het Odulphus lyceum

Rainproof

St. Odulphuslyceum

The Netherlands

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Index:

Preface

We chose the subject Rainproof because it is an interesting subject in our opinion. Next to that Bram wants to study something regarding this subject so for him this was a good preparation for his study. Bram already chose this subject and wanted to work it out alone. Toon then joined him later, and this made it possible for us to make a more comprehensive project. We, for example, came up to take a look at the financial aspects then.

It was around that time as well that we heard that there was a possibility for us to go to Tokyo for the Water is Life 2018 conference. This gave us a huge motivational boost. We always wanted to travel abroad, and this seemed like the ultimate opportunity to do that.

We want to thank Mrs. Anita Meertens for helping, supporting and supervising us. It was really helpful what she did for us. Also we want to thank Mrs. Rosa Daamen from the local authority in Tilburg for sending us the blueprints of the school's building. We want to thank Mrs. Yvonne van Nuland for giving us all the possible collaboration to get access to all the detailed data about the school. Finally we want to thank Mr. Ben Evers Zuidweg for helping us with some practical issues and taking us up to the school's roof. This gave us a clear view of the school's roof and what would be possible to do there.

Introduction

It is expected that in the foreseeable future the climate change will lead to a significant increase in rainfall, mostly expected in the shape of heavier rainstorms. This will eventually lead to problems. But how can we prevent those problems? And is it possible to take an economic advantage of this?

Content

In this report we will research the consequences of the climate change and the impact this will have on the current sewage system of Tilburg, our hometown. In addition to that we will create a plan to make our school-building ‘rainproof’. We will research how the sewage system can be adjusted and set up a plan that would economically feasible.

Main question

Our research will be based on our main question: What are the possibilities to make the Odulphuslyceum in Tilburg rainproof, in an economically feasible way?

Sub questions

We hope to find an answer to this question by means of five chapters. These chapters will be based on five sub questions. The first is what the problem of our school concerning the drainage of rainwater is, followed by why the climate change asks for an adjustment concerning the rainwater policy of the Odulphuslyceum. In the third sub question we will work out possible solutions to make buildings, including our school, rainproof. In the final two questions we will go a bit deeper into the economic aspects. Starting with working out in what matter the plans to make our school rainproof are economically feasible and, finally, what the advantages are for the Odulphuslyceum concerning the financial as well as the environmental aspects.

Research

For our research we will start with collecting all the possible solutions for the rainwater problem. We expect that these could be found on the internet or in books, magazines or newspapers. When all the solutions are clear, we will start to make a plan that would suit our school. This means that we will need a lot of data from our school, and then we will need to calculate every option to see what will be the most suitable.

Hypothesis

We expect that there will be many options (that will vary in price strongly) that can be applied to our school building to make it rainproof. We also expect that there will be a decision to be made where the costs and the efficiency will have to be weighed against each other to get to a rainwater policy that is as cost efficient as possible.

Chapter 1. What is our school's problem regarding the drainage of rainwater?

Recent climate changes worldwide

In recent years climate change has been a hot topic for politicians, scientists and the media. Due to this climate change weather phenomena have become more extreme. In north and Saint Eustatius, in Asia massive floods caused by extreme rainfall and poor central America the strongest hurricane ever recorded destroyed the islands of Saint Martin water management tormented the people of Bangladesh, in Africa due to massive air pressure fluctuations and hard wind caused massive waves with a maximum of 17 meters slammed into the South African coast. In March 2015 the driest town in the world Quillagua, where it had not rained for almost 100 years, had to deal with massive rainfall (60 millimetres) which means that every hour 60 litres of water fell per square metre. In Europe heavy rainfalls caused massive floods in Great Britain. The same rainfall that tormented the British Isles also caused problems in The Netherlands. For example, the Noordwaard polder was flooded on purpose to prevent nearby cities from flooding. The answer to the question why the Dutch did not have to deal with massive floods is quite easily explained. Because 26% of The Netherlands lies beneath sea level, protection against water has always been very important for politicians and engineers. Every year the Dutch government invests a lot of money into new sustainable and eco-friendly ways to protect its people from floods. Despite these safety measures the drainage of rainwater will become a problem for the Dutch too.

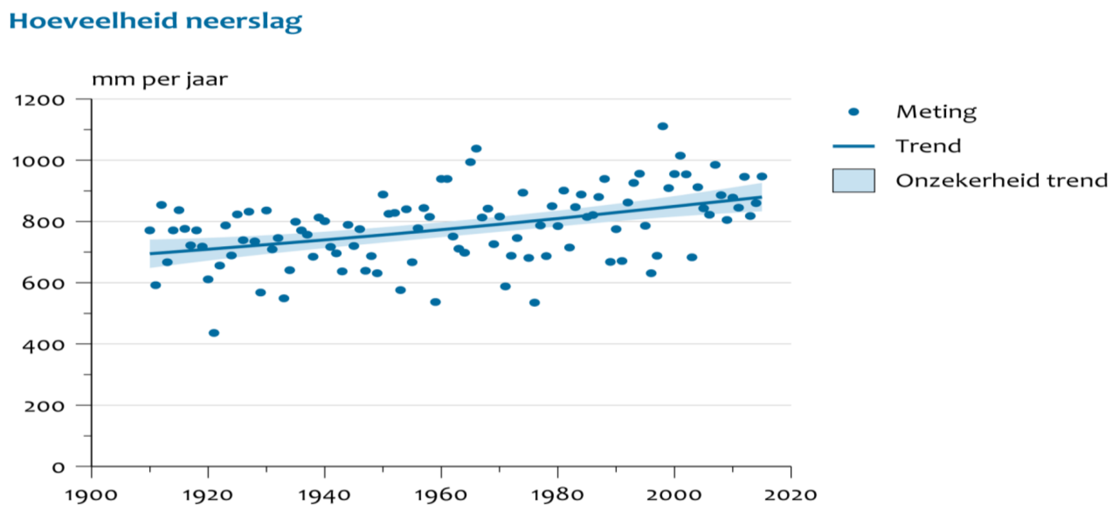
Figure 1: The flooded Noordwaard polder

Recent national changes in climate

The Netherlands is a densely populated country with 504 people living per square kilometre and the Dutch are on place 27 of the world's most densely populated countries. Because of its dense population petrifaction in Dutch cities has become a serious problem. The Dutch population is still growing and to deal with this growth cities and sewer systems have to be expanded, which inevitably means a bigger burdening on the already existing systems. This is not the only problem. Lately Dutch gardens have undergone some changes. Where garden used to consist of a lot of flowerbeds with a lawn in the centre, nowadays they are tiled with some window boxes. The big problem with this transformation is that rainwater does no longer flow into the ground. So every raindrop that falls down on a city will eventually end up in its rainwater sewer. Recent heavy rainfalls have proven that these sewers are no longer able to effectively drain enough rainwater to prevent the streets from flooding.

Figure 2: Traditional Dutch Garden	Figure 3: Modern Dutch garden

Figure 4: Average rainfall table Tilburg 1901-2017



The problem with current Dutch rainwater management

The drainage of rainwater is a national problem in The Netherlands. In order to deal with this problem in Amsterdam, a program called Amsterdam Rainproof was created. Amsterdam Rainproof offers people options to make their house, office or factory rainproof. A rainproof building is a building that uses its rainwater in a way that releases pressure of the sewer system. These options to make buildings rainproof will be given in the next sub-question.

The main problem with our school is the surface. The surface of the entire school premises adds up to a total of 16 000 m^2 . The surface of the main building,

The canteen together with the passage way to the canteen and the P.E. hall, is 2 586,89 m^2. The rainy climate of The Netherlands together with the size of the school ground will cause problems for the people in its surroundings because our school is in a really old part of the city which means that the rainwater sewer system is not designed for the huge amounts of water nowadays. Given this fact the average rainfall per year is 795 mm of rain; this means 795 litters every m^2 . So every year 795 x 2586,89= 2 056 577,55 litres of water have to be drained away. And this is not even half of all the water that is drained every year because the school yard, the parking lot and the areas where students can park their bikes, all have a water resistant pavement which means that literally every raindrop that falls on our school ground will end up in the city's sewer system. This means that every year 795 x 16 000= 12 720 000. The combination of these two facts will cause problems in the near future because the amount of rain will increase and the maximum capacity of the sewer system will stay the same.

Recent photographs of our school are to be found in attachment 3.

Chapter 2. Why does the Odulphuslyceum need an adjustment of the rainwater policy of the due to climate change?

Climate change...

As said before, the climate is changing. The globe is getting warmer because of the huge amounts of carbon dioxide in the atmosphere. Cars and factories are producing loads of carbon dioxide, which is a gas that breaks down the ozone layer. The ozone layer protects the earth from radiation of the sun. When this layer is broken down by all the carbon dioxide, the globe will not be protected as much from the radiation of the sun. One of the consequences is that the temperatures on earth will rise considerably in the future – in fact this has already started.

...leads to problems

This results in many problems, of which we hear in the news almost every day. Think of the melting ice caps of the Arctic and Antarctic. Another consequence of global warming is that the weather will change. It is predicted that in the future it will rain more frequently and in much heavier rain showers in countries at the degree of latitude of The Netherlands, whereas latitudes more to the south will be confronted with a drier climate type. In the Netherlands, the existing sewage systems probably can't handle this increase in precipitation.

Increase in rainfall

There is quite a simple reason for this increase in rainfall: due to the global warming more sea water evaporates this means that the humid air reaching the Netherlands where it collides with cold arctic air and condensation will be a lot more frequent which inevitably means heavier rain falls in the Netherlands and the countries at the same degree of latitude. In 2007, the results of the research of the Intergovernmental Panel on Climate Change (IPCC) were presented in the magazine 'Nature'. They found out that regions close to the oceans will probably have to deal with a sharp rise in rainfall, whereas the regions further inland will get drier. Countries like The Netherlands and England will have to cope with this massive increase of rainfall. The current situation of the sewage systems in these countries is probably too weak to process the showers of the future. This will then cause water troubles.

Change is already visible

The IPCC report was published 10 years ago, and the first signs of these problems have been clearly visible. For example, in 2015 major floods occurred in the southern England. In the Netherlands, the weather has also become more extreme and has got wetter. There hasn't been as much trouble as in England, but flooded streets are quite a common feature. Another sign is the increasing frequency of tornadoes in the Caribbean and the south of the USA. These are also an effect of the climate change.

Regional variations

The IPCC also found out that the degree of latitude is a factor that matters. In areas situated between 40 and 70 degrees northern latitude (this includes the U.K. and The Netherlands) rainfall will increase; countries in the zone between 0 and 30 degrees northern latitude (this includes North-Africa) rainfall will decrease.

The IPCC looked closer at the region in between 40 and 70 degrees northern latitude. In the period from 1925 to 1999 the average rainfall increased by about 46 millimetres. The researchers calculated that 50-85% of this was caused by humanity. After 1999 the increase was even more drastically.

Adjustments

It's clear that the climate is changing and that this will cause great problems in the future. For years now politicians have been debating on how to stop the climate change, but this cannot be stopped so easily. Therefore it might be a better option to be prepared for what the climate change will bring.
One of the foreseeable problems is, as said before, the increase in rainfall. The solution is to make buildings, gardens, and streets rainproof. The rainproof-solutions are described in sub question 3: '*What are possible solutions to make buildings, including our school, rainproof?'*

Odulphuslyceum

The Odulphuslyceum is located in The Netherlands, so it is expected that there will be a lot more rainfall in the future. This will become a problem for the school in the long term. One can already see some small problems with the draining of rainwater. When it has been raining intensely for a long period the school yard is already filled with puddles. At this moment that isn't a big problem, but it is a sign that the sewage system already has some struggles to cope with this amount of rain. If rainy periods are more frequent and heavier in the future, the sewage system will have more problems to drain the water. Then the school buildings will be flooded.

To prevent this, rainproof adjustments would be a good solution. If the drainage system can't handle all the water that has to be drained, not all the water should go through the sewage system.

The water has to be drained in a different way. There are multiple options for that, such as infiltration crates or the rainproof tree construction. The water will then be added to the underground water instead of being led away through the sewage system.

Chapter 3. What are possible solutions to make buildings, including our school, rainproof?

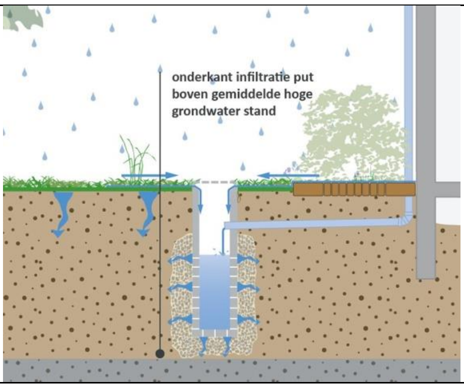
In this sub question fourteen options to make houses or buildings deal with rainwater as efficient as possible are worked out. Subjects like collecting, storing, using and draining of rainwater are taken in to consideration.

In this collage a smal impression of aour school is to be found.

1. Infiltration sinks

An infiltration sink is a long concrete or plastic pipe in the ground that is attached to the rainwater drainage. It is used as a temporary rainwater storage, which evacuates the water slowly to the surface water.
The advantage of an infiltration sink is that it doesn't use space above the ground. They exist in multiple dimensions. They can be meant for a single house but they can also be designed to treat the water from complete house blocks. Another advantage is that through this extra infiltration of rainwater the soil remains healthier. This means that there is less chance for the soil to be damaged. Besides, there is a grid on top of the infiltration sink to make sure that no one falls in.
The disadvantage is that a rainwater infiltration sink has a limited storage space. Although this can be really huge, it may get full in periods of heavy rainfall. Then the water flows directly into the garden (or the schoolyard).

Figure 5: schematic picture of an infiltration well



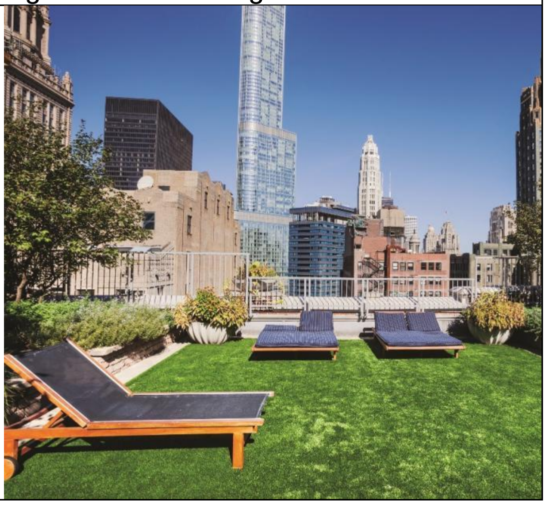
2. Greenroof

A greenroof is a sustainable solution to reduce the pressure on the sewage system during a period of abundant rainfall. Most of the times it's possible to install a greenroof on top of the existing roofing without major adjustments. Greenroofs can be divided in two kinds of greenroofs: intensive greenroofs and extensive greenroofs.

Intensive

An intensive greenroof is more like a roof garden. In terms of maintenance and usage it is quite the same as a normal garden. This means that on an intensive greenroof there may be lawns, shrubs and in some cases even trees. This vegetation is much heavier than the maximal weight most roofs are designed for. Therefore in most cases an adaption of the roof construction is needed. The thickness of the vegetation layer also requires an excellent irrigation system to drain the excess water efficiently and to prevent overloading of the roof.

Figure 6: intensive green roof



Extensive

Extensive greenroofs, that are also called vegetation roofs, are covered with, mostly, moss and succulents. This solution needs less care and in most cases an adaptation of the roof construction is not necessary. Therefore it is usually much cheaper than

an intensive greenroof. This makes that it is more popular than an intensive greenroof. The only necessary adaption is the installation of a layer that is inpenetrable for the roots of plants. Only when in periods of drought some watering is needed.

Figure 7: extensive green roof

Requirements

- For an extensive greenroof, the roof gradient may not exceed 60°. For an intensive greenroof, the roof has to be flat. If the roof is inclined, platforms are required.
- For both types of roofs a good drainage system that is connected to the sewage system or an irrigation system in the garden is required to drain the excess rainwater.
- The construction of the roof has to be strong enough. However the weight varies per type of greenroof the construction has to be strong enough for the type of roof.
- On the roof there must be a layer that is inpenetrable for plant roots. This is to prevent that the roots grow into the existing roofing.
- Further requirements are in the table below.

Feature	Extensive	Intensive
Vegetation	Sedum, grass, herbs	Grass, ornamental bushes, trees
Height	<15 cm	25-100 cm
Irrigation	Mostly not	Always required
Weight	50-150 kg/m²	250-1000 kg/m²
Treadability	Limited	Yes
Water buffer	4-12 mm	18-39 mm
Bearing capacity roof	Mostly satisfying	Requires extra strong construction
Care	Very little	Comparable with regular gardens
Roof gradient	Maximum 60°	Flat or on terraces

Costs

Type of roof	Costs per m^2 (everything included)
Extensive greenroof	€ 45 - € 100
Intensive greenroof	€ 120 - € 200
New inpenetrable layer (if the original is aging or not present)	€ 40 - € 50

Community and environment

Not only the owner of a greenroof benefits from it. The whole community takes advantage. A greenroof absorbs more water than a regular roof and this causes a serious decline in pressure on the sewage system during a period of rainfall. Besides, like every other plant, the plants extract CO_2 from the air and by their photosynthesis process, they turn it into oxygen. This results in a reduction of air pollution in the city. This is the reason why most of the municipalities provide subsidies for the installation of greenroofs.

3. Waterroof

The differences between a waterroof and a greenroof are rather small. A waterroof also holds the water, and this means that it also reduces the pressure on the sewage system. The only difference is that a waterroof does not purify the air due to the lack of plants. That is why people living in cities mainly tend to choose for a greenroof. On the other side, a waterroof can collect water that can be used for example for flushing toilets or watering gardens. Given the fact that an average Dutchman uses about 135 litres of drinking water per day, of which at least 50% is used for purposes that don't require drinking water quality and for which rainwater would do just as well, it is a waste not to use the rainwater. So when the rainwater is used wisely, the waste of drinking water can be reduced a lot, and again the environment will benefit from this.

Types of waterroofs

Just like the greenroofs, there are two types of waterroofs: the permanent waterroof and the temporary waterroof. The major difference is the amount of water that they can buffer. A permanent waterroof can contain about 70 cm of water per m^2 (700 kg/m^2), whilst a temporary waterroof can only buffer about 20 cm of water per m^2 (200 kg/m^2).

Permanent waterroof

Permanent waterroofs are only suitable for new construction projects. There is a choice between open or closed permanent waterroofs. An open permanent waterroof means that there is an open water reservoir on top of the roof. A closed waterroof leaves two choices: water storage with either plastic cassettes (Water shell) or plastic crates (Permavoid Roofsystem). These can be placed under a pavement or a lawn, to prevent that rain boots are necessary.

The other option, an open permanent waterroof, is a flat roof with water on top.

Figure 8: a open and closed permanent water roof

Temporary waterroof

This application is possible on both existing and new buildings because the roof construction is not charged heavily. This is because of the smaller amount of water that is stored. Therefore, in most cases is will not be necessary to adapt the roof construction.

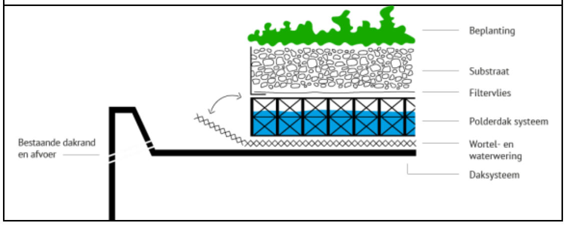
Advantages of a waterroof are:

1. A saving in drinking water costs.
2. The peak pressure on the sewage system decreases. If implemented on a large scale, this means that water troubles can be prevented in the cities.
3. A decrease in usage of groundwater because the water on the roof can be used for garden watering or toilet flushing.
4. Extra isolation of the roof.
5. In most municipalities there is a subsidy available that reimburses the installation costs (partly).

4. Polderroof

A ‘Polderdak’ (polder roof) is a roof garden that, at the same time, works as water storage. The difference between a polder roof and a permanent waterroof is the dike on the edge of a polder roof. In this dike there are integrated locks that are opened and closed from a central control centre. In this way the amount of rainwater that is evacuated to the sewage system can be controlled, in case there are more polder roofs in a district. During periods of abundant rainfall, the rain water will be led to the sewage system in controlled small quantities. Even though there is water being led to the sewer, it will be way less than when there were no polder roofs. A polder roof significantly reduces the risks of water troubles.

Figure 9: schematic image of a polder roof



The dike displayed above exists of a thin plastic layer that is inpenetrable for water or roots, with valves that can be opened or closed.

5. Rainwater utilisation system

As the name already suggests, a rainwater utilisation system offers the possibility to use the collected rainwater indoors.

This kind of installation consists of a reservoir for rainwater retention (a cistern in the garden or a bag in the basement of the house), a pump that generates enough pressure to bring the water up to the tap points, connections to the tap points, an overflow to evacuate excess water and a suppletion facility.

Suppletion means filling the cistern with drinking water in case of long drought or excessive use. In fact it is nice that the toilet can still be flushed after a month without rain. The second reason why suppletion is essential is the fact that the sediment may not shrink through evaporation, because once the cistern will fill again, the water will be polluted by the shrunken sediment, which will mix with the water and will not sink to the bottom.

The suppletion with drinking water can easily be controlled by a float switch. As soon as the water level falls below the float switch, the tap will open. When the water level has risen again to the float switch level, the tap will close. If the float switch is set to the volume of drinking water needed for one day, wasting is minimized.

Figure 10: water bag

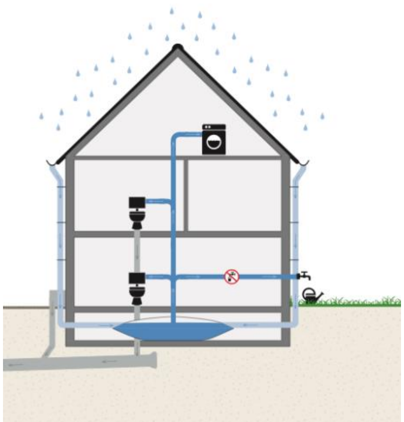
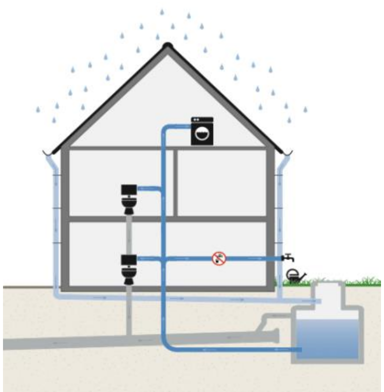


Figure: 11: water tank



If the installation is optimally adjusted to the volume used and the amount of rain fall, the use of water of minor quality – such as for toilet flushing, washing machine and garden watering - can nearly totally be replaced by rain water. However it may happen, during a long period of absence or for any other reason that the cistern fills up completely. Any excess water will then be evacuated to a natural buffer like a pond or, if the soil is appropriate for this purpose, will be infiltrated. When both these options are not possible, the excess water will be evacuated into the sewage system

Water tank

The water tank functions as a buffer, similar to a water bag. The consumer has the choice between a water tank made of plastic or concrete. In most cases the choice depends on the size of the tank and the available space.

The advantage of concrete reservoirs is their durability, which means they can withstand high water pressure. They also have a rough texture which allows micro-organisms to settle on the edges of the tank. The great advantage of micro-organisms is that they break down small polluting particles and by doing so, they cleanse the water. Considering the weight of these reservoirs, there must be sufficient space for a crane to deliver the tank.

If there is less space, usually smaller plastic reservoirs are used. This is because they are easier to put in place because of their lighter weight. In some cases they can be put in the crawl-spaces of buildings - provided that they are not too large, because they have to fit through doors and hatches. When these smaller tanks are connected in the crawl-space a big enough water buffer can be created.

Figure 12: Water tank

Water bag

Most Dutch houses do not have a cellar, but many do have a crawl-space. As water tanks are not practical for such small spaces. Therefore a plastic water bag was designed for crawl spaces. To keep pumps and other technical equipment accessible, these are placed in a water tight shaft inside the house. The bags are made of a flexible but very strong plastic to make sure they will not leak.

Maintenance

These installations require very little maintenance. Except for the regular controls of the water filter, the tank only has to be cleaned once very ten years.

A rule of thumb that can be used for the fine-tuning of this particular system would be:

5 m^3 of reservoir for every 100 m^2 roof surface.

6. Grass-concrete pavement stones and water-passing pavement

These are options that make the infiltration of rain water into the soil possible, even if the ground is paved.

Grass-concrete pavement stones

These paving stones are often laid in honeycomb structures. The gaps are filled with grass. These pavements are ideal for yards and driveways because they make a solid underground and have a cosy look. However, they may not be suited for a schoolyard because the grass has to be mowed and this causes extra work for the school caretakers.

Figure 13: Grass concrete pavement stones

Water passing pavement

Water passing pavement would be an excellent solution to be put in use in streets and squares because it requires no maintenance. The bigger gaps between the bricks are filled with gravel which allows water to seep through and prevents weeds from growing. This reduces the street's effluent to the city sewer system

Figure 14: Water passing pavement

7. Covered gutter

A covered gutter is just like the name suggests a gutter covered with a grid. A covered gutter is ideal for school yards especially when combined with a water passing pavement. Every drop of water that cannot seep through the pavement will end up in one of these gutters. Once in the gutter, the water will be transported to a pond, wadi or the sewer system. Anyway it allows the water to leave school yard easily. Because the gutter is covered with a grid or tiles, the risk of blockages inside the gutters is reduced.

Figure 15: Wadi

Figure 16: Covered gutter

8. Rainwater fence

A rain water fence replaces the old fence. It consists of stacked plastic containers that collect and store rainwater. Subsequently this rainwater can be put to use in many different ways. For instance, a tap can be made in the fence, which allows for lawn watering. A fence can also have integrated plant boxes, which can directly be watered with fence water. These fences are less suited to be attached to toilets or laundry machines because of their exposure to sunlight. This increases the risk of contamination. For rainwater to be used indoors, an underground water reservoir has to be used. Because this prevents daylight from contaminating the water and keeps temperature variations as low as possible.

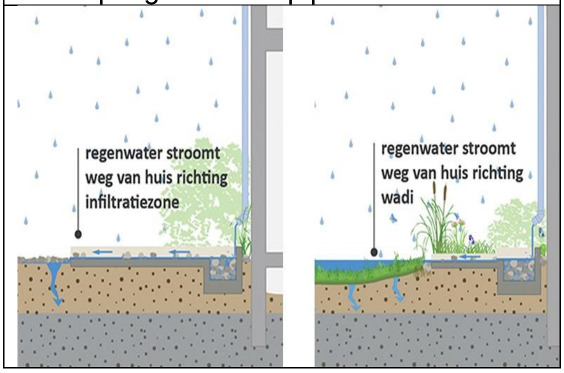
Figure 16: Section rainwater fence

9. Disconnecting the downpipe

Rainwater pipes can be disconnected from the sewer system. The major advantage is that the sewer system is relieved. Most sewer systems in the Netherlands are mixed sewers: rainwater and household wastewater (toilet, shower etc.) are drained through the same sewer pipe. The disadvantage this brings along is that the relatively clean rainwater is not optimally used. Rainwater is appropriate to be discharged to the surface water. This is the reason why downpipes can well be disconnected from the sewer system.

However, the downpipe should be led away from the building to prevent water troubles like leaks and such. The rainwater should be led to a 'green' area or the disconnection of the downpipe should be combined with one of the other rainproof-solutions. This could be a rain barrel, a rainwater pond, a ditch/wade, infiltration crates/-fence, an open gutter, a connection to a ditch or using the rainwater indoors.

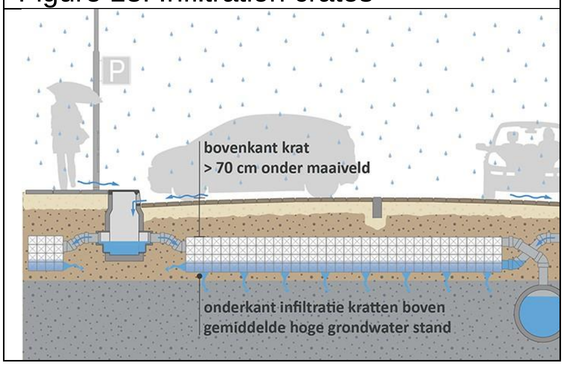
Figure 17: Two possible solutions for uncoupling the downpipe



10. Infiltration crates

Infiltration crates have a very ingenious design. They are made from plastic with a geotextile wrapped around it to make sure dirt won't get into it. This way they will not get blocked and after installation maintenance is barely necessary. One big advantage of infiltration crates is that they do not take any space above ground. The purpose of infiltration crates is to infiltrate the water in the ground gradually. Underground infiltration crates have a much larger storage capacity than aboveground infiltration facilities.
At our school, a system with infiltration crates could look like this: first, rain falls down on the schoolyard. It is discharged from the surface via the drains (just like in the current situation), but instead of leading it into the sewer system, it is led into the infiltration crates underneath the schoolyard. These crates slowly discharge the rain water to the surface water.

Figure 18: Infiltration crates



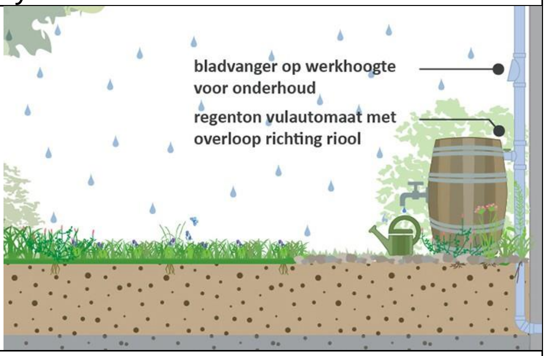
11. Rain barrel

The rain barrel is probably the best known solution concerning Rainproof. This is mainly because this is the most visible solution. It is a barrel in which the water is stored that comes from for example the downpipe. A tap can be attached to the barrel, to use the rain water. Rain water is excellent for example for watering plants. Another big advantage is that a rain barrel is really easy to install. Other solutions often require major alterations to a building, but a rain barrel can be installed within an hour. Furthermore, a rain barrel is a really cheap option. It is often the first rainproof adaption that companies or private individuals make because of the low costs.

Although, a rain barrel has a few downsides. First of all it takes much space and often they are not the most beautiful asset in the garden. Besides, a rain barrel has a limited storage capacity. After heavy showers it may reach its limit and overflow. This problem may be solved by combining the rain barrel to another rainproof-adaption. The rain water overflow can be redirected into the downpipe to be discharged to the sewer system. The downpipe may also lead it to - for example - infiltration crates.

Another point is that the water in a rain barrel freezes easily. This might damage a wooden rain barrel. This can be prevented by installing a plastic rain barrel but these are often less charming than a wooden one.

Figure 19: Possible downpipe-sewage system combination



Rainproof.nl

12. Rainproof tree-construction

The rainproof tree-construction is really simple: trees (and the small green patch that is usually around the tree) hold the water. The tree consumes it and the rest will infiltrate into the soil. This is the reason why there are far less water problems in areas with many trees. The idea of the rainproof tree-construction is that water will be led to a tree. This may be realised by an open gutter or via a downpipe that leads to the tree. The water infiltrates into the soil around the tree. Here, the roots of the tree will soak up all the water that the tree needs. The rest of the water will be discharged to the surface water.

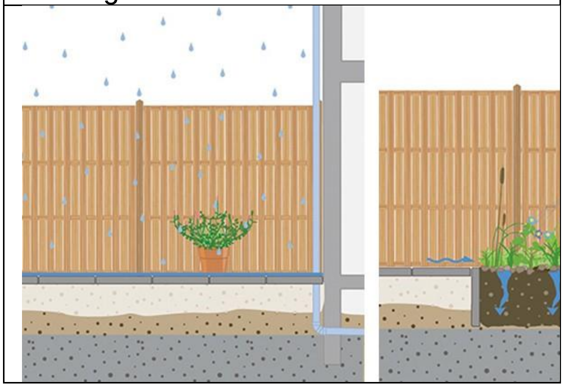
Figure 20: An open gutter leading to a tree

13. Greener schoolyard

The idea of a greener schoolyard is that there would be more green in the schoolyard. Actually, the Odulphuslyceum school yard consists for the biggest part of pavement. Rainwater cannot pass this pavement and therefore it is being led away through drains. It ends up in the sewer system. That is precisely what should be prevented. The solution would be to add more plants the schoolyard. This can be done by making a lawn, which could have a practical use, or by making planted borders. In both cases the advantage is that the rainwater can infiltrate directly into the soil and this way it will replenish the surface water.

Often schools prefer paved school yards because this would not require so much maintenance. However, pavement has to be swept and the weeds have to be removed. Some grass species have to be mowed only twice a year, so vegetation does not imply more maintenance. Moreover, vegetation reduces water problems, lowers temperatures during the summer, makes the soil healthier and results in better air quality.

Figure 21: A paved garden vs. a garden with a green area



Chapter 4. In what ways are the plans to make our school rainproof economically achievable?

In the previous sub questions the problem and the possible solutions have been explained. In this sub question the best financial option to make our school as rainproof as possible is explained.

The cost per solution

1. Infiltration wells:

An infiltration well is quite a good option to use at our school. The cost price is quite low, € 111,95 per unit. If these wells were to be used in 50% of the already existing well holes this would cut down the rainwater drainage of the schoolyard by 50% and the total cost would come down to 25 units which equals 25 x 111,95= € 2 798,75.

2. Greenroof:

In the case of our school we would choose for an extensive greenroof, due to the fact that the building is very old and the roof construction is not strong enough for an intensive greenroof. The cost of a greenroof will be partially subsidised by the municipality Tilburg. This subsidy is in Tilburg 50% of the total acquisition with a maximum of €25,- per m^2. The total amount of subsidy that is available is €25.000,-, which would mean that 1000 m^2 could be placed with subsidy. Considering that the costs of a greenroof of 1000 m^2 are about €117.500,-, the school would still need to fund €92.500,- itself.

3. Waterroof:

For the rest of the roof surface we would want to install a temporary waterroof, which is not subsidised but as the costs are a lot lower than the costs of a greenroof on average € 15,- per m^2, this would come down to a total of 15 x 1 587= € 23 805,-.

4. Polder roof:

A Polder roof is not an option because it is simply too heavy for our school's roof construction.

5. Rainwater utilisation system:

A rainwater utilisation system is too advanced and would be really difficult to install in an old building like the Odulphuslyceum. Moreover, the Dutch law dictates that the maximal capacity of a water tank cannot be more than 1000 m^3 and this would not be enough to support the water consumption of half our school. Therefore it would take too long to earn back the investment.

6. Waterpassing pavement

Installing waterpassing pavement is an interesting option. However, to repave the entire schoolyard right now would be too expensive. However, when the existing pavement needs to be replaced because it has become too old, waterpassing pavement would be ideal. For instance, it is as expensive as the current pavement and it would reduce the quantity of rainwater ending up in the sewer by 40% given the fact that half of the wells would be infiltration wells 50% of the 60% would be infiltrated too. In fact this pavement in combination with infiltration wells would reduce the amount of rainwater ending up in the sewer to 30% of what it used to be.

7. Covered gutters:

Covered gutters are not necessary because they would have no use. The schoolyard is designed to guide the water to the wells, therefore gutters are unnecessary.

8. Rainwater palisade

This option is not possible because there is no existing palisade and it would be a waste of money to place a palisade.

9. Disconnecting rain pipe

Disconnecting a rain pipe is costless which makes it a useful option to get rid of rainwater still coming from the roof.

10. Infiltration crates

Infiltration crates are too expensive the cost of the crates alone is € 250,- per unit. One unit is 1 m^2 and infiltration crates are not subsidised. This makes it too expensive to be used at our school.

11. Rain barrel

Rain barrels are not effective enough plus they do not look well in combination with our schoolbuilding. And at over €200,- a piece and over 30 rainpipes it is way to expensive.

12. Rainproof tree construction

A rainproof tree construction is costless and would be useful to be used when the existing pavement were to be relayed to form a gutter from the closest disconnected rain pipe to one of the three trees on our schoolyard.

13. Greener schoolyard

Although this might seem an easy and cheap idea, it is not practical at all because it needs a lot of maintenance and there is not enough space to make it in a way that it does not collide with the other activities that take place in the schoolyard, for instance, you cannot park your bicycle in the bushes.

Chapter 5. What advantages are there for the Odulphuslyceum concerning the financial as well as the environmental aspect?

These changes to make the school rainproof sound really good of course. But they are all quiet hypothetical. To see if it would make sense to strive for these changes, it should be attractive for the school to append these changes. It could be attractive for the school because of the environmental aspect but in today's society everyone's focus is really capitalistic. So the financial aspect should be concerned just as much. Just not many people or companies will be convinced just by the environmental advantages. That is why we will look further into all the advantages in this chapter.

The installation of a greenroof will save the school quite a bit. Greenroofs isolate better than normal roofs. This would mean that the school would not have to heat the building as much or cool it as much when it is warm outside. This would save the school money and next to that, having to heat the building is bad for the environment and that would be indulged with the installation of a greenroof.
In the summer there's also less need for air-conditioning. Where temperatures could up to 70°C with an ordinary flat roof, a greenroof will ensure that the temperature will not get past approximately 37°C.
This was all tested on an office. This would use around 1250 MJ (mega joules) per m^2 of energy each year without adaptions. Heating the area would contain 39% of the total energy charge. The cooling of the area through air-conditioning would be another 4% of the total energy charge. This would be 538MJ each year. That means that the installation of a greenroof will save an office around 150MJ per m^2 per year. Since the prices are around 63 cents per m^3, that would save around 3 euro's per m^2.The energy charge of the Odulphuslyceum is calculated at €64.377,-. The surface of the school contains 2586,89 m^2. That would mean that the school could save around €7.760,67 per year with the installation of a greenroof.
In addition to that, it is possible in our city to get subsidy for a greenroof. The installation of greenroofs is something that the local authority supports. Therefore they will give you a subsidy. This subsidy is in Tilburg 50% of the total acquisition with a maximum of €25,- per m^2. The total amount of subsidy that is available is €25.000,-. That would mean that 1000 m^2 could be placed with subsidy. Considering that the costs of a greenroof are about €117.500,-, the school would still need to come up with €92.500,- itself.

Figure 21: A really famous greenroof, on top of the library of Delft's University.

Greenroofs will also improve the auditive isolation. This is not necessarily a financial or environmental advantage for the school but it is another advantage that could play a part in the decision.
These advantages will also apply on a waterroof.

The one advantage that they all have in common is that in the end, less water will flow to the sewage system. This is eventually the goal of the project and in our city this will only have environmental advantages. These are, of course, that the sewage system would be indulged. This will prevent us from water trouble in the future. Next to that, clean and valuable water is wasted when the rainwater is led directly to the sewage system.
Some cities provide sewer taxes split up in two parts. A fixed and a variable part. The variable part is based on how much water a company or household drain in the sewage system. If this would be decreased by implementing some of the changes, it could save money. The local authority in Tilburg does only provide fixed sewer taxes. That means that the school pays a fixed amount of sewer tax each year and that it would not make a difference if less water would be drained in the sewage system.
This would be the case when a waterpassing pavement would be installed.

All the other solutions we didn't find suitable for our school. Most of them would cost way too much for the impact that they would have. A rain barrel for example, is not that expensive but since the school is really big, one barrel would not make a real difference. When the school would have to purchase as much rain barrels that it would have impact, the costs would end up really high again.
Next to that the other solutions do not really have a financial advantage for the school. One effect that applies to all of them is that the school would drain less rainwater to the sewage system but as said above that does not give the school any financial advantage. They also do not have any side effects like the greenroof and the waterroof have. They do not bring extra isolation or anything with them that would earn the school money.
They would only cost the school money and the savings on other costs would be minimal. Therefore it would not be profitable for the school.

Conclusion

Our main question was: What are the possibilities to make the Odulphuslyceum rainproof, in an economical achievable way?
The answer to this is by adding a green roof and a temporary waterroof on top of the Odulphuslyceum this will decrease the amount of water going from the roof into the sewer system by 50%. Another improvement that can be made is the usage a water passing pavement in the schoolyard and parking lots. This will decrease the water flow into the sewer system by 90% in these areas.

In order to be able to conclude this we used five sub questions. And answering these questions made us able to answer our main research question.

Our hypothesis was that there would be a lot of options strongly varying in price. This thesis was right. There were a lot of options all varying in price and effectiveness as explained in sub question three. The second thesis statement made was that we thought choices had to be made to make it also financially achievable to make the school rainproof, and in the end we ended up making choices. Otherwise it would have been way too expensive.

Sources

'Klimaat: Tilburg', Climate Data, https://nl.climate-data.org/location/5854/, Geraadpleegd op: 20 september 2017

'Onder waterniveau maar de vraag is nog even welk water', de Volkskrant, https://www.volkskrant.nl/wetenschap/onder-waterniveau-maar-de-vraag-is-nog-even-welk-water~a979214/*, Geraadpleegd op: 22 september 2017*

'Nederland telt 17 miljoen inwoners', CBS, https://www.cbs.nl/nl-nl/nieuws/2016/12/nederland-telt-17-miljoen-inwoners *, Geraadpleegd op: 2 november 2017*

'Klimaatverandering en regenval', Nemo Kennislink, https://www.nemokennislink.nl/publicaties/klimaatverandering-en-regenval/*, Geraadpleegd op: 2 november 2017*

Amsterdam Rainproof, https://www.rainproof.nl/*, Geraadpleegd op: verscheidene data*

'Types groendaken', Green Urbanscape, http://www.green-urbanscape.com/nl/content/types-groendaken*, Geraadpleegd op: 15 januari 2018*

'Groendak', Dakdekker Weetjes, https://www.dakdekker-weetjes.nl/dakbedekking/groendak/*, Geraadpleegd op: 15 januari 2018*

ATTACHMENT 1: FOTO REPORT

In the next photo report we will give an overview of the current situation at school. It starts with an overview of the school's roof. After that there are a few photos of the parking lots and the current drainpipes and wells at school.








attachment 2:

Schematic map of the school.