.02	7%	4.0	0.3
Area 6 /site 27		Low	17.9	16.8	17.6	0.8	8%	4.6	17.6	0.8	2.3	4%	18.2	0.6	1.4	1.6	18.8	2	2%	1.1	1.1
Area 6/site 28		Low	19.5	18.5	20.2	1.8	18%	9.9	20.3	1.85	5.3	9%	20.6	0.3	2.2	2.5	20.7	2.25	2%	1.3	1.1
Area 6/site 29		Low	20.5	19.8	21.5	1.7	17%	9.6	21.7	1.9	5.4	9%	22	0.3	2.2	2.5	22.6	2.8	3%	1.6	0.7
Area 6/site 31		Low	21.2	20.1	21.2	1.1	11%	6.3	21.1	1.01	2.9	5%	21.2	0.1	1.1	1.3	22.2	2.11	2%	1.2	1.1
Area 6/site 32		Low	21.1	20.2	21.35	1.2	12%	6.6	21.6	1.4	4.0	7%	22.2	0.6	2.0	2.3	22.7	2.5	3%	1.4	0.9
Area 6/site 33		Low	21.75	20.6	21.7	1.1	11%	6.3	21.5	0.9	2.6	4%	21.7	0.2	1.1	1.3	22.2	1.6	2%	0.9	1.2
Area 6/site 34		Low		21.0	22.2	1.2	12%	6.8	22	1	2.9	5%	22.1	0.1	1.1	1.3	22.8	1.8	2%	1.0	
Area 6/site 35		Low	21.2	21.4	22.2	0.8	8%	4.6	22.2	0.8	2.3	4%	22.6	0.4	1.2	1.4	23.2	1.8	2%	1.0	-0.2
Area 6/site 36		Low	22.5	21.5	22.7	1.2	12%	6.8	22.9	1.4	4.0	7%	22.9	0	1.4	1.6	22.6	1.1	1%	0.6	1.0
Area 6/site 37		Low	22.4	22.0	22.8	0.8	8%	4.6	22.85	0.85	2.4	4%	23.2	0.35	1.2	1.4	22.4	0.4	0%	0.2	0.4
Area 6/site 39		Low	26.25	26.0	27.6	1.6	16%	9.1	27.8	1.8	5.1	9%	27.6	-0.2	1.6	1.8	28.45	2.45	2%	1.4	0.3
Area 6/site 20		Low	19.62	19.3	19.75	0.5	5%	2.7	19.95	0.67	1.9	3%	21.15	1.2	1.9	2.1	22.2	2.92	3%	1.7	0.3
Area 6/site 40		Low	10.17	9.9	10.6	0.7	7%	4.0	10.5	0.6	1.7	3%	10.7	0.2	0.8	0.9	12	2.1	2%	1.2	0.3
Area 3/site 16		Low	16.2	15.5	17.2	1.7	17%	9.5	17.41	1.88	5.4	9%	17.95	0.54	2.4	2.8	19.28	3.75	4%	2.1	0.7

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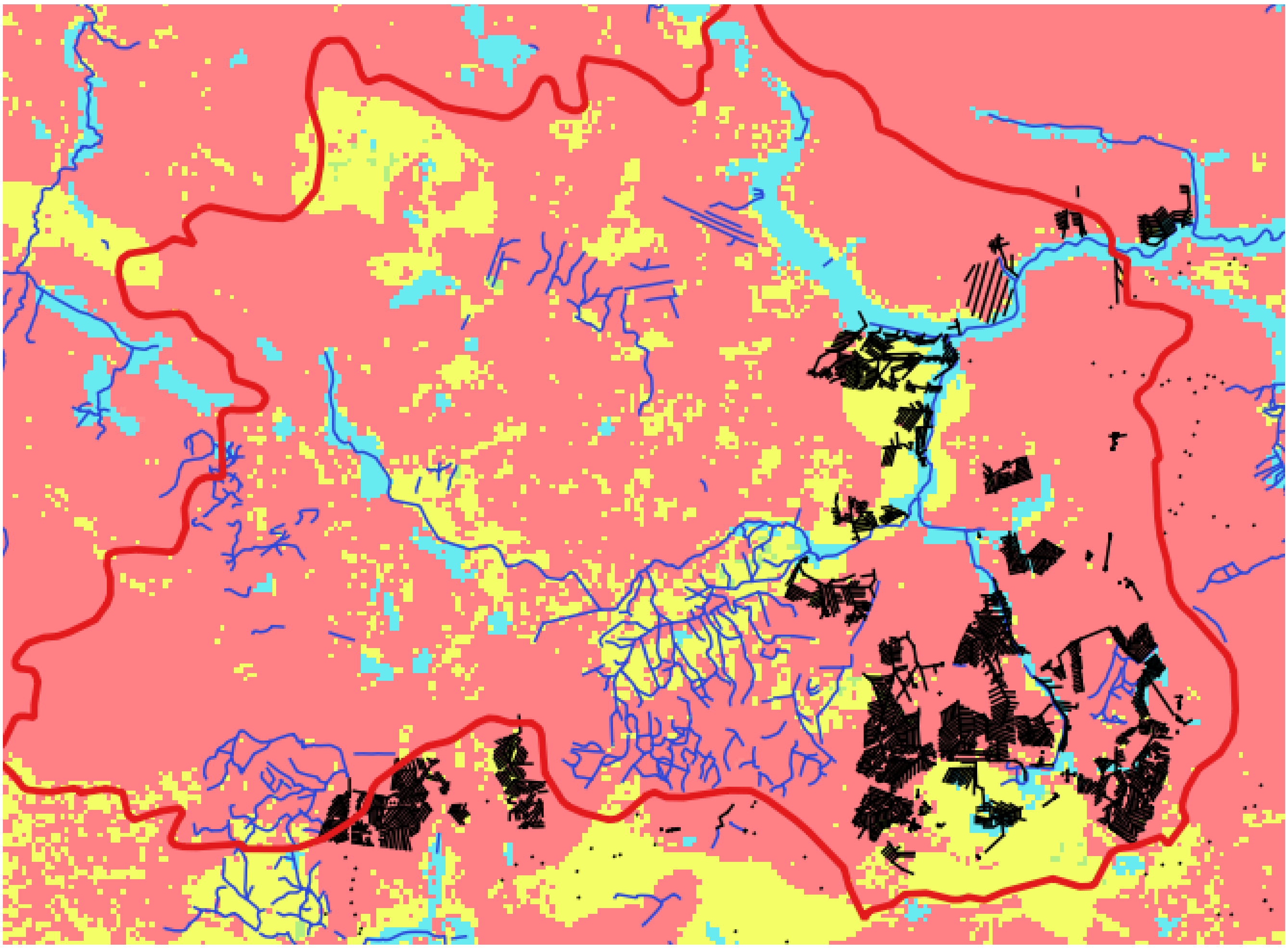
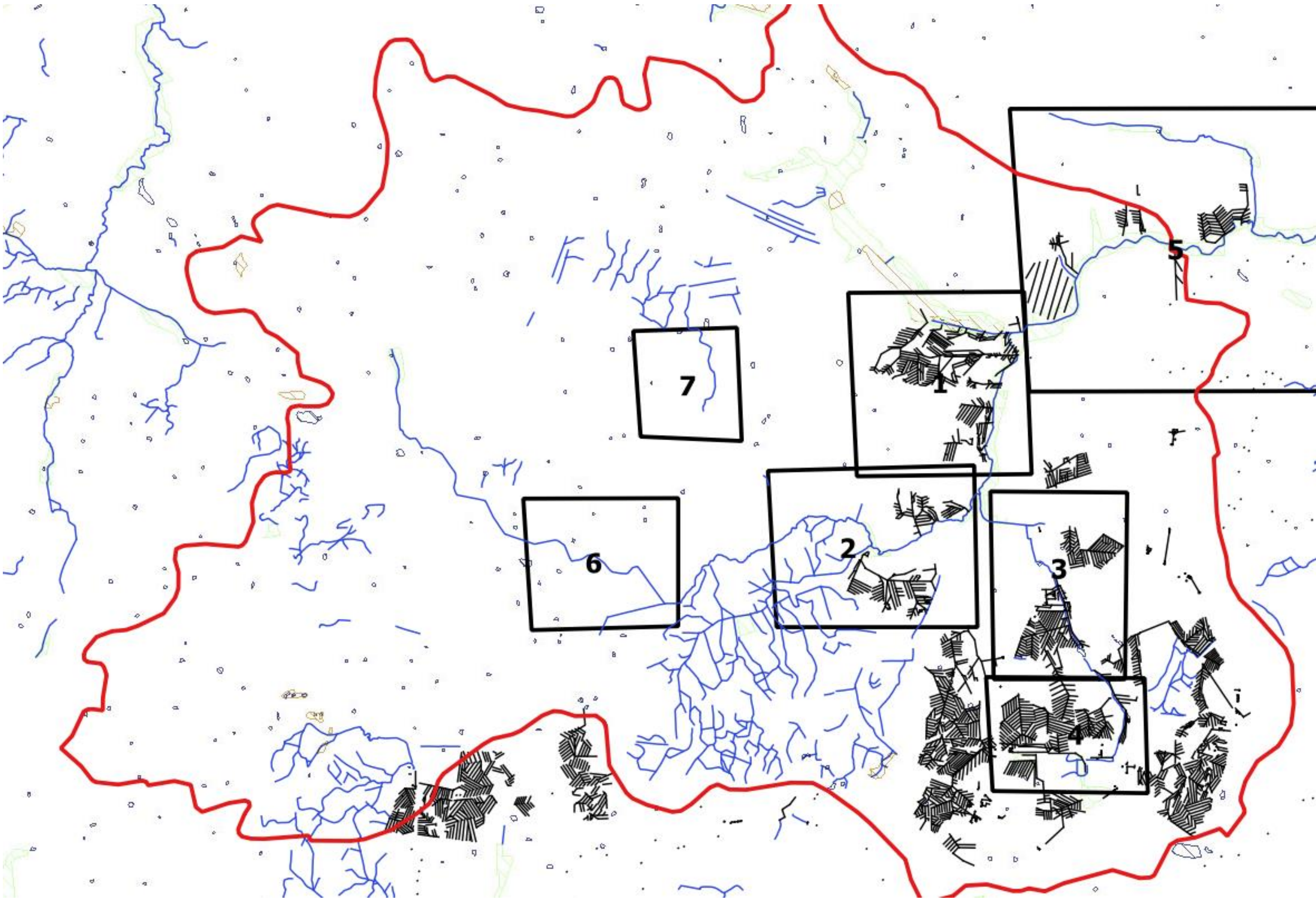
Soil type with high status is mostly JB11 that is found near the stream. Most of the yellow areas were near the stream, soil near the pipes outlets in yellow areas is mostly JB4, some soil type is JB6.

Fig 14. Classification of soil types for C soil horizon in the Sillerup catchment: (Green and blue High status, high status corresponds to JB11, yellow: Medium status, Light red: Poor status).



Nature protected areas in the Sillerup catchment, where restriction for construction of environmental measures such as IBZs apply, are shown in fig. 15. The restrictions are in some places of the areas 1, 2, 3 and 5.

Fig.15 Nature protected areas in the Sillerup catchment (marked in light green and orange).



8. Field work

8.1 Methods

Land owners must be informed about the site visit. Obtaining their permission is necessary to access their land. Moreover, landowners often have important information about the site such as pipes outlets locations, pipes depth and the extent of drained area.
This fieldwork was only a brief, simple site assessment which did not include detailed measurements of slopes, but it is based on a visual assessment of the terrain. Visual assessment often can help to make a better decision in relation to the IBZ site as many features of the terrain – such as e.g. small hills or low places - may help to assess the backwater risk or even a potential size of the catchment area (Frank Bondgaard).

Moreover, I looked for whether pipes location corresponded to data found in SCALGO Live. I also measured **the stream depth** in the middle point, in late November when rainfall is high in Denmark, and the water level in the stream may be the highest or close to the highest in the year. The distance from the water table to the stream bank was also taken.
Measuring the water table in a season with high rainfall can be helpful when predicting the smallest possible difference in distance between the water table in a potential IBZ and the water table in the stream.

The depth of the pipe outlet was taken, if accessible - this can provide some information about the depth of the pipe in the field. This is important for assessing a depth required of an IBZ basin. The depth of an IBZ basin must as a minimum be about 20cm below the pipe outlets.

In many cases, the **watershed area** – the area of a land that a pipe drains water from may be assessed by measuring the diameter of pipes´ outlet. Around 70 years ago, when deciding how big a pipe should be, farmers applied approx. 1 cm of pipe diameter per ha (Brian Kronvang).

Data about predominant soil type is documented for landscapes in Denmark. However, high variations in relation to **soil type** within fields can occur, therefore for assessing a suitable terrain for an IBZ, soil properties such as texture and SOM content must be checked during a site visit.

For this exercise, I took one sample from each site, in a distance of about 10-13 meters from the stream. I used a soil sampler to assess a **soil profile to 75cm depth**.

8.2 Results from the field visits

Table 10 below shows the data collected from the site visits. The graphs and pictures of sites are included in Appendix B.

Table 10. Data from visited sites

Area/site and status based on GIS data	**Stream depth (m)**	**Distance from stream bank to the water table (m)**	**Distance from the pipe to the stream bank (m)**	**Outlet pipe**	**Soil profile**	**Other notes**	**Difference between stream surface and the edge of the stream in SCALGO Live (m)**
Area 2/ site 13 High	0.4 -0.5	2.8- 3	2.8- 2.5	found, pipe diameter 14- 16 cm	generally clay	Meandring river, high variation of soil in the field	1
Area 2/site 14 Medium	0.45 -0.55	1-1.3	1	found	Generally clay, but some mixture of fina and coarse sand with clay in the lower profile		0.4
Area 2/ site 12 Low	0.30- 0.40	0.4	-	not found	high clay		0.35
Area 1/ site 11 High	0.5- 0.6	1- 1.3	1.2	found	high clay, JB 6 or JB7		0.36
Area 1/ site 9 Low	0.7- 0.8	0.85 - 0.95		not found	clay but in lowest 25 cm some coarse sand	standing water in the area	0.04
Area 1/ site 10	0.8- 0.9	0.85- 0.95		possible pipe location found	clay but in lowest profile some coarse sand		0.27
Area 6/ site 28	0.35- 0.45	1- 1.1		not found	high clay content		1.05
Area 6/ site 30	0.4- 0.5	1.1- 1.25		not found	high clay content		0.6

There were strong differences between the data in SCALGO Live in relation to the distance from the water table in the stream to the water bank. This may depend on how the edge of the stream is defined, in this exercise in a field I looked at the highest point near the stream, In SCALGO Live the edge of the stream is not necessarily placed in the highest point. Therefore, we can see variations in my field measurements and data from SCALGO Live. Taking measurements at the stream bank in SCALGO Live can lead to wrong results in relation to the site suitability for an IBZ. This shows that in SCALGO Live, taking the first measurements from at least 10m from the stream are more accurate.

Soil seemed to contain high clay percent on the all sites.

Two out of five pipes were found.

The slope ranking seemed to correspond well to the conditions in reality. This is based on visual assessment.

- Area 1, site 9 and 10 (Low status with backwater risk)
  - The elevation difference within 20 m distance from the stream is suitable for an IBZ.
  - There is water standing in the area, the large part of the site was flooded. The results in SCALGO also indicated high backwater risk.

- Area 1, site 11 (High status)
  - Very high elevation within 50m.

- Area 2 site 12 (Low status)
  - Low gradient, no increasing slope – unsuitable for an IBZ.

- Area 2, site 13 (High status)
  - High elevation near the meandering stream.
  - Elevation difference from the stream up to the terrain was suitable for an IBZ.
  - Elevation, slope on the field seemed suitable for an IBZ.
  - Gradient along the stream slightly decreasing, but potentially suitable for an IBZ.
  - Because of the high elevation from the stream to the terrain, a pipe might have been located too deep for the IBZ. However this should be further investigated, as it was a flexible type of pipe that could have been directed down in the ground just near the stream bank.
  - There was also a strong change of gradient along the stream, that may add difficulties for constructing an IBZ.

- Area 2, site 14 (Medium status)
  - Elevation difference from the stream up to the overlaying terrain. Suitable.
  - Elevation, slope on the field seemed suitable for an IBZ.
  - The most suitable site for an IBZ in regard to slope (based on visual assessment and discussion with Frank Bondgaard).

- Area 6, 30 (Medium status)
  - Suitable in regard to the slope, elevation difference.
  - Landowner can provide information about tile drains and the area drained.

9. Conclusions

Slope:

- Sites I visited with high and medium slope status based on SCALGO seemed to have sufficient slope for IBZs.
- This has been assessed with an expert from SEGES who helped in the process of finding sites for these measures. It was clear that the sites with poor slope status were unsuitable.
- Assessment of the graph shape that shows elevation change can be an effective way for the first, fast initial phase of screening.
- Sites with high slope status at 50m from the stream did not indicate backwater problems on terrain up to 50m. Data is collected at set distance points from the stream, but information about terrain (drop, rise) between these points can be seen from the graph shape.
- The elevation difference between the IBZ and the stream water table should be >= 1.1m for a site with High, 0.8-1.1m for Medium and <0.8 Poor status at 20m.
- For good conditions the slope should also be slightly increasing from 50m to 100m.
- Next, the elevation difference from the distance of 50m to 20m should be assessed. In this exercise, most of the sites have been disqualified because of not sufficient slope increase within this distance.
- Assessing elevation difference from the stream water table to the place where a potential IBZ basin might be located is essential for sufficient hydraulic pressure.
- For more detailed screening of sites in SCALGO Live: The slope along the stream (approx. 70 m) could be checked, because sharp changes in terrain can cause difficulties for an IBZ construction (personal communication Frank Bondgaard).
- For sites that have Medium or High slope status in SCALGO Live, more slope data can be collected e.g. from a pipe outlet every 10m along the stream.
- In my opinion, a person provided with clear instructions can learn main functions in SCALGO Live independently.

Drain tiles:

- There were some differences in relation to the locations of drainage tiles in fields, the pipes we found were located nearby but not precisely according to the coordinates obtained from SCALGO Live.
- Drainage maps can be a very useful tool, on the site visits we found two out of five pipe outlets and one possible location. This is a good result especially in a season with high water table in the stream.

Site visits:

- It is necessary to visit a candidate site and look at the whole landscape, some topography can be visible in SCALGO Live, however, in the field more landscape features can be noticed.

Soil:

- High soil permeability is required for the IBZ, therefore soil in deeper horizons should contain mostly sand and gravel, sols with>10% are not suitable.
- Soil samples taken at the visited sites had high clay content and low sand content. Distinctive layers known as soil horizons, were not visible.
- SOM and humus is a carbon source essential for denitrification. SOM content was expected especially on the sites with JB 11 soil type, however, soil layers with SOM that have characteristic dark brown or black colours were not seen.
- Variations within a field in relation to sand and clay content occur (Frank Bondgaard), this has also been seen by different coloration of soil in a field in Area 2. Moreover, soil profiles, especially below 1m must be investigated further to assess if the site is suitable for an IBZ. On an experimental site in Lillerup, on one out of nine places sampled, soil content was >20% at the depth from 32- 60cm, from there decreased to <10% (60-70 cm), and below no clay content was found (private correspondence with Niels Bering Ovesen).
- Slope data should be taken as the most important factor when choosing candidate sites for IBZs when using GIS data. Though one may disqualify sites with soil of poor status, further soil check on sites with high and medium soil status is necessary.

More data for IBZ site assessment:

- Maps about N and P vulnerable areas, as well as N and P content in streams, can help to focus efforts of finding sites for IBZs in areas of High risk of N and P emissions.

An IBZ fitted to the landscape:

- Results show that only a small percentage of sites may be best suited the IBZ. There may be other restrictions that do not allow IBZ construction in an area e.g. a historic site listing.
- The length and width of the IBZ might have to be adjusted to the landscape. For instance, less productive areas with standing water within a distance up to 50m could be considered, also an IBZ could have a wider water basin.

ACPF tool:

- The US ACPF tool allows to conduct analysis across the broad landscapes down to the field level to identify possible locations for practice installations (Tomer *et al*. 2015). This is based on soil, elevation, streams and land use data (Tomer *et al*. 2015).
- For fast screening of landscapes for conservation practice installations, a GIS toolbox based on the idea of ACPF in the US could be developed for Denmark.

10. Reflections on the internship

I would highly recommend students to undertake an internship at SEGES. It has been a great experience for me. I was very lucky to have a dedicated mentor Frank Bondgaard who was very helpful and always enthusiastic about sharing his experience, knowledge and helping me with field work. Internship allowed me to gain relevant work experience and I am glad I could contribute to the real-life problems with applying the theory I learnt into practise.
I also realised how challenging work can be, especially when working with novel environmental measures and implementing them in practise. Also in this report I had to take responsibility and make decisions in relation to the classification of the sites for IBZs, which make me realise how complex working with the real-life problems can be.

Staff I met at SEGES worked on various fascinating projects and they all were very keen on explaining them to me. The professionals I have met there are fully dedicated to make a positive change.
It was also a cultural experience that gave me an insight into a Danish culture and workplace. People in this small department have different skills and they realise how important the teamwork is.

All people I have met in the company made me feel comfortable, even though I do not speak fluent Danish yet. I would strongly advise international students to look for a work experience in a Danish company as to help them to progress in Danish. I showed the will in learning the language and people were very supportive by talking to me in Danish, so I could practise and inviting me for meetings in Danish.

I took part in company meetings, also ones that did not relate to my project. Among many interesting topics, I have learnt about different environmental measures and now I am inspired to find out more.
My internship involved a variety of tasks such as data collecting in GIS programmes, data analysis, research and fieldwork. The area I worked with was all new to me and I am truly grateful for the support that helped me to make a big progress.

As I decided to follow the similar career path as many people I have met at SEGES I am looking forward to sharing my knowledge and cooperate with them again in the near future.

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Appendix A: Data in SCALGO live from the established sites with established IBZs.

Fig. A-1. GIS data from sites with experimental IBZs.

Site	Water surface in the stream (the lowest point) (m)	Elevation 10 m upward from the stream surface (m)	Difference in elevation from 10m distance to stream surface (m)	Percent slope	Slope angle (°)	Elevation 20 m from the stream surface (m)	Difference in elevation 20 m upwards from the stream	Slope angle (°)	Slope percent from stream to 20 m	Elevation at 50 m distance from the stream	Difference in elevation from 50 m to 20 m	Slope percent from 20 m to 50 m distance	Slope angle (°)	Elevation at 100m (m)	Difference in elevation from 100 to 50 m (m)	Slope percent (from 50 m to 100m)	Slope angle (°)
Lillerup , Godveg	42.0	43.1	1.07	11%	6.1	43.3	1.27	3.6	6%	44.2	0.9	3%	1.7	47.6	3.3	7%	3.8
Odder	3.9	5.3	1.44	14%	8.2	5.8	1.94	5.5	10%	9.1	3.3	11%	6.2	12.3	3.2	6%	3.7
vils, Mors	18.0	20.0	2.00	20%	11.3	19.3	1.30	3.7	7%	19.3	0.0	0%	0.0	19.2	-0.1	0%	-0.1
Sillerup	4.3	5.0	0.70	7%	4.0	5.8	1.41	5.6	7%	8.7	3.0	10%	5.6	9.7	1.0	2%	1.2

Fig. A- 2 Slope of an the area with an experimental IBZ in Sillerup

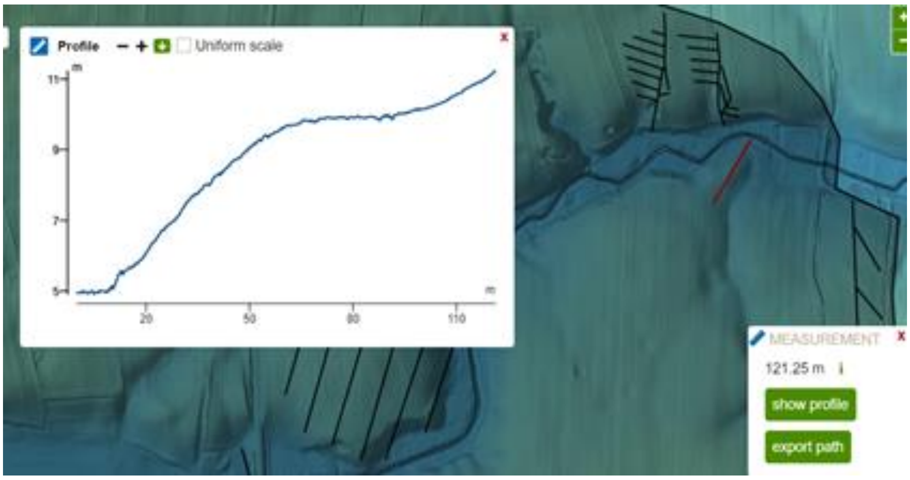


Fig. A- 3. Slope of an the area with an experimental IBZ in Sillerup

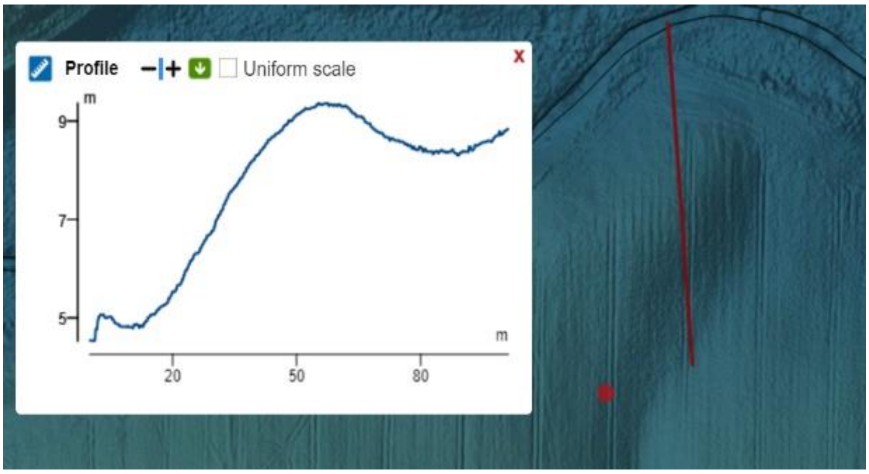
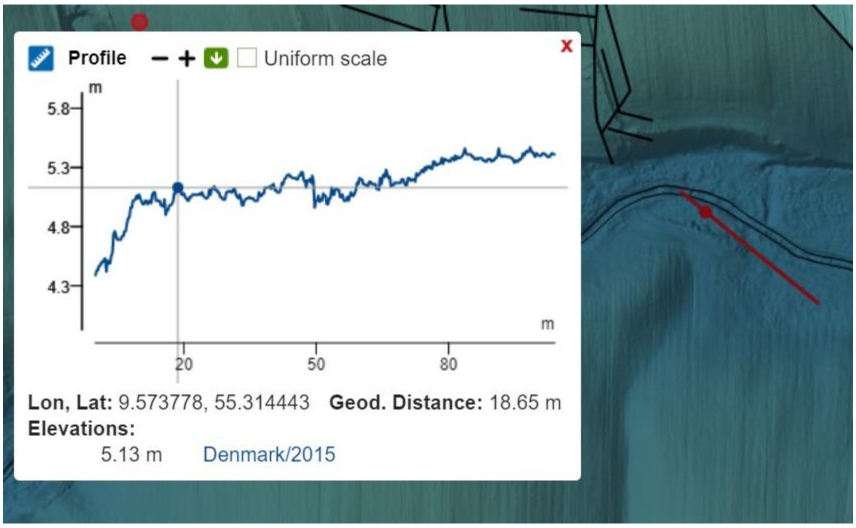
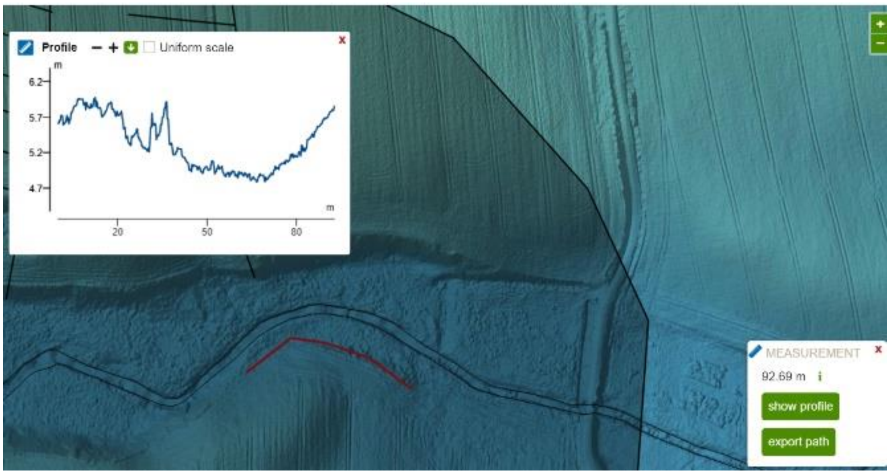


Fig. A- 4. Slope along the stream with an experimental IBZ in Sillerup.



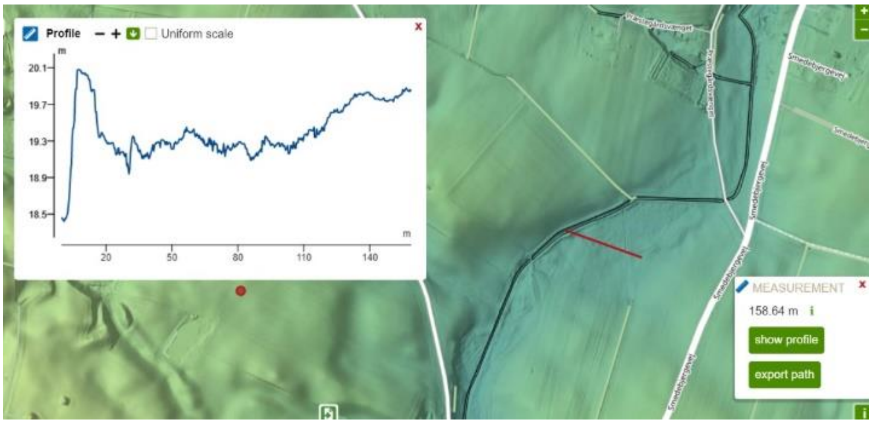
Lon, Lat: 9.573778, 55.314443 **Geod. Distance:** 18.65 m
Elevations:
5.13 m Denmark/2015

Fig. A- 5. Slope along the stream from a site with an IBZ in Sillerup.



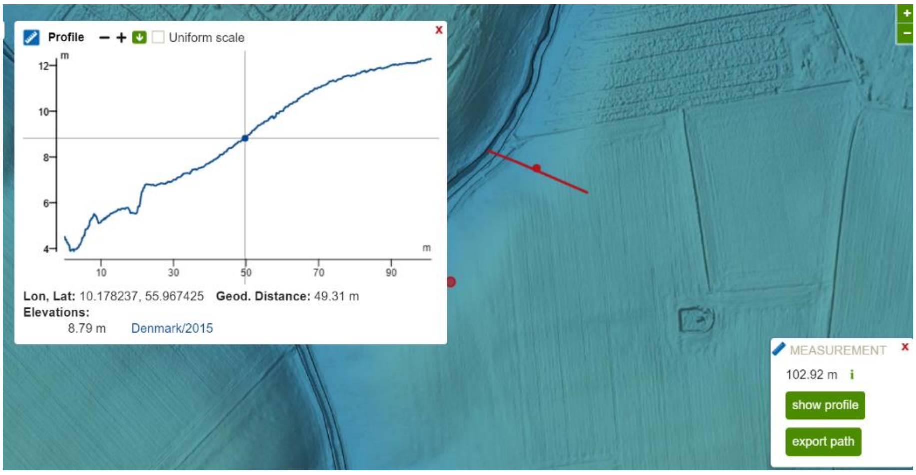
92.69 m

Fig. A- 6. An area with an IBZ in Vills and Mors.



158.64 m

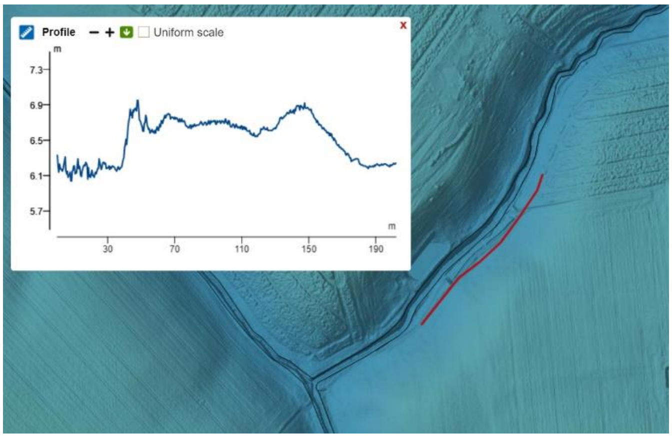
Fig. A- 7. An area with an IBZ in Odder, slope measured upwards from the pipe outlet.



Lon, Lat: 10.178237, 55.967425 **Geod. Distance:** 49.31 m
Elevations:
8.79 m Denmark/2015

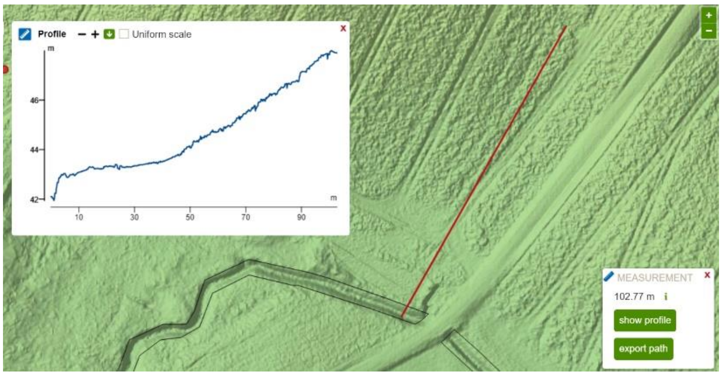
102.92 m

Fig. A,8 Slope measured along the stream on a site with an IBZ near Odder.



a) An area with an existing IBZ in Lillerup, Godveg

Fig. A – 8. Slope at a location where pipe is located at an IBZ site in Lillerup, Godveg.



102.77 m

Fig. A- 9 Slope measured few meters from the pipe outlet on an IBZ site in Lillerup.

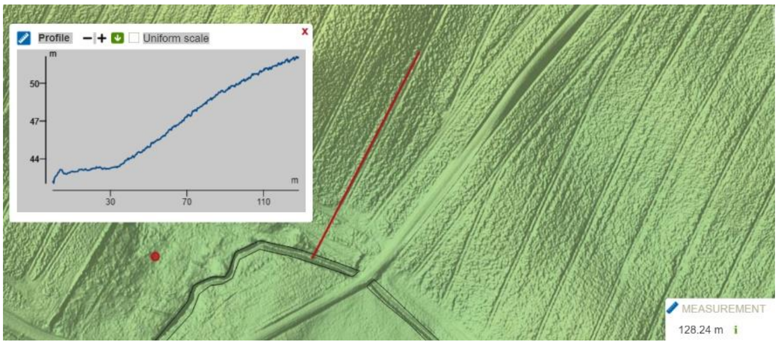


Fig. A-10. Slope measured about 4o m from the pipe outlet on a site in Lillerup

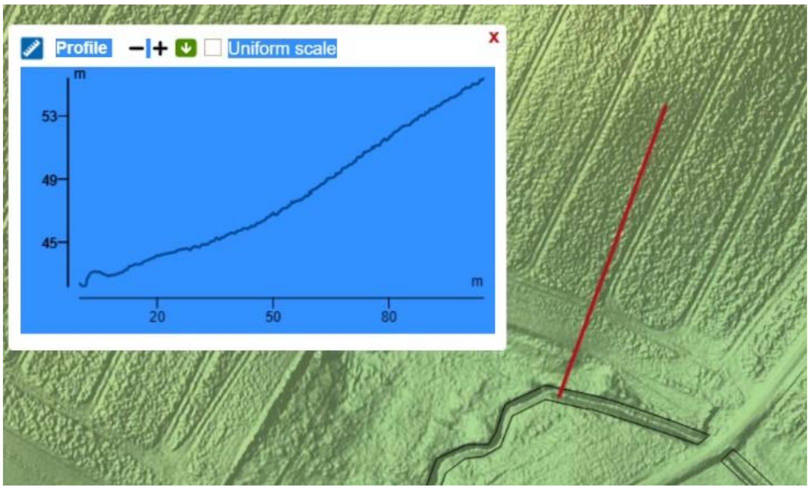
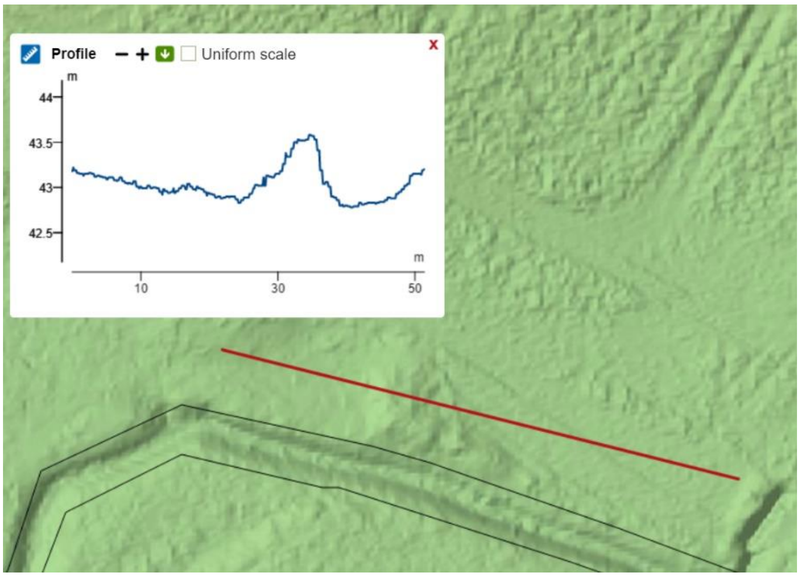


Fig. A- 11 Slope measured along the stream on an IBZ site in Lillerup.



Appendix B: Graphs showing elevation for the visited sites and picures.

Fig. B- 1. Area 1, site 9 slope status poor: main problem backwater risk up to 40 m from the stream.

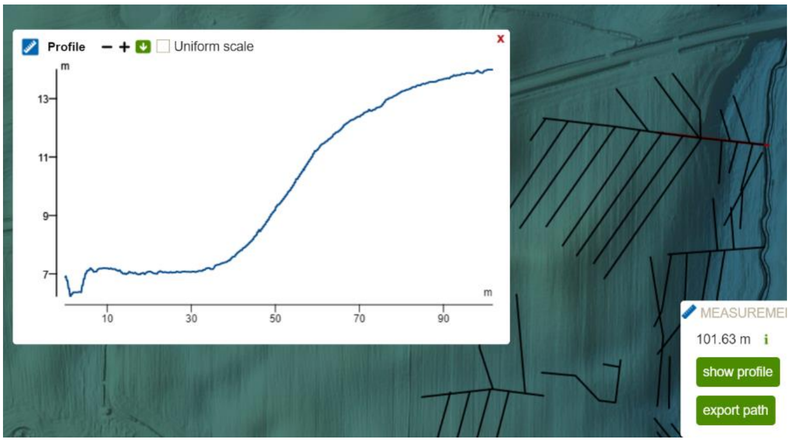


Fig. B-2. A map showing pipe location and terrain use, Area 1, site 9

Fig. B - 3 Pictures from the Area 1, site 9

Fig. B - 4 Area 1, site 11: high status of slope

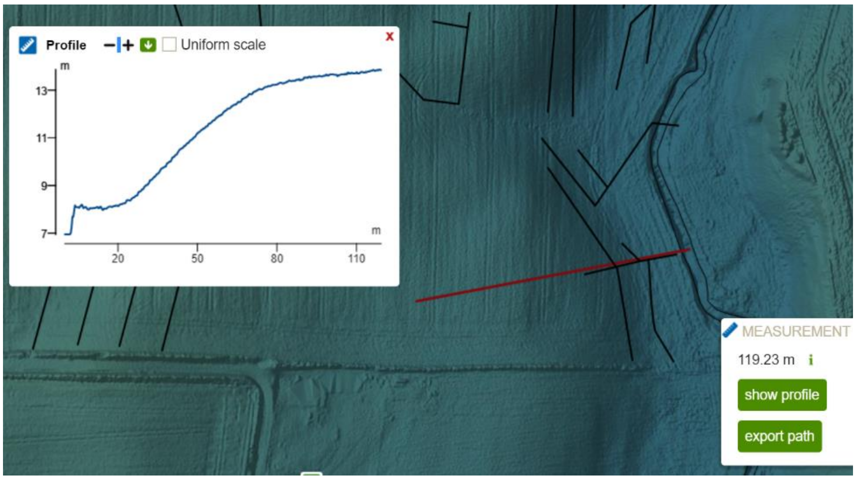


Fig. B- 5. Pipe location and terrain use Area 1, site 11

Fig. B- 6. Slope along the stream, Area 1, site 11-

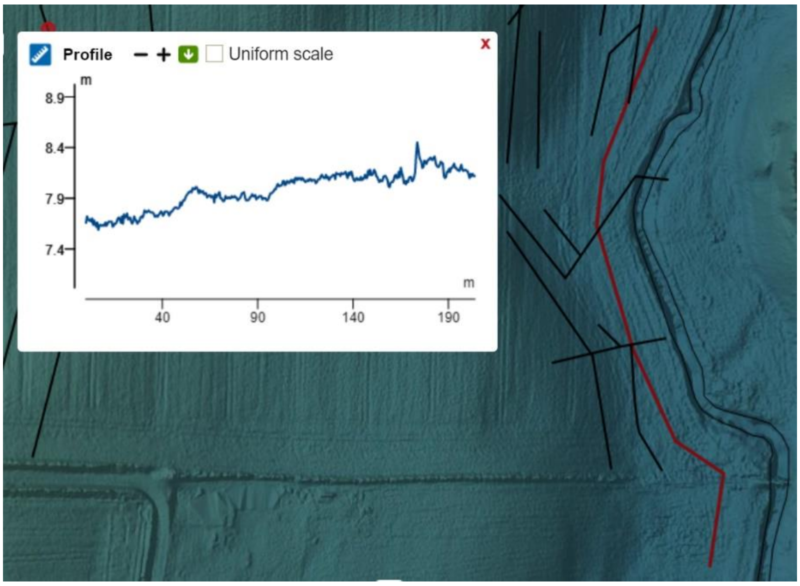


Fig. B- 7 Area 1, site 11.

Fig. B. 8 Area 1, soil samples taken from the 3 sites.

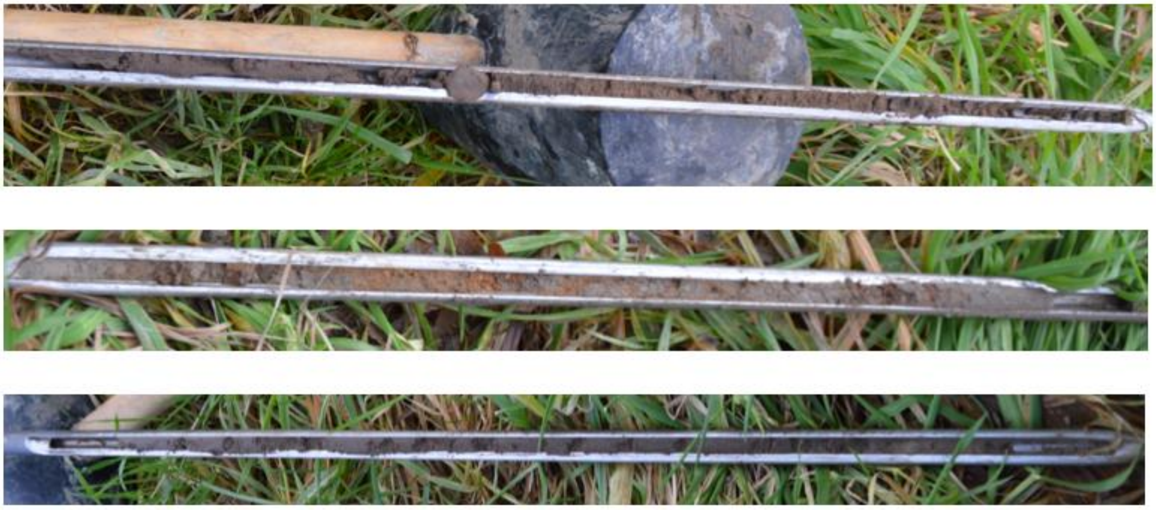
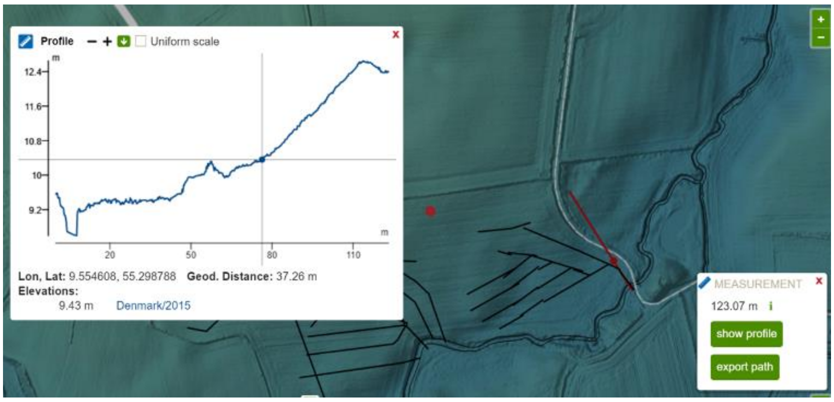


Fig. B- 9. Area 2, site 12 (status poor)



Lon, Lat: 9.554608, 55.298788 **Geod. Distance:** 37.26 m
Elevations:
9.43 m Denmark/2015

MEASUREMENT
123.07 m

Fig. B- 10 Area 2, site 12 (status poor)

Fig.B- 11. Area 2, site 13 (High status)

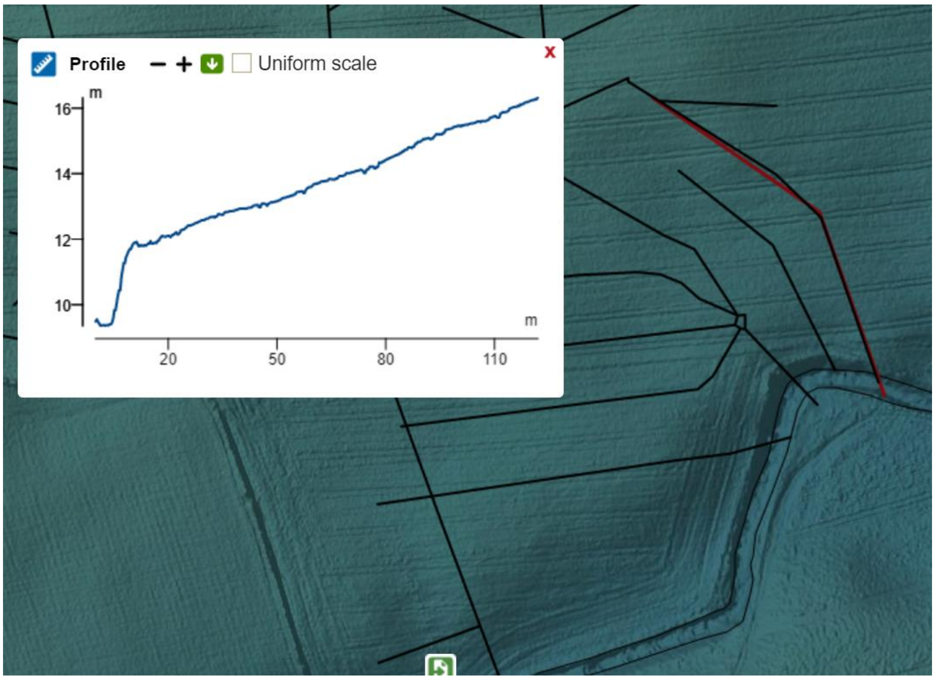
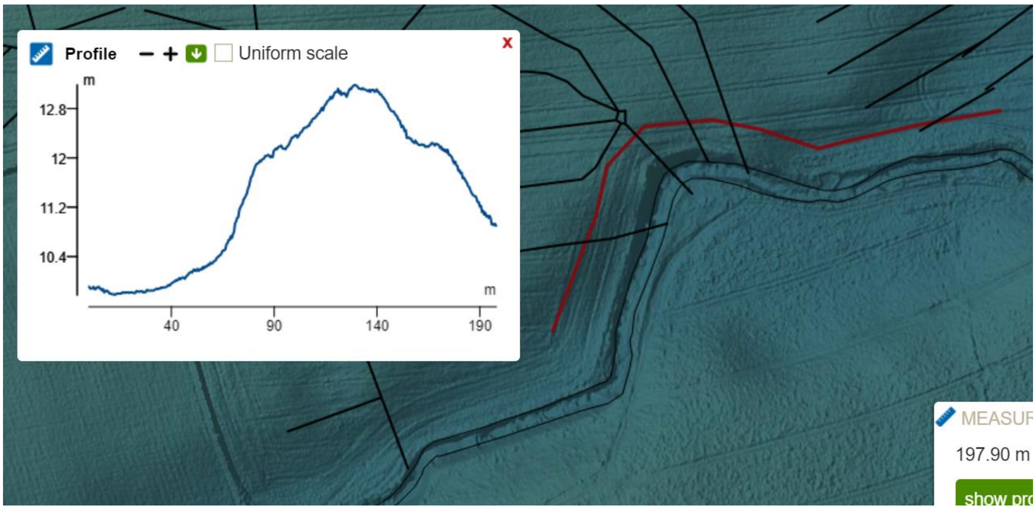


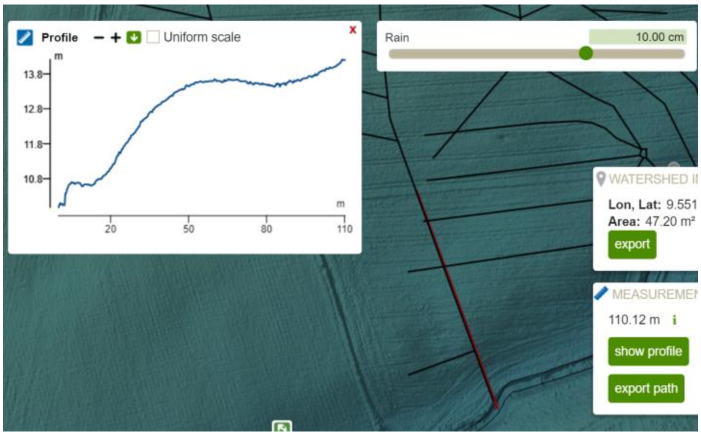
Fig.B- 12. Area 2, site 13 (High status) land use.

Fig.B- 13. Area 2, site 13 (High status)



197.90 m

Fig. B- 14 Area 2, site 14 (medium status)



Rain 10.00 cm

Lon, Lat: 9.551

Area: 47.20 m²

110.12 m

Fig. B- 15 Area 2, site high (higher slope decreasing towards the site 14 (medium status)

Fig. B- 16 pipe outlets found in the Area 2, site 13 and 14.

Fig. B- 17. Soil in the Area 2.

Fig. B- 18 Site 28 Area

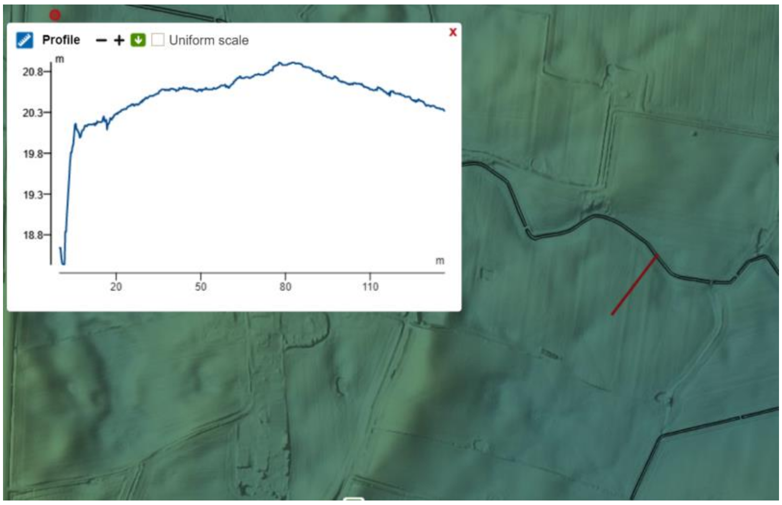


Fig. B- 19, Area 6, site 28

Fig. B 20. Area 6

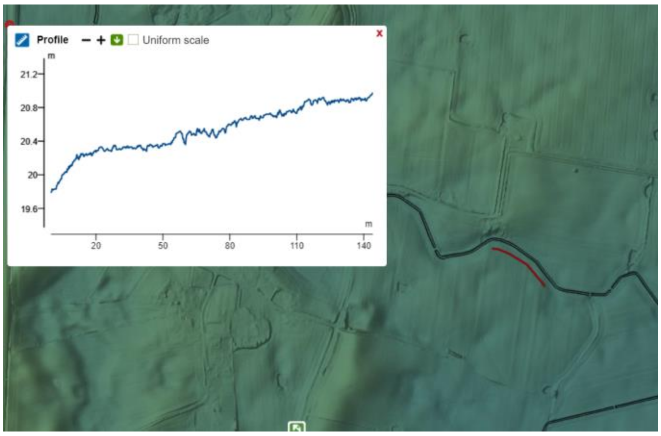


Fig. B 21, Area 6