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Assessment of water footprint for civil construction projects

Analys av vattenavtryck i anläggningsprojekt

Katarina Wärmark

ABSTRACT

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Water is an irreplaceable resource and the strain on it is getting tougher. Around 40 per cent of the water withdrawn in Europe is for industrial use. With a growing population and an increased demand for food and energy per capita, the demand and pressure on our water resources will increase.

CEEQUAL is a rating scheme for the civil construction industry and has raised the water footprint as an important sustainability issue to consider when choosing building materials. There is however little knowledge within the industry of how to do this. This paper offers information regarding available water footprint tools and gives a practical example using two of the most developed methods; the Water Footprint Network (WFN) method and Life Cycle Analysis (LCA).

The case study showed that the results are very dependent on which method one chooses. The LCA method gives a bigger footprint since it is more inclusive than the WFN method. There are however some similarities when looking at which of the materials that are high-risk and low-risk materials when it comes to freshwater footprint. Among the studied products, steel was the material that uses and consumes the most water per kilogram, and could also be imported from water scarce areas. Fill material had a low water consumption and use per kilogram, but the huge amount used in the project makes it the material that used and consumed most water in total. Fill material is most often produced locally because of the large amount used, and was therefore not as significant when weighting the results by a water stress index.

Calculating a water footprint can be used as a part of declaring the environmental performance of a project by including it in an Environmental Product Declaration (EPD), a sustainability report or by setting up an Environmental Profit and Loss (E P&L) account for water. It can also be used to identify and assess risks related to water use.

Keywords: Water Footprint, Water Footprint Network, Life Cycle Analysis, Civil Construction, CEEQUAL, Water Consumption, Water Use

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REFERAT

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Färskvatten är en begränsad, men förnybar resurs som på grund av sina unika egenskaper saknar substitut i många processer och användningsområden. Resursen är ojämnt fördelad över världen och många lever idag i vattenstressade regioner. I Europa står industrisektorn för cirka 40 procent av det totala vattenuttaget. Med en växande befolkning och ökad efterfrågan på mat och energi per capita kommer konkurrensen om vattenresurserna att bli hårdare. Vi måste därför anpassa oss efter denna verklighet och framtid och börja använda våra färskvattenresurser mer effektivt.

Certifieringssystemet CEEQUAL har lyft vattenavtryck för byggprodukter som en viktig fråga vid val av material. Inom branschen vet man i dagsläget inte hur man ska hantera den frågan och utgångspunkten för denna rapport är att ge vägledning bland de metoder som finns tillgängliga idag samt att ge ett praktiskt exempel på två av de mest utvecklade metoderna, Water Footprint Network (WFN) metoden och livscykelanalys (LCA).

Som ett praktiskt exempel utfördes en fallstudie som visade att resultatet av en vattenavtrycksanalys beror väldigt mycket på vilken metod som väljs, vilket innebär att harmonisering inom branschen är viktigt. LCA-metoden ger ett större avtryck än WFN-metoden då metoden inkluderar fler typer av vattenanvändning. Av de studerade materialen visade sig stål vara det som både använder och förbrukar mest vatten per kilogram. Det är också ett material som i betydande grad importeras från regioner som kan vara vattenstressade. Fyllnadsmaterial var ett av materialen med lägst vattenavtryck per kilogram, men då det används i så stora mängder i anläggningsprojekt är det detta material som bidrar med störst totalt vattenavtryck. På grund av den stora mängd som används utvinns fyllnadsmaterial dock oftast lokalt. Detta gör att vattenavtryckets signifikans minskar när det viktas med ett vattenstressindex, då det generellt finns gott om vatten i Sverige.

Vattenavtryck kan användas till deklaration av potentiell påverkan på vattenresurser genom att inkludera resultatet i en miljövarudeklaration eller hållbarhetsrapport. Det kan även användas i ett naturkapitalkonto (E P&L) för vatten eller för att identifiera risker kopplade till vattenanvändning samt ge vägledning vid materialval och val av leverantör.

Nyckelord: Vattenavtryck, Vattenfotavtryck, Water Footprint Network, livscykelanalys, anläggning, CEEQUAL, vattenanvändning, vattenkonsumtion

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POPULÄRVETENSKAPLIG SAMMANFATTNING

Analys av vattenavtryck i anläggningsprojekt

Katarina Wärmark

Anläggningsbranschen bygger objekt som vägar, järnvägar, vattenledningar, kraftnät och byggnader för fysisk aktivitet. I dagsläget bygger man väldigt mycket, och det är stora mängder material som krävs för dessa ändamål. Det är därför viktigt att man gör detta på ett sätt som inte innebär för stor påfrestning på miljön, att man bygger hållbart. CEEQUAL är ett system som genom betygssättning bedömer hur hållbara projekt inom anläggningsbranschen är. I CEEQUAL-systemet tittar man på många olika aspekter, och hushållning med vatten är en av de viktiga aspekterna som tas upp.

Vatten är en otroligt viktig resurs för oss människor och allt liv på denna jord. Vi använder vatten till många aktiviteter, till exempel till att laga mat och sköta vår hygien i hushållen, som bevattning inom jordbruket och till tvättning och kylning inom industrin. I Sverige har vi i allmänhet gott om vatten, men så ser det inte ut överallt i världen. På vissa ställen är det hård konkurrens mellan olika användningsområden och vissa kanske till och med blir utan vatten.

I Europa står industrin för lite mindre än hälften av det totala vattenuttaget. I och med att vi blir fler på jorden och vår levnadsstandard ökar, tror man att detta upptag kommer att bli större. Med ökad handel har det blivit lättare och framförallt billigare att köpa produkter från andra sidan jorden. Detta betyder att produkterna du använder kan vara tillverkade på en plats där vattentillgången inte är lika god som i Sverige. För att se till att vi inte bidrar till ett ohållbart uttag av vatten är det därför viktigt att kunna bedöma vilken påverkan produkter kan ha på vattentillgången där de är producerade.

Detta är såklart väldigt svårt, men med verktyget vattenavtryck, eller ”water footprint” som det även kallas, kan man få ett grovt mått på vilka produkter som kan bidra till ökad vattenstress för människor som lever i områden med ont om vatten. Systemet CEEQUAL efterfrågar att man tittar på vattenavtryck då man väljer byggprodukter, men i anläggningsbranschen vet man inte riktigt hur man ska göra det. Det finns flera olika metoder för att beräkna vattenavtrycket och i denna rapport har information om olika metoder samlats och det ges även ett praktiskt exempel genom en fallstudie från ett vägbygge på hur man kan beräkna vattenavtryck med hjälp av två av de mest utvecklade metoderna, Water Footprint Network-metoden (WFN) och livscykelanalys (LCA).

Fallstudien visade att storleken på avtrycket beror mycket av vilken metod man använder sig av. LCA-metoden ger ett större avtryck än vad WFN-metoden ger då den tar hänsyn till allt vatten som använts medan WFN-metoden endast tittar på den andel som inte återförs efter användning, det vill säga konsumeras. Oavsett vilken metod man använder är dock stål det material som kräver mest vatten per kilogram produkt bland de material som man använt i vägbygget. Man har dock använt väldigt stora mängder fyllnadsmaterial, vilket gör att detta material bidrar till störst totalt vattenavtryck trots att materialet inte kräver så mycket vatten per kilogram.

De olika produkternas ursprung har även använts för att kunna bedöma hur stor stress materialutvinningen kan tänkas ha på vattenresurserna i ursprungsområdet. Det gjordes genom att spåra leverantörskedjan bakåt för att ta reda på vem som tillverkat produkterna. Detta visade sig dock vara mycket svårt då många företag inte alltid köper från samma leverantör, utan från de som erbjuder lägsta pris för tillfället.

Informationen om ursprung har använts för att vikta produkterna, vilket betyder att man ger produkter från vattenstressade områden större avtryck. Detta kan göras på en mängd olika sätt och den metod som valdes i exemplet var Water Stress Index (WSI) som beskrivs i artikeln *Assessing the Environmental Impacts of Freshwater Consumption in LCA* (Pfister et al. 2009). Viktningen medförde att fyllnadsmaterialets vattenavtryck minskade i förhållande till de andra materialens avtryck. Det beror på att fyllnadsmaterialet i allmänhet utvinns lokalt i Sverige där konkurrensen om vattenresurserna inte är lika hög som i andra länder. Det förekommer dock att andra produkter, till exempel stål, ibland köps in från länder där vattentillgången inte är lika god.

En analys av vattenavtryck kan användas för att bedöma och jämföra vattenpåverkan från olika projekt, till exempel för att följa upp om avtrycken minskas efterhand eller för att se om det finns material man bör undvika att köpa från vissa länder eller områden. Det kan även användas för att identifiera eventuella risker kopplade till vattentillgång, till exempel att brist på vatten begränsar råvaruförekomsten eller att priserna påverkas mycket.

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GLOSSARY

Asphalt: mixture of small stones, sand, filler and bitumen.

Bitumen: an oil based substance used in the production of asphalt. In North America it is commonly known as 'asphalt' or 'asphalt cement'. In this report asphalt will be used when referring to the paving material and bitumen as a component of asphalt.

CEEQUAL-assessor: appointed by the CEEQUAL organisation and is allowed to assess projects wanting a certificate according to CEEQUAL.

CEEQUAL-verifier: appointed by the CEEQUAL organisation for reviewing and verifying the assessment and guide the assessors when needed. They are independent from the project or contract team.

Civil construction projects: planning, building, operation, maintenance and decommissioning of infrastructure for freight and passenger transports, facilities for physical training, communication, power supply, water treatment services and flow control, ground work, the design of public spaces and such. Civil construction projects are also known as heavy construction projects.

Concrete pavement: pavement made of concrete instead of the commonly used material asphalt.

Externalities: a cost or benefit that is not included in the market price and is affecting a party not directly related to the activity causing the cost or benefit.

Fossil water: water that has remained sealed in an aquifer for a long period of time (hundreds to millions years of time), also known as paleo water or non-renewable water.

Opportunity cost: the cost of an alternative that must be forgone by choosing another action, i.e. the cost of a forsaken opportunity.

Potable water: water of good enough quality that it is safe for humans to drink, i.e. drinking water.

Real economic value: the amount that a consumer is willing to pay for a product on the free market, often not equivalent to market prices.

Scarcity rent: the marginal opportunity cost placed on future generations by consuming what is more than sustainable.

Water consumption: water that is made unavailable by incorporation into product, evaporation, abstracted from ground- or surface water in a catchment area and returned to another catchment or sea (Hoekstra et al., 2011). It can also include water that is returned to the same catchment area but returned after a long period of time or water that is made unavailable because of degradation in quality.

Water use: use of water by human activity. Water use can be divided into in-stream use and off-stream use. In-stream uses are for example hydro-power, transportation and fishing. Off-stream use is water withdrawal, which means that water use includes (but is not limited to) withdrawal of water.

Water withdrawal: removal of water from any water body. Withdrawal can be temporary or permanent. If permanent it is included in the term water consumption. Water withdrawal is also called water abstraction.

Water scarcity: refers to the lack of adequate water quantity. The withdrawal to availability (WTA) ratio is often used as an indicator. However, scarcity does not have to be due to physical reasons (that there is not enough quantity of water on a national basis) but can be due to lack of investment in water or insufficient human capacity to satisfy water demand, making water unavailable in regions lacking necessary means to utilize an adequate water resource. This is called economical water scarcity.

Water stress: occurs when the amount of water is not enough to satisfy demand or when quality reduces availability to a level lower than the demand. Water stress can occur regardless of the amount of water available.

ABBREVIATIONS

EIA: Environmental Impact Assessment

EPD: Environmental Product Declaration

FAO: Food and Agricultural Organization of the United Nations

GRI: Global Reporting Initiative

IWMI: International Water Management Institute

LCA: Life Cycle Analysis

WFN: Water Footprint Network

WSI: Waster Stress Index

WTA: Withdrawal to availability

1 INTRODUCTION

Water is one of the most crucial resources for humans and life in general. We are dependent on water for many activities since water, with its unique properties, often is irreplaceable (Stikker, 1998). About 70 per cent of the earth surface is covered with water but only three per cent of this is freshwater and the amount of available freshwater is even smaller (WBSCD, 2006). Water cannot be created or destroyed, but it can be transformed into unavailable forms, transported or polluted, making the water unavailable without further treatment (Grover, 2006).

Water resources are unevenly distributed and in several areas, use of water is subject to hard competition (UNEP, 2011). Water is generally abundant in Sweden, and therefore the amount of water is rarely seen as an issue of concern. Here, it is rather the quality of water that is addressed (SGU, 2010). The average person in Sweden uses about 200 litres of freshwater each day, and only about three of these we need to consume (WWF, n.d.). Still, most of us use potable water for all of the other activities as well, which means that there are improvements to be made in Sweden in terms of use of chemicals and energy savings.

Effective use of resources is from a sustainability perspective an important question in Sweden, but imports of virtual water from a region where water availability is not as good might be even more crucial. Today, about 1.1 billion people lack adequate access to clean drinking water and approximately 1.8 million children die every year from diseases caused by unclean water or poor sanitation, making this the second largest cause of child mortality (UNDP, 2006). World population is expected to grow and reach about 9.6 billion in the year 2050 (UN DESA, 2013). Demand for water is however not linear to population growth, since improved wealth and quality of life causes water demand to increase even more (Falkenmark and Biswas, 1995).

Water is inextricably linked to the production of food and energy. This is often called the water-energy-food nexus (Hoff, 2011). Globally, demand for water is estimated to increase by 55 per cent by 2050, and the demand within the manufacturing industry an increase of 400 per cent is projected by the same year. Today, around 20 per cent of the groundwater aquifers are already over-exploited, jeopardising future water supply (WWAP, 2015). As much as two thirds of the world population could be suffering from water stress by 2025 (UN, 1997).

Freshwater availability is not only an issue regulating human health but it is often also a precondition for reaching other sustainability goals, such as poverty reduction and equality. Water stress often hits special groups harder, such as women and children, who usually are responsible for the collection of water in water scarce areas. The resource is also a crucial base for economic development (WWAP, 2015). This has been picked up by the World Economic Forum (WEF), which ranks water as the eighth highest risk with regard to likelihood and first on impact, putting water crisis as one of the biggest overall risks in the coming ten years. A water crisis is seen by the WEF as a risk to both human health and economy (WEF, 2015).

In Europe, as much as 40 per cent of the total water abstraction is destined for industrial use (Eurostat, 2015). As more countries industrialise and as the energy use per capita is expected to increase, this sector will probably use much more water in the future. It is important that this water use is as effective as possible. The water footprint is a simple, comprehendible tool that could help in doing just so. A water footprint is the total amount of water used for a product, a person, a region or a project (Hoekstra et al., 2011). A water footprint can assist us when we are trying to make sustainable choices or we can use it to measure performance. There are however some discrepancies on how to calculate this footprint. This report offers information regarding what tools that are available at the moment and gives a practical example by using two of the most established tools for calculating the water footprint, the Water Footprint Network (WFN) method and the Life Cycle Analysis (LCA) method.

There are several studies performed on water footprints of agricultural products, most of them conducted by scientists within the WFN (Hoekstra and Hung, 2005; Chapagain et al., 2006; Chapagain and Orr, 2008; Aldaya and Hoekstra, 2010; Chapagain and Hoekstra, 2011; Mekonnen and Hoekstra, 2012). Only one study looking at the water footprint for a civil construct has been found during the work of this thesis. The study used the WFN method.

LCA is a tool that has become increasingly popular within the civil construction industry when addressing issues such as climate change. Problems arising from freshwater scarcity have traditionally not been addressed within LCA in a meaningful way (Bayart et al., 2010). Given the increased awareness of water scarcity and the water footprint of different products, several scientists have contributed to the improvement of addressing freshwater within LCA (Ridoutt and Pfister, 2012; Boulay et al., 2011; Pfister et al., 2009; Kounina et al., 2012). However, the LCA community has yet to reach a consensus regarding how to address the water footprint. The International Organization for Standardization (ISO) recently released a water footprint standard (ISO 14046:2014) and hope is that this new standard will help in achieving harmony.

1.1 OBJECTIVE

The objective of this project is to provide information and guidance about existing methods for calculating and assessing water resources in civil engineering projects. The methods studied should be suitable for implementation in the assessment, rating and awards scheme CEEQUAL in Sweden. The following issues shall be answered within this thesis:

- Which laws, regulations and requirements regarding the management of water resources are there in Sweden today?
- Which are the biggest challenges in estimating and valuing the use or consumption of water in CEEQUAL today?
- Which methods for calculating and assessing water use or consumption are available today and which of these are relevant in the framework of CEEQUAL?
- What opportunities and limitations exist for the practical implementation of the relevant methods?

1.2 OUTLINE OF THE REPORT

This report is structured in the following way:

In the following chapter, the theoretical framework for the report is presented. The chapter includes an introduction to the civil construction industry and a summary of the requirements regarding use of natural resources that the business must comply with. Extra focus is given to the issue of water use. The last section of chapter two is concerning how sustainability is being treated within the industry and some information about the rating scheme CEEQUAL is presented.

Chapter three covers some general information regarding different water footprint tools and more information about the two methods chosen for the case study, the Water Footprint Network (WFN) method and Life Cycle Analysis (LCA). Their applicability for the civil construction industry and methods enabling regional assessment is also discussed.

How this project was executed is covered in the fourth chapter, called methodology. This chapter contains information of how data was collected and much focus is given to describe the methodology of the case study, which is foremost presented in chapter five. Information about the case and the results of the case study are also presented in this chapter, called case study.

The report is summed up in the discussion and conclusions, chapter six and seven respectively. The appendices A, B and C contain in the following order information regarding other water footprint tools and initiatives working with water availability in several ways, in-depth information about the WFN and LCA methods and the input data for the case.

2 THEORETICAL FRAMEWORK

Sustainable development is usually defined as in the Brundtland report from 1987 with the phrase "development which meets the needs of the present without compromising the ability of future generations to meet their own needs" (UN, 1987). A simple definition of the word sustainability is that it should be possible to maintain the processes for a very long time.

The civil construction sector is a big sector in Sweden and manages many of the major projects today. Sustainability should be treated as default, but when concluding this section; looking at what is required by the law, the clients and how sustainability issues actually are being treated within the business today, it is clear that a little bit more work needs to be done before we reach sustainability.

2.1 WHAT IS A CIVIL CONSTRUCTION PROJECT?

A civil, or sometimes called, a 'heavy' construction project is defined at the Sweden Green Building Council (SGBC) website as planning, building, operation, maintenance and decommissioning of infrastructure for freight and passenger transports, facilities for physical training, communication, power supply, water treatment services and water flow control, ground work, the design of public spaces and such (SGBC, 2015). This definition will be used for the term civil construction project in this report.

The final products and use of the products from these types of construction projects are various and describing a typical civil construction project can therefore be difficult. There are some general features however, which the following passage aims to describe.

2.1.1 Main parties in a civil construction project

The main parties involved in a civil construction project are the client, designers and contractors. Their role in a typical project is described below.

The client is the one placing an order to build a type of construction. The Swedish Transport Administration is the biggest client in Sweden regarding civil construction projects (Bäckström and Östman, 2007). They are responsible for the long-term planning of the infrastructure systems for roads, railroads, maritime and air traffic (Swedish Transport Administration, 2015a).

The designers can for example be consultants or architects and they give advice and recommendations regarding the features of the construction (Swedish Work Environment Authority, 2015). Depending on the type of procurement, the designers are involved in different stages of the project (Dhanushkodi, 2012).

The contractor manages the production of the project. This can be done in various types of construction contracts, and the type is usually chosen from demands of the client (Zaghloul and Hartman, 2002). The type of construction contract chosen determines the responsibility and legal requirements put on the contractor and client in the project.

2.1.2 Different procurements and construction contractors

There are many different ways to distribute work and responsibilities within construction projects. The law firm Wimert Lundgren is specialised on construction law and have summarised different types of procurements and construction contracts. The following section is based on their description.

There is one key difference between an independent and a general contractor. In the case of a project with independent contractors, the client is employing several different contractors to do different parts of the project. If the construction contract goes to a general contractor however, the general contractor in turn hires subcontractors (figure 1). The general contractor is responsible for ensuring that he/she and all the subcontractors meet the demands put on the general contractor in the tender. There are advantages and disadvantages with both ways of working; one common problem with having many independent contractors is that it can entail difficulties regarding distribution of work. The responsibility of the client is also bigger with an independent contractor than it is when working with a general contractor.

There are a number of different types of procurements. The most common one is the design-bid-build (DBB) and in those cases the client hires a consultant who prepares the construction documents. These documents are then released as an invitation for tenders and a contractor with the best bid is hired. Another procurement type is the design-build (DB) procurement (figure 1). In this case, the client hires one contractor who is responsible for both the designing and building parts. Which contractor that gets to perform the design-build can also be determined through construction bidding.

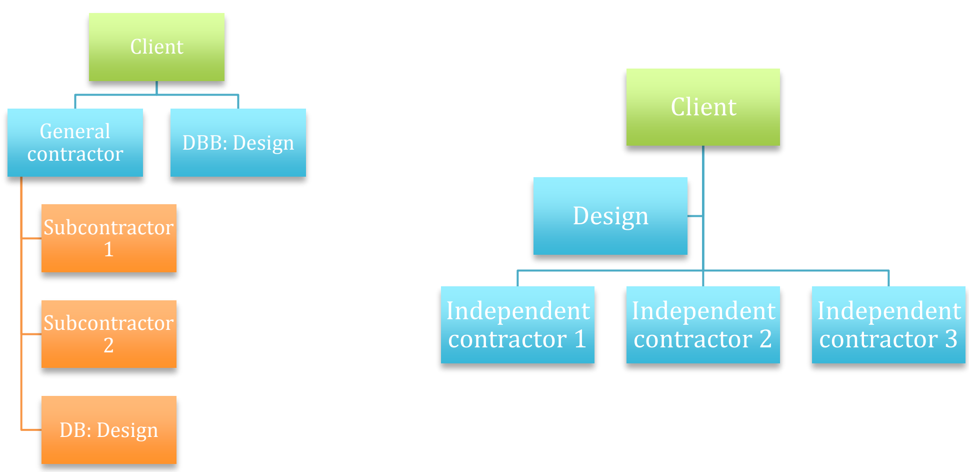

Figure 1. Schematization of different types of procurements and construction contractors.

2.1.3 Stages in a civil construction projects

Bäckström and Östman (2007) account in *Construction projects and environmental demands* for the different stages in a typical civil engineering project. The following section is based on their findings in their master thesis.

A civil engineering project starts with a pilot study. In the pilot study the needs for a new construction are investigated. A more thorough investigation follows, in which the required resources are estimated and specifications for the product are discussed. After this, the process of getting a permit begins and the environmental demands from authorities, clients and others involved are retrieved. For many civil engineering projects, an EIA is required and this is usually a part of the more thorough investigation. A tender is created for construction bidding. When a contractor has won the bidding, the construction process begins.

2.2 REQUIREMENTS ON MANAGEMENT OF WATER RESOURCES IN CIVIL CONSTRUCTION PROJECTS IN SWEDEN

There are several sorts of requirements and laws to follow during a civil construction project. The following segment aims to describe the legal and other requirements regarding management of water resources in civil construction projects in Sweden.

2.2.1 Legal requirements

In civil construction projects, the main Swedish statutes that are regulating use of natural resources in general are the Planning and Building Act (PBA) and the Environmental Code. In the very first chapter of the Environmental Code, the objective of the code is described to be promotion of sustainable development and that the code should be used in order to ensure that ‘the use of land, water and physical environment in general is such as to secure a long term good management in ecological, social and economic terms’. In the second chapter, in the general rules of consideration, conservation of raw materials is once again mentioned (DS 2000:61). It is very clear that these are values that the Environmental Code rests upon but there are not any straightforward laws about conservation of water resources or embodied imported water.

If there are indications that the project might have significant impact on the environment, an Environmental Impact Assessment (EIA) is required according to the Environmental Code. The EIA document must, among other things, contain a description of the direct and indirect, significant, impacts regarding the conservation of land, water and resource use (DS 2000:61). In most of these EIAs however, only the direct impacts on water resources and water use are described.

The Water Framework Directive (WFD) of the European Union is legally binding for all of its member states. The purpose of the directive is, among other things, to promote sustainable water use, which is based on a long-term protection of available water resources. This shall be fulfilled by, inter alia, monitoring the condition of the water resources, creating programmes of measures and implementing full cost coverage for water services (Directive 2000/60/EG). In the WFD there are many rules regarding the management of water and water quality that is to be followed in the member country, but none that treats the indirect impact through bound, imported water in products.

The 8th chapter and 4th paragraph of the PBA state that conservation of water resources is one of the technical characteristics that a construction project should possess (SFS 2010:900). This means that the building should be designed and built in such a way that it promotes conservation of water. Conservation of water should if necessary be a part of the consideration process when it comes to permits for building, and priority during planning should be given to projects that will lead to a sustainable usage of land, water, energy and resources (SFS 2010:900, 2^{nd} Ch. 2§).

If the project concerns a road or a railroad, there are specific requirements in the Road Act (SFS 2014:53) respectively the Railways Act (SFS 2004:519). For building a road, a road plan is required and railway plans for railways respectively. These documents should also contain an EIA (Hedlund and Kjellander, 2007).

2.2.2 Other requirements and guidelines

In addition to laws and other legal regulations there are a number of authorities and organisations that have significant impact on performance of construction projects by setting their own demands. The Swedish Transport Administration is as earlier mentioned the biggest client regarding civil construction projects and they can during tendering make requirements that the contractors, including subcontractors, will have to meet in order to be considered during tendering (Bäckström and Östman, 2007). The Swedish Competition Authority is another state authority that usually makes recommendations for what environmental requirements a client should set for different sectors. In the case of civil engineering constructions however, they refer to the requirements set by the Swedish Transport Administration (Swedish Competition Authority, 2015).

The Swedish Transport Administration has together with the City of Gothenburg, Malmö and Stockholm, created a document called *General environmental requirements in tendering* (In Swedish: generella miljökrav vid entreprenadupphandling). These requirements are the lowest performance that contractors are allowed to have regarding several environmental aspects and be able to win tender offers from any of the organisations (Swedish Transport Administration, 2012). The demands concern, among other things, the establishment of an environmental plan, the environmental performance of the cars and machines used as well as restrictions regarding what and how chemicals are managed and used. Effective use of energy is also considered important, but requirements regarding natural resources are lacking.

The Swedish National Grid has developed special environmental demands for their civil engineering construction projects as well. These can be found in the document Environmental demands in building-, civil engineering- and maintenance construction. One of the demands stated in the document is that contractors have to in turn demand environmental performance from the subcontractors when purchasing material and equipment. The demands on material and equipment are however limited to performance, mostly regarding declaration of the main ingredients in the material, for example by doing an Environmental Product Declaration (EPD), and that illegal chemicals or hazardous materials should not be used (Swedish National Grid, 2009).

The Building Administration is the authority responsible for community planning, building and housing in Sweden. They give advice and set rules regarding building in Sweden. The rules have been assembled in BBR, The Building Administration Building Rules (Building Administration, 2015). According to this regulation, the building material should either be CE-branded (which means compliant with the directives of the European Union), type approved, controlled in manufacturing or approved by other organisation credited for certification by ordinance 765/2008. The requirements for type approval according to another organisation has to, at least, correspond to the basic requirements for CE-branding (BFS 2014:3). In order to get a product type approved one needs to prove how this product is fulfilling the demands regarding, among other things, conservation of water resources (PBL 2011:338, 4th Ch. 9§).

The demands for CE-branding are described in the ordinance for building products (Regulation 305/2011). In order to CE-brand a building product there is a requirement that the building products, the act of building or demolition do not cause pollution of water bodies. Two additional requirements are that the products should promote effective use of energy and contribute to sustainable use of natural resources. The products can contribute to sustainable use by making reuse and recycling of the products possible and to build in such a way that the buildings are endurable. In order to evaluate if the products meet the demands, the use of an EPD is recommended in those cases such a document exists (Ordinance for building products, 305/2011).

Bäckström and Östman (2007) describe in their thesis that in excess of these general environmental demands on civil construction projects there are also specific environmental requirements that depend on the character of the project. These demands can sometimes be written in a tender document called Administrative Regulations (In Swedish: administativa föreskrifter) as well as in various project-specific documents for special areas, which are often developed during the environmental impact assessment process (Bäckström and Östman, 2007).

When summarising the situation, it is clear that there are not a lot of straightforward legal demands or other requirements that prevent the industry to use and consume water resources in the way that this paper is concerned with. There are however some basic value grounds that could be seen as a demand for responsible use of water, especially if one thinks of the requirements as applicable to consumption in other countries. The issues are also starting to get attention, especially if one looks at the requirements set by authorities or other organisations. For example, in the system of EPD the issue of water has gotten a bigger focus. Doing an EPD is however optional and not a legal requirement, so demands of this kind are depending on the clients.

A part of the explanation to why the legal demands are not that specific can be that regulating companies too much, by for example saying which technique to use, could be restrictive on innovation and development. A reason for why water issues in particular are not treated as important in Sweden is that we do not suffer from the consequences of water use in other countries and the question is therefore not prioritized.

2.3 CIVIL CONSTRUCTION PROJECTS AND SUSTAINABILITY PERFORMANCE

As mentioned in the section above, there are a few environmental demands from a number of different involved parties in civil construction projects. The straightforward environmental legal requirements, which usually have great impact of how a project is carried through in practice, are however mainly concerning traditional environmental issues such as hazardous materials, waste and use and management of chemicals.

Sometimes authorities can lead the environmental progress, by setting demands for 'newer' environmental issues. One example is the Swedish Transport Administration that recently added a requirement to use 'Klimatkalkyl' (a LCA-based tool) in their biggest projects in order to assess the impacts a project has on climate change (Swedish Transport Administration, 2015b). These kinds of initiatives can get substantial effect on how sustainability is treated within the industry.

An initiative of producer's responsibility in the building and civil construction sector called *Byggsektorns Kretsloppsråd* (Translation: Council of circulation in the building sector) published a report (2001) regarding the significant environmental aspects of the building sector and civil construction sector. The council estimated that the civil construction and building sector stands for about 40 per cent of the total material and energy use in Sweden and at the time of the study this was corresponding to about 75 million tons (Byggsektorns Kretsloppsråd, 2001). The civil construction industry manages huge projects and with global trade, the environmental impacts from the projects can occur on the other side of the globe. It can be hard to understand the impacts we have and therefore sustainability issues might not get the attention they deserve.

Looking at a similar industry, the house construction industry, sustainability issues have been treated within different rating systems and certifications for some time now and there are a number of different systems available to choose between (Jakubova and Millander, 2012). The sustainability approach within civil construction projects is however often lacking.

A study done by Absér et al. (2014) showed that measures taken to improve sustainability within civil construction projects in Sweden are limited to the measures required by law. However, several involved parties have expressed a will to work with these issues in a more systematic way (Ek, 2013). On the basis of this, the rating system CEEQUAL has received attention. There are however a few problems with its applicability in Sweden and only a few projects or parts of projects have yet to be assessed according to CEEQUAL (Uppenberg, 2015, pers. comm.).

2.3.1 CEEQUAL

Civil Engineering and Environmental Quality Assessment and Award Scheme (CEEQUAL) is a rating, awards and assessment scheme for civil construction projects. It was developed 13 years ago in the UK and has since grown and is now used in several countries (CEEQUAL, n.d.). A manual is used for the rating of civil construction projects and in 2011 an international edition of the manual was released. WSP has for the last couple of years tried to implement the rating system in Sweden as an integrated part of a civil construction project and WSP has today several assessors employed, who are entitled to certify a project. Their experience from working with rating projects and the manual have provided the basis for the information about CEEQUAL in this section.

The CEEQUAL manual is divided into 9 different chapters, addressing various issues. These chapters are Project/Contract Strategy, Project/Contract Management, People and Communities, Land Use and Landscape, The Historic Environment, Ecology and

Biodiversity, Water Environment, Physical Resources and Transport (CEEQUAL, n.d.). Within these chapters there are several questions concerning what the different parties; the client, design and production, have taken into account when executing the project. It is optional to rate all of these involved parties, and the award given is then 'Whole Team Award and Assessment' or one can choose to rate only the client and design, only design, design and production or the production alone (CEEQUAL, 2015).

Most of the questions in the manual are mandatory and shall be assessed within all projects. Some of the questions are however optional. Which of the questions that can be left out are to some extent dependant on the characteristics of the project, which means that they can only be skipped if they are not applicable to the project in question. The assessor determines if the projects have fulfilled the requirements needed for scoring. The assessor's ratings are however evaluated by a third party, a verifier.

The questions are not equally valued and the score of each question, which an expert group at CEEQUAL has decided, lays the basis for the final grade. There are four different grades, Pass, Good, Very Good and Excellent and they correspond to 25, 40, 60 respectively 75 per cent of the maximal score. The score should give an estimation of how well a project has performed from a sustainability point of view in relation to the requirements of the British law (Absér et al., 2014).

The fact that CEEQUAL only relates to British law is a limitation that has been addressed in evaluations of the rating system (Ek, 2013; Absér et al., 2014; Frank and Hederby, 2013). The international edition was a step towards improved implementation in countries outside the UK, but so far the new edition is basically just a translation. CEEQUAL recommends that a valuation survey should be done if the manual is used in countries outside the UK in order to ensure that the weightings of the questions are representative.

Absér et al. (2014) performed a study with the objective of investigating the need for implementing a rating system by analysing how well civil construction projects in Sweden perform when it comes to sustainability issues. A number of civil construction projects were in hindsight rated according to CEEQUAL and the grades given without an extra sustainability focus were analysed. The result showed that in many areas, the grade given to the construction projects was pretty good, but the reason for this turned out to be that Swedish environmental law is much stricter than British environmental law. However, in spite of our strong regulation, the results were poor in certain matters and the conclusion was that there is great room for improvement. With this said, it should be pointed out that CEEQUAL is not seen as a rating system covering all issues regarding sustainability and a certificate is not a proof of a good project, but if used one has good prerequisites for improving the sustainability of the project.

The Swedish construction company NCC has also been working for the implementation of the rating system in Sweden. In 2013, NCC performed a case study about the possibilities and limitations about working with CEEQUAL (Ek, 2013). A conclusion from the report of the study was that CEEQUAL has many advantages compared to other rating systems. One of the biggest advantages is that the system is designed to be used throughout the entire project and is therefore a driving force for sustainable projects, compared to other rating systems that instead either evaluates a project's sustainability focus beforehand or in hindsight. Ek (2013) also thinks it is an advantage that the rating of the client, design and construction are separated because it enables rating of parts of projects. The downsides are according to Ek (2013) that, like any other rating system, it takes extra time and also mentioned the fact that the system is not yet adapted to Swedish conditions or laws.

Water stress is expected to increase in several parts of the world, and the UK is one of those places. It is already experiencing effects from water stress (Environmental Agency and Natural Resources Wales, 2013). CEEQUAL has lifted water as an upcoming issue on the agenda and recently added a question benefitting those who take water footprint into consideration when constructing. In evaluations of the rating system, this question has however been seen as problematic and one of the bigger issues with the rating scheme (Ek, 2013; Absér et al., 2014). When WSP are working with the rating scheme today, the questions regarding water footprint are normally skipped since there is not enough knowledge of how to address the issue. This results in a lot of points lost and a lower grade (Uppenberg, 2015, pers. comm.).

This thesis aims to fill this gap of knowledge and serve as an initial guide to how the civil construction industry can assess issues regarding bound, imported water as well as assist in the assessment within CEEQUAL. Chapter four describe how this was accomplished but first some information about different tools that can be used to calculate the water footprint.

3 WATER FOOTPRINT

Freshwater is a limited, but renewable resource. The amount of water can never increase or decrease but the availability of water can vary depending on the different states of water; solid, liquid or gaseous. Degradation of water quality can also affect availability of water. Water is therefore not always available where and when people need it. One important aspect to consider when addressing water availability is the difference between water withdrawal, use of water and consumption of water.

Use of water is human appropriation of water resources. It includes, but is not limited to water withdrawal since use also includes in-stream use of water (figure 2). Withdrawal of water is removal of water from any water body or drainage basin for off-stream usage, for example irrigation or use as cooling water. Removal can be temporary or permanent. Consumption of water is the fraction of water that after its use cannot be used by others in the same area or for a long time, since the water is permanently removed from its source, for example by evaporation. Any use of water can affect its quality, but in-stream use (for example hydropower) is often assumed not to be affecting water quality.

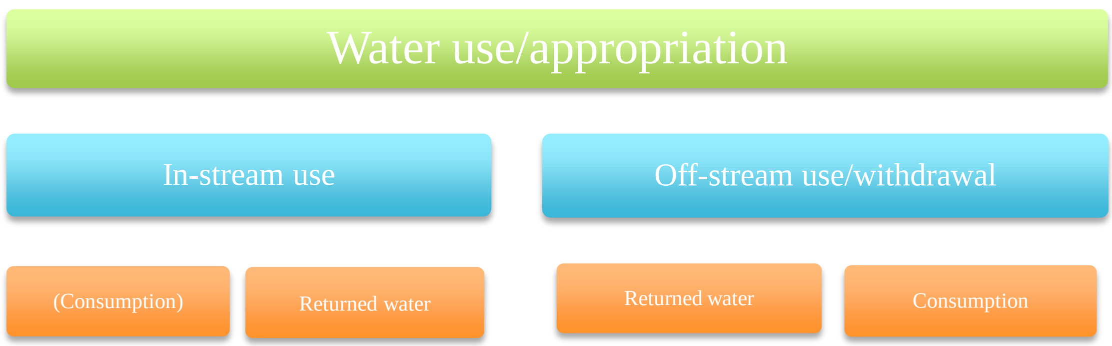

Figure 2. Different uses of water.

The hydrologic cycle is global and water is always moving between different storages (Launiainen et al., 2013). The amount of water is not equally distributed and some regions experience problems with too little water and some with too much of it (Cominelli et al., 2009). The availability of water also varies with time. According to a study done by Hoekstra et al. in 2012, at least 2.7 billion people were, at the time of the study, living in a basin that experienced severe water shortage at least one month of the year.

As globalization and trading increases it is getting easier and cheaper to buy all sorts of goods produced in various countries. Demand and consumption of water intense products in a country where water is abundant, for example Sweden, may cause serious issues regarding water availability for people in exporting countries (Hoekstra and Chapagain, 2008). One striking example is the case of the Aral Sea, which has to great extent disappeared due to the water intense production of cotton. When the effects of our consumption are so far away, it is hard to get a grip of the impact our lifestyle has. The water footprint is therefore a good tool to help us estimate the impact and hopefully help us make better choices.

When someone is talking about ‘water footprint’ they could be referring to the concept in general, somewhat alike the concept of carbon or ecological footprint, or they could be referring to the method of accounting and assessing water footprint that was developed by the Water Footprint Network (WFN). In this report, the term water footprint will be used when referring to the concept in general. When the water footprint according to the WFN is referred to, the term Water Footprint Network/WFN method will be used. Since freshwater usually is the resource of deficiency, other types of water are not a part of the water footprint in this study.

3.1 HISTORY OF THE CONCEPT

Tony Allan introduced the concept of ‘virtual water’ as a potential part to the solution regarding water shortage in the Middle East (Allan, 1996). Virtual water is all the water withdrawn in the processes of making a product. He proposed that the countries in the Middle East could stop their excessive use of water by switching production from water intensive products to water efficient ones and start to import the products that demand a lot of water from water abundant countries (Allan, 1998). The concept of virtual water has since been developed by a number of scientists (Hoekstra and Hung, 2002; Garrido et al., 2010; Zhao et al., 2010). The most common expression for addressing ‘virtual water’ or water embedded in a product today is ‘water footprint’.

Water footprint within the civil construction industry has not yet been addressed. No projects certified with CEEQUAL have reported that they included water footprint as a part of the rating (Uppenberg, 2015, pers. comm). The only study found regarding the water footprint of a civil construct during this master’s thesis was the building of terminal 2b at the Heathrow airport. Balfour Beatty, which has stated in their sustainability plan that water footprint should be a part of their work, executed the project. Parsons Brinckerhoff, who was by that time a part of Balfour Beatty, developed a water footprint tool for the use in the Heathrow project (WRAP, n. d.). They used the Water Footprint Network method (Parsons Brinckerhoff, 2015).

3.2 WATER FOOTPRINT NETWORK METHOD

The concept of water footprint was developed by Hoekstra and Hung (2002) and is based on the concept of virtual water. The water footprint can be calculated for a product, a person, a company or a nation. Hoekstra and Hung (2002) define the water footprint of a nation as the volume of water needed for production of the products and services consumed by all the inhabitants of the nation. A nation’s water footprint is calculated by adding the amount of water used in the country with the virtual water imported from other countries, and subtracting the exported virtual water. The water footprint for a company or person is based on the same principle, except for the fact that people usually do not produce or export goods. The water footprint of a product is the water footprint in all of the process steps in the production chain for a product.

The Water Footprint Network (WFN) is an organisation working for greater awareness regarding water issues. Arjen Hoekstra was one of the initiators to the network in 2008 (Water Footprint Network, 2015a). In 2011, the WFN released a water footprint assessment manual as a response to the growing interest of a standard for addressing the water footprint. The manual entails information of the procedure and calculations when addressing a water footprint (Hoekstra et al., 2011). More information about this is available in appendix B.

The Water Footprint Network was quick to adopt the concept of using different colours for different types of water. Blue water is according to the WFN the water consumption of ground- and surface water sources and green water is the consumption of rainwater. Water consumption is defined in the WFN manual as evaporated water, water incorporated into products, water that is not returned to the same catchment area (it could for example be returned to another catchment area or the sea) or water that is not returned in the same period of time (for example withdrawn in a scarce period and returned in a wet period). The part of the rainwater that becomes run-off is therefore not included since this is not consumed. Use of green water is most often only concerning the agricultural sector, when the products involve a crop, and is rarely used in industry production (with the exception of wood).

The notation of blue water sources was introduced by Falkenmark in 1993 and later developed by Falkenmark and Lannerstad to blue and green water sources (Falkenmark and Lannerstad, 2005). Chapagain and the WFN adopted another division between the different water sources but it is based on the same idea (Chapagain and Orr, 2008). One can also make a distinction between different blue water sources, such as surface-, ground- and fossil ground water. The needed data for this distinction is however often lacking. The main reason for separating the different sources of water is the different opportunity cost of the water bodies. Ground- and surface water are much more valuable if looking at the opportunity costs (Aldaya et al., 2008).

Grey water was added to the WFN method by Chapagain et al. (2006) and is addressing the quality of the water. This is not actual water used, but theoretical water needed to dilute the polluted water in order to reach an acceptable concentration of pollutants. For example, if the nitrogen concentration was increased to one per cent, but the natural background value or guidelines say that only half a per cent is acceptable and we would have to add 1000 litres of water to dilute the water to this concentration, these 1000 litres would be the grey water. The concept of grey water is however quite new and data of acceptable concentrations is often lacking. Its use has therefore been limited.

Different water footprints should be modular according to the WFN manual, which means that it should be possible to add several water footprints together without double counting. If someone were to calculate the water footprint of the production site of for example concrete and then add the water footprint of the concrete product to get the water footprint of the two, it would entail counting the infrastructure twice if this was included for the product as well.

3.2.1 Applicability

With the Water Footprint Network method, consideration is taken to the location of water withdrawal and consumption, but there is no kind of weighting involved. The WFN does not recommend weighted values since a lot of information is lost, and subjectivity is higher. Assessment is done using other methods. In the water footprint tool on their website, the water footprint of products is estimated and plotted on a map showing water availability in the region. An example of this is shown in figure 3 where the blue water footprint of strawberries produced in Spain has been estimated and showed together with the blue water scarcity in the area.

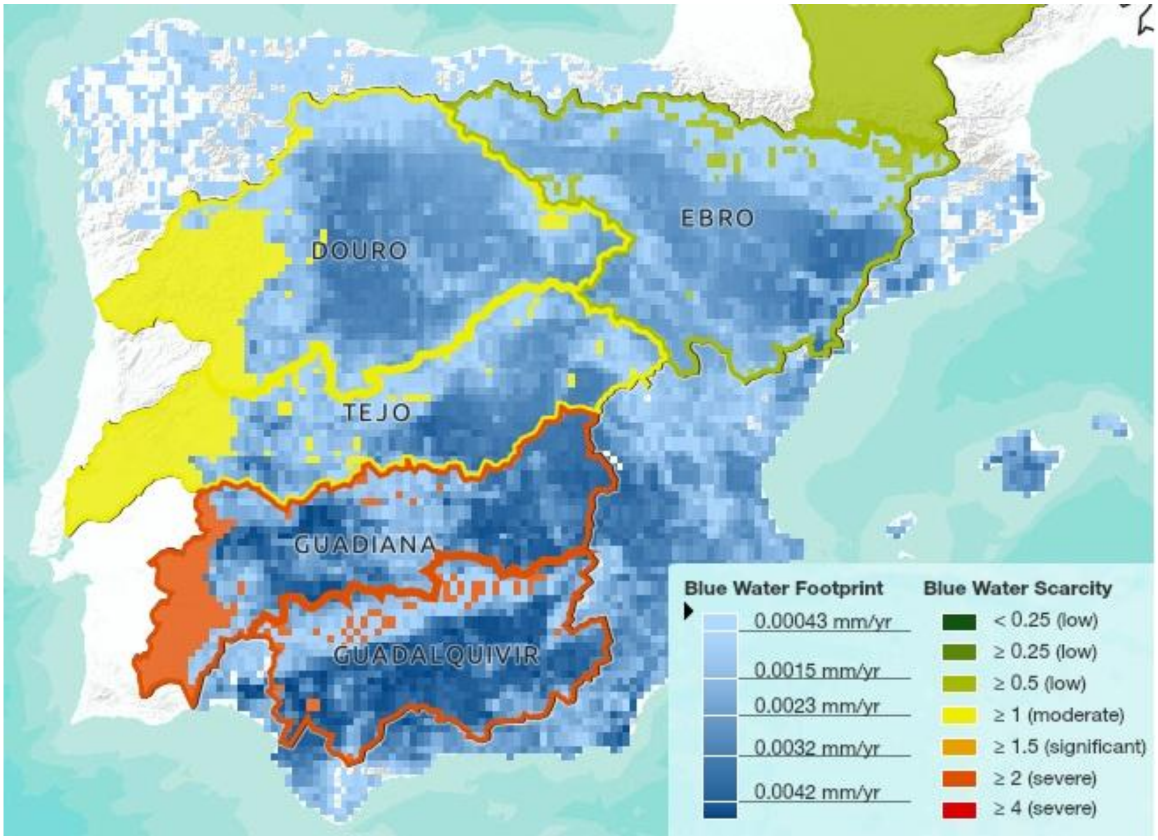

Figure 3. An example of how the WFN assessment tool can be used. The figure shows the blue water footprint of 6000 tons of Spanish strawberries, which is equivalent to Sweden's import each year, and the blue water scarcity in the same region. Source: Water Footprint Network, 2015b.

The WFN also have presented a graph in the assessment manual showing the withdrawal over time along with the water availability over time, which also can be a way to assess the water footprint (Hoekstra et al., 2011). However, the WFN does not aggregate the water footprint and water availability to one single number. This puts a lot of responsibility for analysing the sustainability of the water footprint on the person receiving the information. As the example in figure 3 shows, one has to have a certain level of knowledge to be able to understand that the high blue water footprint (dark blue) in the area with the high blue scarcity (red area) might not be very sustainable.

The water footprint has for a long time been focused on agricultural products, and practically all studies done by the network itself concern agricultural products. A strong reason for this is that approximately 70 per cent of all freshwater consumption is due to food production (Koehler, 2008). The database is therefore also focused on agricultural products and the tool available on their website is mainly limited to this. The studies performed on products in other sectors usually use data from LCA databases if the real values for the processes are unknown. One problem with this is that the two methods have a somewhat different take on infrastructure needed in the production process. As earlier mentioned, the WFN does not recommend inclusion of infrastructure because they want the water footprint to be modular. The LCA community recommends the inclusion of machines whenever this is relevant, which makes it hard to know how much of the water footprint of a product, calculated with LCA, to include in the WFN method if not specifically stated. The reason for why the LCA community recommends the inclusion is that machines and other equipment are required in order to produce the product in question.

Another issue when using LCA data for the WFN method is that the LCA community has only recently started addressing water scarcity issues. The difference between use and consumption of water has not been considered before, and because of this, available data usually does not distinguish between the two. The two methods are however starting to build a consensus regarding water related issues. The water footprint assessment manual proposes that the water footprint according to the WFN can be used as a part of LCA, and since the demand for better data has started to become an issue among the LCA community, databases have started to update information about different water sources and how this water is used.

3.3 LIFE CYCLE ANALYSIS (LCA)

Life cycle analysis is nowadays a common method when assessing environmental impacts from products. The International Organization for Standardization (ISO) has in their 14000-series of environmental management included standards for LCA. These are widely accepted amongst researchers as well as practitioners (Klöpffer and Grahl, 2014). The idea of LCA is to add the material and energy use and the environmental releases of every step of a product’s life cycle, from raw mineral extraction to waste treatment and/or recycling (figure 4). LCA is often used to compare different product systems or to find hot-spots in the production line.

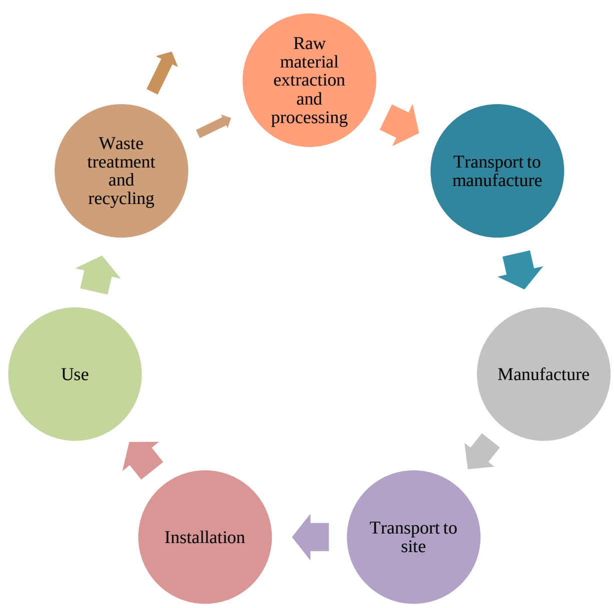

Figure 4. Different life stages in a products life cycle.

When comparing products or steps in production, it is important that these are treated the same way (Klöpffer and Grahl, 2014). It is vital to think about what kind of system model that should be used, what the system boundaries of the product system should be and what functional unit to use. The choices of these parameters usually have great impact on the results of the study and it is therefore important to choose this wisely and to be consistent.

What the right functional unit should be depends on the goal and scope of the study (ISO 14044:2006). The functional unit is how you want to present the product. It is important to think about how the product is going to be used when deciding this. If it is a road, per kilometre road or possible traffic load might be suitable functional units. It goes without saying that this should be the same for all the products or process steps that you are comparing.

The choice of system boundary decides what is included in the system, for example if waste treatment is included or not. This should of course also be the same for all products put up for comparison. Today there are two main models to choose between, the consequential perspective and the attributional. The consequential perspective is useful if one wants to look at the environmental burden of a change in demand, i.e. at the marginal. If one would like to look at the environmental burden of a product however, the attributional perspective is more useful (Thomassen et al., 2008).

The two system models address processes with multiple outcomes in a somewhat different way. Consequential LCAs tries to include the whole system, and therefore expansion is often used. This is applicable if different systems are interconnected and hence affect each other. In the case of attributional LCA, the different outcomes are allocated by a factor that can be mass, economic value or another property, and are cut off when leaving the system (Brander and Wylie, 2011). Take for example the case of steel products. Steel is often recycled to a high degree without significant quality loss. Say that for one kilogram of steel, two thirds of that material is recycled. If using the consequential model, one would account for the input of recycled material by subtracting the environmental burden that two thirds of that material would have had if being new material. If using the attributional however, one would take the environmental burden from recycling (collecting and transforming into useable product, nothing for the material itself) and allocate that with two-thirds (if allocated per mass) and add the environmental burden of producing one-third kilogram of virgin material. The result of these two models can be very different.

The impacts of many of the issues assessed in LCA are global. One example is climate change due to greenhouse gas emissions, which has for a long time been a popular issue to assess in LCA. One tonne of carbon dioxide released in Sweden will more or less have the same impacts as if released in Bangladesh. Impacts due to water appropriation however are, as described earlier, local. This means that requirements of data and assessment of water in LCA is a bit different than other issues.

Water has not traditionally been represented well in LCA, due to the complexity of the issue. Researchers on the subject have developed several new models, but none seems to have been accepted as the right one (see appendix A). Lack of data is an important contributor to this. Actual data from manufacturers and others involved is of course preferred, but this is seldom available. Data is therefore often taken from literature or from the various LCA-databases (Klöpffer and Grahl, 2014). However, current databases only give information of total amount of water used for a process or a product. Type of water source that has been used is sometimes included. Information about where, when and in which state the water is released is non-existent. Therefore assessment of water use is often overlooked in LCA (Bayart et al., 2010). ISO has recently developed a standard for water footprint as a part of the ISO LCA-series, which is known as the standard 14046. ISO recommends that water should be given as quantity of water used as well as type of water source used. Form of water use should also be stated, that is evaporative, transpiration, product integration in stream-use etcetera, which allows for division into consumptive or non-consumptive water use. Water quality and time of use should also be included (ISO 14046:2014).

3.3.1 Applicability

The LCA approach usually has a broad environmental focus and has been used for various products. It is possible to do a LCA-study for water footprint alone, but it is common that a product system is compared using several impact categories. Since LCA was developed quite some time ago and the method is today a well-known method for addressing environmental issues, the available data has improved a lot.

The biggest difference compared to the WFN method is that when using LCA it is common to look at water use, and not consumption. Even though the ISO standard recommends using both, the total water footprint is normally presented as water use. One might question whether this is relevant or not.

Another problem with addressing freshwater is how to tackle the issue of water quality. The dilution approach might be applicable to some pollutants, but it is hardly reasonable for all pollutants. It is also important to consider that quality is often addressed within other impact categories, which can entail double counting for polluting products if the grey water concept is used.

A water footprint can be used as a part of declaring environmental performance in a project. It can be included in an Environmental product declaration (EPD), a sustainability report such as the GRI-report managed by the Global Reporting Initiative or by setting up an Environmental Profit and Loss (E P&L) account for water. It can also be used to identify and assess risks related to water use. In order to identify and assess risks regional assessment is often necessary.

3.4 REGIONAL ASSESSMENT

When assessing a water footprint, regional availability of freshwater is a common aspect to consider when discussing water use or consumption, and this is also recommended for inclusion by CEEQUAL (Uppenberg, 2015, pers. comm.). Several models exist for scarcity assessment, where the Falkenmark Water Stress Indicator is perhaps one of the most basic.

The Falkenmark Water Stress Indicator is based on the estimation that people need about 1700 cubic metres of water per person and year for their basic needs. When the availability of freshwater is between 1000 and 1700 cubic metres per person and year, it indicates that this area is stressed during certain periods. To have less than 1000 cubic metres of water per person and year is labelled as scarcity and less than 500 cubic metres as absolute scarcity (Brown and Matlock, 2011). It is an indicator easy to understand and data is easy to come by, but it has some limitations. The most serious limitation is that it assumes that water will be divided fairly within the population. Besides, it is usually described on a national level, which can mask regional shortage, as well as a demand expressed per year masks variations in demand throughout the year. Furthermore, it is based on the assumption that all water shortage is physical water shortage, which is not the case according to the International Water Management Institute (Comprehensive Assessment of Water Management in Agriculture, 2007). For example, the majority of people suffering from water shortage in the Sub-Saharan Africa, according to the IMWI, are actually doing so not due to physical water scarcity, but due to economic constraints.

Another simple model, the withdrawal-to-availability (WTA) ratio, accounts for the fact that some people can and will withdraw more water than their basic requirements. It takes the total freshwater withdrawal of a country and divides it with how much freshwater that is renewed, i.e. the availability of freshwater. A region with a WTA-ratio between 10-20 per cent is considered to be moderately stressed; over 20 per cent indicates medium stress, whereas over 40 per cent indicates high stress. These levels have been adopted from the fifth session regarding freshwater resources in the Commission on Sustainable Development in 1997 (UN, 1997). The ratio for Sweden is about 1.5 per cent and for Saudi Arabia it is 943 per cent. This means that Sweden will probably be able to maintain the water use for some time, whereas Saudi Arabia is emptying their sources at a quite shocking rate. The ratio gives an indication of the sustainability of the water use in the country and data is readily available at FAO's website. The model does however contain the same problems regarding presenting data in regional and annual form as does the Falkenmark Indicator.

Based on the WTA ratio, several models have developed. One of these is the Water Stress Index (WSI), developed by researcher Stephan Pfister and colleagues (2009). This includes a variability factor, accounting for the fact that availability and demand varies throughout the year by giving a country with a high variability a higher WSI than a country with similar average demand and supply. Furthermore the model is transformed to a logistic function with values ranging from 0.01-1 for the reason that impacts of water scarcity is not considered by the developers to be linear. The result when weighting the water footprint with WSI will therefore always be smaller than the un-weighted volume-based one.

A WTA of 40 per cent (high stress) corresponds to a WSI of 0.5. The WTA, that the WSI is based on, is modelled with a model called WaterGAP2 and can be performed on a regional level (Pfister et al. 2009). However, that exact location for water withdrawal is rarely available.

The Water Footprint Network has also gathered information about water stress in order to enable sustainability assessment of the water footprint. Statistics on blue and green water scarcity are available on their website. One can access monthly statistics for major river basins, which for Sweden at the moment just means the lake Vättern. If one would want to assess per country, the river basins would have to be added manually (Water Footprint Network, 2015c).

Additional to this, several complicated model exists, which try to connect the water footprint to areas of protection such as human health, ecosystem quality and resources by using end-point characterisation factors (Mila í Canals et al., 2008, Bayart et al., 2010, Kounina et al., 2012). End-point characterisation factors tell us something about the impact, such as how many years of lesser quality is the impact from water scarcity. A mid-point characterisation factor however only entails descriptive information, such as an estimation of the reduction in water availability. Both the WTA and WSI are mid-point characterisation factors. An end-point characterisation factor might seem more applicable than a mid-point one, but the interconnections needed for achieving a connection to an end-point characterisation factor get very complicated and the uncertainty in the model increases significantly (Klöpffer and Grahl, 2014). Therefore mid-point characterisation factors are often recommended, as is the case in the ISO standard of water footprint (ISO 14046:2014). The scheme from the article *Review of methods addressing freshwater use in life cycle inventory and impact assessment* gives an example of a complex cause-effect chain for freshwater consumption (figure 5).

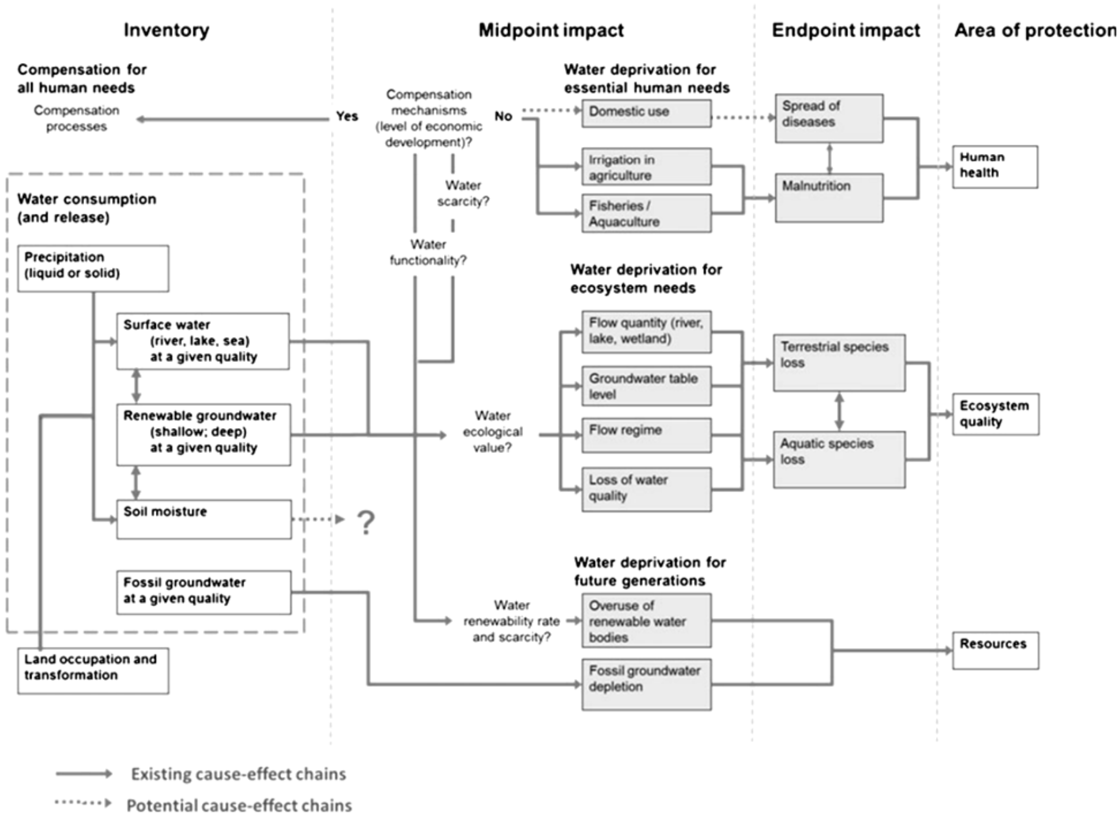

Figure 5. Potential cause-effect chain for water consumption. Source: Kounina et al., 2012.

There is no consensus yet of which water scarcity assessment method to use. CEEQUAL does not give any requirements or recommendations, but ISO recommends using a mid-point impact indicator. The WTA and the WSI by Pfister et al. are both well-known mid-point impact indicators and data is available online.

4 METHODOLOGY

The objective of the thesis was to provide a guide on how to estimate and analyse a water footprint within the civil construction sector. The issues specifying what this means are presented in section 1.1 and the methodology chapter aims to describe how the questions specified in that section were answered.

Before the main study, a pilot study was conducted in order to outline the progress within the area of the thesis. This was basically a survey, done through literature review, regarding available methods for water accounting and assessment. What other companies within the industry as well as other industries were doing when addressing water footprint was also part of the study. From the information gained in the pilot study, the two methods WFN and LCA were considered relevant for the practical application and were therefore studied further. These are described in chapter three. For the complete results of the pilot study, see appendix A.

In the main study, three different methodological tools were used. These are literature review, experiences and knowledge from certified assessors at WSP and practical application by case studies.

At the time of the study, WSP had several assessors employed whose knowledge and experience from the rating scheme and civil construction projects were instrumental to this thesis. Their knowledge was especially helpful when providing information regarding how CEEQUAL is used today in civil construction projects and what is required from CEEQUAL regarding embedded water in building products. One of the assessors was positioned at the same office as the author and was therefore available for questions that popped up during the writing process. The supervisor, Stefan Uppenberg, was positioned at another office but travelled to the Stockholm office once a month. A meeting was then set up every month where information regarding CEEQUAL was gathered through semi-structured interviews. Questions were asked concerning what CEEQUAL in general covers and about the information in the section regarding water footprint. Since difference in phrasing, for example using the words withdrawal, use, consumption and appropriation, is instrumental to understand what CEEQUAL is requesting, the questions asked were quite detailed.

During the case study information was gathered from different suppliers and producers of building materials. This communication would normally be done by email and in some cases by telephone. Questions asked were concerning how their production steps looked like, if they bought ready materials for further distribution or if they bought raw material or components. They were also asked if they knew where the bought material or products came from and if they knew origin or retailers. Some of them were also asked for data of water usage. The information obtained is available in the result section in chapter five.

4.1 REQUIREMENTS PLACED ON THE DIFFERENT WATER TOOLS

The basis of this study is that water footprint is currently not being assessed when certifying a civil construction project according to CEEQUAL. It is therefore important that the methods studied are suitable for the implementation within the scheme CEEQUAL. In order to explain the reasons for why some methods were chosen and others not, the requirements regarding water footprint in CEEQUAL and the requirements that were worked out in collaboration with WSP are described below.

4.1.1 Requirements regarding water footprint in CEEQUAL

There are two inquiries regarding the ‘Water footprint’ within CEEQUAL. The first one is the question if an assessment of the embodied water in the building materials has been done, and the other is asking if the results of the assessments have been used. The Water Footprint Network manual is proposed as source for more information in the guidelines for the questions. The fact that ISO was working on developing a standard for water footprint assessment within LCA when the manual was written is also mentioned. Both of the questions are mandatory and worth quite a lot of points. As earlier mentioned, the section regarding the water footprint is not addressed in CEEQUAL ratings today since there is no knowledge of how to tackle the questions (Uppenberg, 2015, pers. comm.).

If CEEQUAL is demanding assessment of water consumption or water use is from looking at the manual not clear. There are a few differences between the international edition in English and the one translated to Swedish. The term ‘embodied water’ is used in English, and ‘water print’ (In Swedish: vattenavtryck) would be the corresponding word used in the Swedish version (Uppenberg, 2015, pers. comm.). These terms are not considered to be the same thing by other organisations, such as the WFN (Hoekstra et al., 2011). The guidelines of both languages however state that water footprint is equal to the term embodied water, and that the information given should not just be a volume, but also information regarding when and where water is used (Uppenberg, 2015, pers. comm.).

In the introductory text for the question in the English version, the terms water use and water consumption are used as synonyms. They are alternated without any consideration of the difference between the two. In the Swedish version there is no mention of water consumption, the phrase ‘water use’ is the only one used (Uppenberg, 2015, pers. comm.). This could be a misinterpretation during translation, since the difference between the words is not that apparent. However, given that the English version fails to distinguish the two, the probable explanation is that the difference has not been brought to CEEQUAL’s attention.

4.1.2 Requirements that were composed in collaboration with WSP

One of the negative aspects of CEEQUAL is that the procedure usually takes a lot of time. It is therefore important that water footprint accounting and assessment will not make the scheme considerably more time consuming. The concept of water footprint is however relatively new, especially within the construction sector, which can make data hard to find.

Since few previous studies have been done, the perspective taken in this thesis was therefore quite general and rather indicative of the most water consuming materials. Detail and accuracy was hence not the main purpose. Once it is clear which materials that potentially could be damaging when it comes to water, one can strive for detail and accuracy in future studies. It should however be possible to use the result to identify potential areas of improvement.

In order to evaluate which materials that could be a threat to water availability, regional water availability of the production site had to be considered somehow. If this was not included, the method seemed useless. A process is not better than another due to the only fact that it uses less water and vice versa. Nevertheless, a lot of available methods suggest that data of production location should be given at catchment level. To get that exact data over localisation for every production step would be incredible hard and time-consuming. A national level approach, with the knowledge that water stress can vary within a country, was considered an appropriate aspiration for this project.

4.1.3 Choice of water footprint methods

The literature review and discussions with the assessors gave the basis for choosing between the different methods. The criteria of what the methods should account for were too a high degree determined by the requirements from CEEQUAL. These were not many however, so the room for choosing freely and realistically was big.

Due to internal criteria that water availability should somehow be included in the assessment, a water stress index of some sort was to be used for evaluating the water footprint. This meant that the footprint accounting method should allow for an assessment to be made.

The water footprint according to the Water Footprint Network and life cycle analysis method were chosen as appropriate methods. The reason for this was that the methods more or less fulfilled the criterions and seemed to be the ones that had been developed furthest. Since CEEQUAL also is referencing the two in their manual makes it likely that they will require the use of one of these methods in the future. The studies made on building materials or similar products have often used these methods, which makes the results more easily comparable.

For the assessment method, a mid-point indicator seemed to be most appropriate since an end-point indicator entails a lot of uncertainties. The withdrawal to availability (WTA) ratio was appealing in its simplicity and the fact that it considers water stress to be possible regardless of how much water a country might have. The Water Stress Index (WSI) developed by Pfister et al. (2009) is based on the WTA, but also accounts for variability in water availability throughout the year. Both of these indicators are available for practically all countries. Because of the additional dimension of variability in water availability with the WSI, it was chosen as the appropriate indicator.

4.1.4 Choice of case study

The choice of case was to a high degree determined by the availability of data from the civil construction projects. Much of the data for products could be estimated through literature, LCA-databases and previous studies but there were some basic requirements regarding data from the project.

Data regarding what kind of material and how much of it that was used in the construction projects was a basic requirement. Knowledge of where the materials came from was desired, taking into account that this is very rare. Real data of water use or consumption was considered too time consuming and difficult to attain during this project. Data of water consumption and use was therefore gathered from LCA databases, mainly Ecoinvent. This was not seen as an issue since this will also be the case if performing a water footprint for a project within the business.

The project should be finished, so that amounts would be readily available and adjusted. This is the level of detail needed for an Environmental Product Declaration (EPD) for a civil construct project and was therefore seen as a good basis. The Umeå project was considered to be a fitting pilot project since this was also used when developing the method for addressing climate impact in civil constructions (Uppenberg, 2015, pers. comm.).

The goal of calculating the water footprint for this project was to provide a practical example of how this can be done while complying with the requirements set in CEEQUAL. The results of the study should be relevant to the environmental and social aspects of freshwater appropriation. That means that the result should give enough information to make identification of water intense materials needing more attention regarding water appropriation because of their exposed location and to be able to make choices that will reduce the water footprint.

4.1.5 Choices regarding the accounting and assessment phase

The information given about the project included various numbers of amount of materials used and the LCA (Klimatkalkyl) made for climate change. Data of material used can be seen in appendix C. This data is collected from the bill of quantities for the contract, which is the basis for the follow-up of cost for the project. It is therefore the most detailed information available and is normally possible to receive from clients or contractors. Such bills of quantities are also produced on a more generic level in the planning of a project and can thus fulfil the purpose of making sound choices regarding purchase of material when it comes to addressing water risk of different materials and the origin of the high consumer materials.

Much of the material used for filling was categorised as 'fall A'. This means that the material is re-used from within the production site. These were excluded from the study since this is material that has not been produced in the traditional sense. De-construction was not included either since this is not categorized as building material, which the questions about water footprint in CEEQUAL are limited to (see 4.1.1). Other activities such as detailed design, geotechnical investigations, clearance and de-forestation also fall outside of the requirements of CEEQUAL.

A full LCA (cradle-to-grave) is often recommended in order to avoid burden shifting in a life cycle analysis (Klöpffer and Grahl, 2014). This includes all the steps in a product's lifecycle, such as raw mineral extraction, production, use, disposal and/or recycling. The intention of this study was however to identify a method that can be implemented on other cases in the future. It was therefore considered important that the results would not be too specific for this case. Because of this, transport to site and the installation phase were not included as it was seen as too specific.

Waste treatment was not included either as this is tremendously hard to address for a road due to its long life length. A road can last for over 50 years, which makes the assumptions made regarding waste handling and treatment very unpredictable and uncertain since the products and process we are using today might not be useful at the actual time for this end-phase.

Accordingly, the study took what is called cradle-to-gate approach (or sometimes called module A1-A3), which is inclusive of raw mineral extraction and processing, processing of secondary material input, transport to the manufacturer and manufacturing, which also includes energy and waste disposal in manufacturing. This is the approach often taken in an EPD or a LCA done within the industry. It was therefore seen as good for making comparisons of results and made use of available data possible.

Since the water footprint concept is yet to be developed for building products, data for water consumption was to great extent taken from LCA databases. However, the LCA community and the Water Footprint Network have some discrepancies regarding what to include, which meant that some aspects were included in the Water Footprint Network method although they should not be included. This is for example the case for infrastructure of the production sites (see chapter 3). Since LCA data was the only data available in many cases and the fraction of the water footprint that came from infrastructure was not stated the inclusion of infrastructure had to be made for both methods.

Companies producing and selling the types of products used in the project were contacted to confirm and add information regarding the content, water use or consumption during production processes and the origin of the material. Information regarding water use and consumption proved hard to access. In most cases the companies did not have or did not want to share data regarding water use or consumption or in the few cases they did, data was only available for some parts or as a total for a whole factory producing multiple products. Data was therefore mainly collected from various LCA databases such as Ecoinvent, WorldAluminium and EuroPlastics. The choice of which data to use for different products was done after recommendations in the Product Category Rules (PCR) for the EPD of civil constructions, but only if the data was available in the right system model (see section 3.3). In Ecoinvent it is possible to choose different system models, where allocation, cut off by classification was selected since this is the system model most often used for the purpose and also used when making EPDs.

The water use for different products were in some databases divided into type of water use or source of water use, such as water used for cooling or saltwater, water taken from rivers, lakes or wells. Since the objective of the study was to address freshwater scarcity, saltwater was excluded in both methods. The volume of water that had been used for cooling was included in the LCA method, but not in the Water Footprint Network method. The water used for cooling was assumed to be returned to the same catchment within a short period of time or re-used and hence not consumed water.

In some databases the form of water release was also specified, and in this case as water released to air (as evaporation) and water released to water (in liquid form). The evaporated water should clearly be considered as consumed, whereas the released liquid water is a bit trickier. There is no information of where and when this water is released so it is not possible to know that this water is only used water and not consumed. For this reason, all the used freshwater apart from the water specified as water used for cooling or turbines, was considered consumed. The evaporation probably included the salt water as well, so even though this was clearly consumed water it could not be used to represent the fraction of freshwater that was definitely consumed. A simple water-balance was conducted to see that all of the input water equals to output water. The salt water was included in this balance since it could also be a part of the evaporation and release in liquid form.

Information about origin of building products were collected in two ways, one representing the general market in Sweden for the material in question and the other representing the specific origin for the case. The general information was collected through literature review and statistics. For the specific case the contractor provided information regarding where they purchased the material. The suppliers were then contacted to see how far the supply chain could be traced.

The general information about origin gave an overview of what materials that could be high risk when it comes to building materials in civil constructions in general, and could thus be useful for the future use of these methods. Trying to find the origin of the materials used in the specific case provided information and practical experience of how hard it really can be to trace a product. When specific information regarding a product was missing, the general information for this product was used.

The WSI by Pfister et al. (2009) was used as an indicator for weighting the result. When the products consisted of parts that came from more than one country, the country with the highest WSI was used. If the origin was reported to be Europe however, an average number for the European countries was used.

The aim of this study is to find a method suitable for implementation within the rating system CEEQUAL. The rating system is already assessing the direct water quality issues in other sections of the manual and with other types of methods. The indirect impact on water quality can to some extent be treated within other parts of the CEEQUAL manual, such as responsible sourcing, but should also be treated within water footprint. The grey water footprint concept was however not seen as an appropriate way to address this and was therefore excluded from the case study. Instead, water quality was addressed through literature review to highlight any significant impact on water quality or other issues connected to water. The important information was gathered as a small note and incorporated into the Excel file containing the water calculations.

5 CASE STUDY

A case study is a valuable tool when wanting to give a practical example of a method. It was therefore chosen as an appropriate method in line with the objective of this thesis (see section 1.1).

5.1 THE UMEÅ PROJECT

The Umeå project is a road construction project in the Swedish town Umeå, located in northern Sweden. Hope is that the town's problems from heavy traffic in the centre of the city will be solved by building a ring road around the city. Some parts of the ring road are still to be built so the project is in that sense still ongoing, but in this case study a part of the northern link (more specifically contract 5 between Hissjövägen and Ersboda) will be used as a case. This part was built by the company Skanska and was finished in 2012 (Swedish Transport Administration, 2015c).

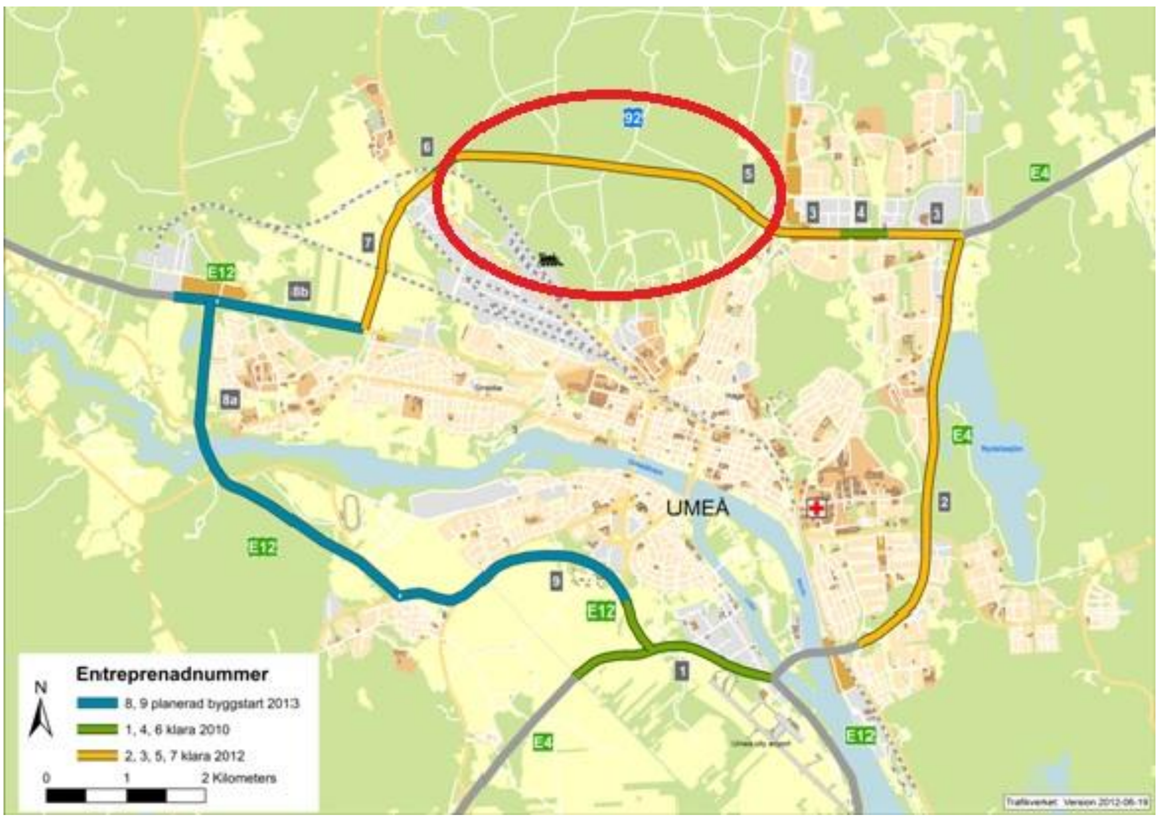

Figure 6. Map showing the different contracts in the Umeå project as they were set in 2012. The western part of the ring road has however been changed, but the parts that were done before 2013 (contract 1-7) are accurate. The case addressed in this study involves contract 5, the part inside the marked area. Source: Swedish Transport Administration, 2015c.

WSP had used the project as a reference case when developing a model for addressing climate impact, 'Klimatkalkyl'. Information regarding the case, material and the specific amount for each material was therefore available at the very start.

The section of the road that is studied in this case is 4.5 kilometres long and has 8 different bridges (Swedish Transport Administration, 2015c). The bridges are made of concrete, reinforcement bars, railings and concrete pavement.

Figure 7. Bridge at the road E12, contract 5 in the Umeå project. Photo: Katarina Wärmark.

The road is constructed with fill material consisting of crushed aggregates. A lot of the fill material was reused, but some had to be bought externally. Asphalt was used as a top layer on the road. In addition to these materials geotextile, paving and cobblestone, railings, road markings, reflectors and signs were also used in the construction. Road markings and reflectors could not be included in the water footprint analysis since information about these products proved too hard to find. In the context however, their impact is considered to be negligible because of the small amount used.

Figure 8. Road E12, contract 5 in the Umeå project. Photo: Katarina Wärmark.

5.2 RESULTS

Because of the nature of the project, attributional LCA was used. Functional unit was chosen to be per kilometre road and year but total water footprint, water footprint per kilogram of the different materials, and weighted water footprint is also presented in this section as this was of interest as well. The total water footprint of the building materials calculated using both methods in the project is presented in figure 9.

Figure 9. Total water footprint of the Umeå project using the LCA and WFN method.

It is clear that the LCA method gives a value that is very much higher than the WFN method (figure 9). This is a basic but interesting fact, especially since CEEQUAL is not particular regarding which one to use.

In order to evaluate which materials that can be considered high-risk or low-risk materials, the water footprint per kilogram material calculated by both methods is also presented (figure 10 and 11).

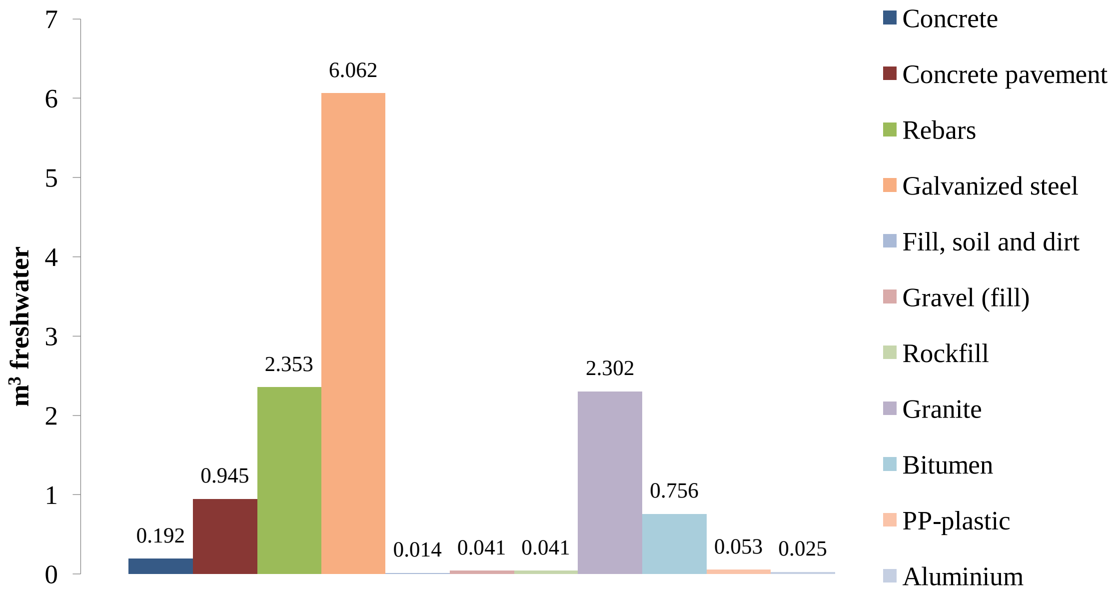

Figure 10. Water footprint per kilogram of the different construction materials with the LCA method.

Galvanized steel is clearly the material where most water is needed in the production of one kilogram. The water footprint of reinforced bar (which is not galvanized, re-used steel) is less than half of this per kilogram, but it is still one of the materials needing the most water in production (figure 10). When re-using the steel, it has to be re-melted, which demands a high temperature and with that a lot of cooling water.

Granite has a water footprint about the same size as reinforced bars (figure 10). This has a lot to do with the water used when cutting the stone.

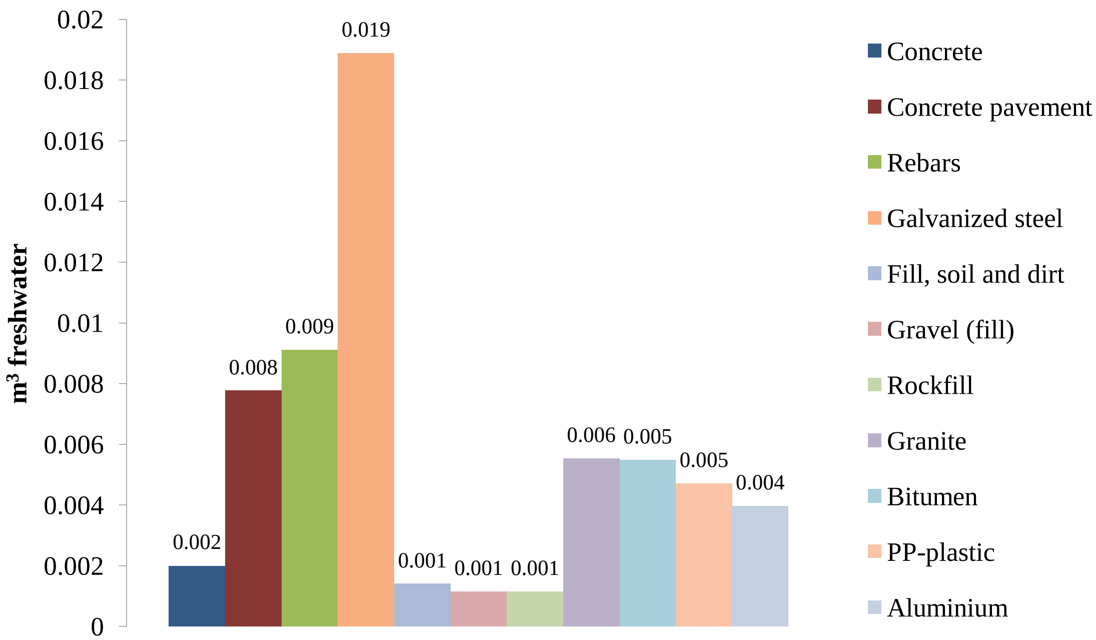

Figure 11. Water footprint per kilogram of the different construction materials with the WFN method.

When looking at the water footprint using the WFN method, it is important to emphasis the difference in scale compared to the LCA method (figure 10 and 11). The other interesting fact is that the order when ranking the materials from high to low water use or consumption changes, i.e. the water footprints of the different materials do not decrease with the same factor. Different materials perform differently according to the two methods. This can be easily noticed if looking at the water footprint for one of the material that changes the most between the methods, galvanized steel, and for one of the materials that changes the least, PP-plastic (figure 12 and 13 respectively).

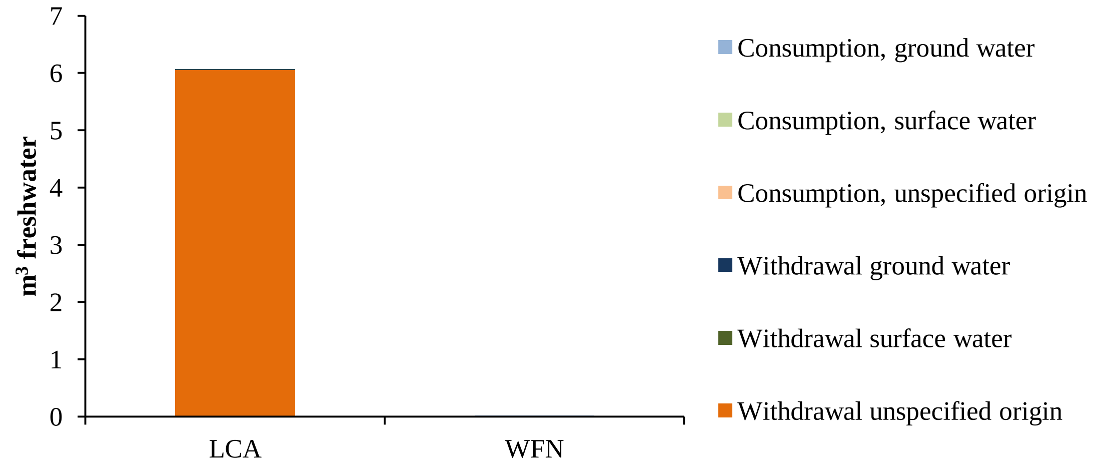

Figure 12. Water footprint per kilogram of galvanized steel, one of the materials with the biggest difference between the two methods LCA and WFN.

The process of making galvanized steel demands a high temperature, which in turn demands a lot of cooling water. A lot of this water can however be recycled, and according to the WFN method the water footprint of steel is not as large in comparison to other products. Looking at plastic, the water use per kilogram material is much lower and the difference between the two methods is smaller (figure 13).

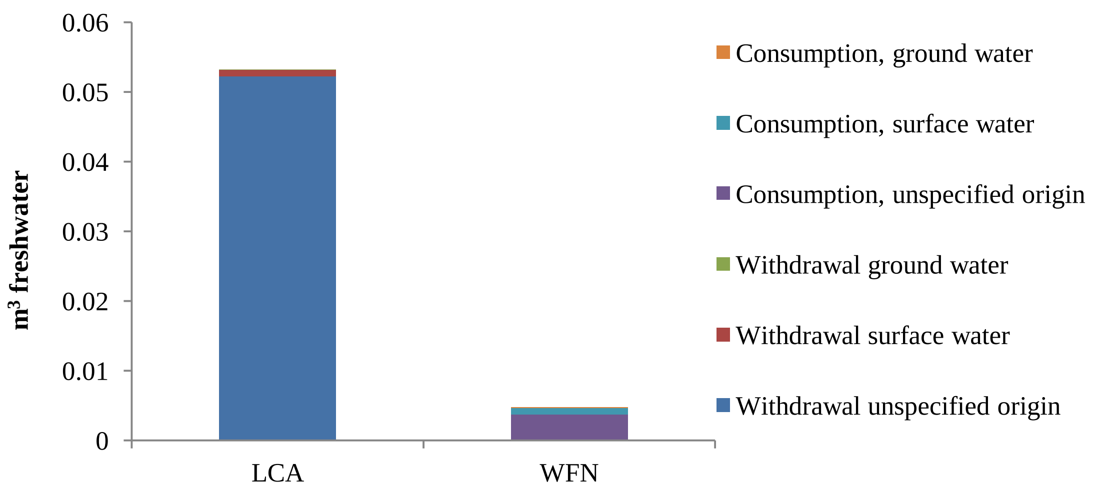

Figure 13. Water footprint per kilogram of PP-plastic, one of the materials with the smallest difference between the two methods LCA and WFN.

PP-plastic is one of the materials for which the calculated water footprint is changing the least when switching method, but even so the water footprint is ten times larger for PP-plastic using the LCA method (figure 13). It might not seem as much, but in the context of a civil engineering project and the amounts used, it can mean a great difference in the total water footprint. This is illustrated in figure 14, presenting the total water footprint of both methods as well as showing the different materials and their contribution to the total footprint.

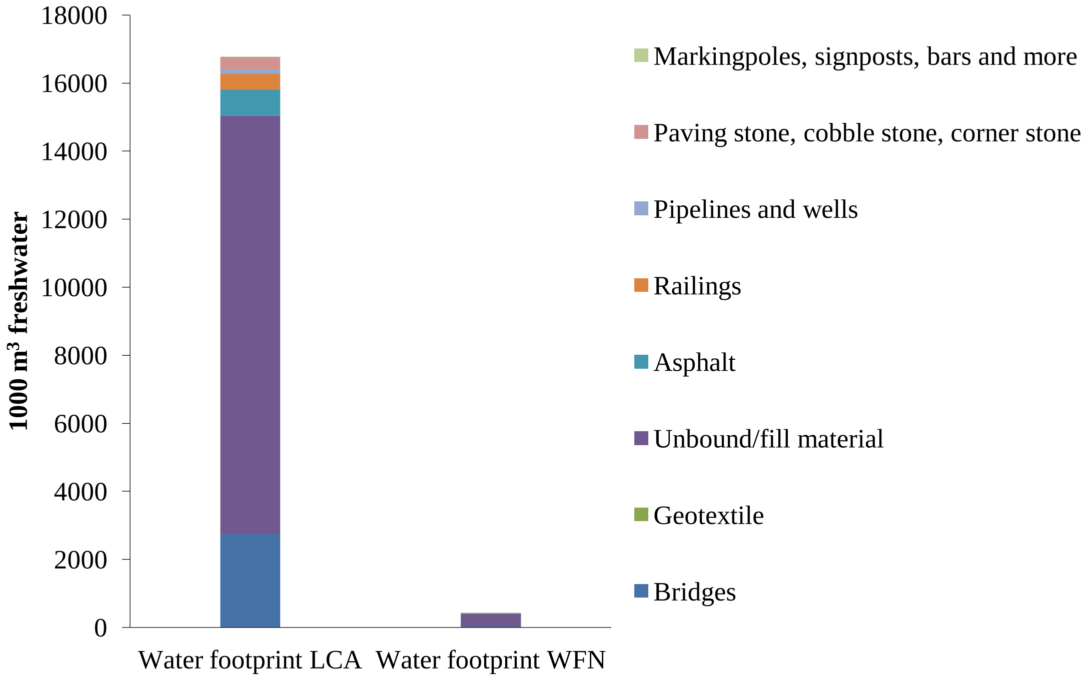

Figure 14. Total water footprint of the construction materials used in contract 5 in the Umeå project using the LCA and WFN method and also showing the contribution to the total footprint by the different materials used.

Fill material, which in the graph of the water footprint per kilogram of the different materials had a very low value (figure 10), is in this graph of total water footprint the major component (figure 14). The reason for this is the extreme amounts of material used. Steel, the major component in railings can be seen as a quite thin line (figure 14), as well as granite which had a somewhat high water footprint per kilogram material (figure 10).

The water footprint was also weighted, in order to see the 'impact' the different materials might have had on water availability. The weighing was based on the Water Stress Index (WSI) of the place where the product was produced. Therefore the suppliers of the different materials and suppliers of them were located and are listed below in table 1.

Table 1. Construction materials used in the Umeå project and the supplier of these materials or components. The hyphen symbol (-) means that the end of the supply chain is reached and question mark (?) means that the end of the supply chain could not be located within this project.

Material	Supplier to Skanska	Supplier to respective supplier	Supplier to respective supplier
Concrete	Skanska Asfalt och Betong[1]	Svartberget Umeå (Sweden)[1]	-
Concrete Pavement	Skanska Asfalt och Betong[1]	Svartberget Umeå (Sweden)[1]	-
Reinforced bars	Celsa Steel Service[1]	Scrap steel from Sweden or Norway[3]	-/? (Recycled)[3]
Pipe-railings, double railings	FMK[1]	Pipe-rail: Germany or Austria[4]	-/?
		Post: Tibro (Sweden) or China[4]	-/?
Cable barriers	Blue Systems AB[1]	Cable: Swedwire[5]	Zink: Boliden[6]
			Steel: TATA (or Mittal)[6]
		Post: Denmark[5]	Post: Poland[5]
Reflective	Blue Systems AB[1]	?	?
Fill	Local (Umeå, Sweden)[1]	-	-
Geotextile	Viacon[1] (Lycksele, Sweden)[2]	Europe[7]	-/? (Recycled)[7]
Bitumen-bound layers (Asphalt base course, Binder course and Surface course)	Skanska Asfalt och Betong[1]	Bitumen from Nynäs[8]	Nynäs buys fine stone material within Sweden if it is not available at their site. Buys raw oil mainly from Venezuela (sometimes from North Sea)[9]
		Fill: Svartberget Umeå (Sweden)[1]	
Sub-base	Bilfrakt Bothnia AB[1]	NLC-park (Umeå, Sweden)[1]	-
Base course	Bilfrakt Bothnia AB[1]	Hössjöberget, (Umeå, Sweden)[1]	-
Binder course	Bilfrakt Bothnia AB[1]	Hössjöberget, (Umeå, Sweden)[1]	-
Concrete slabs	St Eriks AB[1]	Concrete: Sweden (assumed)	-
Pavement stone and cobblestone (Portuguese stone)	St Eriks AB[1]	Portugal[1]	-/?
		Jointing sand: Sweden (assumed)	
Cornerstone of granite, set in concrete (Portuguese stone)	St Eriks AB[1]	Stone: Portugal[1]	-/?
		Concrete: Sweden (assumed)	
Structures for vegetation areas	Local (Umeå, Sweden)[1]	-	-
Road and surface markings	Cleanosol[1]	Dolomite: Norway[10]	?
		Sand: Sweden[10]	-
		Oil, rubber, resin:	?

		Thailand/Brazil/Other[10]	
		Glass beads: China/Austria[10]	?
		Titanium white: Slovenia[10]	?
Signposts	AB Blinkfyrar[1]	Poles (steel): Austria/Poland[11]	-/?
		Aluminium sign: Sweden[11]	- (Recycled)[12]
Road delineators (PP-plastic)	AB Blinkfyrar[1]	-/? (Recycled)[13]	-
Culvert (Galvanized steel)	Viacon[1]	Wuppermann GmBH (Austria)[2]	?
Culvert (Concrete)	St Eriks AB[1]	Concrete: Sweden (assumed)	-
		Reinforcement: Scrap steel from Sweden (assumed)	?
Pipes (PP-plastic)	Dahl Sverige AB[1]	Upnor and Wavin[14]	Austria[15]
Drainage wells (PP-plastic)	Dahl Sverige AB[1]	Upnor and Wavin[14]	Austria[15]

Source: 1. Kemppainen, 2015, pers. comm. 2. Sandberg, 2015, pers. comm. 3. Söderkvist, 2015, pers. comm. 4. Andersson, 2015, pers. comm. 5. Heinevik, 2015, pers. comm. 6. Antonsson, 2015, pers. comm. 7. Petersson, 2015, pers. comm. 8. Ericsson, 2015, pers. comm. 9. Hennung, 2015, pers. comm. 10. Fredriksson, 2015, pers. comm. 11. Mäkelä, 2015, pers. comm. 12. Ekendahl, 2015, pers. comm. 13. ATA, 2015. 14. Lundgren, 2015, pers. comm. 15. Upnor, 2006.

Some parts of the supply chain were not possible to trace within the project. These materials would have to be assumed. The level of certainty in these data is varying, some is general data taken from the companies' websites and some is data specific for this project. The effect this lack of data has on the results however was considered to be negligible.

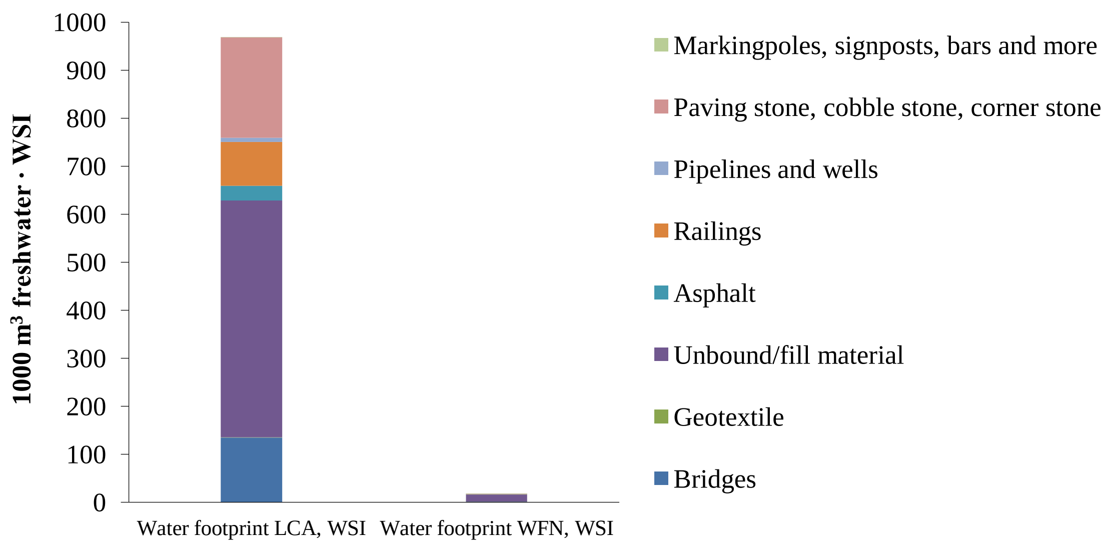

Figure 15. Weighted total water footprint of contract 5 in the Umeå project using LCA and WFN method and also showing the contribution to the total footprint by the different materials used. Weighting was performed using the WSI method by Pfister et al. (2009).

One can quite easily see that the contribution to the total water footprint that different materials have is changing when weighted (figure 15). Before weighting, fill material was the material completely dominating the water footprint. It is still big, but materials such as railings and stone (which consist of mostly granite) have increased in proportion.

To compare this weighting to what the results would have been if the origin for every product was Sweden, they were all weighted with the WSI of Sweden (figure 16).

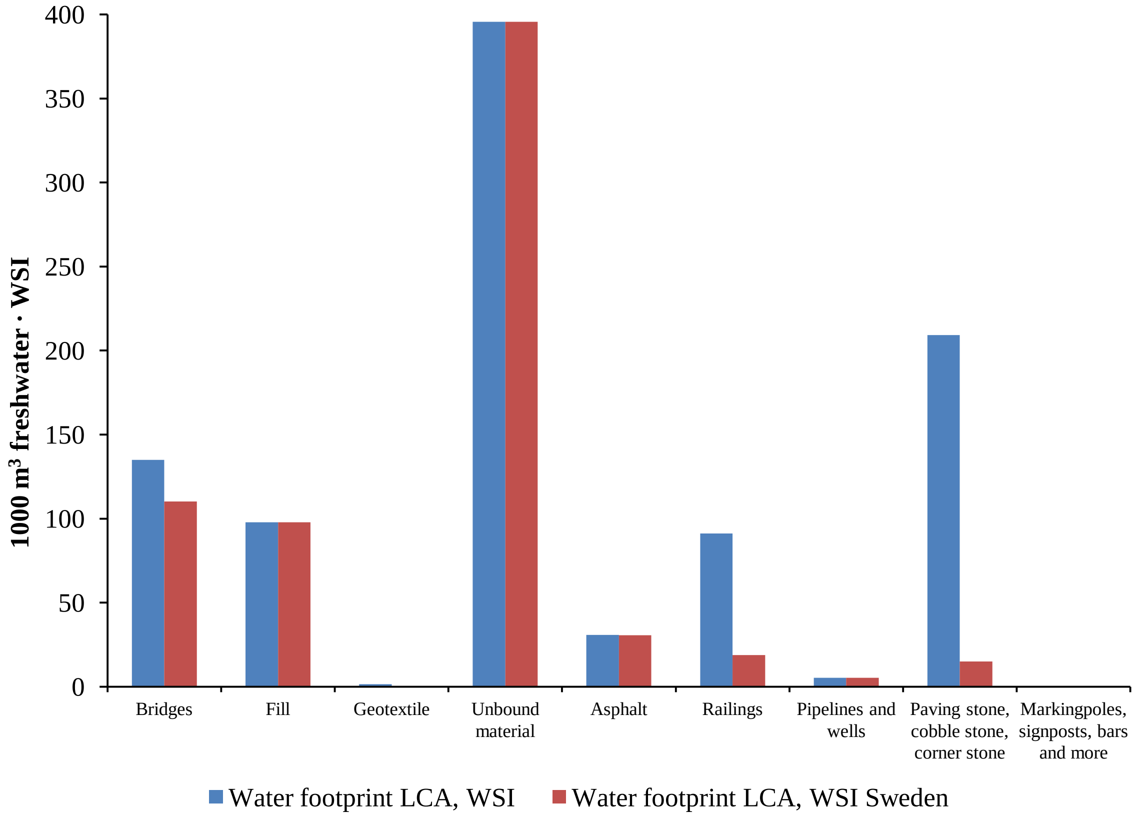

Figure 16. Weighted water footprint of the different construction materials using the supplier in the Umeå project compared to using only Swedish suppliers.

For many of the materials the result is the same since the origin is mainly from Sweden. For other materials however, the results changed quite a bit.

As the construction materials used have different life-lengths and since one might wish to compare this case to other road projects, the results are also presented as water footprint per functional unit, which was chosen to per kilometer and year (figure 17).

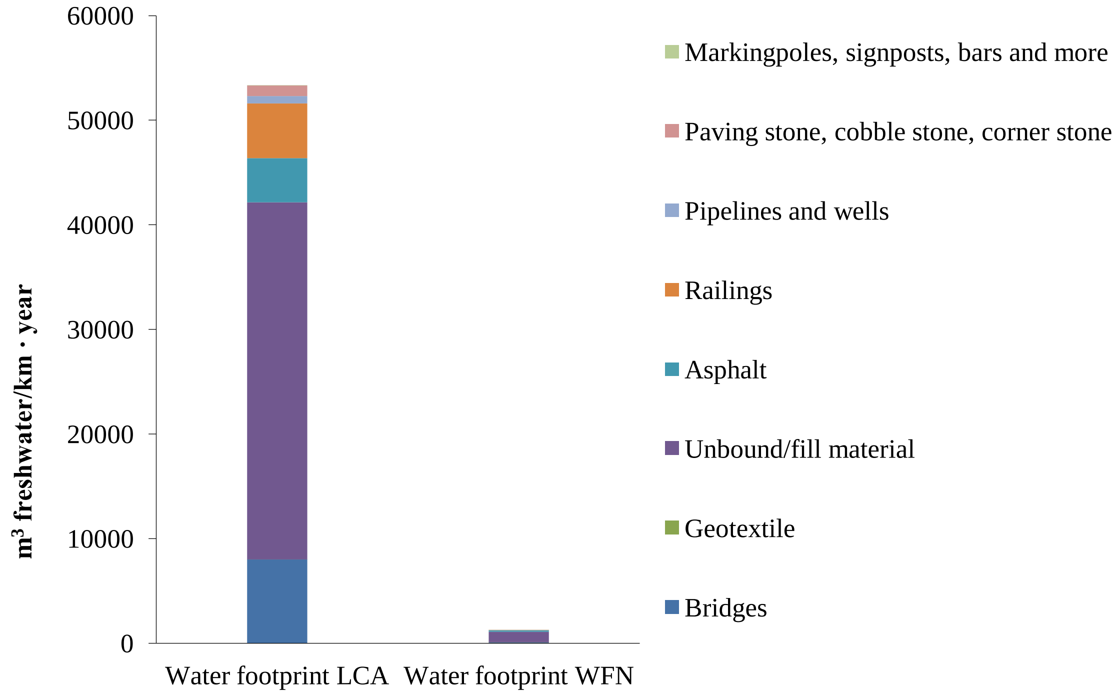

Figure 17. Water footprint per functional unit (kilometer and year) of contract 5 in the Umeå project.

The significant change of presenting the results and using the functional unit is that railings are contributing even more to the total water footprint, whereas paving, cobble and setting stone is not as significant any more (figure 17). Railings have an expected life-length of 20 years, whereas cobble stone is expected to last for 80 years. When their water footprints are allocated by year, the proportion of the water footprint of railings is thus increasing.

6 DISCUSSION

The concept of water footprint has been discussed in this report, which has two of the most developed methods today in focus; the Water Footprint Network (WFN) method and life cycle analysis (LCA). Calculating a water footprint can be used as a part of declaring environmental performance in a project by including it in an EPD, a GRI-report or by setting up an Environmental Profit and Loss (E P&L) account for water. It can also be used to identify and assess risks related to water use.

Calculations and assessment of the water footprint of building materials in a civil construct project have also been performed to analyse differences between the methods and to assess what materials that are important to address when trying to reduce the water footprint.

Summarizing the situation of sustainability within civil construction projects in Sweden today, it is clear that there is not much regulation controlling how sustainability issues are being treated. It is also clear that practitioners today do not really know how to tackle the question of water footprint, but on the other hand the reaction from the business during contact relating to the project has been very enthusiastic and positive.

The distinctive way of conducting a project within the civil construction sector might affect the possibilities of being flexible and progressive in the work with ‘newer’ environmental issues, such as the water footprint. There are a lot of different actors involved and the responsibility each actor has varies from project to project. However, in the end it is the demands of the client and the legal framework that sets the ambition regarding environmental performance of the project. In the house construction sector, a sector that is very alike the civil construction sector and has a similar structure when conducting a project, environmental issues have a completely different status. Therefore I see no particular limitations for achieving a more ambitious and progressive environmental effort within this sector. Taking on the question of water footprint could be a part of this.

There are several methods and tools available for assessing water use or consumption, however most of them are quite general and some outright impossible to apply to the civil construction sector. The more advanced methods use the WFN method or some sort of life cycle analysis. Since these are also the methods CEEQUAL are mentioning, I would recommend continuing working with one of these so that one is familiar with the method if CEEQUAL decides to become more fixed in their criterions.

A general challenge when studying a water footprint is that there are not any good guidelines on how to calculate the water footprint with the LCA method. There is not a consensus yet, not even regarding if the focus of the study should be consumptive water, used water or water withdrawal. Hopes were that the ISO standard would bring harmony but the standard is actually just combining both methods and requiring data for it all – a requirement that would be quite time-consuming, but possible, to meet. The guidelines for the WFN method are more specified, but the problem with this method is that it is not adjusted for the civil constructions or even building material in general. Because of this, LCA databases are used as data source, which unfortunately implies that data is not allocated in the recommended way nor does it provide the information needed regarding the fate of the water used. This leaves a lot of the decisions and assumptions up to those who are conducting the water footprint study, which is not optimal. For this reason I think that the LCA method probably has a better chance at becoming the standard for the civil construction sector.

It is important to shed light on the question of what is reasonable and what is desirable to describe with these methods. One could argue that the use of water does not make any impact for the rest of society since the water is returned to the catchment and is thus still available. This is however debatable, in the case of India, water use of steel plants have caused protests (Babu et al., 2013) since the amounts of water used can be very high. One of ThyssenKrupp's steel plants uses as much water as a small town and even though this water is still present in the same catchment, it is not available for other users (ThyssenKrupp, 2009). Using the WFN method, this use of water would not show.

The new ISO standard recommends looking at all different kinds of use when relevant. The results in the case study performed in this thesis can be seen as an example of looking at both use and consumption in LCA, since the WFN method actually is based on LCA data and is thus corresponding to the consumed part of water used in LCA.

In addition to reflect upon what should be described, is also important to reflect upon what cannot be described using these methods and if it is the most effective method for addressing this issue. If the goal is to reduce water use, putting a tax on water might be more efficient. However, if a client wants to prioritise the issue, introducing taxes might not be possible. In order for the analysis to be effective however, it is important to not just demand a calculation but also an action according to the results.

The WFN method is focused solely on freshwater shortage and does not look at other issues regarding water (such as flooding) nor sustainability issues other than water (for example climate change, social welfare or impact on ecosystem). LCA is broader in the sense that it is not a method restricted to water availability. One can choose to assess climate change, water footprint, eutrophication and ozone depletion as well as other issues. This being said, LCA has its limits too. Water footprint methods within the LCA society today are focused on water shortage and does not account for flooding or other issue involving too much water. Quality of water has also proven hard to address, but is to some extent possible.

One thing that neither of these two methods normally addresses is the difference in opportunity cost of surface water and ground water. In the WFN method, they are both treated as blue water and are presented separate of green water. The new ISO standard however states that when relevant, type of water used shall be communicated, which includes the distinction of fossil and non-fossil ground water (ISO 14046:2014). The total water footprint is however presented as total water withdrawal. Thus they could be treated differently during weighting according to scarcity, but this is normally not done.

Seeing that there are so many different ways to present a water footprint, CEEQUAL should really consider choosing one method, since this can change the outcome of the result quite a bit. There has also been some discussion about introducing more performance metrics (certain levels or numbers to aim for) in the next version of CEEQUAL (Uppenberg, 2015, pers. comm.). Determining what method shall be used for calculating the water footprint and giving clear instructions on how to calculate it then becomes inevitable if the rating system is to maintain credibility. Even so, there are several issues with including a performance metric for water footprint that would actually entail a step backwards in reaching a useful tool for assessing sustainability. Water is often needed in a lot of these operations for safety reasons and can be hard to substitute. Taking aggregates extraction as an example, this is the material that has the largest contribution to the total water footprint. If one were to stop using water in the process, which is mainly dust suppression, this would become a health issue instead. It is therefore very important to consider the whole situation when looking at this. However, if one were to collect rainwater and use it for dust suppression instead of potable water, this would generate a lower water footprint. But it is important to realize that the result of these two alternatives would look the same, and would probably be given the same points if it was based on metrics, even though they are not equally sustainable.

There are many opportunities for different companies with varying interests to use the method and system model suitable for the product they are producing. Steel companies for example, would probably prefer the WFN method, whereas plastic producers might prefer the LCA model, since this makes their product water footprint smaller in comparison to others. Both steel and plastic are materials where a significant part is recycled; without doubt, they would prefer the consequential LCA model where substitution is used. This is also the system model the World Steel Association and EuroPlastics use in the LCI-dataset present at their website at the moment. This data is often used and combined with data from other sources, which is creating problems for effective comparison of water footprints.

Use of system model is also a very interesting theoretical question. Within LCA it is practice to choose the allocation model when looking at the total footprint of a product. This becomes an issue when the second hand market for certain products is very strong. In the case of steel, the high recycling rate does not mean that extraction of new material is not done; the demand for this product is continuing to increase. This implicates that using recycled material from the recycled market will affect the market for virgin steel. Steel is exceptional in this matter though; the same cannot be said for concrete. When two markets (such as the markets for virgin and recycled material) are affecting each other in this manner, the best way to describe the situation would be to use the consequential approach. Mixing system models is not to recommend however, so the attributional approach was chosen for all products.

The biggest practical challenge is definitely locating the supply chain. It is time consuming and a lot of suppliers can only (if even so) account for the company they bought their material from, very few companies know where the raw material was extracted. Another important thing regarding this information is that it proved to be very erratic since the choice of supplier often turns out to be based on the lowest price for the moment. If a company were to ask their supplier for the supplier of a pipe, the purchase of this particular pipe might have been done several months ago. Getting this information is not that stimulating either, since this investigation would have to be done all over again for every new project, even though the same materials are included. The ideal level would be to describe this information on a general basis for Sweden by describing the proportion of market. This is however hard to do beyond import. This is a challenge regardless of method chosen, as long as impacts are to be estimated. Without estimation of impacts however, the whole footprint would be useless.

The model used for assessing the potential impact also needs to be put up for some critical discussion. The WTA ratio, which most of these methods are based on, does not entail any information of the regions' resilience concerning water use or consumption. Although Greece is a lot drier than Germany, using the WTA model, they have about the same WTA, since withdrawal is a lot less in Greece. However, this does not tell us how respective places would respond if we installed ten steel plants.

In addition to this, the model only entails information about physical scarcity, and not economic, which can be more common in certain regions. It does not tell us anything about the distribution of water within the population either. Water shortage often hits particular groups of people harder, for example women, due to limited power and influence (Comprehensive Assessment of Water Management in Agriculture, 2007).

The WTA is an average number, and can therefore hide variations within a country. The WSI according to Pfister however accounts for this by giving a country with high variability a higher index. This is a great advantage of this method.

One limitation is that the WTA and WSI only look at the needs of the human population. In order to be truly sustainable, the earth would need some of this water as well as the ecosystem both in water and on land. This problem can be adjusted by using a more complex model, but once again, because of the dynamic nature of the problem, this would not be satisfying since it would entail too much work keeping the model up to date.

Looking at the results from the case study, one can draw some general conclusions regarding which of the materials that are a high risk when it comes to addressing freshwater scarcity and which materials that are not. It should be said that the case study was done on a quite general level and the accuracy of these numbers is not very high, but it can be used as a general guide. Since the databases are well-known and usually used during climate calculations by LCA, it is safe to say that if performing a water footprint within the industry, the results would be similar. Other studies have shown similar results when it comes to which materials are consuming and using the most as well as the materials consuming and using the least water (WRAP, n.d.; Ilgar, 2011). One exception is the value of aluminium, which got a lower water use and consumption than expected based on the results from other studies (Ilgar, 2011) and the fact that the process of melting aluminium also requires quite high temperatures, which would entail a high water use (World Aluminium, 2015).

Some materials are high in water use per kilogram, but materials with low water use per kilo can still be contributing more to the total water footprint, since there are used in such massive amounts (figure 10, 11 and 14). By weighting the results with a water stress index, the distribution of impact on the overall results changes (figure 15).

The material contributing the most is filling material, which is not surprising since the amounts handled within these kinds of projects, is enormous (figure 14). Fill material is both a low consumer per kilo and produced locally and since water is abundant in Sweden it is considered to be a low-risk material. Other figures for water footprint from aggregates show that per kilo it is a low consumer (CEMEX, 2013; Lafarge, 2011). However, even though this material is not a risk-material per say, the amount of water used imposes that it might be wise to consider using alternative sources if reasonable, such as harvested rainwater, trying to recycle the water used or using brackish water. Using other water sources or creating closed loop system might also be a good idea for granite as well, one of the materials with high water footprint per kilo (figure 10 and 11), but not a very high user when looking at the total figures (figure 14). Doing so would save a lot of energy now used to produce potable water.

The granite used in this case is Portuguese stone, but China is also a big exporter of the product. Granite is also produced within Sweden, but this type of granite is more expensive. However, because of the weight, transport can also be expensive and thus need to be weighted towards the reduced costs of buying the material from another country. Due to this, it is mostly high-value stone that are transported very far, and usually not the simple stone used in infrastructure projects (Jaakkola, n.d.). Buying Swedish stone would lower the water footprint quite a bit (figure 16).

Plastic is a material that is a low-consumer of water per kilo and the amount used in a project is in comparison to other materials quite low (figure 11 and 14). In addition to this, geotextiles and drainage pipes usually have high quality requirements, which makes the contractors buy certified material from within Europe. There are exporters from outside of Europe claiming to meet the requirements of the standard, but contractors do not fully trust this and are scared to use material bought from outside of Europe since they will be responsible if the quality is too low (Tegsell, 2015, pers. comm.). An implementation of a similar certification within the steel sector might give the same results for steel products.

Steel is the material to be careful with when it comes to water, since this is both a high consumer and often imported from all over the world (figure 10, 11 and 15). However, it is important to note that most of the water in modern steel production is used and not consumed, and it is possible to recirculate most of the water. In a long-term perspective a solution would be to demand that all the suppliers have water efficient systems when producing steel. If someone wants to react to the results now and get the water footprint down, the easiest solution would probably be to buy the material from a country where water is abundant. Another way to reduce water footprint of steel (and probably any material in general) is to re-use and/or use recycled material (figure 10).

The opportunity of addressing this question now mostly consists of using these challenges for the practitioner's own benefit. The industry wants to address this, but does not know how. The fact that this is not yet addressed is a huge opportunity to go ahead and lead the development of this question. The trend is crystal clear, freshwater scarcity is a growing issue that people in the 'developed' world just now are starting to see the effects of. Many of the products we buy today will not be produced in the same way as before and definitely not for the same price, and water availability is a big part of the reason why.

7 CONCLUSIONS

A freshwater footprint analysis has been carried out using the approach developed by the Water Footprint Network (WFN) and Life Cycle Analysis (LCA). These are the two most prominent methods available today for addressing water footprint of products. The results have been weighted with the Water Stress Index developed by Pfister et al. (2009). A water footprint can be used as a part of declaring environmental performance in a project by including it in an EPD, a GRI-report or by setting up an Environmental Profit and Loss (E P&L) account for water. It can also be used to identify and assess risks related to water use.

The results obtained from the two methods used are very unalike, since they include different things. When analyzing which materials that might be high risk it is important to look at the water use or consumption per kilo as well as the total water footprint. Some materials are characterized by high water use per kilogram, but ones with low water use per kilo can still be contributing more to the total water footprint, since there are such massive amounts used.

Weighting according to water scarcity in origin country changes the distribution of the contribution of the different materials. Regarding weighting, several methods are available for this purpose too. Using a mid-point impact index, such as the WTA or the Water Stress Index by Pfister et al. is to recommend as an end-point index will contain too many uncertainties. The Water Stress Index has the advantage of accounting to some part for the variability in water availability throughout the year, but the simplicity of the WTA indicator is also appealing.

The case study gave results that are in concordance with other water footprint studies made on building materials. Conclusions from the results are that plastic and fill are considered low-risk materials since they are low consumers of water per kilo and are not transported any greater distance. However, fill is used in such masses that one could probably save a lot of energy by trying to use harvested rainwater for dust suppression. Steel is the material to be careful with when it comes to water, since this is both a high consumer and often imported from all over the world. However, most of the water in steel production is used, not consumed. Using the WFN method, this water demand would not show. One could argue that water use is not as bad, but on the other hand opening of a steel factory have caused protests because of the immense water use (WWF India, 2013) and one of ThyssenKrupp’s blast furnaces, used for steel production, uses 8 million litres of water for cooling per hour, which is as much water as a medium sized town requires (ThyssenKrupp, 2009).

Granite is also a material that consumes quite a lot of water and is sometimes imported from far away. Long transport distance (and therefore more likeliness of the stone coming from a water scarce area) is most frequent for stone with higher value and usually not for the ones used in infrastructure projects. When looking at the water footprint with the functional unit in mind, the significance of this material is decreasing since it is expected to last a long time (figure 17). This is therefore seen as a medium-risk material in civil construction projects.

Since the results are dependent to such a high degree on the choice of method it is important to achieve harmony within the business. CEEQUAL could contribute to this by deciding upon a system and if they are to introduce metrics this is inevitable. They should also adjust their terminology to be consistent with the main methods described in this thesis and to be clearer of what they are asking for.

It is also important to acknowledge the limitations of a water footprint analysis. It should not be used as a single base for the selection of materials, as there are other issues that can grow more severe as water use decreases. Preferably, a water footprint analysis should be accompanied with other analyses such as responsible sourcing and climate impact. One should also consider if it is the appropriate and most effective method for reducing the impact of water use before conducting a study.

7.1 RECOMMENDATIONS

The industry should continue working with the LCA method when doing a water footprint analysis as this is the method perceived as the one method with greatest potential of development in the civil construction industry.

When doing a water footprint analysis, it should be taken into account as a part of a more comprehensive evaluation of the sustainability of the building materials, for example by addressing it within a rating scheme such as CEEQUAL or by doing a LCA with several impact categories.

CEEQUAL should adopt the terminology used when discussing water footprint, for example the one stated in ISO 14046 and should recommend using a certain method for regionalisation, for example the WTA or WSI by Pfister et al. (2009).

If a metric of water footprint is to be introduced in CEEQUAL, it should not be based on a fixed amount, but rather using a proportionate reduction base.

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8.3 PERSONAL COMMUNICATION

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Antonsson, Pär. Planning and Purchase at Swedwire. 24 March 2015.

Ekendahl, Peter. Sales at Sapa. 17 April 2015.

Ericsson, Jonas. Production Manager at Skanska Asfalt och Betong. 20 March 2015.

Fredriksson, Magnus. Construction Manager Road Markings at Svevia. 14 April 2015.

Heinevik, Mats. Manager at Blue Systems AB. 16 March 2015.

Hennung, Karin. Manager Product HSE at Nynäs. 23 March 2015.

Kemppainen, Erik. Production Manager at Skanska. 13 March 2015.

Lundgren, Simon. Sales at Dahl. 31 March 2015.

Mäkelä, Mattias. Operations Manager at Blinkfyrar. 21 April 2015.

Petersson, Carl. Sales, technics at Viacon. 16 March 2015.

Sandberg, Anders. Production Manager at Viacon. 26 March 2015.

Söderkvist, Johan. Business Development Manager at Celsa Nordic. 20 March 2015.

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APPENDIX A OTHER WATER FOOTPRINT TOOLS AND INITIATIVES

There are a number of different methods available for estimating, calculating and assessing water use and/or consumption. As a part of this thesis, a survey of which methods are available today has been performed. The survey showed that there are a lot of different methods available and used with different levels of detail and accuracy. Some methods take more aspects into account than others; some methods are developed for personal use of water, some for a certain type of industry. Some of the available tools are focused on the water accounting part and some on the assessment part. The author of this thesis is not trying to suggest that this overview provides a full list of the available methods, but it includes the methods given most attention today. However, some tools that could be well implemented and developed may have been overseen since they have limited access and were for this reason not included in the study. This overview will begin by mentioning some of the tools directed against private persons wanting to reduce their water footprint but since this is not the focus of the thesis some methods for addressing water issues within companies will be more thoroughly described.

The Water Footprint Network has, as mentioned in the main report, made water footprint tools available for individuals, companies, processes, products and nations. On their website there is a tool that calculates the water footprint of an individual based on consumption patterns and ways of living (Water Footprint Network, 2015). This is based on information such as how many showers one takes per week and how many times a week laundry is done. It is very general but useful if one wants to know how to best reduce their water footprint. There are a lot of websites using the same method for addressing the water footprint of an individual (Water Footprint Network, 2015d; National Geographic, 2015; Grace Communications Foundation, 2015 etc.).

Many tools available today can offer help with the assessment of water footprint. There are not as many that can offer guidance when it comes to collecting data and calculating the water footprint. This is often the hardest part of the water footprint, since real data is often lacking. If one however knows how much water is used, consumed and when and where, one can really choose between different methods.

CDP Water disclosure is an initiative from the organisation Carbon Disclosure Project (CDP). They are a non-profit organisation and have, according to the website, the largest database for corporate self-reporting regarding emissions of carbon dioxide and water use. The form for filling this data is available on their website. The questions are concerning quantity of water used, consumed and released as well as the quality of this water. They also ask from which catchment this water is withdrawn and what risks the company sees with using and consuming water in this way (CDP, 2015).

The global reporting initiative (GRI) has a similar approach regarding their Water performance indicators. There are three different sections that treat water issues specifically. These sections are concerned with total amount of water withdrawn from different water sources, how this water withdrawal is affecting the catchment and how much of the water that is being recycled or returned to the catchment. The GRI organisation is solely collecting data; there are no tips or requirements for improvement. The reporting is only concerned with water quantity, water quality is not included (GRI, 2015).

Global Environmental Management Initiative (GEMI) has for some years developed models to address water issues in a simple way. The tool ‘Connecting the drops’ was developed in 2003 and consists of 5 different modules. It is information-focused and you go through the modules learning about how the company might affect water bodies and risks connected to decreasing availability of water. There is a form available on their website with different questions regarding water issues that one should think about and it is possible to fill out quantities of water use, but there is no help regarding how to calculate or estimate this quantity of water used. The form is focused on direct use of water, not embodied, imported water (GEMI, 2015). In GEMI’s tool ‘Collecting the drops’ developed in 2007 however, there’s a tool that estimates water consumption of a process step. This is a very simple input-output based calculation, which requires that one have access to the exact data of the process. You start by filling in how much water that is put into the process and which processes that are creating water losses through for example water evaporation. You also fill out how much water that is released as wastewater. Based on these numbers, one gets an estimation of the ‘error’ in the calculation (which is the water losses) and a comparison with their data on what error is acceptable depending on the volume that you handle in the process step (GEMI, 2015). After this one can read different available cases on how to minimize water use and losses. The tool is also only concerned with direct water use.

Direct water use and consumption is a lot easier to access data for and to address when trying to reducing water use and consumption. On WWF’s website however one can access the form ‘Water Risk Filter’, which addresses the whole product chain. It does require that you know a lot about the process since it is only the assessment of the water use and consumption, not the accounting part. The form contains sections of estimations of your dependence on a water stressed areas and the results are given as a risk assessment. It is also possible to fill out information for the supply chain, but at the moment it is only possible to do so for one supplier (WWF, 2015).

GEMI have developed a tool specifically focused on the supply chain, the GEMI supply chain sustainability tool. It is however very simplistic and the only data to report is how much a product cost, in dollar, and you get an estimation of the carbon dioxide and water used to produce this product. The idea is to analyse where to focus water use reductions most effective in order to make the most profits (GEMI, 2015). The Water Management Application (WaterMAPP), another tool created by GEMI, is also focused on potential financial savings by reducing water use. Is consists of two steps, the water scorecard and efficiency calculator. The water scorecard aims at estimating the water efficiency of different buildings and in the efficiency calculator the amount saved with different strategies for water use reduction is presented (GEMI, 2015).

Water brief for business are directed towards companies that wants to learn more about identifying risk and developing strategies regarding water use. No tool is developed; it is more focused on assessment than accounting. The founder is the organisation Business Roundtable which is a network consisting of CEO's for different leading companies in the US (WBCSD, 2010).

Three organisations working to raise awareness regarding water issues through certifications and branding are the European Water Partnership, the Water Stewardship Initiative and the WaterSense Program. The European Water Partnership is directed towards businesses and has created a standard for certifying companies' work towards a more sustainable water usage (WBCSD, 2010). The Water Stewardship Initiative also offers certification, predominantly to water intense industries and companies in Australia. The initiative has however spread to parts of Asia (WBCSD, 2010). The WaterSense program has a similar approach. They are trying to create a trademark, the WaterSense, to help customers pick water efficient products. Today is it mainly active within the US (WBCSD, 2010).

A tool focused on the accounting part is the MCA water accounting framework, created by the Ministerial Council on Mineral and Petroleum Resources and the Minerals Council of Australia. It is a simple input-output model compatible with GRI. It is developed for the mining industry in Australia (WBCSD, 2010). Due to the water stress in Australia, the authorities have developed a firm water efficiency policy, which makes Australia very progressive in this area (Environment Protection and Heritage Council, the Natural Resource Management Ministerial Council and the Australian Health Ministers' Conference, 2006).

The Corporate Water Gauge is a tool created by the Centre for Sustainable Innovation. To access this tool one must pay a fee for education about the tool, but after this, use is free. This limited the evaluation of this tool, but according to WBCSD it is assessing total water use and is using GIS-technique to assess the local conditions needed on a catchment level. It is not however possible to report the water use as different process steps so it is more focused on the assessment part (WBCSD, 2010).

Growing Blue was developed by Veolia Water and is a website trying to raise awareness about water use. On their website there is a tool, called the Growing Blue Tool, where one can see maps with different types of water stress indicators layered on top. They have also developed a tool called the Water Impact Index that is more focused on accounting. In the Water Impact Index one can fill out how much water is used, what source this water comes from and what quality is has when it comes to chemical substances. How this water was treated after its use and how efficient the treatment was is also a part of the tool. One can also add water use from use of energy, chemicals, produced waste as well as sold energy (which gives a negative value). The result is in gallons or m^3-WIIX equivalents and can be presented as water use per year, week or day. One can also add site information regarding withdrawal and release (Growing blue, 2015). The model uses the Water Stress Index by Pfister et al. (2009) for water scarcity assessment.

Impact from the release of chemicals is assessed through the grey water concept, that is the amount of freshwater it would take to dilute the volume to acceptable standards. What level of pollution that is acceptable is based on French standards developed by the French government. The chemical release or other degradation of quality of water from energy production and use, chemical usage and waste management is estimated using the Water Database developed by Veolia and Quantis (WBCSD, 2010). The Quantis Database is the same one incorporated into the Ecoinvent database version 3 (Lévová, 2013). Researcher Jean-Baptist Bayart is a former employer at Veolia and is at the moment employed at Quantis and he has been promoting sustainable water use in their name for some time.

WRI Aqueduct is developed by the World Resource Institute and is a free online database for addressing risk indicators connected to water. The tool is divided into three parts. The first one measures water availability and the other measures financial risks connected to water. The last one measures potential of disturbance. The tool considers quality and quantity, risks connected to climate change, legal restrictions, socioeconomic factors and population, industry and agricultural density (CEO water mandate, 2015). The tool is graphically very pleasing but the information about how the tool is working and what assumptions are made regarding accounting and impacts of water use or consumption are lacking (WRI Aqueduct, 2015).

The WBCSD Global Water Tool (GWT) is perhaps the most advanced excel-tool available today with the purpose of addressing water footprint. It is connected to google earth and compatible with several other tools, such as the GEMI Local water tool (LWT), which can be used to assess the results and has a focus on business risk connected to water. The GWT is also compatible to GRI reporting as well as CERES Aqua Gauge. The CERES Aqua Gauge is focused on management strategies to reduce or eliminate the risks connected to water dependency. The different tools also work independently if one wishes to fill out data for water use or consumption directly in for example the GEMI Local Water tool. It is possible to report from which source the water comes from (type of water and catchment) and how much water that is released and the fate of this released water. Information regarding water stress in the area of water uptake is included in the tool. The tool also asks about the population growth in the country (GEMI, 2015).

The two most developed and commonly accepted and used models for addressing water use and consumption are the water footprint and LCA, and these are also the ones used in the main report. Information regarding these methods can therefore be found in the chapter 3 but a few different versions of these methods will be described here since they are not included in the main report.

Water Neutral offset calculator is a calculator developed in order to spread knowledge and start discussions regarding the footprint tourists make when visiting South Africa. Hoekstra and Chapagain, founders of the WFN, have been involved in creating this tool (WBCSD, 2010).

Within the LCA community a lot of different models exist when it comes to water assessment. One version recalculates all of the consumption and use to what they call exergy. This is the amount of energy that it would take in order to, as in the example of water; make the water into freshwater again. For water that is used in-stream and not polluted, for example hydropower, the potential energy of the water is used. With this recalculation it is possible to add all kinds of resource use together (Berger and Finkbeiner, 2010).

The Environmental Design of Industrial Products (EDIP) program has developed a number of impact categories within LCA in order to address consumption and use of resources. Freshwater consumption of a product is expressed in relation to available water per capita for the reference year 1990 (Berger and Finkbeiner, 2010). The method is weighted according to Danish environmental goals (Swedish University of Agricultural Sciences, 2015).

The ecological scarcity method is another LCA-method and is sometimes also called eco-points or the UBP-method. Rolf Frischknecht, who has been very active in the development of the Ecoinvent LCA-database, formed the method with some colleagues in 1990 and it has been further developed in order to fit into the demands of the ISO standard. The ecological scarcity method is a Life Cycle Impact Assessment (LCIA) model that aims to quantify water stress with a characterisation factor. Ecopoints (the characterisation factor) exists for several substances and resources. They are based on political environmental goals and the tougher the goal, the larger the eco factor. This has been subject to critique, since a substance can therefore have different ecopoints depending on where it is released (Danielsson, 2013). Another downside is that the method does not account for different sources of water and that the weighting factors needed in the model does not exists for all countries. They are available for most OECD-countries, but for other areas estimations have to be made. A further limitation is that the eco factors for pollutants are based on the situation in Switzerland, which is also the origin of the model. If the model is used outside of Switzerland one has to account for this by adjusting the eco factors. A positive thing with the ecological scarcity method is however that it is possible to consider time differences between uptake and release of water within the model. The result of the assessment is presented as ecopoints, or EP, which can be a bit confusing since this is not a commonly known unit (Danielsson, 2013).

Pfister and colleagues published in 2009 a paper describing a LCA model that has components similar to the ones in the WFN method. The model only considers blue water consumption however. A water stress index is used for the assessment. This Water Stress Index (WSI) is based on withdrawal-to-availability (WTA) on catchment level and is also the one used in the main report. It has been calculated for more than 10 000 catchments by using a model called WaterGAP2 and accounts for varying water availability throughout the year.

For the impact assessment, three different impact categories or area of protection have been pointed out as important when addressing water consumption. These are human health, ecosystem quality and resources. Negative effects on health are described in disability adjusted life years (DALYs), which was developed for the WHO and is nowadays often used in health impact assessment. The ecosystem effects are described as potentially disappeared fraction of species (PDF). Normalization and weighting are accordingly to factors from the eco-indicator 99 model (Pfister et al. 2009).

Pfister and Ridoutt later published an article describing a model also addressing the issue of water quality (Ridoutt and Pfister, 2012). For quality of water it uses the same principle as the WFN method, they calculate the water needed to dilute the substances. In order to account for local impact, the Water Stress Index (WSI) by Pfister et al. (2009) is used. The results are given as H_2Oe, 'water equivalents' and it is connected to the ReCiPe-points, which can be found in LCA-databases (Danielsson, 2013).

The model Milà í Canals et al. presented in *Assessing freshwater use impacts in LCA: Part I* divides water into even more categories. They are accounting for green water, blue water, fossil blue water and water use due to change in land use. The use of water is also to be divided into evaporative and non-evaporative use. The model sees 4 potential outcomes from less available water. These are:

- Water use leads to shortage of freshwater and is creating health issues.
- Unsustainable use of fossil and aquifer ground water leads to less water available for future generations, freshwater depletion.
- Water use leads to shortage of freshwater and is creating issues related to quality of ecosystem, freshwater ecosystem impacts.
- Change of land use leads to change in water availability and is creating issues related to the quality of the ecosystems, freshwater ecosystem impacts.

In order to relate water use to ecosystem impacts the abiotic depletion potential is used. For connecting water use to human health a water stress indicator is used (Milà í Canals et al., 2008). This indicator is however not the same as the one used in Pfister et al. (2009). This indicator includes a small flow, minimum for sustaining the environment, which is called water use per resource indication (Milà í Canals et al., 2008). Pfister et al.'s model however, includes only the withdrawal to availability ratio and a variation factor (Pfister et al., 2009). This makes the WSI used in Milà í Canals et al. study more advanced but a problem is that this WSI is only calculated for the biggest rivers, which limits its use globally (Berger and Finkbeiner, 2010).

Because of availability, being to regional or industry specific, giving a too aggregated value or being too simplistic, these tools were not considered suitable for the task of addressing the water footprint in this thesis. The water footprint network method and the water footprint within LCA seemed like the two most developed methods up to date and were therefore chosen. Both of them were chosen however since there are some elementary differences between them. You can read about these in chapter 3 in the main report.

In addition to these many tools there are a number of initiatives, some of which created many of these tools. These will be described as well since they could be of interest for anyone looking for more information regarding water issues/footprints and how one can act to minimize impact regarding these issues.

Several times mentioned as a source of information in this report is the World Business Council for Sustainable Development (WBSCD). They are working to make sustainable development as part of a business strategy, and have developed the Global Water tool with the purpose of mapping water use of a company and identifying risks connected to water use (WBCSD, 2015).

The Global Environmental Management Initiative (GEMI) and the United Nations CEO Mandate are also directed towards companies. GEMI's goal is to raise awareness and creating environmentally sustainable solutions by providing free tools assisting companies in their sustainability work. The UN CEO Water Mandate have not developed any tool, instead they are evaluating the ones that already exists (CEO Water Mandate, 2015). Their ultimate goal is to fulfil the millennium sustainability goals, in which goals regarding water availability and sanitation are included.

Since the water footprint is focused on agriculture, it is not surprising that soda and other drinking companies were fast in calculating their own water footprint. The Beverage Industry Environmental Roundtable (BIER) Water Footprint Group is an industry-collaboration with 23 members like Coca-Cola, Carlsberg and SAB Miller. They are working to improve environmental sustainability within the production of beverages (Bier Roundtable, 2015). They have adopted the Water Footprint Network approach for water calculations and assessment (WBCSD, 2010).

Britain has set a goal to reduce the virtual water use within the beverage industry by 20 per cent by 2020 compared to the reference year 2007. The UK Food and Drink Federation and Envirowise want to help beverage companies to achieve this goal and have therefore started the initiative UK Federation House Commitment to Water Efficiency (WBCSD, 2010).

The Stockholm International Water Institute (SIWI) has a progressive stand when it comes to water issues. They have helped companies within the textile industry addressing their water footprint in the initiative Stockholm Textile Water Initiative (STWI, 2015).

The United Nations Environment Programme (UNEP) /SETAC Life cycle initiative consists of several scientists within LCA and have tried to find consensus on issues regarding LCA. Water Use within Life Cycle Assessment (WULCA) is a part of that initiative and focus on finding consensus on how water use is treated in LCA. They want to make comparisons of products possible by developing indicators for human health, ecosystem and freshwater resources connected to the use of freshwater resources. They want to include these in the 14040 LCA standards. Veolia Environnement in Zürich and scientists Koehler, Bayart and Pfister have been active within the initiative (WBCSD, 2010).

The UNEP division of technology, industry and economics have started a project called Water Footprint, neutrality and efficiency umbrella project with the objective of evaluating different water footprint methods and want to find synergies and create compatibility between the methods (WBCSD, 2010). The project resulted in a report called Corporate Water Accounting (UNEP, 2011, Part 2).

The Alliance for Water Stewardship (AWS) is an organisation consisting of several corporations and organisation that wants to promote sustainable use of water. Members are among others the Nature Conservancy, the Pacific Institute, the Water Stewardship Initiative, WWF, Water Witness, Water Environment Federation, the European Water Partnership, International Water Management Institute, Marks and Spencer, Nestlé, UNEP, The CEO Water Mandate (AWS, 2015). The goal of the organisation is to create an international standard that focuses on the direct and indirect social and environmental consequences of water use on a regional level and are offering certification of water efficient products. They are using the WFN method (WBSCD, 2010).

The Water Stewardship Initiative is also offering certification for sustainable water users. The initiative started in Australia and its main focus is there, but the system has spread to parts of Asia (WBSCD, 2010).

APPENDIX B ADDITIONAL INFORMATION ABOUT THE MAIN METHODS

This section complements the information about the Water Footprint Network method and the LCA method given in chapter three.

B.1 WATER FOOTPRINT NETWORK METHOD

The organisation Water Footprint Network has published a manual that describes the procedure of doing a water footprint for a person, nation or product (Hoekstra et al., 2011). Information about the Water Footprint Network method is mainly taken from this manual. Since the water footprint calculations in the report only concern products, the following description of the water footprint will have the focus of calculating water footprint for a product.

The water footprint assessment by WFN consists of 4 phases; goal and scope, accounting, assessment and response strategy. It is however not necessary to perform all of the steps, one can choose depending on how the information is to be used.

Goal and scope is where the processes of the products are being described. This will to a high degree decide the level of detail in the calculations. If the goal is awareness rising, the WFN considers the level of detail to be less important than if the goal is hot-spot identification or even more so if the goal is policy formulating and setting reduction targets. The system boundaries are set in the scope-phase. Since the water footprint concept is quite new, no standards have yet been developed for setting the scope. The scope is also highly connected to the goal of the study and the importance of accuracy in the study. The general rule according to the WFN manual is that the water footprint of all processes should be included, but one could also do a water footprint of the 'significant' processes. The processes that are considered to be significant can be selected through a criterion, for example that they should stand for more than one or ten per cent of the total water footprint of the product. A rule of thumb that the WFN gives is that one can assume that agricultural products are significant when it comes to blue and green water consumption, and industrial products for grey water.

The detail of temporal information is important due to the fact that water availability is dependent on seasons. An average number cannot fully describe the impact of the water footprint. Water availability also varies between years, since precipitation and temperature varies. It is therefore important to be careful about what conclusions to draw from a water footprint calculated for a specific year or time, and one should always state the time duration for used numbers. The WFN is not critical to choosing different time frames for different things however. One can for example choose to use numbers for production and yield from 5 years, but data from precipitation and temperature from 30 years.

Transport and labour are two common issues when doing a water footprint. Labour, which is a common issue during general life cycle studies, are excluded as a rule of thumb by the WFN, in order to minimize double counting. Transport should be included when it is significant, and the WFN especially recommend it when biofuels are used as fuel or if hydropower is used as a source of energy.

Calculation consists of quantifying and locating, in both time and space, the different water sources needed for the product. As a final step, all of these can be summed together. The result is hence a volume, but it also consists of more dimensions such as water source and an estimation of the water degradation. This is expressed as different colours of water; blue, green and grey water. The fact that water footprint by WFN is inclusive of the type of water consumed is what makes it different to the other methods.

Blue water is the water consumption of ground and surface water sources and green water is the consumption of rainwater. Water consumption is defined in the WFN manual as evaporated water, water incorporated into products, water that is not returned to the same catchment area (it could for example be returned to another catchment area or the sea) or water that is not returned in the same period of time (for example withdrawn in a scarce period and returned in a wet period). The part of the rainwater that becomes run-off is therefore not included since this is not consumed. Since green water is rarely used in industry production, this is often only applicable when the products involve a crop or the forest industry.

The water consumption of a product in the use phase is not included in a product's water footprint. This is considered by the WFN to be a part of consumer's water footprint, not the product itself. The water footprint of a product does not include reuse, recycling or disposal phase either since this is part of the business performing that activity and the consumers that benefit from that service. The water footprint according to the WFN does not include other water issues that are not scarcity related, such as flooding, lack of infrastructure for drinking water supply or sanitation or issues that are connected to, but not purely freshwater scarcity, such as biodiversity or climate change (Hoekstra et al., 2011).

B.1.1 Calculations

The calculation section will describe how to calculate the blue and green water footprint of a process as well as the total water footprint of a product. For the calculations of grey footprint or the water footprint of a person or a nation, see the WFN manual (Hoekstra et al., 2011).

The blue water footprint shows the consumption of blue water of a process, i.e. consumption of ground and surface water. The equation for calculating blue water consumption is given below.

$$WF_{proc,blue} = BW_{evap.} + BW_{incorp.} + LostReturnFlow \quad \text{(B1)}$$

The blue water footprint of a process is the sum of blue water that has evaporated ($BW_{evap.}$), blue water that is incorporated to the product ($BW_{incorp.}$) and the 'LostReturnFlow'. The 'LostReturnFlow' is the water that is returned to another catchment or returned in another period. The unit of the blue process water footprint is volume per time unit. According to the WFN the evaporation part of the water footprint is the biggest. All types of production-related evaporation should be included, for example evaporation during storage or evaporation of heated water that is not recollected.

The equation for consumption of green water is similar:

$$WF_{proc,green} = GrW_{evap.} + GrW_{incorp.} \quad \text{(B2)}$$

In the water footprint for green water the term LostReturnFlow is not included since green water is normally not withdrawn. If one would locally collect rainwater for usage from rooftops or other hard surfaces, this would according to the WFN be categorized as consumptive blue water. The green and the blue water footprint of a process are together the water footprint of a process. The next step is to relate the process to the product.

The equation used for calculating the water footprints of the different products depends on if the result of the processes are one single product or several different. To calculate WF if it is a single product, the equation below is used.

$$WF_{prod}[p] = \frac{\sum_{s=1}^{k} WF_{proc}[s]}{P[p]} \quad \text{(B3)}$$

WF_{prod} is the water footprint of the product p and WF_{proc} is the water footprint of process s. The different water footprints for processes s to k are then summed together. This is divided with the production quantity of the product p (P[p]) in order to get the volume water per product mass. The unit is volume per mass. It is however more common that a process is more complicated than this. In order to avoid double counting, a step-by-step approach is taken. For this, equation (B4) is used.

$$WF_{prod}[p] = \left(WF_{proc}[p] + \sum_{i=1}^{y} \frac{WF_{prod}[i]}{f_p[p,i]}\right) \cdot f_v[p] \quad \text{(B4)}$$

where $WF_{proc}[p]$ is the water footprint of the process of making z output products from y input products, expressed in water use per unit of processed product p [volume/mass]. This means that the water footprints of the input products must be normalized according to their product fraction of the process steps. This is done with the product fraction parameter, which is also used for dividing the $WF_{prod}[i]$, the water footprint of the products i to y.

The product fraction is the parameter $f_p[p,i]$ and explains how much output product one gets (in mass) from the input products (in mass). This is clarified in the equation below,

$$f_p[p,i] = \frac{w[p]}{w[i]} \quad \text{(B5)}$$

where w[p] is the mass product output and w[i] is the mass product input. If a product is produced using various input products, but the process only results in one type of output product, the water footprints of the different input products and the water footprint of the process step are simply added. If the process results in several products however, the fraction of the production that the product in question contributes with is used. How the product is contributing to the process can be measured in various ways. The Water Footprint Network mentions mass and economic value, but recommends the economic value since they think that mass is less meaningful. The ‘value fraction’ is represented by the $f_v[p]$ in equation (B6):

$$f_v[p] = \frac{price[p] \cdot w[p]}{\sum_{p=1}^{z}(price[p] \cdot w[p])} \qquad \text{(B6)}$$

and is the price of the product p (in monetary unit/mass) times the mass per product, divided by the sum of the price of the z output products times the mass of respective product. If the process only results in one product, the value fraction will be one.

The water footprint assessment manual uses the word price, which could be misrepresentative when a market is distorted or even non-existent. They recommend that one should take the real economic value if this is available.

A problem with the value fraction is that prices often vary from year to year. In order to minimize the influence of this they recommend taking an average price of at least the last 5 years. It is however also important to consider that taking an average of too many years will give an out-dated number. The choice of how many years to use for the average can therefore change the results quite much.

The results of the calculation is as earlier mentioned one or more volumes. This does however not say much about how the water use is affecting the place where it is withdrawn. For this, the assessment plays an important role.

B.1.2 Assessment

The assessment can be done in various ways, using various aspects of sustainability. One can choose to look at different environmental, social and economic aspects of water footprint, and the level of detail needed to be able to do so also varies. It is therefore important to determine the scope of the assessment.

The WFN recommends a couple of sustainability criterions in order to assess the sustainability of the water footprint. These are divided into the three dimensions of sustainable development; environmental, social and economic. The environmental sustainability is to large extent determined by pollution according to the manual. It is also important that the extraction of water is not too high; the run-off needs to be enough in order to ensure the health of the ecosystems and people dependent on these ecosystems. The WFN recommends using ‘ambient water quality standards’ for pollution and ‘environmental flow requirements’ for determining if the run-off is sufficient.

Looking at the social sustainability assessment a minimum amount of water needed for domestic use and a minimum for food production need to be reserved to the human population. The water left can thus be allocated to ‘luxury’ goods.

The water must be used in an economic efficient way in order to be economically sustainable. This means that the result from using a water footprint should outweigh the full cost for the footprint, including the externalities, the opportunity costs and scarcity rent.

According to the WFN, the sustainability of a water footprint of a product is depending on the sustainability of the processes needed to create the product. The water footprint of a process is unsustainable if it is located in a river basin with an unsustainable water footprint at the time of water consumption. It is also considered unsustainable if it is possible to reduce the water footprint of the process to an acceptable societal cost.

The water footprint is a description of the primary impact, i.e. the change in volume of water or quality of water due to human use. One can also use that to describe secondary impacts such as biodiversity loss or degradation of life quality.

B.2 LCA

The International Organization of Standards (ISO) has developed principles for the process of performing a Life Cycle Analysis. These standards are gathered in the ISO 14040-series and are today widely accepted. For this reason, the standards have been used as the foundation for the following information about LCA and the processes of performing one.

LCA consists of 4 stages, goal and scope, inventory, impact assessment and interpretation. The process of doing a LCA is however iterative and interpretation is done in all of the stages (ISO 14040:2006). Life cycle inventories (LCI) was conducted as early as in the 1880s by a Scottish economist and biologist named Patrick Geddes, but the modern methods was developed sometime in the 1970s (Klöpffer and Grahl, 2014).

The idea is to look at a product’s whole life cycle and assess the impacts from raw materials extraction, production, use and waste treatment, including transport and energy needed in and between the different stages. The whole life cycle approach is often called ‘cradle-to-grave’ analysis.

In the goal and scope phase, one states the purpose of the study and how the results will be used. The system boundaries and the functional unit are stated in this phase. Like the goal and scope in the Water Footprint Network method, this will decide the level of accuracy needed and the possible assumptions and omissions (ISO 14040:2006).

B.2.1 Life Cycle Inventory (LCI)

The inventory phase is similar to the phase called accounting by the Water Footprint Network. This is when the data of all the relevant activities are gathered.

If a process produces more than one product, the water used needs to be allocated to the different products. The standard 14044 contain information about how this allocation should be executed. An important rule is that this is only done for products, not waste.

Waste can never be burdened since generally no one would solely produce waste (ISO 14044:2006).

Allocation can be done using various bases for allocation or by doing a system expansion or reduction. ISO recommends changing the system boundaries if possible. If allocation is unavoidable they recommend physical allocation as the first choice of base for allocation, allocation per mass as second and economic value as third choice. They think this is the order with the highest level of scientific grounds at the first choice, but they also state that this may vary between product systems depending on their properties (ISO 14044:2006).

The values obtained from each step or activity is added and presented as a single number, for example as tonnes of CO_2 or CH_4 emissions. When it comes to addressing water, withdrawal or use of water is the data that has often been reported, so most of the data available do not differ between use and consumption of water. Although ISO recommends dividing between different usages of water, the total number is presented as water use or withdrawal, not consumption (ISO 14046:2014). A full life cycle analysis includes assessment of the values obtained in the inventory phase (ISO 14040:2006).

B.2.2 Life Cycle Impact Assessment (LCIA)

The assessment phase can be done in various ways. The mandatory steps according to ISO 14044 are choosing impact categories, category indicators and characterisation models. Classification of the data obtained from the inventory phase and calculation of category indicator results (characterisation) are also mandatory steps (ISO 14044:2006).

The impact categories are the issues that the study will assess. These could be climate change or eutrophication potential for example. ISO does not provide any list over recommended impact categories; the choice is to be made by the person performing the study (ISO/TR 14047:2003). There are several characterisation models available that estimates the relations between the impacts that different inventory data could have. It is also possible to create new ones if the available impact categories do not satisfy the goal of the study. One commonly used impact category when addressing water is a water scarcity, using a model such as WTA or WSI as a characterisation factor (Kounina et al., 2012).

One important aspect to consider when including water quality as an aspect in the freshwater impact category is that this if often included in other impact categories of LCA, such as eutrophication and toxicity. The risk of double counting is therefore quite high (Berger and Finkbeiner, 2010).

APPENDIX C INPUT DATA FOR THE CASE STUDY

Input data for the Umeå project is presented here. The data consisted of materials used and the amounts of materials used. The data was readily available at WSP as this project had been used as a reference project before when developing a model addressing climate impact.

Projektnamn **Umeå projektet 2, etapp 1 norra länken, del 3. MF , delen Hissjövägen - Ersboda, Entreprenad 5**	Entreprenad **E5**	Datum **12-10-18**
BYGGHANDLING,		
Text	Enhet	Mängd
Denna mängdförteckning är upprättad enligt AMA 98		
BYGGNADSVERK		
BROAR		
Jordschakt kategori A för broar	m3	7920
BROAR FÖR VÄGTRAFIK		
Bro över väg 92 1,5 km O tpl Grubbänget i Umeå på enskild väg, enligt TBb och ritning 5 41 K 20 03		
	-	-
Längd	m	68,3
Bredd	m	10
Area	m2	683
Stödhöjd, medel	m	9
Betong	m3	588
Slitbetong	m3	52
Armering	ton	87
Räcken	m	158
Bro över enskild väg 2,0 km O tpl Grubbänget i Umeå på väg 92, enligt TBb och ritning 5 41 K 20 04	-	-
Längd	m	11,7
Bredd	m	14
Area	m2	163,8
Stödhöjd, medel	m	5,5
Betong	m3	217
Slitbetong	m3	6
Armering	ton	24
Räcken	m	36
Bro över Djupbäcken 2,2 km O tpl Grubbänget i Umeå på väg 92, enligt TBb och ritning 5 41 K 20 05	-	-
Längd	m	32,9
Bredd	m	14
Area	m2	460,6
Stödhöjd, medel	m	6,5

Betong	m3	473
Slitbetong	m3	29
Armering	ton	59
Räcken	m	72
Bro över GC-väg 1,0 km NV tpl Sandahöjd i Umeå på väg 92, enligt TBb och ritning 5 41 K 20 06	-	-
Längd	m	
Bredd	m	
Area	m2	0
Stål	ton	17
Bro över GC-väg 0,7 km NV tpl Sandahöjd i Umeå på väg 92, enligt TBb och ritning 5 41 K 20 07	-	-
Längd	m	
Bredd	m	
Area	m2	0
Stål	ton	17
Bro över väg 92 0,5 km NV tpl Sandahöjd i Umeå på enskild väg, enligt TBb och ritning 5 41 K 20 08	-	-
Längd	m	75,6
Bredd	m	5
Area	m2	378
Stödhöjd, medel	m	7,6
Betong	m3	339
Slitbetong	m3	25
Armering	ton	52
Räcken	m	168
Bro över GC-väg 4,3 km vid Green zon		
Längd	m	11,1
Bredd	m	14
Area	m2	155,4
Stödhöjd, medel	m	3,3
Betong	m3	160
Slitbetong	m3	24
Armering	ton	17
Räcken	m	38
BROAR FÖR GÅNG- OCH CYKELTRAFIK		
GC-bro över väg 92 0,5 km O tpl Grubbänget i Umeå på lokalväg (Tavelsjöleden), enligt TBb och ritning 5 41 K 20 02	-	-
Längd	m	67,5
Bredd	m	5
Area	m2	337,5
Stödhöjd, medel	m	8,4
Betong	m3	295
Slitbetong	m3	32
Armering	ton	38
Räcken	m	138
UTFÖRDA UNDERSÖKNINGAR O D		
Befintliga ledningar	-	-

UNDERSÖKNINGAR O D		
Undersökningar av mark- och vattenförhållanden m m	-	-
Avvägning, pejling m m	-	-
Undersökningar av ledningar	-	-
INMÄTNINGAR		
Inmätning av mark, anläggning m m	-	-
UTSÄTTNINGAR		
Utsättning för bro	-	-
Utsättning för väg	-	-
Utsättning för ledning	-	-
HJÄLPARBETEN I ANLÄGGNING		
Tillfällig avledning av vatten	-	-
Grundvattensänkning eller portrycksänkning	-	-
Tillfälliga åtgärder på angränsande byggnad eller anläggning	-	-
Åtgärd för rörledning i mark	-	-
Åtgärd för el och telekablar o d i mark	-	-
Åtgärd för mätpunkt o d	-	-
Åtgärd för vägtrafik	-	-
Tillfällig väg med bitumiös beläggning	-	-
Tillfällig vägtrafikanordning	-	-
RIVNING		
Rivning av hel rörledning		
Vägtrumma BTG dim 300	m	8
Vägtrumma BTG dim 400	m	8
Vägtrumma BTG dim 500	m	14
Vägtrumma Plast dim 400	m	18
Fv-kulvert	m	60

Rivning av bitumenbundna lager, hela lagertjockleken		
Tjocklek 0-100 mm	m²	271
Tjocklek 100-250 mm	m²	2850
Sågning av bitumenbundna lager, hela lagertjockleken	m	15
Rivning av enheter bestående av stolpfundament, skyltstolpe och skylt		
Vägmärken	st	3
TRÄDFÄLLNING, RÖJNING M M		
Fällning av samtliga träd inom angivet område	m³	2450
RÖJNING	m²	273151
BORTTAGNING AV MARKVEGETATION OCH JORDMÅN		
Borttagning av markvegetation och jordmån inom område för väg, plan o d, kulturmark		
Fall B, tjocklek 0,2-0,4 m	m³	0
Borttagning av markvegetation och jordmån, inom område för väg, plan o d, skogsmark		
Fall A, tjocklek 0,1-0,3 m	m³	0
Fall B, tjocklek 0,1-0,3 m	m³	12952
UPPLÄGGNING OCH LAGRING AV TILLVARATAGEN MARKVEGETATION OCH JORDMÅN		
Uppläggning och lagring av tillvaratagen markvegetation och jordmån för vegetationsetablering	-	-
JORDSCHAKT		
Jordschakt kategori A för väg, plan o d		
Fall A	m³	113928
Fall B	m³	128646
Fall B, tipp i direkt anslutning till arbetsområdet sekt 0/200 - 0/800	m³	0
Fall B, tipp vid Ersmarksberget	m³	74482
Fall B, tipp Dova i anslutning till värmeverket	m³	6751
Bortschaktning av tillfällig förbifart	m³	1948
Tillägg yt- och jordblock >3 - 5 m^3	st	50
Jordschakt kategori B för väg, plan o d		

Fall A	m³	16508
Fall B	m³	11274
Tillägg yt- och jordblock >3 - 5 m3	st	0
GC-väg Godsvägen		
Fall A	m³	1884
Fall B	m³	2378
Tillägg yt- och jordblock >3 - 5 m^3	st	
Jordschakt kategori A för utskiftning, utspetsning och utjämning		
Fall B	m³	6502
Tillägg yt- och jordblock >3 - 5 m3	st	0
Jordschakt kategori B för utskiftning, utspetsning och utjämning		
Fall B	m³	150
Tillägg yt- och jordblock >3 - 5 m3	st	0
Sten- och blockrensning kategori A under underbyggnad för väg, plan o d	m²	55081
Tillägg för block >2-5 m3	st	0
Jordschakt för va-ledning		
Fall A	m³	4021
Fall B	m³	9053
Tillägg yt- och jordblock 1-3 m3	st	5
Jordschakt för vägtrumma		
Fall A	m³	20
Fall B	m³	2633
Jordschakt för el- och telekabel o d	m	674
Jordschakt för mast, torn o d		
Fall B	m³	180
Jordschakt för bankdike		
Fall B, Area > 1.0 m^2	m³	3120
Yt- och jordblock 1.0 - 3.0 m^3	st	0
Jordschakt för terrängdike		
Fall B, Area > 1.0 m2	m³	0
Yt- och jordblock 1.0 - 3.0 m3	st	0
Avtäckning av berg	m²	9997
Urgrävning för väg, plan o d		
Fall B	m³	9634
Urgrävning för ledning		
Fall B	m³	2423
Borttagning av överlastmassor		

Fall A	m³	0
		150
BERGSCHAKT		0
Bergschakt kategori A för väg, plan o d		
Fall A	m³ (tf)	8792
Tillägg bergs överyta bergschaktdjup ≤ 1,0 m	m²	6143
Tillägg bergs överyta bergschaktdjup > 1,0 m	m²	3854
Djupsprängning, djup 2,1 m	m²	9997
Bergschakt av ytblock > 5,0 m³		
Fall A	m³	0
Bergschakt av jordblock > 5,0 m³		
Fall A	m³	400
FYLLNING FÖR VÄG, BYGGNAD, BRO M M		
Fyllning kategori A med grovkornig jord och krossmaterial för väg, plan o d		
Fall A	m³	20952
Fyllning kategori A med bland- och finkornig jord för väg, plan o d		
Fall A	m³	120284
Fall B av beställaren tillhandahållna massor för bankfyllnad av bro mot jvg	m³	10100
Fyllning kategori B med bland- och finkornig jord för väg, plan o d		
Fall A	m³	16408
GC-väg Godsvägen		
Fall A		1884
Fyllning kategori A efter schakt för utskiftning, utspetsning och utjämnning		
Fall B	m³	9554
Fyllning kategori B efter schakt för utskiftning, utspetsning och utjämnning		
Fall B	m³	912
Fyllning med grus eller gruskrossmaterial för grundläggning av mur, trappa m m		
Fall B	m³	29
Fyllning med förstärkningsmaterial mot bro, mur o d		
Fall B, avser bef jvg-bro	m³	0
		10811
Fyllning mot fundament		
Fall B	m³	180
Fyllning för förbelastning för väg, plan, byggnad,		

järnväg o d Fall B	m³	0
FYLLNING FÖR LEDNING, MAGASIN M M		
Fyllning efter urgrävning till viss nivå för ledning Fall B	m³	1436
Fyllning för tjälskydd av trumma med tjock trumbädd under ledningsbädd Fall B	m³	1558
Ledningsbädd för va ledning Fall B	m³	60
Ledningsbädd för vägtrumma Fall B	m³	55
Ledningsbädd för el- och telekabel o d	m³	65
Kringfyllning för va-ledning Fall B	m³	846
Kringfyllning för vägtrumma Fall B	m³	2505
Kringfyllning för el- och telekabel o d	m³	197
Kringfyllning för avstängningsanordning, nedstigningsbrunn m m Fall B	-	
Resterande fyllning för va ledning Fall A	m³	4021
Resterande fyllning för vägtrumma Fall A	m³	20
Resterande fyllning för el- och telekabel o d	m³	139
TÄTNINGS- OCH AVJÄMNINGSLAGER FÖR VÄG, BYGGNAD, JÄRNVÄG, BRO M M		
Tätning och avjämning kategori A av bergterrass för väg, plan o d utan krav på lagertjocklek Fall B	m²	6305
LAGER AV GEOTEXTIL		
Materialskiljande lager av geotextil, under överbyggnad för väg, plan o d Bruksklass N3	m²	91482

OBUNDNA ÖVERBYGGNADSLAGER FÖR VÄG, PLAN O D		
Undre förstärkningslager kategori A		
Fall B	m³	101254
Undre förstärkningslager kategori B	m³	2287
GC-väg Godsvägen	m³	1595
Förstärkningslager kategori A till överbyggnad med flexibel konstruktion och med bitumenbundet slitlager, betongmarkplattor m m		
Fall A, avser överlastmassor	m³	0
Fall B	m³	31763
Förstärkningslager kategori B till överbyggnad med flexibel konstruktion och med obundet slitlager	m³	2300
GC-väg Godsvägen	m³	1311
Obundet bärlager kategori A till belagda ytor		
Tjocklek 80 mm	m²	78627
Obundet bärlager kategori B till ytor med obundet slitlager		
Tjocklek 80 mm	m²	673
Tjocklek 150 mm	m²	9390
GC-väg Godsvägen		
Tjocklek 80 mm	m²	1944
Slitlager av grus kategori B och C		
Tjocklek 50 mm	m²	8735
GC-väg Godsvägen		
Tjocklek 50 mm	m²	1767
Justeringslager av obundet bärlager kategori A till belagda ytor		
Fall B	ton	45
Stödremsa av obundet bärlager kategori A till belagda ytor, normalt utförande	m³	870
Stödremsa av obundet bärlager kategori A till belagda ytor, utförande vid räcke	m³	190
Stödremsa av slitlager av grus kategori A till belagda ytor, normalt utförande	m³	130
Stödremsa av slitlager av grus kategori A till belagda ytor, utförande vid räcke	m³	40
Stödremsa av slitlager av grus kategori B till belagda ytor, utförande vid räcke	m³	12

BITUMENBUNDNA ÖVERBYGGNADSLAGER FÖR VÄG, PLAN O D		
Bärlager kategori A av asfaltgrus vid nybyggnad		
AG 22, tjocklek 55 mm	m²	0
AG 22, tjocklek 70 mm	m²	0
AG 22, tjocklek 90 mm	m²	3395
AG 32, tjocklek 80 mm	m²	0
AG 22, tjocklek 70 mm		65764
Bindlager kategori A av asfaltbetong vid nybyggnad		
ABb 16, tjocklek 45 mm	m²	3348
TJ 55		3348
ABb 22, tjocklek 65 mm		65296
Slitlager kategori A av tät asfaltbetong vid nybyggnad		
ABT 16, tjocklek 40 mm	m²	650
Slitlager kategori A av stenrik asfaltbetong vid nybyggnad		
ABS 16, tjocklek 40 mm		63838
ABS 16, tjocklek 45 mm	m²	0
ABS 16 med PMB, tjocklek 45 mm	m²	3325
GC-väg Godsvägen		
Tjocklek 45 mm	m²	1151
MARKBELÄGGNINGAR AV GATSTEN, BETONGMARKPLATTOR, BETONGMARKSTEN, MARKTEGEL O D		
Beläggning av smågatsten	m²	560
Beläggning av kullersten	m²	95
Beläggning av valmplattor	m²	40
SLÄNTBEKLÄDNADER OCH EROSIONSSKYDD		
Erosionsskydd av jord och krossmaterial		
Fall A, avser slänter enligt tvärsektioner	m³	2858
Fall A, avser terrängdiken och trummändar	m³	707
Fall A, placeras i samråd med beställaren	m³	8358
Tilläggspris		11923
ÖVERBYGGNADER FÖR VEGETATIONSYTOR		
Växtbädd typ 2		
Fall B, tjocklek 100 mm	m²	5000
Avjämning m m av växtbädd	m²	5000
SÅDD, PLANTERING M M		
Sådd av gräs	m²	5000

FÄRDIGSTÄLLANDESKÖTSEL		
Gräsklippning, slåtter av gräsyta	m²	5000
Ogräsbekämpning av gräsyta	m²	5000
Vattning av gräsyta	m²	5000
Påförande av tillvarataget markskikt	m²	3561
KANTSTÖD		
Kantstöd av granit, satta i betong med motstöd av betong		
Typ RF 2, raksten	m	375
Typ RF 2, R=0,6 m	m	16
VÄG- OCH YTMARKERINGAR		
Extruderad markeringsmassa på trafikyta		
H(0,20)VB, TYP 1 enligt normalsektion	m	8890 8890
H(0,30)VB, TYP 2 enligt normalsektion	m	8750 8750
H(0,30)V	m	530
H(0,40)V	m	360
I(0,10)V 1+2	m	140
I(0,15)V 3+9	m	860
I(0,20)V 1+2	m	45
Väjningslinje	st	32
Fyllda ytor	m²	10
Pilar, Överstorlek	st	20
FÖRTILLVERKADE FUNDAMENT, STOLPAR, SKYLTAR M M		
Förtillverkande enheter sammansatta av fundament, stolpe och skylt		
Enligt vägmärkesförteckning	st	1
	st	14
Skylt för brunn, avstängningsanordning m m	st	14
RÄCKEN, STÄNGSEL, STAKET, PLANK M M		
Rörräcken	m	0 2469

Dubbelsidig	m	186
Slänträcken	m	0
		871
Stållineräcken	m	0
		4495
Förankringar av stållineräcken		
Mitträcke	st	0
		4
Förankringar av rörräcken		
L=12 m	st	0
L=4.6 m	st	
L=12 m		18
L.6 m		20
L=6 m, dubbelsidigt		1
Förankringar av slänträcke	st	0
		12
MARKERINGSSTOLPAR, BOMMAR M M		
Kantstolpar för placering på mark	st	180
KABELSKYDD I ANLÄGGNING		
Kabelskydd av plaströr		
Delade kabelrör SRS-D d=110 mm	m	0
DIVERSE ANLÄGGNINGS KOMPLETTERINGAR		
Räckesreflexer		
Övre	st	0
Undre	st	140
Övre		140
ÅTERSTÄLLNINGSARBETEN I MARK		
Återställande av naturmarksyta	m^2	12461
SKÖTSEL AV MARKANLÄGGNING UNDER GARANTITIDEN		
Skötsel av gräsyta under garantitiden	m^2	5000
KONSTRUKTIONER AV BETONGELEMENT I ANLÄGGNING		
Konstruktion av betongelement i mark kategori A	m	90
RÖRLEDNINGAR I LEDNINGSGRAV		
Vägtrumma av vågprofilerad, förzinkad stålplåt		

Trumma dim 600 mm	m	12
Halvtrumma av rör av vågprofilerad, förzinkad stålplåt		
Halvtrumma dim 1800 mm	m	45
Ledning av betongrör, avloppsrör, i ledningsgrav		
Trumma dim 1500 mm	m	35
Trumma dim 1200 mm	m	40
Trumma dim 1000 mm	m	115
Trumma dim 800 mm	m	33
Ledning av PP-rör, standardiserade markavloppsrör.		
Dim 160 mm	m	306
Dim 300 mm	m	281
Dim 400 mm	m	320
ANORDNINGAR FÖR FÖRANKRING, EXPANSION, SKYDD M M AV RÖRLEDNING I ANLÄGGNING		
Förankring av självfallsledning eller trumma	st	10
BRUNNAR PÅ AVLOPPSLEDNING		
Tillsynsbrunn av plast		
Dim 600 mm	st	8
Dagvattenbrunn av plast utan vattenlås, med sandfång		
Dim 400 mm	st	8
AVSTÄNGNINGSANORDNINGAR M M I MARK		
Höjdjustering av befintliga avstängningsanordning på vattenledning	st	2
RELATIONSHANDLINGAR FÖR ANLÄGGNING		
Relationshandlingar för väg, plan o d	-	-
Relationshandlingar för rörledningssystem	-	-
Relationsritning bro	-	-
VERIFIERING AV ÖVERENSSTÄMMELSE MED KRAV PÅ PRODUKTER	-	-
ANVÄNDNING AV DRIVMEDEL, KEMIKALIER OCH EL		
Maskintimmar	st	35090
Diesel	l	781596
Hydraulolja	l	4150
Fett	kg	1095

Motorolja	l	175
El	kWh	381000
MATERIALTRANSPORTER		
Trummor	ton	298
Armering, bro	ton	277
Betong	ton	5376
Räcken	ton	205
Asfalt	ton	27500
Rörbroar	ton	34
ÄTA		
4. Fall A fyll myrurgrävning, maskintimmar	maskintim	2845
15. Kontrollplats 2/700, maskintimmar	maskintim	270
25. Schakt av mtrl 3/800-4/050, jordschakt	m3	800
37. Extra urgrävning väg 363, maskintimmar	maskintim	224
37. Extra urgrävning väg 363, bergkross	ton	2527
40. detaljschakt av slänter med erosionsskydd, maskintimmar	maskintim	420
54. Tillkommande arbete ny bro 4/436, PM6, bro 1943		
56. Återställning av ersmarksberget, maskintimmar	maskintim	490
63. Avtäckningsmassor i slänter 4/000-4/400, maskintimmar	maskintim	160