FLEMISH ENVIRONMENT AGENCY (VMM)	**Analysis of the Water Footprint Index Methodology**
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Subject	Water Footprint Index – Analysis by the Flemish Environment Agency (VMM, Flemish region, Belgium)
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Description	Summary and extended note - Analysis of the objectives and beneficial use of the Water Footprint methodology, with critical notes on the methodology as described in the Water Footprint Manual (version 2009). – Discussion text.

A. SUMMARY NOTE

1. Context

The Water Footprint Index (WFI) was introduced in 2002 by Arjen Hoekstra (University of Twente) and has since been developed at an academic level. After the installation of the Water Footprint Network (WFN) in 2008, the WFI gained a lot of public attention. It has been largely applied throughout the world and benefits from the promotion by NGOs, in particular the World Wildlife Fund (WWF). At the governance level, both interest and criticism are growing and the WFI is now the subject of discussion at local, national and international level. The WFI concept seems an attractive tool for environmental policy and management, e.g. on sustainability as formulated in the Stiglitz report or regarding the "Beyond GDP initiative"[1], but there is still a lot of confusion and doubt about the meaning of WFI figures.

The WFI aims to provide figures about the "real" water use related to particular activities or products. It therefore relates to production and consumption processes. With the WFI, the idea of transboundary water flows by trade and transport and embedded water in products ("virtual water") has been introduced. The WFI developed a tool to analyse the production and consumption process from abstraction to end user, as well as algorithms to quantify these flows. WFI figures must raise public and political awareness and convince farmers, industry and consumers to reduce water use in order to protect water systems.

2. Beneficial use and advantages of the WFI

The WFI focuses on the production and consumption processes and on the international trade of water. It therefore uses a water balance approach and methods have been developed to quantify these flows. As such, the WFI allows a complete analysis of water uses. All this is innovative and fits current national and international policy. From a conceptual point of view, the WFI must be sustained. The WFI is also a practical tool suitable for resource efficiency analysis, allowing steering of industrial processes, agricultural practices or consumer habits. Further investigation is needed to find out if the WFI tool can be used in a more integrative approach of lifecycle analysis (LCA), material flows analysis (products – waste), air emissions, energy use and/or environmental accounting.

3. Remarks on the WFI

Regarding the meaning of 'footprint'. The WFI claims to be a footprint, comparable to the ecological footprint. However, a footprint must reflect an environmental impact (a human disturbance of the environment). This is not the case and, in fact, the water footprint figures represent volumes of water use only, not related to the water availability or abstractions of water systems. What is meant with

[1] The Stiglitz report highlights the need to develop global indicators for environment and social welfare, beside the economic GDP indicator. The "Beyond GDP initiative" – with European Commission, European Parliament, Club of Rome, OECD and WWF – aims to develop (combined) indicators on social, economic and environmental progress. Gross Domestic Product (GDP) is the best known measure of macro-economic activity. GDP = private consumption + investment + government consumption + (exports − imports).

‘water footprint’ is identical and restricted to ‘water use’. The public gets a wrong idea about products, supposing a high water footprint value equals a large environmental impact.

Regarding calculating an ‘index’. The WFI intends to produce a single figure covering the whole water usage process by combining water from land (green water), from surface and ground water systems (blue water) and waste water (grey water) into 1 index value. In order to provide a single value, the WFI attempts to combine water quantity and quality aspects. This approach has to be rejected, because of:

- the application of the dilution principle. This approach violates the stand-still principle and does not take into account excessive pollution loads based on exceeding environmental quality standards.
- the fact that water quality impacts cannot be ‘transformed’ into a volume of unavailable water.

Regarding ‘Green water’. Green water represents the water use for agricultural purposes (crop cultures). The total water consumption of crops (evapotranspiration) is calculated and not the additional water needs compared to natural vegetation. This partially explains the huge figures that are communicated to the media, but it also hampers a real environmental impact analysis.

Regarding ‘sustainability’. The WF manual recognises that the WFI is still incomplete regarding economic and social aspects. Surprisingly, cost aspects have not been further elaborated, considering the WF aims to change current production and consumption patterns. This meets the criticism of experts that the only value of the WFI is to raise public awareness. Also, some economists are convinced that the WFI is not suitable for influencing the economy because opportunity costs – the driving force of international trade – are not taken into account.

Other remarks. Although introducing new aspects of water policy and management, the WFI is still incomplete and in many ways erroneous:

- A wide range of terms, definitions and descriptions are not used properly or according to common practice, are sometimes conflicting or do not fit the algorithms developed. The manual is sometimes very confusing, becoming almost unreadable in some cases.
- The ‘environmental part’ needs further elaboration. Environmental processes are incomplete or not described properly (What about rainwater harvesting?)
- A number of algorithms must be criticised or need further explanation. Some have to be completely rejected.

4. Conclusions

- The WFI is in some ways innovative and integrative and has therefore real potential for beneficial use for environmental policy and management.
- The WFI, as developed thus far, is a useful tool for ‘resource efficiency’, allowing the comparison of products and production and consumption processes. However, a critical analysis of the algorithms developed is needed.
- The WFI is not a footprint or an impact indicator and the figures for ‘water consuming products’ that are communicated to the media are misleading in that sense.
- WFI figures are not correct as the WF relies on fundamentally wrong assumptions and principles.
- A profound evaluation of the whole manual is needed, in particular of the streamlining of terminology and the tools developed.
- As long as the methodology is fundamentally questioned, the WF remains unsuitable for governance.
- In global terms, the current status of the WFI is as follows: the basic idea and concept of the WF are OK, the tools developed are disputable and/or incomplete, the results must be rejected.

B. EXTENDED NOTE

This extended note is intended to clarify the general statements of the summary note and therefore provides some arguments and remarks, aiming at fostering the WF debate. It is not a detailed page-by-page analysis that requires an in-depth discussion with the developers. Therefore, a large number of small remarks are not mentioned. Remarks in this note relate to the Water Footprint Manual, version 2009 (Hoekstra *et al.*, 2009).

1. <u>The Water Footprint as a concept</u>

The basic assumption of the Water Footprint Index (WFI) is that water use affects the environment within the own territory or abroad and needs to be reduced as much as possible. It therefore aims to provide a single figure that reflects the *whole water use and impact* issue in order to raise the awareness of producers, consumers and policy makers. The WFI quantifies the water needs of a process or a product within the production chain, which is presented as an impact on the water system. Although it may be expected that in numerous situations a high level of water use will damage ecosystems, this cannot be stated in general. Water footprints will, depending on the case, differ according to the amount, the production step, the geographic area or the ecosystem type.

The WFI considers the 3 main factors of sustainability, based on the integration of economic, social and environmental aspects. The WFI methodology provides a tool that is largely applicable to an environmental analysis (physical data) and offers opportunities for an economic analysis (water accounts). This is an important step towards an integrated approach, aiming for an integrative environmental index comparable to the economic GDP. The WFI is innovative in the sense it addresses trade & transport and virtual water, beside a more detailed analysis of the production process. In that sense, it also relates water flows to water accounts.

The WFI combines information from the water system and the water chain (production and consumption) and therefore basically relies on the idea of water cycles and related water mass balances. This goes further than most of the existing approaches, even indicators, based on simple ratios of 2 variables. Hence, the WFI opens up the political and policy discourse on water use and trade in an international context, also addressing the 'impact' side of the issues. However, the methodology still needs improvement since flow charts and balances are well developed for the production chain (water chain, supply chain), but remain incomplete for the whole of the environmental cycle. As a result, the methodology is still not suitable for policy-making.

The WFI is related to the disturbance chain (DPSIR) and focuses on the pressures (P) by calculating water abstraction and use. Algorithms apply to pressure calculations. However, the WF does not take into account all DPSIR factors. At least the (monitored) environmental status (S) is not taken into consideration, although indispensable for impact analysis. This hampers the practical application of the idea of 'impact' analysis, which makes the WF less policy sensitive.

The idea is defended that the *"water footprints per ton of product need to be reduced everywhere when possible, also in water-abundant areas"* (p. 68). This relates to the concepts of water footprint offset and water neutrality. This is going beyond the common practice of using standards (EQS, emission limit standards, etc) as a (legal) basis and common objective and therefore may conflict with common policy. Table 5.3 (p. 74) lists options for governments to reduce WFs, but the calculation of water mass and load reductions is not mentioned, although this is the most efficient tool to allocate water resources and/or measures.

2. <u>The meaning of 'footprint'</u>

<u>Statement:</u> The WFI claims to be a footprint, comparable to the ecological footprint. However, a footprint in the strict sense of the word should reflect an environmental impact (a human disturbance of the environment). This is not the case and, in fact, the water footprint figures represent volumes of water use only, not related to the water availability or abstractions of water systems. What is meant with 'water footprint' is identical and restricted to 'water use'. The public gets a wrong idea about products, supposing a high water footprint value equals a large environmental impact.

Terminology

Before discussing the methodology and the value of the Water Footprint Index (WFI), it is worthwhile describing the meaning of footprint indices in general:

- An index is synonymous to an 'indicator', and therefore must provide an indication of something. An indication gives an idea of a status or change and is therefore not always constant over a period or absolutely correct. On the contrary, good indicators provide objective and quantified figures and are susceptible to changes. This sensitivity makes them useful for policy making.
- A 'footprint' refers to an impact of humans on the environment. To be useful, footprints should be numerically quantifiable, expressed as a ratio of a share to the total. This allows different activities, regions, products etc. to be compared and eventually the processes related to them.
- A water footprint is in fact a thematic restriction on the footprint concept. Beside water, other themes may be carbon or energy. These restrictions imply that a total footprint only can be obtained by combining all separate footprints. Policy decisions based on a water footprint may therefore differ from those based on other footprints or indicators. In the case of indicators being negatively correlated, policy that improves one indicator or environmental disturbance may worsen others.

Water footprint: environmental impact or resource efficiency?

The Water Footprint Manual states about the WF that "*It is* not *a measure of the severity of the local environmental impact of water consumption and pollution. (…) Water footprint accounts give spatiotemporally explicit information on how water is appropriated for various human purposes.*" (Hoekstra *et al.,* 2009: 9). It may be argued that it is not expected and that there is no need for the WFI to reflect the environmental status (SoE), but anyway it needs to include or be based on an impact analysis. Impacts initiate the political debate, but there is no need to if there is no environmental harm (which means: significant impact) at all. Otherwise, if there is really an impact, policy is needed. The use of a WF as it has been developed thus far seems only meaningful if strictly applied to the water chain. Water savings then equal economic profits. But national water policy is much broader than mere water saving at plant level. National policy needs impact analyses to address the issues at national or sector level and Hoekstra *et al.* (2009: 9) provide good arguments for that: to know national dependency on foreign water resources, to know the sustainability of water use related to water-intensive products, to know whether human activities do not violate environmental flow requirements or water quality standards, to know the relationship between scarce water resources and low-value export crops or the supply chain. Further, the WF process includes *"the phase of sustainability assessment, in which the water footprint is evaluated from an environmental perspective, as well as from a social and economic perspective"* (Hoekstra *et al.,* 2009: 10).

The WFI should reflect *impacts,* with each impact considered as a relationship between pressures and the environment. Distinction should be made between green, blue and grey water (referring to water flows or volumes) and their green, blue and grey water footprint (= their impact on the environment). Impact analyses require comparison of different flows, volumes or loads and hence can only be calculated if expressed as similar units.

- If WF were to stand for environmental impact then the Blue WF (as well as Green WF) must be calculated as the ratio of water use and water availability. This relates to the 'EPI Water Stress Indicator', defined as *"the percentage of a country's territory affected by oversubscription of water resources"* and to the Water Scarcity Index, calculating the 'overuse of water resources'.
- An index such as the WFI cannot combine water use (expressed as Q) and water impacts (expressed as a ratio or %) in a single figure. A WFI restricted to water use only does not reflect an impact and is therefore not a footprint. Calling the WFI a *resource efficiency index* (water use of production, trade & transport and consumption) would be more appropriate.

Water footprint = water use = resource efficiency

The WFI claims to be integrative, including both water mass and pollution. Both can be related to the water system and the supply chain (= water chain, = the economy). Resource efficiency tools relate to water masses and flows only, impact analyses to both water masses and pollution loads. A clear distinction should be made between the processes (e.g. water system, production, trade & transport, consumption) and the related water flows (abstraction versus use, with further distinction between treatment, supply and waste water production):

- There is a difference between water use (related to the source and part of both production and consumption) and water consumption (as the final step of the production in a consumption process).
- Water use should cover the production process (or supply chain: water abstraction – production – trade – consumption), with figures allowing comparison with other processes, products, etc. (= resource efficiency, RE).
- Needs further consideration: communication to the consumer and policy-maker should strive for one figure into which the values of footprint/impacts and water use are combined (= one figure for WF + RE). This is not easy as units are different (WF is expressed as a ratio, water use as a volume).

3. The calculation of an 'index'

Statement: The WFI intends to produce a single figure covering the whole water usage process by combining water from land (green water), surface and ground water systems (blue water) and waste water (grey water) into one index value. In order to provide a single value, the WFI attempts to combine water quantity and quality aspects. This approach has to be rejected, because of:

- the application of the dilution principle. This approach violates the stand-still principle and does not take into account excessive pollution loads based on exceeding environmental quality standards.
- the fact water quality impacts cannot be 'transformed' into a volume of unavailable water.

Calculating a total WFI?

From a conceptual point of view, there are a number of reasons to sustain the effort to apply a single and simple algorithm to obtain one figure encompassing the total stress on the ecosystem. However, the water flow chart and related water balance are more complicated as different processes are involved, resulting in separate figures with different units and thus becoming incomparable. Green and Blue water are volumes and can be compared to water availability, Grey water is a load and can only be compared to water quality. Therefore, the total WFI cannot be the sum of Green WF, Blue WF and the Grey WF, but must exclude the latter:

- Grey water represents pollution (loads) and therefore cannot be added to flows (volumes) to be combined into one index. Grey water must be totalled as the (un)treated waste water from different steps related to water use. The Grey WF is then the impact of the Grey water on the receiving water system. Impact analysis of Grey WF must be based on pollution loads and not on water masses only. Therefore, the Grey WF cannot be added to the Blue and Green WF to produce a single WFI in the way the WFI methodology describes.
- Combining Green/Blue and Grey WF into a single index value however needs specific attention at this meets the efforts to develop a "composed environmental pressure indicator" (partim water).
- It must be recognised that in some cases water pollution makes water use impossible, which means a volume of water is unavailable. Normally, this is technically solved by sanitation, making water volumes available for use in return for a higher economic cost. Nevertheless, water use hampered by low water quality is an additional stress and must be considered further, but the dilution principle cannot be applied:
  - The WF methodology applies the dilution principle to add Grey water to Blue and Green water. From a volumetric point of view, this is a double counting.
  - applying the dilution principle for policy purposes is not recommended since it is not compliant with the stand-still principle ("*dilution is no solution for pollution*");

Why dilution is not suitable for quantifying water quality impacts

Water pollution impacts are called *"water pollution levels"*, quantified by calculating the ratio of the Grey WF to the water flow *("run-off")* from a catchment (p. 59), which is the same as calculating the dilution. Dilution is about comparing volumes of two different fluids, whereas the objective of water quality impacts is to obtain an idea of the harmfulness of a substance. Impact calculations at the level of the water system rely on a comparison between the observed (= monitored) status and a previous observed status or an EQS. Any other approach (e.g. by means of dilution) is an inappropriate water quality impact analysis. (Note: dilution is a comparison between the inflow from sources and the receiving water body, expressed as a ratio or percentage, not allowing further calculations).

The WFI 'transposes' the pollution impact into water mass using the dilution principle. Dilution cannot be used to replace water load balances and must therefore be omitted. Water quality impacts must be based on (pollution) load balances, comparing waste water production (emissions) to the monitored water quality and related EQSs of the receiving water system. Load balances are flow charts, quantified with figures on loads; loads (weight/time) are calculated by multiplying a water flow Q (volume/time) by a concentration C (weight/volume).

4. Green water

Statement: Green water represents the water use for agricultural purposes (crop cultures). The total water consumption of crops (evapotranspiration) is calculated and not the additional water needs compared to natural vegetation. This explains partially the huge figures that are communicated to the media. But also, it hampers a real environmental impact analysis.

Production as a natural process or related to the supply chain

It can be agreed that, according to the general footprint rule, *"water footprint accounting must "include the water footprint of all processes within a production system (production tree) that 'significantly' contribute to the overall water footprint."* (Hoekstra *et al.,* 2009: 12). Although, the term 'significantly' should not refer to the largest amounts of water, but to the most relevant parts of water that distinguishes natural and non-natural water flows. Plant growth is a biophysical process, resulting in the production of biomass, which requires water. Biophysical processes however are inherent to the functioning of organisms and do not reflect human disturbances and plant growth is therefore part of a natural water-consuming process. This means: natural water cycles will differ according to vegetation and region and the water cycle will differ accordingly. A high level of (natural) water use is therefore not to be considered as negative (and consequently, a low water use does not equal a positive situation). Biological hot spots are very often habitats of high water turnover (e.g. rainforests, marshes, mangroves).
Water consumption will be different depending on considering a solitary plant, a single-layer vegetation or a multi-layer plant association - or – in case a single species is considered, a single species vegetation or an ecosystem. Impact analyses must consider the different reference conditions according to the area considered: one crop replacing another in industrialised regions may affect the water system, but will be less prominent than replacing a rainforest by a crop vegetation.

Distinction should be made between water consumption as being part of the growth process and water use within the supply chain. Within the supply chain, total water use can be accounted for. Production within the supply chain should only refer to the water volumes needed for the production of products: cleaning, treatment, conservation and other activities directly or indirectly requiring/using water. Therefore, it is surprising labour (see manual on p. 13) is not accounted for. Otherwise, plant growth impacts should only consider the relative water uptake compared to the natural/pristine/former vegetation. In this case, only the difference in water consumption should be accounted for.

Conclusion: Water use of a single product does not reflect the impact on the ecosystem. Hoekstra & Chapagain (2008: 7) confirm that most of the water use of some food products is part of the plant growth process.

5. Sustainability

Statement: The WF manual recognises the WFI is still incomplete regarding economic and social aspects. It is remarkable that cost aspects have not been further elaborated, considering the WF aims to change current production and consumption patterns. This meets the criticism of experts that the only value of the WFI is to raise public awareness. Also, some economists are convinced that the WFI is not suitable for influencing the economy because opportunity costs – the driving force of international trade – are not taken into account.

Can the WF contribute to sustainability?

As such, any initiative – like raising public awareness - must be welcomed if contributing to water resource efficiency. It is likely that a significant number of well-educated, green-oriented civilians will change their consumption pattern in some way, and a small number drastically, as a result of sensitization only. But it is doubtful that the majority of the people will do that to the extent that the huge global water resources issue will be solved. Global issues requiring far-going measures in a relative short term are the subject of a political discourse and international decisions. Even agreeing that sustainability needs a new equilibrium, the WF approach seems to reduce the complexity by: 1) omitting the consequences of economic and environmental changes on the social capital, 2) assuming that influencing the economy will restore the water balance and that a restored water balance will undo habitat impacts (very often, undoing impacts does not result in complete or real environmental restoration), 3) assuming that raising awareness of the consumers will lead to a change in consumer behaviour which will replace political decision-making. Moreover, decision-making at that scale is now expected to be evidence-based, providing impact analyses of concrete measures. This impact analysis should also include the effects on other natural resources (carbon release, energy consumption). Beside the fact the WF does not provide information on environmental impacts and the WFI values – expressed as volumes per unit – are not suitable for decision-making, the lack of (reliable) environmental accounts is a major drawback. Economic aspects, in particular the international trade issue, have been discussed by Wichelns (2010). At this moment, it is rather doubtful whether the WFI can be used as an economic instrument suitable for policy steering.

There is a common agreement that the WF is a valuable tool for raising public awareness. This means: to get people to start thinking about their consumption patterns and their transboundary responsibility. The use of the WF for common and global policy is limited. For management however, the WF provides a useful tool for calculating the water use of a production unit, allowing comparison between technical processes, industrial plants or comparable products. The basic problem remains that real water footprint values of different products do not allow simple comparison because these values may differ depending on the step of the production and consumption process. The message that one cup of tea equals a water use of 30 litres is no indication of the impact of tea cultivation on vulnerable habitats, provides no information of the total water use and is no basis for opting for alternative products. This conflicts with the objective of getting a response by public awareness, which largely depends on the simple and clear messages that are communicated.

6. Other remarks

Statement: Although introducing new aspects of water policy and management, the WFI is still incomplete and in many ways erroneous:

- A wide range of terms, definitions and descriptions are not used properly or according to common practice, are sometimes conflicting or do not fit the algorithms developed. The manual is sometimes very confusing, becoming almost unreadable in some cases.
- The 'environmental part' needs further elaboration. Environmental processes are incomplete or not described properly (What about rainwater harvesting?)
- A number of algorithms must be criticised or need further explanation. Some have to be fully rejected.

Non-exhaustive list of specific remarks:

1. *Methodology*
   - Distinction must be made between WF and water use;
   - Harvested rainwater is not included in the water balance. This requires the 'virtual' allocation of rainwater to the terrestrial and aquatic ecosystems.
   - the re-use of Grey water must be included.

2. *Terminology*
   - *Ambient water quality standards (p. 25) > Environmental Quality Standards (EQSs)*
   - *Ambient water system (p. 70) > water system*
   - *Assimilation capacity (p. 55) > dilution? Notes: 1) Assimilation is a wrong word as it refers to an active (physiological) process; 2) is not similar to carrying capacity.*
   - *Business > production, production step, activity*
   - *Consumption > use & consumption: if consumption is used to indicate volumes of water consumed by consumers, it may not be used to refer to "loss of water from the available ground-surface water body in a catchment area (…)" (p. 8).*

- *Distinction between use, production, trade and consumption. This distinction is needed to avoid continuous misinterpretation of WF calculations. Example section 3.5 on the WF within an area (p. 37) defines the WF as the total of consumption and pollution, whereas the calculation relates to the production processes. Trade is in between production and consumption. Other examples: definition Direct WF (p. 121).*
- *Domestic: context and distinction must be clarified*
- *Evaporation (E), transpiration (T), evapotranspiration ET) (p. 21): are different terms and need to be described properly. In plant ecology, distinction is made between interception (I), evaporation (E) and transpiration (T).*
- *Fresh water > Usable water?*
- *Fresh water appropriation (p. 56) > allocation*
- *Pollution versus Waste water production/generation. Pollution normally refers to the degree of impact of activities of substances on an environmental compartment. This is not what is meant in a production (p. 31) or consumers' context (p. 36). 'Pollution' must therefore be replaced by 'waste water production' or 'waste water generation'.*
- *Water footprint versus Virtual water (p. 124 etc.): terms are different and the one cannot replace the other. Distinction must be made between: i) (virtual) water reflecting the amount of water embedded in a product, ii) virtual water reflecting the amount of water used for production (of that product), iii) the footprint of a product reflecting the environmental impact. Footprints/impacts compare an existing status to a 'standardised' status; calculated water volumes may be used to compare similar processes, but do not reflect impacts.*
- *Rainwater (p. 57) > precipitation water*
- *Runoff : definition?*
- *Water withdrawal = water abstraction*
- *Water volume/time (p. 57) > water flow*

3. Definitions
- *Distinction must be made between virtual water and water footprint (p. 31)*
- *Distinction must be made between embedded water in a product and the water used in the production process of that product*
- *Virtual-water budget of a nation (p. 39): definition is missing*

4. Formula and algorithms
- *Direct water footprint (p. 36): formula is missing*

7. Literature

Hoekstra A.J. & Chapagain A.K., 2008. Globalization of Water – Sharing the Planet's Freshwater Resources. Blackwell Publishing. 208 p.

Hoekstra A.J., Chapagain A.K., Aldaya M.M. & Mekonnen M.M., 2009. *Water Footprint Manual. State of the Art 2009.* Water Footprint Report, November 2009. Water Footprint Network, Enschede, The Netherlands. 127 p.

Wichelns D., 2010. *An Economic Analysis of the Virtual Water Concept in relation to the Agri-food sector*. Organisation for Economic Co-operation and Development (OECD). 29 p.