QUANTIFYING THE ARMY SUPPLY CHAIN WATER BOOTPRINT

AEPI Report

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Water is highly likely to become a focus of future competition and conflict sparked by increased demand and dwindling availability. Projected climate changes will likely exacerbate water scarcity in high-risk areas. Army policy does not address supply chain or indirect water use, and, suppliers and most of industry do not track their own indirect water use or water used to manufacture products. The Army undertook this water bootprint study as an initial step toward quantifying the amount of water used by suppliers to produce the goods and services it procures through the supply chain. A primary concern driving the study is that timely provision of critical goods and services could be at risk if water-intensive production lines suffered unforeseen water shortages. To calculate the water bootprint for the supply chain, the authors applied water-use factors to known quantities of purchased fuels and utility energy, and a high-level economic model that estimates water use per million dollars of activity by market sector to the remaining supply chain components. The latter includes data from requisition and acquisition databases, local purchases, and military and civil works construction and, international and interagency support provided by the US Army Corps of Engineers. The study findings will help the Army make supply-side policy decisions before water availability issues can adversely affect critical supplies and services, thus hindering operational readiness and training.

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Preface

This report was prepared under contract for the Army Environmental Policy Institute (AEPI) by LMI. The views expressed do not necessarily reflect the official policy or position of the Department of the Army, Department of Defense, or the United States Government.

The mission of AEPI is to assist the Army Secretariat in developing forward-looking policies and strategies to address environmental issues that may have significant future impacts on the Army. In the execution of this mission, AEPI is further tasked with identifying and assessing the potential impacts on the Army of emerging environmental issues and trends.

This report discusses the efforts conducted under the US Army Corps of Engineers Contract, LMI Task Number CE003, Army Water Bootprint Study. The purpose of the task is to identify the components and suppliers of the Army supply chain with respect to water use and product content to determine the corresponding Army water bootprint. AEPI tasked LMI to focus on indirect water use, create a baseline to quantify water used to produce the goods and services the Army obtains through the supply chain, including purchased energy, and begin to identify related risks, sustainability issues, and policy implications. The study findings will help the Army make supply-side policy decisions before water availability issues can adversely affect critical supplies and services, thus hindering operational readiness and training.

The project's principal goals are to identify the components and suppliers of the Army supply chain with respect to water use and product content to determine the corresponding Army water bootprint; identify the components and suppliers that support the Army Civil Works and Military Construction programs with respect to water use and product content to determine the corresponding Army water bootprint; determine how information on the Army's water bootprint can be incorporated into the Army's annual sustainability report in conformance with the Global Reporting Initiative protocol; and to develop recommendations for incorporating the Army's water bootprint into Army strategic policy, sustainable procurement, planning documents, and investment strategies.

Army policy does not address supply chain or indirect water use, and, suppliers and most of industry do not track their own indirect water use or water used to manufacture products. We recommend that the Army identify and investigate its largest and most critical supplies for their specific water use, including those that require quick turnaround or ramp-ups in production where water use restrictions could delay the ramp-up; educate senior leaders on the risk of water scarcity to the supply chain and incorporate this consideration into key policy documents; revise its water and energy security policies and procedures to incorporate indirect water use; and evaluate the feasibility of revising supply chain-related contracting procedures to require reporting of indirect water use or encourage reduced water use.

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Executive Summary

The Army Environmental Policy Institute undertook this water footprint (bootprint) study as an initial step toward quantifying the amount of water used by suppliers to produce the goods and services it procures through the supply chain. A primary concern driving the study is that timely provision of critical goods and services could be at risk if water-intensive production lines suffered unforeseen water shortages. For example, severe drought conditions in McKinney, TX, could disrupt production of weapons fire control systems for the Army's M-1 Abrams main battle tank. The study findings will help the Army make supply-side policy decisions before water availability issues can adversely affect critical supplies and services, thus hindering operational readiness and training.

To calculate the water bootprint for the supply chain, the authors applied water-use factors to known quantities of purchased fuels and utility energy, which fall under supply Class III, and a high-level economic model that estimates water use per million dollars of activity by market sector to the remaining supply chain components. The latter includes data from requisition and acquisition databases, local purchases, and military and civil works construction and, international and interagency support provided by the US Army Corps of Engineers (USACE).

From the analysis, we estimated Army indirect (embedded) water use through the supply chain over 12 months at 258 billion gallons (minimum),[1] roughly the equivalent of more than 400,000 Olympic-size swimming pools. Approximately 249 billion gallons, or 96 percent, of the total represents withdrawal, while approximately 9 billion gallons, or 4 percent, of the total represents consumption.

Of that amount, approximately 65 percent is attributable to purchases through the Logistics Metrics Analysis Reporting System, LogiQuest, International Merchant Purchase Authorization Card purchases, and the Army and Air Force Exchange Service, less fuels and utility energy; 32 percent to USACE Civil Works and Military Construction activities; and 4 percent to purchased fuels and utility energy.[2]

Although this number is large, it almost certainly underestimates actual water use because of the imprecision of the economic model used to estimate water withdrawal by sector and the incomplete procurement data available in the Army wholesale and retail logistics databases. In spite of these issues, the resulting Army water bootprint estimate does provide a baseline with which to compare future estimates and to draw pertinent conclusions and recommendations as outlined below.

[1] Direct water use refers to the water used (withdrawn) in support of daily installation operations and activities inside the fence line, such as water used for drinking, washing vehicles, and watering lawns.

[2] Total exceeds 100 percent due to rounding.

Climate change effects predicted to increase drought may contribute further to past scarcity trends. Army policy does not address supply chain or indirect water use, and, suppliers and most of industry do not track their own indirect water use or water used to manufacture products. We recommend that the Army identify and investigate its largest and most critical supplies for their specific water use, including those that require quick turnaround or ramp-ups in production where water use restrictions could delay the ramp-up.

Further, as policy, the Army should educate its senior leaders on the risk of water scarcity to the supply chain and incorporate this consideration into documents such as the Army Campaign Plan and Army Posture Statement. The Army should revise its water and energy security policies and procedures to incorporate indirect water use and, where appropriate, include water-use requirements in life-cycle-cost evaluations.

For procurement, the Army should evaluate the feasibility of revising supply chain-related contracting procedures to require reporting of indirect water use or encourage reduced water use.

Contents

Chapter 1 Introduction....1-1

STUDY OBJECTIVES....1-1

KEY DEFINITIONS....1-1

BACKGROUND....1-2

Related Army Water Policy....1-9

Water Footprint (Bootprint) Basics....1-10

Army Supply Chain....1-12

Other Indirect Water Users....1-14

REPORT STRUCTURE....1-14

Chapter 2 Technical Approach....2-1

WATER BOOTPRINT CALCULATION....2-2

Identify Supply Chain Data Sources....2-3

Apply the Eco-LCA Model....2-4

Identify Purchased Electricity and Fuel Water Factors....2-4

SCOPE AND LIMITATIONS....2-5

Data Limitations....2-5

Estimation Limitations....2-5

Chapter 3 Quantifying Supply Chain Water Use....3-1

REQUISITION/ACQUISITION DATABASES....3-3

LMARS and LogiQuest....3-3

IMPAC Local Purchases....3-8

AAFES—Class VI....3-11

Civil Works and MILCON....3-13

USACE IIS....3-16

FUEL CONSUMPTION AND OTHER ENERGY PURCHASES METHOD....3-20

Primary Fuel Consumption....3-20

Utility Energy Purchases....3-30

Chapter 4 Conclusion....4-1

RESULTS....4-1

Summary 4-1
Objectives Achieved 4-3
CONCLUSIONS 4-5
RECOMMENDATIONS 4-6
Operational 4-6
Policy 4-6
Procurement 4-7

Appendix A Eco-LCA Method
Appendix B Requisition/Acquisition Databases Additional Information
Appendix C Abbreviations

Figures

Figure 1-1. The Water Cycle 1-3
Figure 1-2. Water Use during Production Process 1-4
Figure 1-3. Water Sustainability Index 2050 1-7
Figure 1-4. Army Total Water Bootprint Components 1-12
Figure 2-1. General Steps of Method 2-3
Figure 3-1. Water Bootprint Eco-LCA Process 3-1
Figure 3-2. Water Bootprint Energy Water Factor Process (Primary Fuel Consumption and Utility Energy Purchases) 3-2
Figure 3-3. National Stock Number (NSN) Breakdown: Sample NSN 3-5
Figure 3-4. Purchased Electricity and Steam per eGRID Primary Fuel (MWh) 3-35
Figure 3-5. Water per eGRID Primary Fuel (gallons) 3-36
Figure 4-1. Army Water Bootprint Distribution by Data Source 4-2
Figure 4-2. LMARS Water Bootprint Distribution by FSC 4-2

Tables

Table 3-1. Army 12-Month Water Bootprint 3-2
Table 3-2. LMARS Requisitions Summary—Army 3-4
Table 3-3. LogiQuest Purchase Summary—TACOM 3-4
Table 3-4. LMARS Water Bootprint Summary 3-6
Table 3-5. LMARS Water Bootprint Summary by Federal Supply Code 3-6
Table 3-6. LogiQuest Water Bootprint Summary 3-8
Table 3-7. Estimated IMPAC Purchase Summary—Army 3-9
Table 3-8. GPC Merchant Group—Eco-LCA Model Market Sector Match 3-10
Table 3-9. IMPAC Purchases Bootprint Calculation Summary 3-11
Table 3-10. AAFES—Eco-LCA Model Market Sector Match 3-12
Table 3-11. AAFES Water Bootprint Calculation Summary 3-13
Table 3-12. FY10 USACE Civil Works Program Summary 3-15
Table 3-13. Civil Works/MILCON—Eco-LCA Model Market Sector Match 3-16
Table 3-14. Civil Works/MILCON Water Bootprint Calculation Summary 3-16
Table 3-15. FY10 USACE Interagency Support 3-17
Table 3-16. FY10 USACE International Support 3-18
Table 3-17. USACE IIS Program—Eco-LCA Model Market Sector Match 3-19
Table 3-18. USACE IIS Program Water Bootprint Calculation Summary 3-20
Table 3-19. Water Consumption Factors for Primary Fuel Sources 3-23
Table 3-20. Primary Fuel Consumption Water Consumption Total 3-24
Table 3-21. Calculating Gasoline Water Consumption 3-25
Table 3-22. Crude Oil Water Consumption Estimates 3-25
Table 3-23. Renewable Fuel Water Consumption 3-27
Table 3-24. Coal Water Consumption 3-28
Table 3-25. Natural Gas Water Consumption 3-29
Table 3-26. Average Estimated Energy Purchases by Source (MWh) 3-31
Table 3-27. Water Consumption Factors for Primary Fuels and Electricity Generation 3-32
Table 3-28. Water Consumption for Purchased Electricity and Steam 3-34

Chapter 1
Introduction

STUDY OBJECTIVES

This study looks at the Army's indirect water use from the supply chain to evaluate risk to and sustainability of the Army's mission. The Army's direct water use attributed to operations within installation fence lines has already been estimated.[1] By focusing on indirect water use, we create a baseline to quantify water used to produce the goods and services the Army obtains through the supply chain, including purchased energy, and begin to identify related risks, sustainability issues, and policy implications.

Specifically, the Army Environmental Policy Institute wanted to determine the following:

- Identify the components and suppliers of the Army supply chain with respect to water use and product content to determine the corresponding Army water bootprint.
- Identify the components and suppliers that support the Army Civil Works and Military Construction (MILCON) programs with respect to water use and product content to determine the corresponding Army water bootprint.
- Consult with other organizations, including those in private industry, that have created, maintain, and actively monitor a sustainable supply chain.
- Determine how information on the Army's water bootprint can be incorporated into the Army's annual sustainability report in conformance with the Global Reporting Initiative (GRI) protocol.
- Develop recommendations for incorporating the Army's water bootprint into Army strategic policy, sustainable procurement, planning documents, and investment strategies.

KEY DEFINITIONS

This study incorporates the following U.S. Geological Survey (USGS) definitions for water use, water withdrawal, and consumptive use.

[1] US Army Audit Agency, *Water Conservation Resources*, Audit Report: A-2010-0158-FFE, August 18, 2010.

- *Water use*. Water withdrawn for a specific purpose, such as for public supply, irrigation, thermoelectric-power cooling or industrial processing.
- *Water withdrawal*. Water removed from the ground or diverted from a surface-water source for use.
- *Consumptive use*. The part of water withdrawn that is evaporated, transpired, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment.[2]

In addition, the following definitions relate to Army water use:

- *Direct water use*. Direct, or operational, water use refers to the water used (withdrawn) in support of daily installation operations and activities inside the fence line, such as water used for drinking, washing vehicles, or watering lawns.
- *Indirect water use*. Water used or withdrawn (embedded) to produce the products and provide the services the Army procures through the supply chain.
- *Army water bootprint*. The total amount of direct and indirect water use by the Army.

In this report,

- **water "use" and water "withdrawal" are used interchangeably, and**
- **only the indirect component of the Army water bootprint is quantified.**

BACKGROUND

Although water is the most abundant natural resource on earth, only 2.5 percent is fresh water, almost 70 percent of which is in glaciers and ice caps. The other 30 percent is found in the atmosphere, ground water, soil, lakes, and rivers.[3] Current water quality and accessibility issues—which vary widely by geographic location—will likely continue to be exacerbated by worldwide population growth and economic development, increased regulation, alterations in weather patterns due to climate change, and other variables.

Many of the industries that produce metals, wood and paper products, chemicals, munitions, gasoline and oils, and other items the Army procures through the

[2] USGS, "Estimated Use of Water in the United States in 2005," Circular 1344, 2009.

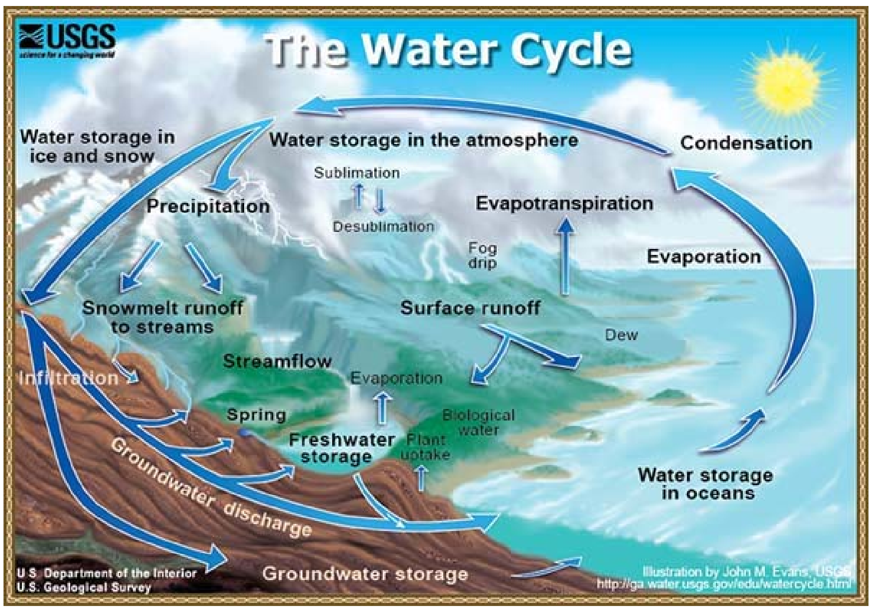
[3] National Aeronautics and Space Administration (NASA), "The Water Cycle" *Earth Observatory*, http://earthobservatory.nasa.gov/Features/Water/, accessed August 5, 2011.

supply chain are major users of water. Probably every manufactured product uses water during some part of the production process. Industry uses water for fabricating, processing, washing, diluting, cooling, or transporting a product; incorporating water into a product; and sanitation in the manufacturing facility.

Water used for industrial purposes is withdrawn from surface or ground water sources. For example, the USGS reports that industrial water withdrawals in 2005 were an estimated 18.2 billion gallons per day, 4 percent of the nation's total withdrawals and about 9 percent of total withdrawals for all categories, excluding thermoelectric power. Surface water supplied 83 percent of total industrial withdrawals, while ground water accounted for 17 percent. Nearly 92 percent of the surface-water and 99 percent of the ground-water withdrawals for industrial use were fresh water.

Most withdrawn water, for industrial or other purposes, largely follows the hydrogeologic (water) cycle (Figure 1-1), meaning it is withdrawn, but eventually returns to the atmosphere and replenishes the supply.

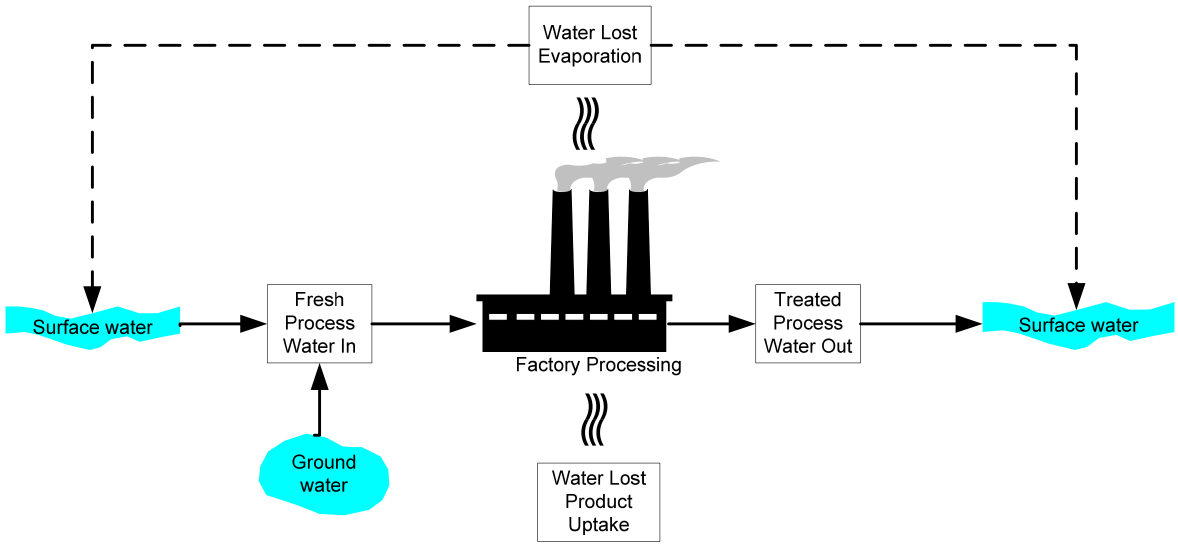
Figure 1-1. The Water Cycle



Source: USGS, Water Science for Schools, ga.water.usgs.gov/edu/index.html, accessed December 14, 2011.

For example, during production, some water is lost through incorporation into the product or evaporates into the atmosphere. However, most of the withdrawn water is treated after use and is returned to the surrounding watershed. Even the water lost during production will largely return to a watershed somewhere (local or non-local) through direct release or the natural evaporation, condensation, and precipitation cycles (Figure 1-2).

Figure 1-2. Water Use during Production Process



The return of water to the atmosphere helps replenish water supplies. But not all water is returned and some that is withdrawn returns to a different source. For example, areas subject to drought can receive less water back than they contributed, the water taken from an aquifer may not be replenished at the rate of withdrawal, and some water may become contaminated and not usable again. Meanwhile, population and income growth increases the demand for water almost everywhere. Thus, the recycling of water does not mean that water will not become scarcer in some areas or that demand will not increase relative to supply.

Water is highly likely to become a focus of future competition and conflict sparked by increased demand and dwindling availability. In its 2009 report on water scarcity and climate change, the Pacific Institute summed it up this way:

> Water is crucial for the economy. Virtually every industry…relies on it to grow and ultimately sustain their business. Yet water is becoming scarcer globally and every indication is that it will become even more so in the future. Decreasing availability, declining quality, and growing demand for water are creating significant challenges to businesses and investors who have traditionally taken clean, reliable and inexpensive water for granted. These problems are already causing decreases in companies' water allotments, shifts toward full-cost water pricing, more stringent water quality regulations, growing community opposition, and increased public scrutiny of corporate water practices.[4]

Projected climate changes will likely exacerbate water scarcity in high-risk areas. Another 2009 report found that climate change has already altered the water cycle. Although precipitation is likely to increase in the Northeast and Midwest during certain seasons, it is likely to decrease in the already stressed West and

[4] Pacific Institute, *Water Scarcity and Climate Change: Growing Risks for Businesses and Investors*, February 2009.

Southwest. Snowpack is projected to melt earlier, leading to less flow in the critical late summer.[5]

The findings of the Pacific Institute study and other research have motivated some businesses to look more closely at how their production processes and supply chains affect the water resource, as well as at how water shortages pose risks of their own continued sustainability. Businesses are also concerned that the cost of water is going to rise and are looking for ways to economize.

For example, in its effort to enhance its corporate water stewardship, Coca-Cola undertook a study to determine how much fresh water is actually used (directly at the bottling facility and indirectly through the supply chain) to produce Coca-Cola in a 0.5 liter polyethylene terephthalate (PET) bottle in the Netherlands.[6] It concluded that roughly 35 liters of fresh water were needed to produce a mere 0.5 liter of product. Similar studies have shown that about 280 liters of water are needed to produce a single 8-ounce cup of coffee,[7] while 2,720 liters are needed to produce a single cotton shirt.[8]

Quantifying total water use in this manner can help consumers and producers use water more efficiently and better understand, and hopefully minimize, affects on the supporting watersheds in which they live and work. This understanding enables sustainable and strategic decision making based on vulnerability and fragility throughout the process of bringing a product or service to market.

The Army is not a "business" in the strict sense of the word, but its global operations and activities that support the "business of defense" clearly create substantial demands on the water resource as do those of Coca-Cola, Walmart, Ford, General Motors, and other large corporations that manufacture, purchase, or otherwise provide goods and services globally.

Should this be cause for concern for the Army? Indeed, in its earlier Energy and Water Campaign Plan for Installations, the Army recognizes the following:

> Water scarcity may be the most underestimated resource issue. World water use has tripled in the past 50 years. Forty percent of our food supply now comes from irrigated lands, as part of an increased reliance on irrigation in the world food economy. While the demand continues to

[5] Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, eds., *Global Climate Change Impacts in the United States*, Cambridge University Press, 2009, http://downloads.globalchange.gov/usimpacts/pdfs/climate-impacts-report.pdf.

[6] Coca-Cola Company and the Nature Conservancy, *Product Water Footprint Assessments: Practical Application in Corporate Water Stewardship*, September 2010.

[7] A. K. Chapagain and A. Y. Hoekstra, "The water footprint of coffee and tea consumption in the Netherlands," *Ecological Economics*, 64(1):109–118, 2007.

[8] A. K. Chapagain, A. Y. Hoekstra, H. H. G. Savenije, and R. Gautam, "The water footprint of cotton consumption: An assessment of the impact of worldwide consumption of cotton products on the water resources in the cotton producing countries," *Ecological Economics.* 60(1): 186–203, 2006.

> rise, the amount of fresh water supply provided by the hydrologic cycle remains relatively constant, but aquifers are increasingly stressed and challenged.
>
> Water remains a very affordable commodity to most citizens, especially for non-irrigation needs. Water availability and costs show considerable regional variability. In many areas of the country, water (and wastewater treatment) rates are rising faster than energy, especially in the arid West and in parts of the East coast. In regions that have abundant water supplies and low commodity costs, Army installations have less incentive to use the water wisely and most efficiently.
>
> The growing demands of increasing populations increasingly burden water supplies that are limited by relatively stable hydrologic cycles. This pattern of growing consumption is unsustainable, as evidenced by declining water tables [*sic*] levels in many parts of the world, particularly in the Western United States. More efficient use and re-use of water are the best options to address this dilemma and to mitigate potential regional crisis.[9]

These concerns were echoed in a recent National Resources Defense Council report on the sustainability of projected water demands under future climate change scenarios.[10] The report presents a "projected water supply sustainability index" that incorporates future demand and projected water availability on the basis of predicted precipitation across the United States (Figure 1-3).

The majority of the US Southwest is projected to suffer from extreme water supply sustainability challenges. Water supplies to Army installations in these areas may be stressed and could be compounded if political stress develops over water usage by Army installations. Army suppliers in these areas will have similar difficulties.

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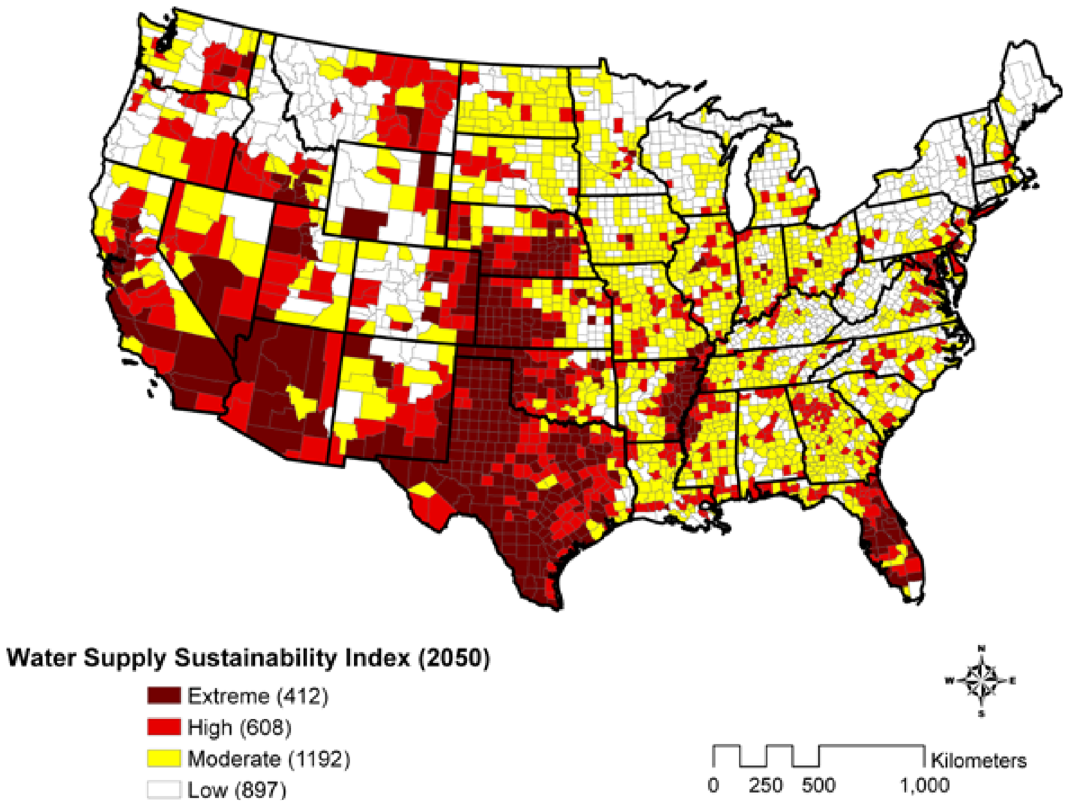
[9] US Army, *Army Energy and Water Campaign Plan for Installations: The Army's 25 Year Plan in Support of POM [program objective memorandum] FY [fiscal year] 2010–2015*, December 1, 2007.

[10] Tetra Tech, Inc., *Evaluating Sustainability of Projected Water Demands Under Future Climate Change Scenarios*, prepared for the National Resources Defense Council, July 2010.

Figure 1-3. Water Sustainability Index 2050



In FY09, the Army used 58.2 billion gallons of potable water at US and overseas installations (not including use in contingency operations).[11] The Army published two studies in 2011 investigating water sustainability for its installations in the United States and overseas.[12] They assessed regional water scarcity for a set of locations, considering affects of increased development, climate change, and other regional competition. They consider the effect on the Army's installations, but not on its supply chain.

Recognizing the need to ensure the long-term sustainability of its installations and their supporting ecosystems, the Army recently announced a Net Zero Water initiative (as a component of its Net Zero Energy, Water, and Waste triad). For an installation to qualify as being Net Zero Water, it must minimize water use and return 100 percent of all water used to the supporting watersheds.

[11] Department of Defense (DoD), *Annual Energy Management Report—Fiscal Year 2009*, May 2010.

[12] US Army Corps of Engineers (USACE) Engineer Research and Development Center (ERDC), Construction Engineering Research Laboratory (CERL), *Water Sustainability Assessment for Ten Army Installations*, March 2011, http://www.aepi.army.mil/docs/whatsnew/ERDC-CERL_TR-11-5%20Water%20Sustainability%20Assessment%20for%20Ten%20Army%20Installations.pdf; USACE ERDC CERL, *Army Overseas Water Sustainability Study*, June 2011, http://www.aepi.army.mil/docs/whatsnew/ERDC-CERL_TR-11-15.pdf.

Net Zero Water is a major step toward better management of direct water use, but it does not address the question of how much water is embedded in the products and services the Army procures through the supply chain—its indirect water use.

Why should the Army care about indirect water use? Consider a future scenario where one or more Army suppliers uses copious amounts of water to produce a critical weapons system component at a production facility located in an extreme water sustainability index area. Under these circumstances, losses of process water could impede production, in turn jeopardizing weapons system operational readiness and, ultimately, mission accomplishment.

Predicting where or when this scenario might unfold is difficult, but it is clearly within the realm of possibility. For example, as recently as August 2011 the city of McKinney, TX, imposed drought measures that restricted water use by all residents in response to an ongoing drought that presented "a serious threat to [the] water supply."[13] A major defense contractor (Raytheon Combat and Sensing Systems) operates a plant in McKinney that manufactures the weapons fire control system, a critical component, of the Army's M-1 Abrams main battle tank.

Because water is key in the production process, this restriction directly threatens the Army's ability to secure these systems. Furthermore, even if the city made an exception for Raytheon—granting it more water to ensure continued production—workers at the plant and other key inhabitants of the community would be affected. Thus, McKinney shows that not only direct water use to make a weapons system component, but also indirect use—to sustain worker families, schools, fire departments, stores, and other components of the civilian infrastructure—would be affected, making continued production at the plant difficult, if not impossible.

Eventually, shifting production away from a defense contractor endangered by water shortages or importing water from elsewhere to supplement local supplies might be possible. However, without careful analysis where such shortages might appear and thoughtful backup plans to handle such eventualities, the Army could suffer serious disruptions in the meantime.

In another scenario, consider an Army installation located in a stressed desert ecosystem that operates under near continuous water-use restrictions. The Army fields a new weapons system at that installation—one manufactured at a nearby factory drawing enormous amounts of process water from the same sole-source aquifer that supplies the installation. In other words, the decision to field the weapons system at the installation could inadvertently compound already serious water supply issues that threaten the installation's continued sustainability.

Water requirements feeding into the supply chain are substantial, but there is no estimate or baseline of the exact nature and scale. More accurately quantifying

[13] City of McKinney, TX, "McKinney Initiates Stage 2 Drought Measures," press release, August 19, 2011, http://www3.mckinneytexas.org/uploadedFiles/New_McKinney_Home_page/DroughtStage2.pdf, accessed December 14, 2011.

water use will allow the Army to make better informed decisions concerning the sustainability of its supply chain. This knowledge will also help the Army formulate policy regarding supply-side water sustainability and serve as a basis for critical strategic decisions.

Related Army Water Policy

Mitigating risk from water scarcity, especially regionally, requires an understanding of how the Army uses water. Army direct water use is driven by activities that require it to withdraw or receive water from a utility or municipality, including individual use, process use, operations and maintenance, dining services and food preparation, and on-site irrigation. Existing Army policy that influences direct water use on its installations includes the following:

- Executive Order (EO) 13514, "Federal Leadership in Environmental, Energy, and Economic Performance," prescribes the Army's direct water-use goal. This EO directs agencies to reduce potable water intensity (gallons per square foot) by 26 percent by FY20—2 percent each year from FY07—and to reduce industrial, landscaping, and agricultural water intensity 20 percent by FY20 (from FY10).
- EO 13514 includes a goal that at least 15 percent of an agency's existing building portfolio meets the standards of the Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings. These principles, developed in response to EO 13423 section 2(f) and the Energy Independence and Security Act of 2007, include building-specific water efficiency standards, preferred purchasing for water-efficient products, and stormwater management requirements.
- The Army Sustainability Campaign Plan and, the Installation Management Campaign Plan for both address these water requirements and set goals and actions for achieving better water performance.[14]
- The Army Green Procurement Guide supports purchasing products that use water efficiently, which effects direct water use, but does not require the product itself to be manufactured efficiently.[15]
- Army Regulation (AR) 200-1, Environmental Protection, asserts Army policy to comply with applicable federal, state, and local laws for water resources management, coastal zone and wetland permitting, and drinking water requirements. It affirms policy for participating in development of

[14] US Army, Army Sustainability Campaign Plan, 2010, http://aec.army.mil/usaec/sustainability/campaign-plan_2010.pdf; *Army Energy and Water Campaign Plan for Installations*, http://army-energy.hqda.pentagon.mil/docs/campaign_plan_01_08_06.pdf, accessed December 14, 2011.

[15] US Army, *Army Green Procurement Guide*, 2006, https://www.alt.army.mil/portal/page/portal/oasaalt/documents/Army%20Green%20Procurement%20Guide%20-%20July%202006.doc, accessed December 14, 2011.

regional water resource initiatives and using a watershed approach to resource management. This regulation cites a large number of technical manuals on managing safe water supplies at installations (including the Technical Manual 5-813 series).

- AR 420-1, Army Facilities Management, cites as a water program guideline making water efficiency and availability a factor in the "design, development, procurement, production and operation of equipment, weapon systems and facilities" (22-6.d).[16] This regulation makes it clear that water conservation should support or not conflict with maintained levels of readiness and training, Soldier well-being, life-cycle economic analysis, and accepted conservation practices.

- As mentioned, the Army recently launched a Net Zero Water initiative, the goal of which is to manage natural resource sustainably. The Army hopes to achieve more than financial benefits, such as maintaining mission capability and enhanced community relationships. By 2020, the Army hopes to have five Net Zero Water installations.[17]

Together, the policies, drivers, and initiatives like Net Zero Water are a major step in better management of direct water use, but they do not address indirect water use: the total amount of water used in producing goods and providing services through the supply chain to support mission accomplishment.

Although the Army does not have policy drivers for measuring or reducing indirect water use, it recognizes this risk, as reflected in the Army Sustainability Campaign Plan (ASCP). The ASCP notes that water is "essential to sustaining troops, producing materiel, and operating and maintaining combat/support/service systems," but does not address objectives associated with supply chain procurement.

The Army evaluates vulnerabilities in its supply chain as part of the procurement and acquisition process, but it has not considered vulnerabilities associated with possible shortfalls in indirect water supply availability.

Water Footprint (Bootprint) Basics

According to the Water Footprint Network (WFN), water footprinting is a relatively new technique: most studies—national and global, regional and river basin, company, and individual product—have been completed since 2007.[18]

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[16] AR 420-1, *Army Facilities Management*, February 12, 2008; http://www.apd.army.mil/pdffiles/r420_1.pdf.

[17] US Army, "Army Vision for Net Zero," last updated May 18, 2011, http://army-energy.hqda.pentagon.mil/netzero/default.asp, accessed July 14, 2011.

[18] Arjen Y. Hoekstra, Ashok K. Chapagain, Maite M. Aldaya, and Mesfin M. Mekonnen, *Water Footprint Assessment Manual*, Table 7-1, WFN, 2011, http://www.waterfootprint.org/downloads/TheWaterFootprintAssessmentManual.pdf.

The International Organization for Standardization is developing a method and protocol for estimating the life-cycle water effect of an organization and expects agreement on a proposed method. For products, life-cycle effects includes water used in the extraction of raw materials, processing, packaging, transportation, use, and then disposal of a product. An organization's water footprint would include all the products it uses.

This report defines the Army bootprint as only including water use up to the products' delivery to the Army. The water use involved with product use (operational water) or disposing of it is not considered here.

Several companies, including Coca-Cola, are using the WFN's Water Footprint Assessment Manual to begin to estimate their water footprint.[19] This manual provides guidance on how to calculate a water footprint, including four distinct phases of a water footprint assessment: (1) setting goals and scope, (2) water footprint accounting, (3) water footprint sustainability assessment, and (4) water footprint response formulation.

The water footprint, hereafter bootprint, is an indicator of water use that incorporates both direct and indirect water used by a consumer or producer. The water footprint of a product is typically expressed as the volume of water used to produce one unit or piece (e.g. as previously illustrated 35 liters per 0.5-liter bottle of Coca-Cola). Depending on the product, the water footprint could also be expressed as the volume of water per unit of energy, per unit of money, or per unit of weight.

The water footprint of a product is the sum of the water footprints of all the process steps taken to produce it, including the entire production process and supporting supply chain. It considers the water used to produce a product, including mining, extraction, or otherwise obtaining raw materials, as well as water used to manufacture the product and transport it to market.

To set the scope of the footprint, an organization should decide whether to estimate water withdrawn or consumed, whether to include rain water consumed by crops, how far down the supply chain to travel, and whether to consider water quality impacts.

Consider once again the 0.5-liter bottle of Coca-Cola—something the Army procures in substantial quantities as both a Class I (sustenance/food) and Class VI (personal demand/Army and Air Force Exchange Service [AAFES]) item. To determine the water footprint, the study team had to assess the water used for Coca-

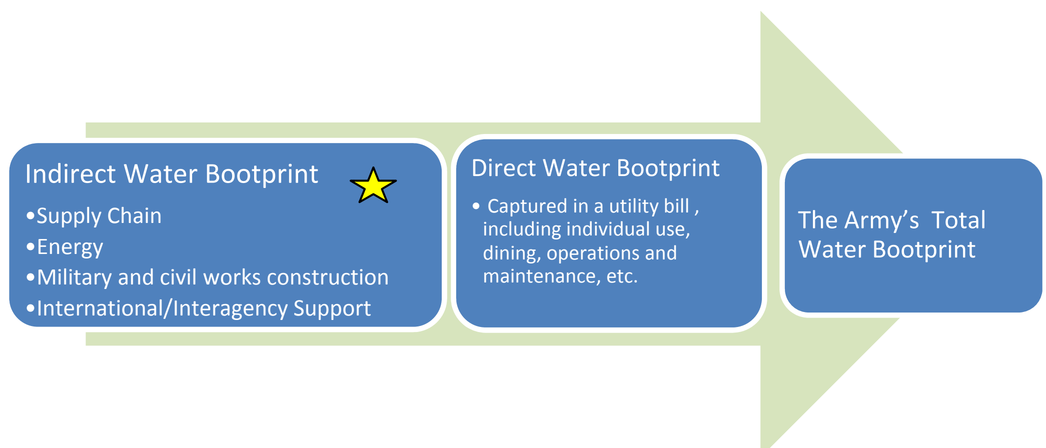
[19] See Note 18.

Cola product packaging, the basic ingredients, and production operations at the bottling plant as follows:

- *Product packaging*. Water used to produce the plastic (PET) bottle and cap, labeling, tray, tray carton, tray shrink film, shipping pallet stretch wrap, and shipping pallet itself.
- *Product ingredients*. Water used to produce beet sugar, phosphoric acid, caramel, caffeine, and carbon dioxide (CO_2).
- *Plant operations*. Water used to mix and blend the ingredients and to clean and fill the plastic bottles.[20]

From the Army's perspective, direct water use refers to the water used in support of daily operations and activities, such as water used for drinking, washing vehicles, and watering lawns. Indirect (supply chain) water use refers to water that is "embedded" in the energy, materials, and other products the Army procures through the supply system (such as lumber, clothing, equipment, vehicles, and weapon systems). Water that is used directly or indirectly is either consumed or returned to the watershed (Figure 1-4).

Figure 1-4. Army Total Water Bootprint Components



As noted earlier, this report focuses on the indirect-water-use component (★) of the Army's total water bootprint.

Army Supply Chain

The Army procures millions of individual items in any given fiscal year. For instance, as reported in one Army requisitions database, the Logistics Metrics Analysis Reporting System (LMARS), the Army procured items from athletic T-shirts (more than 3.1 million), flat washers (more than 3.0 million), machine bolts (more than 1.7 million), and various types of ammunition cartridges/blanks (more than

[20] See Note 6.

175 million) to much larger items such as combat tank parts and components (more than 200) and utility trucks (more than 4,800). For a given year, thousands of other items were found in this system alone.

The supply chain is the network of manufacturers and producers, retailers, distributors, transporters, storage facilities, and suppliers that participate in the production, sale, and delivery of a specific product.

DoD defines supply chain, or supply chain management, as the linked activities associated with providing materiel from a raw material stage to an end user as a finished product. Supply control is the process by which an item of supply is controlled within the supply system, including requisitioning, receipt, storage, stock control, shipment, disposition, identification, and accounting.

AR 711-1, Supply Chain Management, defines the Army supply chain as "the material and informational interchanges in the logistics process stretching from the acquisition of raw materials to the delivery of finished products to the end user. Vendors, service providers, and customers are links in the supply chain."

For the purposes of this study, the supply chain primarily consists of the 10 categories of products and services the Army routinely procures through the supporting supply system and purchased energy. DoD established these 10 classes to group supplies:

1. *Class I*. Subsistence (food) and gratuitous health and welfare items.

2. *Class II*. Clothing, individual equipment, tents, tool sets and tool kits, hand tools, and administrative and housekeeping supplies and equipment.

3. *Class III*. Petroleum, oils, and lubricants (POL): petroleum fuels, lubricants, hydraulic and insulating oils, preservatives, liquid and compressed gases, chemical products, coolants, deicing and antifreeze compounds, together with components and additives of such products, and coal.

4. *Class IV*. Construction materials, including installed equipment and all fortification and barrier materials.

5. *Class V*. Ammunition and explosives.

6. *Class VI*. Personal demand items (nonmilitary sales items), which are procured through AAFES.

7. *Class VII*. Major end items—a final combination of end products ready for its intended use and principal items (for example, launchers, tanks, mobile machine shops, and vehicles).

8. *Class VIII*. Medical material (equipment and consumables), including repair parts peculiar to medical equipment.

9. *Class IX*. Repair parts.

10. *Class X*. Materiel to support nonmilitary programs (for example, agriculture and economic development) not included in Class I through IX. Many Class X items are nonstandard items (windmill parts, kits, and plows, for example).

Most of the supply classes are further defined by subclasses (subclass A defines aviation, aircraft, and air drop equipment; subclass B defines troop support material).

Data on the supply chain purchases are not readily available per class in a single or discrete number of databases. Chapter 2 describes the approach taken to evaluate the water use of these different sources of supply.

Other Indirect Water Users

In addition to the 10 basic classes of supply, other Army operations and activities result in substantial indirect water use, including the purchase of energy, such as electricity and natural gas.

Chapters 2 and 3 detail these operations and activities and the approach used to calculate the associated indirect water use.

REPORT STRUCTURE

The remainder of this report details each component of the Army supply chain, the results of the associated water bootprint calculations, and summary findings and recommendations.

Chapter 2 describes the overall technical approach used to develop the Army water bootprint, including data availability, courses of action, data sources, and assumptions.

Chapter 3 quantifies water use in the Army's supply chain using data from wholesale and retail procurement databases, International Merchant Purchase Authorization Card (IMPAC) purchase records, the AAFES sales records, Civil Works and MILCON expenditures, interagency and international support (IIS) expenditures, primary fuel consumption totals, and purchased utility energy totals.

Chapter 4 provides an analysis of water use, summary findings, and recommendations.

Chapter 2
Technical Approach

In this study, we assessed three approaches to calculating the water bootprint for the Army supply chain:

- Obtain water-use data directly from suppliers
- Apply water-use factors to each product or service line the Army buys
- Use an aggregate model to calculate sector water use by economic activity.

The most direct approach would be to obtain water-use data directly from each producer or supplier. If such data were available, they would provide a highly accurate account of the bootprint. However, product water footprints require significant data on output and input materials.[1] Unfortunately, few (if any) producers or suppliers have this type of information readily available. For example, in a typical year, AAFES alone, which procures solely for Class VI, uses more than 32,000 suppliers worldwide, almost all small businesses. When other supply chain data sources are considered, the sheer number of different suppliers and items makes use of this approach for this study impractical.

A somewhat less direct approach would be to identify a water-use factor for each item the Army procures, such as X gallons of water used for each unit of item Y purchased, and then multiply the total number of items purchased by that factor. However, the sheer number of products procured makes this approach unwieldy. Nevertheless, we did use this second method to estimate water consumption for primary fuel consumption and utility energy purchases. For these commodities, water-use factors were available. Further, the Army generates approved and verified fiscal year consumption data by fuel type.

A third option is to use an aggregated life-cycle assessment (LCA) input-output model. Input-output models relate quantities of inputs to amounts of economic output in a particular sector. Use of these models requires careful analysis to ensure they capture water usage as defined in the water footprint. The models may assess full life-cycle effects from extraction to use to disposal or may only include effects through user receipt of the output. We used the latter for the Army bootprint; an aggregate input-output model of the water life-cycle use up to where the products are finished by the producer.

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[1] Arjen Y. Hoekstra, Ashok K. Chapagain, Maite M. Aldaya, and Mesfin M. Mekonnen, *Water Footprint Assessment Manual*, Table 7-1, WFN, 2011, http://www.waterfootprint.org/downloads/TheWaterFootprintAssessmentManual.pdf.

We used several data sources to obtain information for this study including

- requisition data from LMARS,
- rurchase data from the LogiQuest database,
- IMPAC data,
- AAFES data,
- Civil Works and MILCON data, and
- IIS data.

Water Bootprint Calculation

We used the Ecologically-Based Life Cycle Assessment (Eco-LCA) model,[2] developed by Ohio State University's Center for Resilience, to estimate indirect water use from Army procurement and other activities—except for fuel and utility energy purchases. We used literature-identified water factors to estimate indirect water use from primary fuel consumption and utility energy purchases.

Eco-LCA is an input-output type model that incorporates ecological services into its framework. Like similar models, it relates quantities of inputs to dollars spent in a particular sector, but it also includes various natural resources in its mix. For example, the model describes the oil or natural gas used per dollar spent within a particular sector, the amount of land, and the amount of water. Eco-LCA is one of two identified models that include water use, the only one in the public domain.[3]

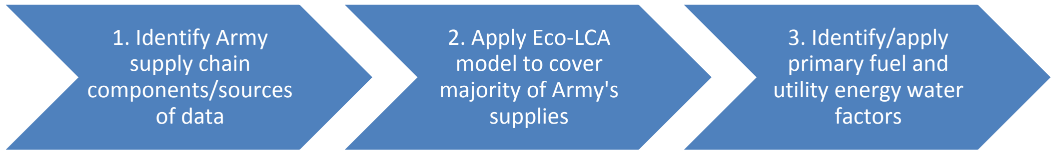
Our approach took the following steps (Figure 2-1):

1. Identify readily accessible supply chain components and data sources that contribute to the Army's water bootprint and sources of these data.
2. Apply the Eco-LCA model to cover the majority of the Army's supplies.
3. Identify and apply primary fuel and purchased utility energy water factors to the known quantities procured.

[2] Ohio State University Center for Resilience, Eco-LCA software, http://resilience.eng.ohio-state.edu/eco-lca/index.htm, accessed December 14, 2011.

[3] We also assessed the Carnegie Mellon Economic Input-Output LCA model, very similar to Eco-LCA, but it is not in the public domain.

Figure 2-1. General Steps of Method



Identify Supply Chain Data Sources

For this study, we compiled a large portion of the Army's purchases and expenditures across all supply classes and purchased energy. No single source of all of the Army's acquisitions and procurement data is readily available.

A large portion of Army requisitions data are maintained in the principal wholesale database, LMARS. Data were also available for a small portion of the retail procurement via the LogiQuest database. FY03–10 data from these databases were used as reported in Chapter 3. As LogiQuest houses only a small portion of Army procurements, there is a gap in Army retail purchases.

LMARS and LogiQuest provided historical requisition and procurement data via direct query for various items covered under all of the basic supply classes except Class VI. AAFES personnel provided gross calendar year (CY) 2010 Class VI sales data in the four major categories they track include gasoline, retail less gasoline, food and beverages, and concessions.[4]

DoD Smart Pay served as the primary data source for local purchases made using IMPAC cards, but was only available for the first three quarters of FY10. The data were extrapolated for the last quarter of FY10. Different purchasing patterns in the last quarter could bias this total.

Various headquarters, USACE information briefings, and budget documents cited herein served as the primary sources for USACE Civil Works, MILCON, and IIS program expenditure data. This information was available for FY10.

For primary fuel and utility energy purchases, the Army provided a comprehensive Army greenhouse gas (GHG) inventory from the Environmental Division, Installation Services Directorate, Office of the Assistant Chief of Staff for Installation Management. This data set was submitted to DoD for its annual GHG and Sustainability Data Report.[5]

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[4] Michael J. Smietana, Vice President, Support Division, Real Estate Directorate.

[5] *FY 2010 Federal Government Greenhouse Gas Inventory by Agency*, http://explore.data.gov/d/vzm3-edjq, accessed December 14, 2011.

We offer additional information on these data sources in subsequent sections. Unfortunately, the databases provide an incomplete representation of total Army expenditures, but they do enable a rough estimate of water use.

Apply the Eco-LCA Model

The Eco-LCA model is calculated for market sectors within the US economy. By relating classes of Army purchases as closely as possible to sectors represented in the Eco-LCA model, we roughly estimated the Army's water use. The analysis used dollars spent on different products and services as outputs in the Eco-LCA model to estimate inputs of water required to produce these products and services.

The model and Army purchase data differ, however. The model calculates input use through the production stage, but not for distribution after that stage. Army purchase data refer to final point of sale. On the one hand, insertion of the point-of-sale data into the model results in an overestimate of water use at the production stage. On the other, the model fails to provide water use after that stage. In effect, the analysis uses the model's production results to estimate overall water consumption through the end stage—as if distribution water use per unit of sales were the same as that for production. This method possibly introduces a bias into the calculations, but data on water use in production and distribution are insufficient to even know which direction the bias may be, under-or-over estimation of water use are both feasible.

To deploy the Eco-LCA model to calculate the amount of water used during a given economic activity, we first searched and selected the sector in which the target economic activity fell. We then entered the economic value for analysis, such as $1 million of economic activity, selected the data set to visualize (water use in liters, for example), and ran the model. The model provided the total liters per million dollars of activity. Because Eco-LCA is based on the Department of Commerce's 1997 LCA input-output model of the US economy, all annual Army sales data were adjusted for inflation since 1997 by applying Consumer Price Index (CPI) data obtained from the Bureau of Labor Statistics.

Identify Purchased Electricity and Fuel Water Factors

This analysis used water factors for primary fuel consumption (Class III POL) and utility energy purchases (steam and electricity), including energy accounted for under the Army Energy and Water Reporting System and gasoline sales from AAFES in CY10. A literature survey identified life-cycle water consumption factors specific to steam and electricity production and the extraction, production, and refinement of fossil fuels, ethanol, biodiesel, and biomass. Chapter 3 specifies how water factors were applied to primary fuel consumption and utility energy purchases.

SCOPE AND LIMITATIONS

The Army's bootprint is calculated for a representative year, using 1 or 2 years of activity data, either fiscal year or calendar year as available. It includes products procured by or acquired for the Army and used inside and outside the United States, but does not distinguish between products produced inside or outside the United States. The bootprint is limited by both availability of data and by the estimation methods themselves.

Data Limitations

The data used to estimate water use for the majority of the supply chain are incomplete:

- The procurement and expenditure data used only represent the items being requested. The full supply chain would account for the material from the point of requisition, to procurement, to receipt, to point of issue, and then use.
- LogiQuest's records of retail procurement are only complete for one organization within a single command. LogiQuest is a commercial database that obtains data through Freedom of Information Act (FOIA) requests.
- IMPAC purchases are only available for three quarters, necessitating extrapolation for the last quarter.

Estimation Limitations

As for the estimation method, calculating a water footprint requires consideration of the way water is used and disposed. The term consumptive use or consumption typically refers to water taken from a source and made unavailable for reuse in the same basin, such as through direct removal of the liquid water or changes to the physical or chemical properties of water. Water consumption may be categorized further as green water (rain water), blue water (ground or surface water used for irrigation), or gray water (water contaminated during production) sources.

Limits based on this categorization include the following:

- Neither Eco-LCA nor the water factors used for primary fuel consumption and utility energy purchases capture gray or green water, instead accounting only for "blue water." All water use was assumed to be fresh water, though some water use is not.
- Eco-LCA is based on water withdrawn instead of consumed. The energy calculations are based on water consumed in the energy production processes instead of withdrawn.

- Eco-LCA is an input-output model that only includes fresh water withdrawn and not rain water or waste water.

- This study does not capture secondary water losses due to salinization or chemical impairment caused by waste streams or runoff from mining. It does include secondary water losses from oil and gas extraction.

- Except for electric purchases, this study does not capture spatial relationships of water use (Figure 1-3).

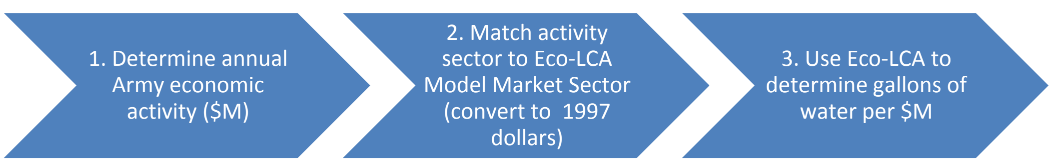
Chapter 3
Quantifying Supply Chain Water Use

This chapter details how the water bootprint was calculated, including

- use of major acquisition/procurement databases,
- IMPAC purchase data,
- AAFES data,
- Civil Works and MILCON data,
- IIS data,
- primary fuel data, and
- purchased utility energy data.

The majority of the products and services procured by the Army through the supply chain align with comparable Eco-LCA model market sectors. Once the products and services are aligned to the appropriate model market sector, Eco-LCA water factors per dollar of activity or purchase can be multiplied by the specific Army activity level to generate an estimate of the amount of water used (Figure 3-1).

Figure 3-1. Water Bootprint Eco-LCA Process



For primary fuel consumption and purchased utility energy, we use water factors from the literature, which provide water use per unit of energy (Figure 3-2). This provides more specific data for this critical resource.

Figure 3-2. Water Bootprint Energy Water Factor Process (Primary Fuel Consumption and Utility Energy Purchases)

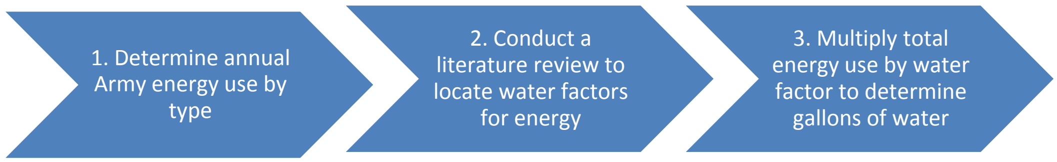


Table 3-1 summarizes the total amounts procured and estimated water bootprint for the Army over 12 months. We estimate the total Army water bootprint at 258 billion gallons, a combination of withdrawals and consumption.

Table 3-1. Army 12-Month Water Bootprint

Meth-od	Data sources	12-month cost ($ million)	12-month water bootprint (million gallons)	Gallons/$
Eco-LCA	LMARS[a]	18,945	117,319	6.19
	LogiQuest Database[a]	1,443	8,367	5.80
	IMPAC[b]	3,788	12,175	3.21
	AAFES[c]	3,835	29,078	7.58
	Civil Works/MILCON[a]	12,444	46,041	3.70
	IIS[a]	10,021	36,003	3.59
	Subtotal	50,479	248,983	4.93
Litera-ture	Primary fuel consumption[d]	N/A	3,267	N/A
	Utility energy purchases[d]	N/A	6,110	N/A
	Subtotal	N/A	9,377	N/A
Total		N/A	258,360	N/A

Note: The costs in this table are in nominal dollars.
[a] FY10 data.
[b] Three quarters of FY10 data with extrapolation to a full year.
[c] CY10 data.
[d] Average of FY08 and FY10 data.

Ignoring fuel and energy, $50 billion of spending results in 249 billion gallons of water used (Table 3-1). This dollar amount represents approximately 0.3 percent of the gross domestic product (GDP). The 249 billion gallons, in turn, represent approximately 0.17 percent of annual US water use. These percentages are close, as they should be since Eco-LCA translates GDP into water withdrawal.

This study would be more illustrative in terms of water use through the supply chain if all data used had been assigned to a Federal Supply Code (FSC). This would have made it possible to divide the gallons by FSCs to display the types of products that use the most water throughout the supply chain. Unfortunately, however, only the LMARS and LogiQuest databases provided this information. For example, the top 30 FSCs in LMARS for FY10 resulted in approximately 91 billion gallons of water being withdrawn and, coupled with the remaining 465 FSCs added for FY10, resulted in approximately 117 billion gallons of water being withdrawn (Table 3-5). The remaining sections detail the data sources and explain the limits of the chosen method, first with the Eco-LCA method and then the literature-based method (Table 3-1).

REQUISITION/ACQUISITION DATABASES

In FY10, major Army acquisition and requisition databases showed an estimated 126 billion gallons of water were used annually for purchases in almost all classes of the supply chain, except Class VI. These databases account for the majority of the Army's product and services requisitions and a small portion of the Army system acquisitions, which cover almost all classes of supply in the supply chain.

LMARS and LogiQuest

No single source contains Army system acquisition and product requisition data. Our analysis uses the major supply databases, LMARS and LogiQuest. These databases cover many items purchased across the supply chain classes, excluding Class VI, personal demand items.

LMARS is a government requisition database that captures supply chain data on orders placed on the DoD wholesale system from suppliers, including the Defense Logistics Agency (DLA), General Services Administration (GSA), and the other DoD components. It provides information on order processing times and on individual orders, such as the priority, stock number, mode of transportation, and how the order was filled. The Defense Automated Addressing System Center operates LMARS using all the electronic transactional data that passes through the center.

LogiQuest is a commercial system that mostly reports on catalog and procurement information collected from the government. It provides information on what the Army as a purchaser is buying from its commercial suppliers, compared with what is requisitioned through LMARS. LogiQuest collects its data from a number of government sources, including the Defense Logistics Information System.[1]

LogiQuest's Army information is restricted to from FY03–10 data from the Tank-Automotive and Armaments Command (TACOM), a subordinate command of the Army Materiel Command (AMC).

[1] LogiQuest collects procurement information through FOIA requests.

REQUISITIONS AND ACQUISITIONS

This study uses data on closed procurement requests to capture only materials actually being purchased (Table 3-2 includes a summary of LMARS data for FY03–10, and Table 3-3 includes the same information for LogiQuest).

Table 3-2. LMARS Requisitions Summary—Army

FY	Records	LMARS-reported value ($ billion)	Value converted to 1997 equivalent ($ billion)
2003	252,313	9.8	8.5
2004	275,041	11.0	9.4
2005	274,204	12.2	10.1
2006	258,066	12.7	10.1
2007	256,032	13.0	10.1
2008	256,038	12.9	9.6
2009	255,922	11.8	8.8
2010[a]	246,482	18.9	13.9
Total	2,074,098	102.3	80.5

[a] We removed 10 primary fuel records from the FY10 number of records to avoid duplication with the primary fuels portion of this report.

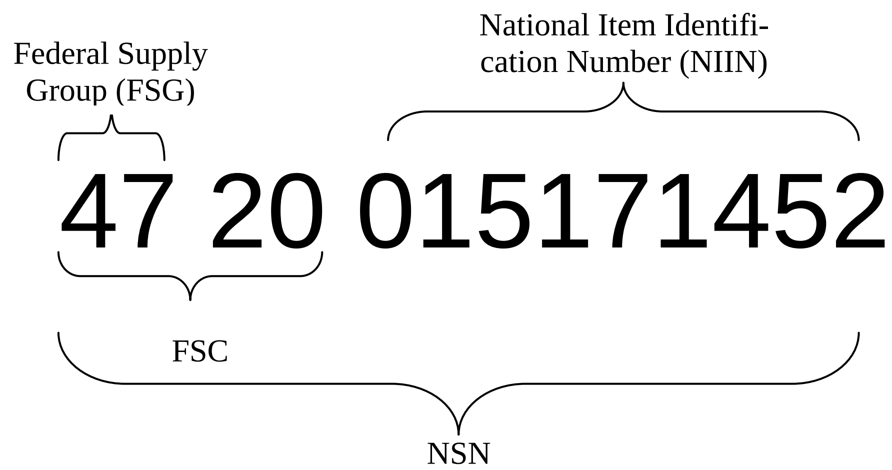
Table 3-3. LogiQuest Purchase Summary—TACOM

FY	Records	LogiQuest-Reported Value ($ billion)	Value Converted to 1997 Equivalent ($ billion)
2003	2,556	7.5	6.5
2004	3,220	3.9	3.3
2005	3,579	6.4	5.2
2006	3,121	5.0	4.0
2007	2,497	4.4	3.4
2008	2,224	4.8	3.6
2009	1,944	8.4	6.3
2010	1,051	1.4	1.1
Total	20,192	41.8	33.4

WATER BOOTPRINT

Multiple possible identification codes are available from a single stock number, all of which are available in both LMARS and LogiQuest (Figure 3-3).

Figure 3-3. National Stock Number (NSN) Breakdown: Sample NSN



We queried Army purchase data from LMARS and LoqiQuest. LMARS provided 2.1 million records, representing more than $102 billion in requisitions by NIIN in FY03–10, which reflect wartime needs. The LoqiQuest data set provided more than 20,000 records representing nearly $42 billion in items procured over 8 years.

These purchases required some processing to use with the Eco-LCA tool. Mapping a single supply class (Classes I–X, Chapter 1) to one Eco-LCA model market sector was not possible because information was insufficient. Also, LMARS includes some assignment of supply class, but LogiQuest does not.

Assigning Eco-LCA model market sectors based on FSGs was also insufficient. At least FSC data, and, in some cases, NIIN data, have the detail needed to assign representative Eco-LCA sectors.

Assigning the Eco-LCA model market sectors to the FSC-coded records requires some judgment. Some records in LMARS have no supply class assigned, some have supply classes other than I–X assigned, and many FSGs and FSCs are linked to more than one supply class. LMARS FY10 data have 554 records with no supply class entered, 105 records with a supply class of 0, and 67 FSGs (of 77 total FSGs in FY10) with more than one supply class (between I and X). When taken to the FSC level, 304 FSCs (of 495 total FSCs in FY10) have more than one supply class (I–X).

To match the Eco-LCA model market sectors to FSC, or when necessary, FSC-NIIN combinations, we did the following:

1. Identified model market sectors in the data set with key word searches. Using the FSC descriptors or the LMARS Item Nomenclature field, searched key terms in the Eco-LCA tool to identify appropriate model market sectors.

2. Identified the best fit of Eco-LCA model market sector for each FSC or Item. Linked the master list of current FSCs to the best match model market sector in Eco-LCA for each FSC or FSC-NIIN combination (see the LMARS section for more detail).

3. For any FSCs that could not be linked to Eco-LCA, defaulted to the Eco-LCA general wholesale model market sector (Appendix A).

LMARS

Once records were matched with Eco-LCA model market sectors, we calculated the number of gallons of water using the Eco-LCA model water factors converted from liters per million dollars to gallons per dollar units. To obtain the number of gallons, the Eco-LCA model market sector water factors were multiplied by the 1997 dollar equivalent for all line items in the database.

Table 3-4. LMARS Water Bootprint Summary

FY	Value converted to 1997 equivalent ($ billion)	Gallons (billion)
2003	8.5	76.0
2004	9.4	85.6
2005	10.1	90.6
2006	10.1	88.0
2007	10.1	88.9
2008	9.6	85.0
2009	8.8	81.5
2010	13.9	117.3
Total	80.5	712.9

As noted previously, LMARS records are assigned to specific FSCs. (Table 3-5).

Table 3-5. LMARS Water Bootprint Summary by FSC

FSC	FSC name	Records	LMARS-reported value ($ million)	Equivalent 1997 value ($ million)	Gallons (million)
5950	Coils and transformers	328	7,150	5,261	35,993
2350	Combat, assault, and tactical vehicles, tracked	23	2,583	1,901	16,352
8415	Clothing, special purpose	1,745	478	352	6,734
2320	Trucks and truck tractors, wheeled	145	825	607	4,569
1270	Aircraft gunnery fire control components	86	156	115	2,229

Table 3-5. LMARS Water Bootprint Summary by FSC

FSC	FSC name	Records	LMARS-reported value ($ million)	Equivalent 1997 value ($ million)	Gallons (million)
1615	Helicopter rotor blades, drive mechanisms and components	966	333	245	1,791
2520	Vehicular power transmission components	1,911	186	137	1,373
2530	Vehicular brake, steering, axle, wheel, and track components	3,665	185	136	1,365
1240	Optical sighting and ranging equipment	401	92	68	1,315
1005	Guns, through 30 mm	2,107	245	180	1,298
8465	Individual equipment	328	88	65	1,246
2835	Gas turbines and jet engines; non-aircraft prime mover, aircraft non-prime mover, and components	161	240	177	1,191
6120	Transformers: distribution and power station	27	4	3	1,090
2540	Vehicular furniture and accessories	5,226	144	106	1,064
8430	Footwear, men's	804	75	55	1,058
2840	Gas turbines and jet engines, aircraft, prime moving; and components	371	242	178	1,054
2815	Diesel engines and components	1,352	181	133	1,050
8340	Tents and tarpaulins	354	80	59	1,050
2510	Vehicular cab, body, and frame structural components	4,508	149	110	1,043
1305	Ammunition, through 30 mm	94	159	117	911
8405	Outerwear, men's	793	60	44	842
5680	Miscellaneous construction materials	90	260	192	800
2610	Tires and tubes, pneumatic, except aircraft	347	78	57	775
8470	Armor, personal	172	102	75	751
5530	Plywood and veneer	64	65	48	731
4240	Safety and rescue equipment	691	117	86	725
6140	Batteries, rechargeable	294	66	49	647
8145	Specialized shipping and storage containers	386	53	39	636
1376	Bulk explosives	5	104	76	633
1325	Bombs	10	101	74	576
	All Other FSCs (465 FSCs)	219,028	4,344	3,197	26,427
Total		246,482	18,945	13,942	117,319

LogiQuest

We calculated total gallons of water from LogiQuest using the same method used for LMARS (see Table 3-6). LogiQuest gallons of water were calculated using the

Eco-LCA water factors and total dollars, adjusting the requirements values to 1997 equivalent amounts with the same assumptions used for LMARS.

Table 3-6. LogiQuest Water Bootprint Summary

Fiscal year	Equivalent 1997 value ($ million)	Gallons (billion)
2003	6.5	51.8
2004	3.3	27.0
2005	5.2	48.0
2006	4.0	26.6
2007	3.4	25.0
2008	3.6	29.4
2009	6.3	48.7
2010	1.1	8.4
Total	33.4	264.9

IMPAC Local Purchases

IMPAC purchases accounted for approximately 12 billion gallons of water use. In addition to supply chain requisitions, GSA's Federal Supply Service contract with Rocky Mountain Bank Card System, Inc. provides government-wide commercial credit cards and associated services for civilian and military government employees. These cards allow purchases under the small purchase threshold ($25,000.01) for official government use.

This method of local procurement, IMPAC, is widely used across the Army and other DoD agencies under the auspices of the Government Purchase Card (GPC) Program.[2] The GPC is centrally managed for all DoD agencies by the Defense Supply Service–Washington.

IMPAC Purchase Data

We used IMPAC purchase data from October 1 to June 30, 2010. Assuming that purchases for the last quarter of the fiscal year are on average comparable to other quarters, we used 133 percent of the recorded totals for the first three quarters.

Army FY10 IMPAC purchases through June 30, 2010, totaled $2.8 billion, which was extrapolated to a total $3.8 billion for FY10 (see Table 3-7). This extrapolation could under- or over-estimate the total annual purchasing, depending on

[2] The GPC program saves money government-wide by reducing the administrative costs associated with the purchase of commercially available goods and services. The GPC replaced the paper-based, time-consuming purchase order process, thereby eliminating procurement lead-time, saving transaction costs, reducing procurement office workload, and facilitating payment.

patterns in the last quarter.[3] Also, the purchasing patterns of certain GPC Merchant Groups could differ.

Table 3-7. Estimated IMPAC Purchase Summary—Army

GPC merchant group	FY10 purchases ($ million)
Wholesale trade	1,360.7
Business expense	784.9
Other	387.5
Office services	356.6
Building services	215.3
Office supplies	103.8
Hotels	102.0
Mail/telephone	95.2
Medical	87.8
Maintenance, repair, and operation (MRO) supplies	85.6
Vehicle expense	66.3
Food and Beverages	56.8
Other travel	28.1
Money	22.3
Auto/recreational vehicle (RV) dealers	15.2
Rental cars	7.6
Landscaping and horticultural services	5.7
Retail services	3.1
Veterinary services	2.0
Agricultural cooperative	0.8
Airline	0.7
Total	3,788

Water Bootprint

As with most other classes, we employed Eco-LCA. To run the model, we first had to correlate the 21 credit card merchant group sales categories to the most appropriate model economic sector (Table 3-8).

[3] Spending in the final quarter of a fiscal year is often constrained due to budget or encouraged due to end-of-year spending. The pattern differs from one spending office to another and from year to year, so no definite conclusion can be reached as to whether it is likely to be greater or less than spending in any other quarter.

Table 3-8. GPC Merchant Group—Eco-LCA Model Market Sector Match

GPC merchant group	Eco-LCA model market sector
Wholesale trade	Wholesale trade
Business expense	Business support services
Other	Other support services
Office services	Office administrative services
Building services	Services to buildings and dwellings
Office supplies	Office supplies except paper manufacturing
Hotels	Hotels and Motels
Mail/telephone	Business support services
Medical	Retail trade
MRO supplies	Facilities support services
Vehicle expense	Petroleum refining
Food and beverages	Food services and drinking places
Other travel	Transit and ground passenger transportation
Money	Monetary authorities and depository credit
Auto/RV dealers	Automotive equipment rental and leasing
Rental cars	Automotive equipment rental and leasing
Landscaping and horticultural services	Environmental and other technical consulting services
Retail services	Retail trade
Veterinary services	Veterinary services
Agricultural cooperative	Civic, social, professional, and similar organizations
Airline	Travel arrangement and reservation services

These correlations are not precise, but they are the best we can draw given the currently available data, information, and analytical tools. Overall, GPC water bootprint based on the adjusted model outputs totaled 12.1 billion gallons (Table 3-9). The expenditures were adjusted using CPI conversion factors and then multiplied by the appropriate water-use factor.

Table 3-9. IMPAC Purchases Bootprint Calculation Summary

GPC merchant group	FY10 purchases ($ million)	CPI	FY10 purchases ($ million adjusted)	Water use (gallons/ $1 million)	Total water use (gallons)
Wholesale trade	1,360.7	0.740	1,006.4	4,177,473	4,204,004,903
Business expense	784.9	0.740	580.5	3,363,722	1,952,525,462
Other	387.5	0.740	286.6	3,982,538	1,141,336,912
Office services	356.6	0.688	245.4	2,501,593	613,978,270
Building services	215.3	0.688	148.2	2,501,593	370,682,208
Office supplies	103.8	0.809	84.0	7,095,803	595,881,063
Hotels	102.0	0.729	74.3	9,264,382	688,784,227
Mail/telephone	95.2	0.740	70.4	3,363,722	236,770,241
Medical	87.8	0.689	60.5	7,536,079	456,061,632
MRO supplies	85.6	0.740	63.3	3,031,566	191,871,694
Vehicle expense	66.3	0.425	28.1	11,659,569	327,950,318
Food and beverages	56.8	0.723	41.1	28,462,191	1,168,841,365
Other travel	28.1	0.742	20.9	3,308,965	69,049,551
Money	22.3	0.742	16.5	1,884,946	31,132,328
Auto/RV dealers	15.2	1.044	15.9	3,467,184	55,016,978
Rental cars	7.6	0.740	5.6	3,467,184	19,506,008
Landscaping/ horticultural services	5.7	0.688	3.9	2,767,843	10,919,998
Retail services	3.1	0.740	2.3	7,536,079	17,087,642
Veterinary services	2.0	0.688	1.4	10,199,603	14,037,417
Agricultural cooperative	0.8	0.688	0.6	8,307,757	4,573,489
Airline	0.7	0.742	0.5	10,371,951	5,128,812
Total	3,788		2,756.2		12,175,140,516

AAFES—Class VI

For CY10, we estimate the AAFES water bootprint, excluding gasoline sales, at 29 billion gallons of water use. Supply chain Class VI consists of personal demand items (nonmilitary sales items) primarily sold through retail facilities owned and operated by AAFES.[4] This is the only class of supply captured in one source in this report.

AAFES product and service consumers include active-duty military, National Guard members, reservists, retirees, and their families. This military organization has a twofold mission: (1) to provide quality merchandise and services to

[4] AAFES summary information throughout is from the *AAFES Supplier Handbook*, http://www.shopmyexchange.com/Images/doingbusiness/handbook.pdf, accessed December 14, 2011.

Soldiers, Airmen, and their families wherever they are stationed around the world and (2) to generate reasonable earnings to support Army and Air Force Morale, Welfare, and Recreation programs.

AAFES Data

In 2010, AAFES retail sales totaled nearly $10 billion worldwide. Of that amount, approximately $4.6 billion came from Army exchange facilities. Products and services sold by AAFES mirror those sold by major retailers such as Walmart, Sears, Target, and Kohl’s, and typically include automotive parts and products, casual home furnishings, clothing/accessories, food and beverages, housewares and electronics, sporting and recreational goods, equipment, stationery, tobacco, toiletries, and healthcare products.

For accounting purposes, AAFES tracks its retail sales in four broad categories: gasoline, retail less gasoline, food and beverages, and concessions (personal care services). These categories were used to calculate the bootprint.

Water Bootprint

Developing an accurate water bootprint for AAFES products and services is complicated by many factors, not the least of which are the sheer volume of products sold (tens of thousands of line items) and the large number of suppliers (more than 32,000) from which AAFES procures items. This study uses calendar year data from AAFES through direct communication with the Vice President, Support Division, Real Estate Directorate.

We calculate AAFES contribution to the Army water bootprint using the Eco-LCA model for all retail sales categories except gasoline sales. Gasoline sales and the related water bootprint are included in the Energy/Utilities section.

We matched the three remaining AAFES retail sales categories (minus gasoline) to the most appropriate model economic sector (Table 3-10).

Table 3-10. AAFES—Eco-LCA Model Market Sector Match

AAFES market sector	Eco-LCA model market sector
Retail less gasoline	Retail trade
Food and beverages	Food services and drinking places
Concession	Personal care services

These correlations are broad. For example, personal care services include more than just the operation of typical AAFES concessions, such as barber shops, dry cleaners, and fast food outlets. They also include activities one would normally not find on an Army installation, such as hair replacement services, tanning salons, and health resorts. Nevertheless, it is the best correlation given the data and analytical tools currently available.

Using this categorization and the 2010 adjusted retail sales, AAFES/Class VI water bootprint is approximately 29 billion gallons (Table 3-11).

Table 3-11. AAFES Water Bootprint Calculation Summary

AAFES—Eco-LCA model market sector	CY10 retail sales ($ million)	CPI factor	CY10 retail sales ($ million adjusted)	Water use (gallons/ $ million)	Total water use (gallons)
Retail less gas/ retail trade	2,840.2	0.811[a]	2,303.4	7,536,079	17,358,347,953
Food and beverages/ food and drinking places	412.8	0.723[b]	298.5	28,462,191	8,494,683,147
Concession/ personal care services	582.4	0.793[c]	461.9	6,982,491	3,225,073,088
Total	3,835.4		3,063.8	42,980,761	29,078,104,188

[a] 0.811 = 141.7/174.6.
[b] 0.723 = 159.1/219.98.
[c] 0.793 = 163.9/206.6.

Civil Works and MILCON

The USACE Civil Works and MILCON programs account for an estimated 46 billion gallons of water use per year. Each year the Army executes hundreds of projects via its Civil Works and MILCON programs. For the most part, this construction is managed by USACE with oversight for the Civil Works program from the Deputy Assistant Secretary of the Army for Installations, Housing, and Partnerships for MILCON.

Principal components of the Civil Works construction program used in this analysis include the following:

- *Construction*. Construction of water resource projects considering net economic and environmental returns per dollar invested or to prevent significant risk to human safety, dam safety assurance, seepage control, and static instability correction.
- *Operation and maintenance*. Maintenance of key commercial navigation, flood and storm damage reduction, and other facilities.
- *Investigations*. Evaluation of the need, engineering feasibility, and economic and environmental return to the Nation of potential solutions to water and related land resource problems.
- *Mississippi River and tributaries*. Construction, operation and maintenance, and investigation activities related to the 1,600 miles of levees and

related features on the main stem of the lower Mississippi River and in the Atchafalaya Basin.

- *Flood control and coastal emergencies*. Operations and activities to ensure preparedness for floods, hurricanes, and other natural disasters.
- *Regulatory program*. Execution of federal regulatory permit programs needed to protect the Nation's waters and wetlands.
- *Expenses*. Activities needed to ensure adequate executive direction and management of the Civil Works program.
- *Assistant Secretary of the Army (Civil Works), OASA(CW)*. Internal operating budget.
- *Formerly Utilized Sites Remedial Action Program (FUSRAP)*. Identification, investigation, and cleanup or control of the Nation's early atomic energy and weapons program before the creation of the Department of Energy (DOE).[5]

In addition to the Civil Works program, USACE also executes a large number of MILCON projects each year on behalf of various customers, including Army activities, the Air Force, and, other DoD agencies and activities.

The Army's MILCON program provides real property assets needed for Soldiers and their families to work, train, and live. The Army's MILCON program is separated into five appropriations: MILCON Army, MILCON Army Reserve, MILCON Army National Guard, Army Family Housing Construction, and Base Realignment and Closure (BRAC).

Facilities for the Army mission, readiness initiatives and quality-of-life improvements are also in the Army MILCON Program.[6]

MILCON Data

In FY10, Army MILCON appropriated funding was $7 billion, a decrease from $10.8 billion in FY09.[7] Funding in FY11 and beyond may continue to decrease with the completion of BRAC and implementation of projected budget cuts across the Future Years Defense Program. If activity levels decrease, so will required water inputs.

[5] USACE, Civil Works Budget Summary, February 2010.

[6] *Army Posture Statement*, FY09.

[7] USACE MILCON Summary, Directorate of Military Programs, August 31, 2010.

Civil Works Data

FY10 funding for the Civil Works program was $5.4 billion.[8] (Table 3-12) We chose FY10 for consistency with other data sets used in this water bootprint study. However, FY11 funding requests totaled $4.881 billion (a 10 percent reduction). Historically, inter-annual Civil Works spending has varied greatly, causing the Civil Works contribution to the Army's water bootprint to do the same.

Table 3-12. FY10 USACE Civil Works Program Summary

Civil Works program component	FY10 funded ($ million)
Construction	2,028
Operation and maintenance	2,400
Investigations	162
Mississippi River and tributaries	340
Flood control and coastal emergencies	0
Regulatory program	190
Expenses	185
OASA(CW)	5
FUSRAP	134
Total	5,444

Water Bootprint

Because specific water factors are not available for these activities, we again used the Eco-LCA model. The study matched the nine Civil Works program component categories and MILCON to the most appropriate model economic sector (Table 3-13).

[8] FedSources Analysis, November 15, 2010, based on Office of Management and Budget FY11 Budget of the US Government, February 1, 2010.

Table 3-13. Civil Works/MILCON—Eco-LCA Model Market Sector Match

Civil Works/MILCON component	Eco-LCA model market sector
Construction	Other new construction
Operation and maintenance	Other new construction
Investigations	Architectural and engineering services
Mississippi River and tributaries	Water, sewer, and pipeline construction
Flood control and coastal emergencies	Social assistance
Regulatory program	Other federal government enterprises
Expenses	Other new construction
OASA(CW)	Office administrative services
FUSRAP	Waste management and remediation services
MILCON	Other new construction

In consideration of the foregoing discussion, and after adjusting FY10 funding to FY97 using the appropriate CPI conversion factors, the overall Civil Works/ MILCON water bootprint was approximately 46 billion gallons (Table 3-14).

Table 3-14. Civil Works/MILCON Water Bootprint Calculation Summary

Civil Works/ MILCON component	FY10 funded ($ million)	CPI factor[a]	FY10 expenditures ($ million adjusted)	Water use (gallons/ $ million)	Total water use (gallons)
Construction	2,028	0.74	1,501	4,854,981	7,287,326,913
Operation and maintenance	2,400	0.74	1,776	4,854,981	8,622,446,767
Investigations	162	0.74	120	2,834,062	340,087,467
Mississippi River and tributaries	340	0.74	252	5,486,590	1,382,620,686
Regulatory program	190	0.74	141	10,220,591	1,441,103,328
Expenses	185	0.74	137	4,854,981	665,132,436
OASA(CW)	5	0.74	4	2,501,593	10,006,370
FUSRAP	134	0.74	99	11,554,580	1,143,903,426
MILCON	7,000	0.74	5,180	4,854,981	25,148,803,071
Total	12,444	N/A	9,210	N/A	46,041,430,464

[a] 0.74 = 160.5/218.1.

USACE IIS

USACE's IIS work accounts for an estimated 36 billion gallons of water use per year. In addition to the Civil Works and MILCON programs it executes each year, USACE is charged with providing a variety of technical and construction-related support to civilian federal agencies and international customers. This work is managed under a program known as IIS.

IIS provides technical assistance to non-DoD federal agencies, state and local governments, tribal nations, private US firms, international organizations, and foreign governments. Most IIS work is reimbursable, which means that annual funding for the program is not provided via the annual budget process. Instead, customers directly provide funding for the work they request USACE to oversee and execute on their behalf.

IIS services include engineering and construction services, environmental restoration and management services, research and development assistance, management of water and land related natural resources, relief and recovery work, foreign military sales, and other management and technical services.

The international component of IIS includes DoD MILCON and Foreign Military Sales (FMS);[9] Department of State economic support funding (Iraq), Bureaus of Diplomatic Security, and International Law Enforcement and Counternarcotics; US Agency for International Development reconstruction efforts; Millennium Challenge Corporation economic grants; foreign government military construction and civil works projects; and support to other international organizations, such as the Asia Development Bank.

IIS DATA

USACE provided just over $2 billion in interagency support under IIS in FY10.[10] (Table 3-15).

Table 3-15. FY10 USACE Interagency Support

Supported department or agency	FY10 funded ($ million)
Department of State	630.0
Department of Veterans Affairs	348.7
Environmental Protection Agency	308.2
Department of Homeland Security, Customs and Border Protection	254.2
Department of Homeland Security, Federal Emergency Management Agency	86.1
Department of Interior	55.6
Department of Energy	51.0
NASA	28.1
Department of Justice	17.7
Department of Homeland Security, Other	16.6
Department of Commerce	16.3

[9] The Defense Security Cooperation Agency manages the FMS program, which is the government-to-government vehicle for selling US defense equipment, services, and training.

[10] Headquarters, USACE, , Robert Slockbower, presentation to Associated General Contractors of America, Headquarters, USACE, April 29, 2010..

Table 3-15. FY10 USACE Interagency Support

Supported department or agency	FY10 funded ($ million)
Agency for International Development	13.0
Capitol Building, Architect of the Capitol	12.6
Department of Health and Human Services	11.8
Department of Agriculture	10.7
Department of Transportation	9.4
Government Corporations and Commissions	8.6
Arlington National Cemetery	5.4
National Science Foundation	4.2
GSA	2.1
Department of Housing and Urban Development	1.3
Office of Personnel Management	1.2
Other federal agencies	2.5
State, local, tribal, and private sector	118.6
Total	2,013.9

USACE provided $8 billion in international support in FY10 (Table 3-16).[11]

Table 3-16. FY10 USACE International Support

Geographical support area or other support category	FY10 funded ($ million)
Europe	746
South America	86
Pacific	2,307
Middle East	3,867
FMS (construction)	940
Cooperative Threat Reduction (CTR) Program	59
Civil-Military Emergency Preparedness	2
Total	8,007

WATER BOOTPRINT FOR USACE IIS

Before applying the Eco-LCA model, we first had to correlate the various IIS support area component categories to the most appropriate model economic sector. The data sources available gave little indication of the actual economic sector, so we assumed all of this economic activity to be within the broad category of civil works construction. For the international support component, we assumed

[11] See Note 10.

that all support to Europe, South America, the Pacific, and the Middle East fell within military construction. We assumed FMS primarily includes construction of military support facilities, such as Apache helicopter facilities in Egypt, and humanitarian construction projects, so we assumed this civil works construction would also best model this activity.[12]

The CTR Program is assumed to be military construction. The CTR Program focuses on eliminating, securing, or consolidating weapons of mass destruction (WMD), related materials, and associated delivery systems and infrastructure at their source in partner countries. Accordingly, we assumed that USACE's role primarily consists of dismantling WMD facilities and related infrastructure. Therefore, we assigned the economic sector to other new construction.

Civil-military emergency preparedness typically includes projects designed to prepare for and respond to floods, hurricanes, earthquakes, and the like. This was assigned to the social assistance Eco-LCA Model Market sector (Table 3-17).

Table 3-17. USACE IIS Program—Eco-LCA Model Market Sector Match

USACE IIS program component	Eco-LCA model market sector
Interagency support	Other new construction
International support, Europe, South America, Pacific, and the Middle East	Other new construction
International support, FMS	Other new construction
CTR	Other new construction
Civil-military emergency preparedness	Social assistance

Considering these factors and adjusting FY10 funding to FY97 using the appropriate average CPI conversion factors the overall USACE IIS water bootprint is based on the adjusted model outputs (Table 3-18).

[12] Does not include FMS managed by DoD; only includes services provided and funded by the Army via USACE.

Table 3-18. USACE IIS Program Water Bootprint Calculation Summary

IIS program component	FY10 funded ($ million)	CPI factor[a]	FY10 expenditures ($ million adjusted)	Water use (gallons/ $ million)	Total water use (gallons)
Interagency Support[b]	2,014	0.74	1,490.0	4,854,981	7,233,921,690
International Support, Europe, South America, Pacific, and Middle East[b]	7,006	0.74	5,184.0	4,854,981	25,168,221,504
International Support, FMS[b]	940	0.74	696.0	4,854,981	3,379,066,776
Cooperative Threat Reduction[b]	59	0.74	44.0	4,854,981	213,619,164
Civil-Military Emergency Preparedness[c]	2	0.74	1.5	5,486,590	8,229,885
Total	10,021	N/A	7,415.5	N/A	36,003,059,019

[a] CPI Factor 0.74 = 160.5/218.1.
[b] Model sector = other new construction.
[c] Model sector = social assistance.

FUEL CONSUMPTION AND OTHER ENERGY PURCHASES METHOD

All of the databases and estimations above use the Eco-LCA model. In this section, we discuss the limitations of the literature-based water factors used for estimating water use of primary fuel consumption and energy purchases. Appendix A includes an analysis of water factors for primary fuel consumption and energy purchases calculated using Eco-LCA and literature-based factors.

Primary Fuel Consumption

The Army's water bootprint for primary fuel consumption amounts to approximately 3.3 billion gallons of water use. This section considers water consumed in the process of extracting and delivering primary fuels. Primary fuels include material the Army uses for transportation, heating, or the generation of electricity or steam. Electricity and steam purchases, which also include the water consumed in generation, are discussed in the Utility Energy Purchases section.

Primary fuel consumption is captured as Class III products in the supply chain. These fuels include coal, oil, natural gas, gasoline, diesel, aviation gas, jet fuel, liquefied propane, and biofuels, such as ethanol, biodiesel, and biomass.[13]

This section considers these fuels as products purchased for Army use and includes only off-site processing and production.

[13] This study only includes primary fuels reported in the Army's FY10 and FY08 GHG inventory; it does not include Army nuclear facilities.

The literature provides specific water consumption factors for energy, and the Army has energy consumption data relevant to these factors. The Army believes using water factors for a specific product is likely more accurate at predicting water consumption than the Eco-LCA model. The following subsections contain the background and necessary assumptions for using these factors.

PRIMARY FUEL CONSUMPTION DATA

We used data collected to support Army's reporting of its GHG inventory including installation energy consumption data from the Army Energy Management Data Report, mobile fuel data reported to the Federal Automotive Statistical Tool, and data collected by DLA.[14]

The purchase of each fuel type varies from one year to the next. Thus, we calculated the average consumption of each fuel from fuel use data (available for FY08 and FY10 only) that then serves as the Army's representative consumption.

The Army GHG data include continental US (CONUS) and outside continental US Active and Reserve Components, but not USACE energy use, which is reportedly separately from DoD. Data associated with forward-operating, temporary, or expeditionary bases or contingency operations are captured where bulk fuel was procured from DLA—but they are incomplete. In addition, some primary fuel use at government-owned, contractor-operated facilities is captured by this data set.[15] We had no basis for estimating the gap in fuel data, so we assigned it a value using the same data set as the Army GHG inventory.

Primary fuel consumption also includes fuel purchases at AAFES stations located in the United States and abroad. This was not reported in the Army GHG inventory, but was pulled from the data provided by AAFES for this report.

Because AAFES fuel purchase data are available only in US dollars, we estimated gallons of fuel purchases using Energy Information Administration (EIA) weekly regular conventional retail gasoline prices for CY10. These statistics are aggregated into eight regions and a handful of states. To calculate gallons of gasoline purchased, we divided fuel use at each market by the applicable average regional EIA price. For retail stations located overseas, we assume AAFES prices equal the highest domestic price in CY10, or the price for Washington State.[16] This is included in the total gasoline usage under crude oil.

[14] The energy reporting and Federal Automotive Statistical Tool reporting are available on the aggregate DoD level: DoD Annual Energy Management Data Report, http://www.acq.osd.mil/ie/energy/energymgmt_report/main.shtml and FAST Report, https://fastweb.inel.gov/, accessed December 14, 2011.

[15] Personal communication with Army staff.

[16] AAFES policy is to price gasoline sold overseas based on a monthly average of US market prices at CONUS stations.

Water factors in this subsection reflect water consumed, not total water withdrawn, and include the following activities:

- Mining, extraction, beneficiation and production of raw fuels to create end-product fuel for stationary or mobile combustion
- Transportation of natural gas
- Refining of crude oil and biofuel feedstocks.

We found the literature generally refers to water consumption estimates developed by Peter Gleick in 1994 using DOE data from around 1980.[17] Gleick conducted one of the first in-depth studies relating water consumption to fuel mining and refining, and studies since tend to build upon Gleick's work. Although technical advances in exploration, extraction, production, and generation methods over the past 30 years may have changed fuel/water relationships somewhat, Gleick's estimates still appear to be the most comprehensive for crude oil exploration, production, and refining.

We selected additional water factors from Argonne National Laboratory (ANL) and DOE studies to supplement Gleick's water factors and estimate water consumption for biofuel feedstock irrigation and refining.[18] When these studies provided multiple water consumption factors for a water-use category, we took the median of the highest and lowest estimates to produce a single water consumption factor.

A major omission from the primary fuels water factors is water consumed during the transport of crude oil from extraction to refining and of refined products to the military installations. Water consumption estimates for transportation rely on distance traveled, for which data are unavailable; the study excludes water consumption associated with the transportation-to-market components of the supply chain in our analysis.

This exclusion follows the King and Webber assessment of water intensity of transportation, which also neglects crude oil and refined product transport.[19] Transporting fuel requires the use of fuel. Thus, excluding water consumption associated with transportation likely underestimates the Army's water consumption estimate. The magnitude of this underestimate is uncertain (Table 3-19).

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[17] Peter H. Gleick, "Water and Energy," *Annual Review of Energy and Environment*, Vol. 19, 1994, pp. 267–299.

[18] ANL, *Consumptive Water Use in the Production of Ethanol and Petroleum Gasoline*, ANL/ESD/09-1, 2009; DOE, *Energy Demands on Water Resources, Report to Congress on the Interdependency of Energy and Water*, December 2006.

[19] C. W. King and M. E. Webber, "Water Intensity of Transportation," *Journal of Environmental Science and Technology* 42(21), 2008, pp. 7866–7872.

Below, we summarize the steps used to estimate water use from primary fuels. These same steps were used to capture the water used for the primary fuels used to generate electricity and steam purchased, as detailed in the Utility Energy Purchases section.

1. Collect energy consumption data.

2. Apply water consumption factors for each fuel type.

Table 3-19. Water Consumption Factors for Primary Fuel Sources

Energy source	Water use category	Water consumption factor (gal/gal)	Source
Crude Oil	Exploration	0.0004	Gleick 1994
	Production	5.7	Gleick 1994, ANL 2009
	Transportation	0.0	N/A
	Refining	3.2	Gleick 1994, ANL 2009
	Transportation	0.0	N/A
	Total	**8.9**	
Biodiesel	Crude Oil Exploration	0.0	Gleick 1994
	Feedstock Irrigation	1,143	DOE 2006
	Crude Oil Production	1.0	Gleick 1994, ANL 2009
	Transportation	0.0	N/A
	Biodiesel Refining	0.1	DOE 2006
	Crude Oil Refining	0.6	Gleick 1994, ANL 2009
	Transportation	0.0	N/A
	Total	**1,144.7**	
Ethanol	Crude Oil Exploration	0.0	Gleick 1994
	Feedstock Irrigation	81	ANL 2009
	Crude Oil Production	0.4	Gleick 1994, ANL 2009
	Transportation	0.0	N/A
	Biodiesel Refining	2.6	ANL 2009
	Crude Oil Refining	0.2	Gleick 1994, ANL 2009
	Transportation	0.0	N/A
	Total	**84.2**	

Primary fuel accounts for more than 3.5 billion gallons of water (Table 3-20).

Table 3-20. Primary Fuel Consumption Water Consumption Total

Fuel type	Water consumption (billion gallons)
Gasoline	1.390
Jet fuel/aviation gas	0.470
Liquefied Petroleum Gas (LPG)/Propane (mobile fuels)	0.0003
Diesel	0.401
Fuel oil	0.087
LPG (electricity)	0.006
Residual oils	0.025
Biodiesel	0.694
Ethanol	0.112
Coal	0.015
Natural Gas	0.067
Total	3.267

Crude Oil

Calculations

The literature includes water factors for crude oil, but not the specific end products used by the Army, such as gasoline and jet fuel. To create a water footprint estimate using an end use product, the crude oil water factors are multiplied by the percentage of refinery output that is the end product per gallon of crude oil. The result is a water factor for the end product that is specific to that fuel type.

First, to compensate for the extraction of multiple products from a single gallon of crude, we ascribed the water factor associated with each product/fraction. We determined the amount of crude oil required to produce what the Army used, and then the water used only for that portion the Army used. We did not consider crude lost in the processing of other fuel types.

To approximate the breakout of refined products from crude oil, we used EIA refinery output statistics to determine the total amount of crude oil required to produce the petroleum that the Army uses. We assumed that for each gallon of crude oil that enters the refinery, the EIA statistics indicate the percentage that is refined into each type of fuel, for example, gasoline, diesel, or jet fuel. We averaged refinery output statistics over the past 5 years, from 2005 to 2009, to determine the appropriate allocation.

The refinery output includes five categories: gasoline, diesel (or distillate fuel oil), LPG (or propane), jet fuel, and residual fuel oil. For jet fuel, the study matched the Army's jet fuel and aviation gas use to the EIA refinery output statistics for jet fuel and kerosene. We also combined the refinery output statistics for residual fuel oil and other products, though they are not a Class III POL bulk fuel, to represent the Army’s combined use of lube oils and residuals.

For example, EIA statistics indicate that gasoline averages 47.2 percent of crude oil refining output over the past 5 years. From the literature, we estimate that 8.87 gallons of water are consumed during the refining of each gallon of crude oil. Applying the refinery output statistic for gasoline, we estimate that 4.18 gallons of water per gallon of crude oil are allocated to gasoline. We then multiplied the Army’s gasoline use by this water factor to approximate gallons of water consumed per gallon of gasoline. This was repeated for each fuel type.

For gasoline, we calculate the 4.18 gallons of water per gallon gasoline by multiplying water factors for crude oil exploration, refinement, and refining by the total to the amount of gasoline consumed (Table 3-21).

Table 3-21. Calculating Gasoline Water Consumption

Gallons water per gallon gasoline			Army gasoline use (gallons)		Total water consumption for gasoline (gallons)
Crude oil exploration	0.0002				
Crude oil production	2.6888				
Gasoline refinement	1.4957				
Gasoline water consumption factor	4.1847	×	332,133,814	=	1,389,880,371

This calculation does not include water consumption associated with transportation because water consumption factors require transport distance which is not available.

Class III POL water use totals approximately 2.4 billion gallons (Table 3-22).

Table 3-22. Crude Oil Water Consumption Estimates

Fuel type	Water consumption (billion gallons)
Gasoline	1.390
Jet fuel/aviation gas	0.470
LPG/Propane	0.0003
Diesel	0.401
Fuel oil	0.087
LPG	0.006
Residual oils	0.025
Total	2.3793

Assumptions and Limitations

We made several assumptions to estimate water consumption associated with crude oil production and refining data. First, the methods to extract crude oil include primary, secondary, and tertiary recovery methods. For primary consumption, we use the Gleick water consumption factor for onshore primary extraction and all offshore extraction.[20] For onshore secondary methods, we use ICF to account for the reinjection of saline water for water flooding.[21] Multiple sources were used to identify water consumption factors for tertiary extraction methods which include CO_2 or steam injection and forward combustion. We use ANL estimates for technology shares of onshore and offshore US crude oil recovery to weight the portion of crude oil extracted from each method.[22,23]

Second, international sources of crude oil and refined products account for a signification portion of US fuel use. We did not seek water consumption metrics on each country's crude oil exploration and production or refining processes. Instead, we assume methods to explore, extract, and refine crude oil overseas mimic US methods and water consumption metrics.

Third, we exclude unconventional sources of oil, such as synthetic fuel derived from oil shales or oil sands. These sources, especially oil sands, are not widely produced in the United States, but come primarily from Canada. We do not expect this to represent a significant gap in our analysis given that Gleick water consumption estimates for tar sands amount to 6.92 gallons water per gallon of crude oil,[24] which is slightly more than our estimate of 5.70 gallons of water per gallon crude oil.

Fourth, we exclude calculations for compressed and liquefied natural gas used in vehicle transportation. The amounts reported for FY08 and FY10 were negligible.

Biodiesel and Ethanol

Calculations

The Army purchases alternative fuels, which include blends of biodiesel (B20) and ethanol (E85) with fossil fuels derived from crude oil. The renewable components have different patterns of water use than the crude oil-derived fuel.

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[20] See Note 17.

[21] ICF Consulting, "Overview of Exploration and Production Waste Volumes and Waste Management Practices in the United States," 2000.

[22] Onshore and offshore recovery methods use different amounts of water to produce crude oil.

[23] See Note 18.

[24] See Note 17.

For B20, we used DOE water consumption estimates for the irrigation of soybean feedstock and refining of biodiesel,[25] joining them with the water consumption estimates for diesel fuel. Because B20 represents a blend of 20 percent biodiesel and 80 percent diesel, we weight the water consumption coefficients for biodiesel and diesel on the basis of this mixture.

The Army purchases ethanol in the form of E85 fuel which represents a blend of 85 percent ethanol and 15 percent gasoline. To calculate ethanol water consumption, we found ANL the most comprehensive source for water factors on the irrigation of corn grain feedstock and refining. ANL provides water consumption irrigation statistics for the top three ethanol producing regions in the United States which represent 95 percent of ethanol feedstock production.[26]

We used the 95 percent estimate to calculate the remaining 5 percent of ethanol feedstock production not included in the main regions. This analysis joined the estimates from ANL with the gasoline consumption factor to produce a total water consumption factor for E85 (see Table 3-23).

Table 3-23. Renewable Fuel Water Consumption

Fuel type	Water consumption (billion gallons)
Biodiesel	0.694
Ethanol	0.112

Assumptions and Limitations

We assume the Army's procurement of B20 includes biodiesel produced solely from soybean feedstock and ethanol in E85 produced solely from corn grain feedstock. Although other types of feedstock can produce biodiesel or ethanol, soybeans and corn grain are the primary feedstock for biodiesel and ethanol production in the United States. This is a safe assumption because EIA reports that more than half of B20 is produced from soybean oil,[27] and 90 percent of fuel ethanol is produced from corn.[28]

[25] See Note 18.

[26] See Note 18.

[27] EIA Monthly Biodiesel Production Survey December 2009, released October 2010, http://www.eia.gov/cneaf/solarrenewables/page/biodiesel/biodiesel.pdf.

[28] DOE Alternative Fuels and Advanced Vehicles Data Center, http://www.afdc.energy.gov/afdc/ethanol/feedstocks_starch_sugar.html.

Coal

Calculations

Primary fuel water consumption estimates also include coal used for stationary combustion, such as for heating or electricity production on site. For this analysis, we include only water consumed during off-site exploration, mining, washing, beneficiation, and thermal processing of coal—not how the fuel is combusted within the installation.

Mining of coal includes surface and underground methods that require varying degrees of water consumption, water recycling, and reclamation. To account for such variance, this analysis used EIA statistics on coal production by state and mine type from 2008 and 2009 to approximate the regional distribution coal mining approaches for Appalachian, Interior, and Western coals.

Our estimate of water consumed in the processing of coal excludes

- refuse recovery, as it was not included in the EIA statistics;
- transport of coal, given the mode and distance is not available;
- water affected by contamination as a result of mining operations; and
- international sources of coal.

These exclusions likely result in an underestimation of the Army's water consumption associated with coal purchases (see Table 3-24).

Table 3-24. Coal Water Consumption

Fuel type	Water consumption (billion gallons)
Coal	0.0147

Assumptions and Limitations

We made several assumptions in calculating the coal water consumption factor:

- The Army procures coal at a rate equivalent to EIA production totals for each region.
- Fifty percent of surface mines require reclamation, whereas the other half have no re-vegetation requirements.

- Half of underground mines recycle water and half use a once-through process.[29]

- Eighty percent of Appalachian and Interior coal is washed, and no Western coal requires washing.[30,31]

Natural Gas

Calculations

We calculated water consumption associated with natural gas using estimates from Gleick and Elcock.[32] Unlike the other primary fuels, this calculation includes an estimate of transport for pipeline operation.

Natural gas production focuses on three primary geologic sources: oil and gas reservoirs, coalbed methane, and shale gas. The literature indicates that natural gas derived from shale gas (hydraulic fracturing) consumes water,[33] while water consumption associated with natural oil and gas well production is negligible,[34] and coal bed methane processes are net producers of water.[35]

To account for the Army's use of natural gas derived from shale formations, we relied on EIA statistics for natural gas withdrawals from 2008 and 2009. These statistics estimate the percentage of natural gas from conventional and unconventional sources. We included water consumption associated with oil and gas wells, coalbed methane, and shale gas extraction in our estimate, and combined this with Gleick estimates for natural gas processing and pipeline transport. We did not include negligible amounts of water consumption for natural gas exploration (see Table 3-25).[36]

Table 3-25. Natural Gas Water Consumption

Fuel type	Water consumption (billion gallons)
Natural gas	0.0669

[29] The literature provided insufficient data to make a more precise allocation of processes nationwide for the second and third assumptions. However, these different processes result in very different water use so some assumption of their use was necessary.

[30] In terms of coal-producing regions, the Interior Region (with the Gulf Coast) includes Arkansas, Illinois, Indiana, Kansas, Louisiana, Mississippi, Missouri, Oklahoma, Texas, and Western Kentucky, per EIA, *Annual Coal Report 2009*, DOE/EIA-0584, 2009, p. 68.

[31] See Note 18.

[32] See Note 17; Deborah Elcock, "Future US Water Consumption: The Role of Energy Production," *Journal of the American Water Resources Association*, 46: 447–460, 2010.

[33] See Note 32.

[34] See Note 17.

[35] See Note 32.

[36] See Note 17.

Assumptions and Limitations

The estimate of water consumption associated with natural gas transportation assumes all transport is piped from extraction to processing plants and from these plants to delivery. We also assume the Army's use of natural gas is representative of the national average of withdrawals by source.

Biomass

Biomass is a broad term that includes any organic matter used for fuel. Given this broad classification and wide range of potential organic fuel sources, we are unable to calculate a water consumption coefficient for biomass at this time.[37]

Utility Energy Purchases

Water consumption associated with electric and steam purchases averaged approximately 6.1 billion gallons annually (for 2008 and 2010). In addition to the purchases of primary fuel used for transportation, heating, and stationary combustion on site that are discussed above, the Army also purchases electricity and steam from off-site sources to power its installations. This analysis estimates total water consumption for these electricity and steam purchases, including water consumed in providing the primary fuel used to generate the electricity and steam, as well as the generation process itself.

Only water consumption associated with the purchase of electricity and steam from off-site sources is included. Water consumption associated with the on-site generation of steam, electricity, or heat is considered a direct consumptive use by installations and is not within the scope of this report.

Water consumption associated with fuel products purchased for the generation of steam, electricity, or heat on site at the installation (such as heating oil or coal) is addressed in the Primary Fuel Consumption section.

UTILITY ENERGY PURCHASES DATA

This analysis used consumption data for purchased steam, purchased renewable energy, and total electricity purchases from the Army's GHG inventories for FY08 and FY10. We also consulted primary data sources used in generating the GHG inventories, such as installation energy consumption data reported in the *Army Energy Management Data Report*.

[37] We assume that water consumption is negligible for biomass burned to generate electricity because such biomass typically is waste material. Our allocation scheme would fully distribute water consumed to the value-added product and not the waste material. For example, corn is planted for food not stover, so water consumption would count for the corn, but not the residual plant material. We also assume that biomass converted into transportation fuel is also negligible.

We used the Emissions and Generation Resource Integrated Database (eGRID) for 2010 and eGRID 2010 Technical Support Document to determine the primary fuels used to generate electricity per subregion.[38] By correlating Army electricity purchase data and eGRID, we were able to break down its electricity purchases by source, identifying purchases in megawatt hours (MWh) for coal electric, oil electric, gas electric, nuclear electric, hydroelectric, and other sources. This distribution of primary fuel source is approximate and based on eGRID subregions; certain installations may use different mixes on the basis of their local circumstances.

Electricity purchases averaged approximately 10.8 million MWh for 2008 and 2010. Coal electric was the most significant category, constituting 42 percent overall. Natural gas and nuclear were the next highest categories constituting approximately 16 percent and 17 percent, respectively (Table 3-26).

Table 3-26. Average Estimated Energy Purchases by Source (MWh)

	Electric	Steam	Total
Coal	4,486,854	0	4,486,854
Oil	319,211	0	319,211
Gas	1,753,742	0	1,753,742
Nuclear	1,852,467	0	1,852,467
Hydro	728,064	0	728,064
Biomass	300,253	1,177,164	1,477,417
Wind	101,447	0	101,447
Solar	6,970	0	6,970
Geothermal	21,434	0	21,434
Other fossil	37,670	0	37,670
Other unknown	5,282	0	5,282
Total	9,613,393	1,177,164	10,790,558

WATER BOOTPRINT

To calculate water consumption of electricity and steam purchases, source-specific water consumption factors (in gallons per unit of energy) were multiplied by energy purchases (in units of energy). The approach used in developing source-specific water consumption factors for primary fuels and the generation of electricity and steam is described below. It also describes how source-specific energy purchases were estimated and explains the method and limitations for estimating the water consumption associated with electricity and steam purchases.

[38] Environmental Protection Agency, *eGRID 2010 Technical Support Document for Year 2007 Data*, http://www.epa.gov/cleanenergy/documents/egridzips/eGRID2010TechnicalSupportDocument.pdf.

ELECTRICITY AND STEAM GENERATION

Multiple sources were used to calculate water consumption for electricity and steam purchases (Table 3-27)

Table 3-27. Water Consumption Factors for Primary Fuels and Electricity Generation

Energy source	Water use category	Water consumption factor (gal/MWh)	Source
Coal	Primary Fuel Source	12.6	Gleick 1994
	Electricity Generation	285.3	NETL 2009
	Total	**297.9**	
Natural gas	Primary Fuel Source	8.5	Gleick 1994
	Electricity Generation	98.6	NETL 2009
	Total	**107.1**	
Oil (diesel)	Primary Fuel Source	50.0	Gleick 1994
	Electricity Generation	285.3	Gleick 1994
	Total	**335.3**	
Hydro[a]	Primary Fuel Source	0.0	NA
	Electricity Generation	4490.4	Gleick 1994
	Total	**4490.4**	
Nuclear	Primary Fuel Source	25.6	Gleick 1994
	Electricity Generation	380.8	NETL 2009
	Total	**406.4**	
Solar	Primary Fuel Source	0.0	NA
	Electricity Generation	469.9	DOE 2010
	Total	**469.9**	
Wind	Primary Fuel Source	0.0	NA
	Electricity Generation	0.0	Gleick 1994
	Total	**0.0**	
Biomass (waste-to-energy [WTE])	Primary Fuel Source	0.0	NA
	Electricity Generation	285.3	NETL 2009
	Total	**285.3**	
Geothemal	Primary Fuel Source	0.0	NA
	Electricity Generation	369.9	DOE 2010
	Total	**369.9**	

Table 3-27. Water Consumption Factors for Primary Fuels and Electricity Generation

Energy source	Water use category	Water consumption factor (gal/MWh)	Source
Other fossil fuel/unknown	Primary Fuel Source	12.6	Gleick 1994
	Electricity Generation	285.3	Gleick 1994
	Total	**297.9**	

Sources: (DOE National Energy Technology Laboratory (NETL), Estimating Freshwater Needs to Meet Future Thermoelectric Generation Requirements, September 30, 2009; DOE, Concentrating Solar Power Commercial Application Study: Reducing Water Consumption of Concentrating Solar Power Electricity Generation, Report to Congress, 2010).

[a] The water consumption factor for hydroelectric production is extremely high relative to other water consumption factors due to the significant volume of water lost to evaporation and seepage from reservoirs. The losses greatly vary since they depend on climatic conditions, the surface area of the water body, and the design of the hydroelectric plant.

For each fuel and technology category, we selected a limited number of sources of data. In general, we preferred US government sources, such as DOE, its national laboratories, and the National Academy of Sciences, and gave non-profit references a secondary weight.

Where appropriate, the water consumption factors associated with primary fuel (discussed above) were used in calculating the fuel component of electricity and steam. We adjusted the factors to account for water used in electricity generation, including for cooling water, make-up water, and flue gas desulfurization. In some cases, the primary fuel factors differ between the calculations in the Primary Fuel Consumption and Utility Energy Purchases sections, due to different use patterns from large-scale production of electricity by utilities.

Primary fuel water consumption factors for coal and oil differ from those identified earlier. The factor for coal has been adjusted upward to account for some coal transported via a slurry pipeline in the production of electricity and steam, whereas none was considered for purchases of primary fuels. From available data, we estimated that 10 percent of coal used in the generation of electricity was transported by slurry pipeline.

For electricity generated with oil, we assumed that all oil was diesel. In the case of some renewable energy sources, water consumption associated with primary fuels was negligible or did not apply for example, hydroelectric, solar, and wind. We derived water consumption factors for the electricity and steam generation component using basic assumptions about the technologies, designs, and operating parameters of electric utilities. Should this analysis be refined or the method applied to a specific case or location, modifying factors to consider the prevalence of a specific technology type or operating environment may be appropriate.

Calculations

To calculate water consumption associated with energy and steam purchases, we multiplied water consumption factors for each source (in gallons per MWh) by the quantity of energy purchased (in MWh) to obtain total gallons by source. Approximately 6.1 billion gallons of water were consumed for purchased electricity and steam which is based on an average of energy purchases for FY08 and FY10 (Table 3-28).

Table 3-28. Water Consumption for Purchased Electricity and Steam

Generation type	Water consumption (billion gallons)
Coal Electric	1.337
Oil Electric	0.107
Natural Gas Electric	0.188
Nuclear Electric	0.753
Hydroelectric	3.269
Biomass (WTE)	0.432
Wind	0.000
Solar	0.003
Geothermal Electric	0.008
Other fossil fuel Electric	0.011
Other unknown	0.002
Total	6.110

Assumptions and Limitations

Because water consumption factors and the eGrid subregion resource mix have inherent limitations, the electricity water coefficients are subject to considerable uncertainty. However, some observations are valid. Although hydroelectric accounted for only 7 percent of energy purchases, it accounted for nearly 54 percent of water use. The water consumption factor for hydroelectric production is extremely high relative to other water consumption factors due to the significant volume of water lost to evaporation and seepage from reservoirs. The losses greatly vary since they depend on climatic conditions, the surface area of the water body, and the design of the hydroelectric plant.

Coal electric was the next highest consumer, accounting for more than 21 percent of water use, primarily on the basis of the quantity of coal electric purchases, the highest category.

Wind energy consumes a negligible amount of water, and because it is such a small percentage of energy purchases, it has very little effect on overall consumption. The same holds for “other unknown.”

The relationship between total MWh of electricity and steam use with total water associated with that use (Figure 3-4) does not necessarily reflect the largest water users with the biggest percentage providers of MWh (Figure 3-5).

Although the potential for reducing water consumption associated with electricity and steam purchases may be constrained by the availability of energy sources and the inability to select specific production technologies or fuel types, these data identify indirect benefits of Army initiatives to reduce electricity use that result in water savings.

With an average annual electricity purchase of 10.8 million MWh consuming approximately 6.1 billion gallons of water, a reduction in electric purchases of 1 percent (108 MWh) annually would result in savings of approximately 61 million gallons of water. The analysis also may influence decisions regarding on-post energy generation and water consumption that is beyond the scope of this report.

Figure 3-4. Purchased Electricity and Steam per eGRID Primary Fuel (MWh)

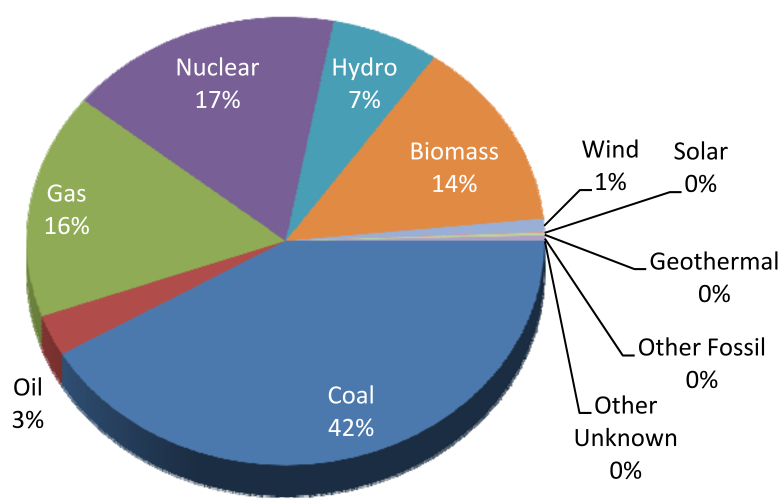
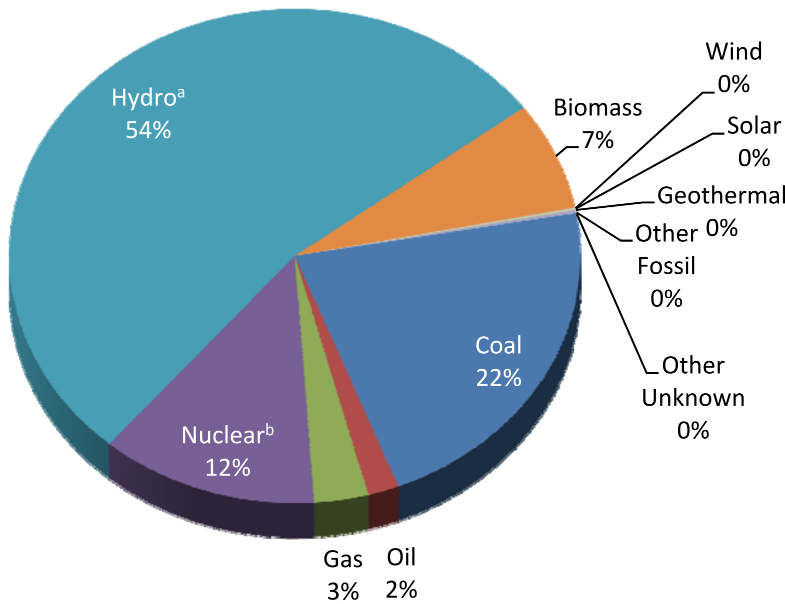


Figure 3-5. Water per eGRID Primary Fuel (gallons)



[a] The water consumption factor for hydroelectric production is extremely high relative to other water consumption factors due to the significant volume of water lost to evaporation and seepage from reservoirs. The losses vary greatly since they depend on climatic conditions, the surface area of the water body, and the design of the hydroelectric plant. This 54 percent does not include the water that simply flows over the turbines since that water is not truly consumed or even withdrawn.

[b] Evaporation, rather than pass-through cooling water, accounts for the majority of nuclear water consumption.

Chapter 4
Conclusion

RESULTS

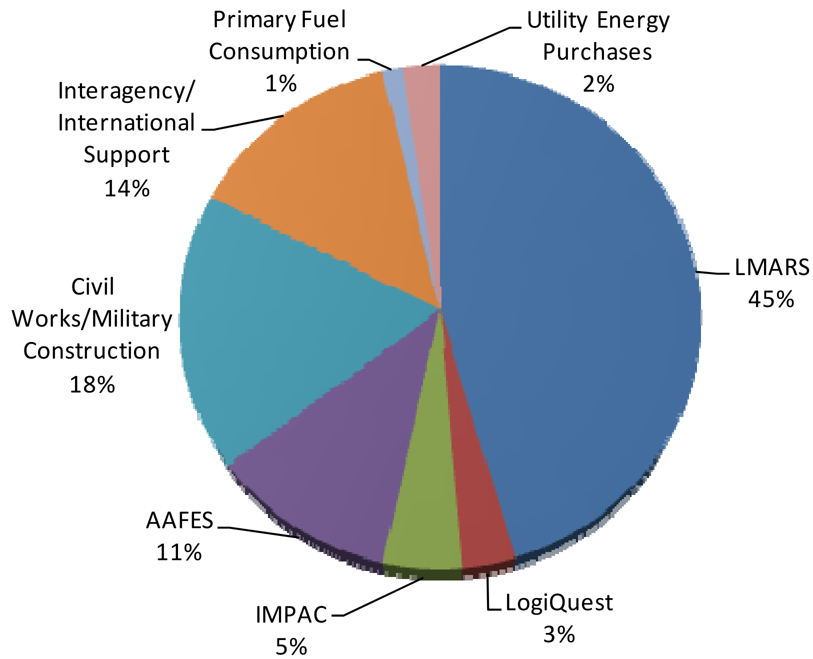
Summary

The Army Environmental Policy Institute undertook this study as an initial step in quantifying the amount of water used by the Army's suppliers to produce the goods and services it procures to achieve its ongoing mission. The study does not include direct water use by Army installations and activities. It does include products and services procured through standard Army wholesale/retail logistics systems, purchased fuel and utility energy, local purchases, and military/civil works construction and international/interagency support provided by USACE. Quantifying indirect water usage will enable the Army to begin developing strategic policy to address potential water vulnerability issues involved in supplying the Army with critical goods and services that support operational readiness and training.

After completing the analysis, we estimated the Army's indirect water use through the supply chain over 12 months at more than 258 billion gallons equivalent to more than 400,000 Olympic-sized swimming pools. The Army's largest water use is captured in its requisition and procurement databases which reflect goods and services purchased by the Army, excluding construction, AAFES, local purchases, and fuel (Figure 4-1). Considering LMARS, LogiQuest, AAFES (less fuel), and IMPAC in the same category, 65 percent of the water bootprint is from these various product databases. Energy is approximately 4 percent, and USACE MILCON, Civil Works, and other support services are 32 percent.

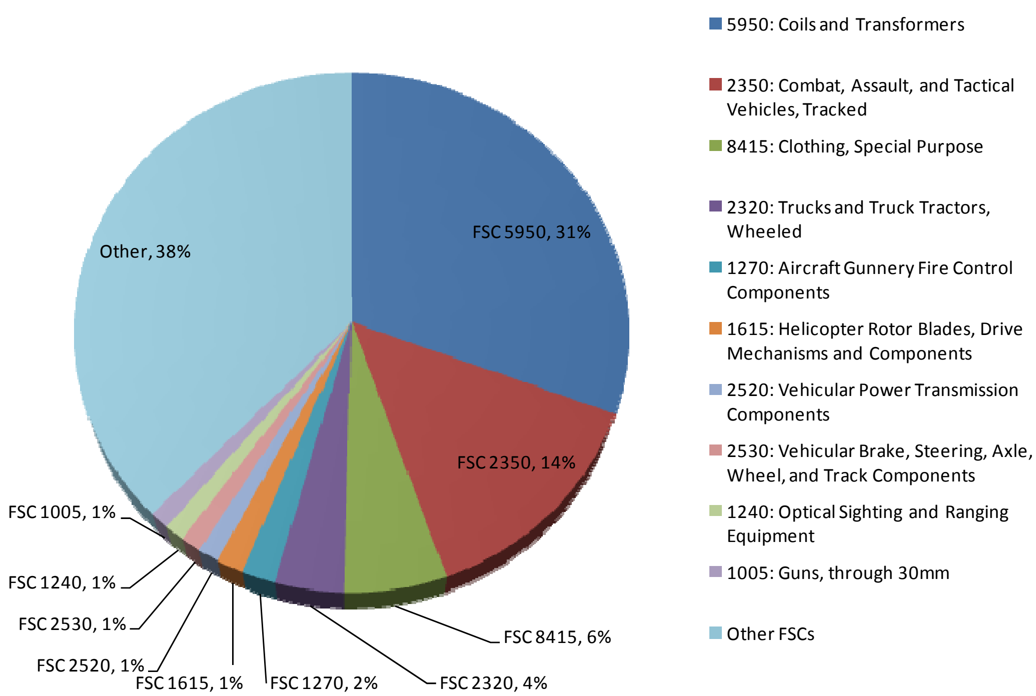
LMARS requisitions represent about 45 percent of the water bootprint, and FSCs are assigned to LMARS records (Figure 4-2). FSC 5950 (Coils and Transformers) is at the top of the FSC list, accounting for 31 percent of the LMARS water bootprint. Combined, the top 10 FSCs account for 62 percent of the LMARS water bootprint, whereas all other FSCs represent 38 percent of the LMARS water bootprint.

Figure 4-1. Army Water Bootprint Distribution by Data Source



Note: Percentages in Figure 4-1 do not equal 100 percent due to rounding.

Figure 4-2. LMARS Water Bootprint Distribution by FSC



Several factors affect the accuracy of this result:

- A major drawback of the Eco-LCA model is that each economic sector includes a large number of activities, each of which partially contributes to the water-use factor. For example, gasoline refining is one of 50 activities included in the petroleum refining sector. As a result, applying Army gasoline purchases to that sector likely results in an estimate that is higher than actual water use for only gasoline refining activities.
- Another drawback of the Eco-LCA model is that it is producer based rather than purchaser based. That means it does not include water use associated with product transportation to point of sale or the wholesale and retail trade margins associated with each product. Because we could not obtain detailed Army transportation or supplier profit margin information, we did not adjust the model outputs for these uses.
- The major supply databases, LMARS and LogiQuest, were used to quantify items purchased across the supply chain classes, excluding Class VI—personal demand items. However, LogiQuest includes data only from TACOM, a subordinate organization of AMC. The data set does not include the two other Army commands, the nine Army Service Component Commands, or 11 Direct Reporting Units. This may represent a significant shortfall, and in view of this, the resulting Army water bootprint estimate may be underestimated, even in consideration of inflated values produced by the Eco-LCA model.

In spite of these issues, the resulting Army water bootprint estimate, although coarse, does provide a baseline with which to compare future estimates. Thus, year-to-year comparisons of water bootprints should yield useful information. However, over time the Army should expect water footprint estimation methods to become more precise, with more detailed data used to construct more accurate estimates of water usage per unit of production. As that occurs, earlier estimates may need to be adjusted to compare them with later estimates.

Objectives Achieved

In aggregate, we partially achieved the stated objectives as detailed below.

Objective 1. Identify the components and suppliers of the Army supply chain with respect to water use and product content to determine the corresponding Army water bootprint.

Results achieved. A high-level, coarse estimate, probably substantially low, of the supply chain water bootprint, giving the Army an approach to estimating indirect water consumption that results in a reasonable number on the basis of actual measured physical relationships.

Objective 2. Identify the components and suppliers that support the Army Civil Works and MILCON programs with respect to water use and product content to determine the corresponding Army water bootprint.

Results achieved. A high-level, coarse estimate of supply chain water bootprint that is probably substantially low.

Objective 3. Consult with others who have created, maintained, and actively monitor a sustainable supply chain, including private industry.

Results achieved. Limited consultations with Walmart, the Water Footprint Network, and consultants who supported several well-regarded national and product water footprint studies, but no water footprint studies of even remotely comparable scale have been completed.

Objective 4. Determine how information on the Army's water bootprint can be incorporated into the Army's annual sustainability report in conformance with the GRI protocol.

Results achieved. Water bootprint quantification results at this level are too coarse to add value to the Army Sustainability Report (ASR). Including the results of this study in the next ASR is premature, but the next ASR should describe the bootprint effort, highlighting that the Army has begun to examine this issue and related policy implications. None of the GRI indicators cover indirect water footprints, instead asking for total direct water withdrawal by source, such as ground water or municipality, water sources affected by this withdrawal, and percentage of water recycled, Environment Indicators (ENs) EN8 to EN10. Taking the initiative to mitigate the water usage of its supply chain would partially address EN26, which asks for initiatives to mitigate environmental impacts of the organization's products and services—of which water is one criterion.

Objective 5. Develop recommendations for incorporating the Army's water bootprint into Army policy, green procurement, planning documents, and investment strategies.

Results achieved. We made conclusions and formed recommendations for Army policy and procedures (see below).

Objective 6. Enable the Army to render proactive supply-side policy decisions before water availability-related issues can adversely affect operational readiness and training.

Results achieved. We identified a number of areas where further analysis would help the Army better understand its water footprint and its implications for future plans and actions. We also determined the magnitude of the water required to sustain the Army supply chain, allowing us to make some relevant conclusions and provide pertinent recommendations (see below).

CONCLUSIONS

We conclude the following regarding Army water use:

- Aggregate Army direct and indirect water use—the Army water bootprint—is substantial and has the potential to exacerbate water supply problems in geographic areas where water supply sources may be at risk in the future.
- Some producers of critical Army supplies, services, or weapon systems and components are in geographic areas where water supply sources may be at risk in the future.
- Annual indirect water use by the Army's suppliers is at least 258 billion gallons, withdrawn and consumed, and could be much higher. Of that amount, approximately 65 percent is attributable to purchases through LMARS, LogiQuest, IMPAC purchases, and AAFES (less fuels and utility energy); 32 percent to Civil Works and MILCON activities of USACE; and 4 percent to purchased fuels and utility energy.
- Although most water withdrawn for direct and indirect Army use is returned to the surrounding watershed, it is unavailable while it is being used and, depending on how it was used and treated, it may be returned in a form that restricts its use by others. For example, potable water withdrawn from the source may no longer be potable when returned, instead being classified as grey water. Thus, Army and Army supplier water use could contribute to water scarcity. This in turn can lead to increased competition, tension, and water resource stress, especially in high risk areas that are already experiencing water shortages. In Chapter 1, we discuss the spatial relationships of water scarcity; in these areas, the choice to locate critical goods manufacturing facilities, move large operations, or choose water-intensive energy sources could exacerbate water scarcity conflict.
- Indirect water use can affect the availability of water for direct use by Army installations and activities when producers withdraw water from the same supply sources; by the same reasoning, direct water use can affect availability of water for indirect use.
- As highlighted in the discussion of Army policy (Chapter 1), existing Army policy does not specifically address water use or conservation issues related to the supply chain.
- The Army does not currently track water used to produce the goods and services it procures through the supply chain.

- Climate change effects are projected to create water sustainability problems in the future. The projected water shortages in the West and South will affect installations and Army suppliers (Chapter 1).

RECOMMENDATIONS

Operational

We recommend the Army do the following in regard to operations:

- Analyze the largest commodity and service suppliers and their principal water sources in more detail.
- Identify the most critical supply chain products and services that are also large water users. We found that matching Eco-LCA model market sectors with FSC product codes made a large difference in the final estimate of water use. In general, wholesale products are fairly low in water intensity and specialty or complex items are much larger water users. Critical, water-intense products, are the most important to identify.
- Work with DLA to identify products and services that require quick turnarounds and that may be delayed by water restrictions.
- If necessary, develop a comprehensive strategy that identifies suppliers of critical products and services that are at risk of production stoppage or curtailment when water supply shortages occur. Ensure that the strategy provides reliable alternative means to procure these critical products and services in a timely manner.

Policy

We recommend that the Army do the following in regard to policy:

- In conjunction with ongoing water and energy security strategic planning, identify the critical questions that must be answered to ensure current and long-term indirect water security.
- Educate Army senior leaders on the importance of identifying and addressing embedded water bootprint issues, including the affects that unexpected water shortages can have on key suppliers in the industrial base, how disruptions in the supply of key weapon system components and other commodities can affect operational readiness and training, and how climate change could exacerbate the situation. Appropriate venues for driving this agenda include the
    - Army Plan

- Army Campaign Plan
- Army Posture Statement
- Army input to the Quadrennial Defense Review.

- Revise Army water and energy security policies and procedures to incorporate producer water-use requirements and related risk.
- Identify installations dependent on water-intensive energy sources located in areas likely to experience increased water scarcity.
- Where appropriate, ensure that life-cycle cost estimates include an evaluation of water-use requirements, availability, and potential risks.
- Include in future ASRs a section that highlights the Army's progress in completing the supply chain bootprint. As improvement in water-use data detail allows, incorporate results in addressing applicable GRI performance indicators.
- Ensure that resources needed to execute the Army Campaign Plan Major Objective in water security are programmed in future POM cycles; assess the need to establish a separate management decision package (MDEP) for water security programs, or perhaps a combined water and energy security MDEP.

Procurement

We recommend that the Army evaluate the feasibility of the following:

- Revising supply chain-related contracting procedures to require Army suppliers to monitor and report annual water use per unit of production and to include in their proposals specific procedures they will use to reduce water use in their production processes.
- Requiring producers of critical supply items whose production facilities are located in high risk water shortage areas to develop and present to the Army detailed facility water security plans to instill confidence that the production of needed supplies will not be disrupted in the event of water shortages.
- Considering potential implications of climate change, not only in terms of the availability, cost, and demand for water, but also in potential technology changes that may dictate greater consumption of water by electric utilities for CO_2 capture technologies. Current CO_2 capture technologies involve a water-based process that requires more water for cooling the flue gas, CO_2 compression, and other processes. In addition, the parasitic power, or power needed to operate the process, is estimated at

30 percent.[1] Water consumption for coal electric technologies could increase 50 to 90 percent with CO_2 capture.[2]

[1] Barbara Carney, Thomas Feeley, and Andrea McNemar, *Department of Energy, National Energy Technology Laboratory, Power Plant-Water R&D Program*, 2008, http://www.netl.doe.gov/technologies/coalpower/ewr/water/pdfs/NETL%20Paper%20Unesco%20Conference.pdf, accessed December, 14, 2011.

[2] Kristen Gerdes and Christopher Nichols, *Water Requirements for Existing and Emerging Thermoelectric Plant Technologies*, Office of Systems, Analysis, and Planning, NETL, DOE, 2009.

Appendix A
Eco-LCA Method

MODEL LIMITS

The Eco-LCA model measures the ecological effects of product purchases via several metrics, including water use. It relates quantities of inputs to dollars spent in a particular sector to other sectors on the basis of proportional money relationships, in 1997 dollar values. This model uses economy-scale relationships as a rough approximation of more complex interactions.

For its water indicators, Eco-LCA uses USGS national estimates of total water withdrawal for the year 2000.[1] USGS organizes its estimates into eight water-use categories, though only four—public supply, irrigation, livestock, and thermoelectric power—are included in the Eco-LCA model. Eco-LCA assumes these estimates, which total 94 percent of US withdrawals, correlate with the farming sectors; power generation and supply sector; and the water, sewage and other systems sector (Table A-1).

Table A-1. USGS Estimates of US Total Water Withdrawals (2000) Included in Eco-LCA

USGS water-use categories	Water withdrawals total (Mgal/d)	Percentage of total withdrawals[a]	Eco-LCA NAICS sectors[b]
Public supply	43,300	11.0	Water, sewage and other systems
Domestic	3,589	1.0	Multiple sectors
Irrigation	136,900	34.0	Farming
Livestock	1,757	0.4	
Aquaculture	3,700	1.0	
Industrial	19,757	5.0	Multiple sectors
Mining	3,494	1.0	
Thermoelectric power	194,909	48.0	Power generation and supply
Total	407,406	101.4	

[a] Note: Totals exceed 100 percent due to rounding
[b] Note: NAICS = North American Industry Classification System.

[1] USGS. Estimated use of water in the United States in 2000. http://pubs.usgs.gov/circ/2004/circ1268/htdocs/text-ps.html.

Eco-LCA then relates these sectors to the other sectors and industries on the basis of proportionate relationships of water withdrawal per monetary unit of economic activity. For example, the model divides the total water withdrawals estimated by the USGS for irrigation, livestock, and aquaculture by the economic size (measured in dollars) of the farming sectors. The result is a water-withdrawal-per-dollar indicator.

The Eco-LCA model probably is as good an approach to assessing an aggregate water footprint as is available at the moment. However, its rough nature should be recognized. The consequences of using this model are as follows:

- The Eco-LCA estimates rely on many model coefficients, representing water use by particular product classes. The methods used to estimate these coefficients are unclear, as are the data with which they were constructed.
- The relationships represented by these coefficients are subject to change over time, whereas the model is based on several year-old numbers that are periodically updated. The model was constructed in 1997 and processes have changed in the intervening years. Currently, there is no way to correct for changes whereby less water is needed to produce an item or regulatory changes that may require more water to produce an item manufactured in 1997.
- The model is highly aggregated and each sector covers many industries and companies whose production relationships may greatly differ. This results in water use coefficients based on unweighted averages that are subject to change as individual industries wax and wane.
- The model does not account for water use involved in product disposal.
- The model's coefficients do not distinguish imported from domestically produced goods. The production of an imported good or an imported input to production of a domestic good, might use more or less water than a domestically produced similar item, but this is not captured in a US-based input-output model.
- The Army's purchases may relate to only a subset of the industries and companies represented within each sector.

Over time, the Army should expect water footprint estimation methods to become more precise, with more detailed data used to construct more accurate estimates of water use per unit of product produced. As that occurs, adjusting earlier estimates may be necessary to discover trends in water use or to be able to make comparisons through time.

Comparison of Eco-LCA to Direct Water-Use Factors for Fuels Derived from Crude Oil

We used petroleum-use data from the Army's GHG inventory report to compare water footprint estimates from the Eco-LCA model and, product and process-related water factors for crude oil. The comparison relied on GHG inventory report data for both purchase prices and fuel quantities.

To run the Eco-LCA model for petroleum-derived fuels, the Army first selected the Census Bureau NAICS industry sectors that match up with crude oil exploration and production activities. The supply chain of crude oil—from exploration to delivery of gasoline, diesel, and jet fuel or aviation gas—includes six NAICS industry sectors, only five of which relate to the Army's data or the available literature-based water consumption coefficients. The activities we focus on include

- exploration,
- drilling oil and gas wells,
- support activities for oil and gas operations,
- crude petroleum and natural gas extraction, and
- petroleum refineries.

Using 1997-adjusted dollar purchases for primary fuels, we used Eco-LCA estimates for gallons of water withdrawn per dollar spent on crude oil. Because Eco-LCA is based on water withdrawal rather than consumption, it seemed likely that the model would return a higher estimate of water use than the direct crude oil factor method. As hypothesized, for bulk fuel purchases, the Eco-LCA approach results in a water footprint eight times larger than a footprint that uses literature-based water consumption factors. The Eco-LCA output estimates a total of 8 billion gallons of water withdrawal averaged for FY08 and FY10, compared with 1 billion gallons of water consumed using the water consumption factors for the same amount of fuel.

Appendix B
Requisition/Acquisition Databases Additional Information

OVERVIEW

LMARS

The LMARS data represent completed requisitions; requisitions that have a positive quantity and price). For FY03–10, LMARS data display items purchased through the Army, Air Force, Coast Guard, DLA, GSA, Marine Corps, and Navy.

LogiQuest

Unfortunately, aside from TACOM, the data set does not include the two other Army commands, nine Army Service Component Commands, or the 11 Direct Reporting Units (Table B-1). This is a very significant shortfall and the resulting Army water bootprint estimate is underestimated. We did not have a basis to assume from TACOM's records what other Army organizations are buying.

Table B-1. Army Alignment of Command

Army Commands	Army Service Component Commands	Army Direct Reporting Units
• FORSCOM • TRADOC • AMC	• Army Europe • Army Central • Army North • Army South • Army Pacific • Army Special Operations Command • Surface Deployment and Distribution Command • Strategic Missile Defense Command • Eighth Army	• NETCOM • MEDCOM • INSCOM • CIDC • USACE • MDW • ATEC • USMA • USARC • IMCOM • Acquisition Support Center

Note: See Appendix C, "Abbreviations" for definitions.

CALCULATING WATER BOOTPRINT OF LMARS AND LOGIQUEST ADDITIONAL INFORMATION

General

For LMARS and LogiQuest, we took the following steps to calculate the number of gallons for each record and individual fiscal year. First, all FSCs (or FSC-NIIN combinations, when necessary), were assigned to Eco-LCA model market sectors. Additional information concerning this process is found in the following sections regarding LMARS and LogiQuest.

Next, each fiscal year dollar value was converted into 1997 dollar equivalent values using a conversion factor based on the CPI. The All Items CPI was used for each year from FY03 to FY10. For the purposes of converting to 1997 dollar equivalent amounts, we assumed fiscal year is equal to calendar year (Table B-2).

Table B-2. CPI for All Items and Conversion Factors Used

CPI year	CPI (all items)	Conversion factors
2003	184.0	0.872282609
2004	188.9	0.849655903
2005	195.3	0.821812596
2006	201.6	0.796130952
2007	207.3	0.774240232
2008	215.3	0.745471435
2009	214.5	0.748251748
2010	218.1	0.735900963

The CPI conversion factor was determined by dividing the 1997 CPI (All Items = 160.5) by each individual year's CPI for All Items. For instance, 2003 Conversion Rate = 160.5/184.0 = 0.872282609. The appropriate conversion factor was then multiplied times each requirement value in LMARS and LogiQuest to obtain 1997 dollar equivalent values.

Next, Eco-LCA water factors were converted first from liters per million dollars to gallons per million dollars (0.264172052 gallons = 1 Liter), and then to gallons per dollar. The 1997 dollar equivalent value for each record was then multiplied times the Eco-LCA model market sector water factor (in gallons per dollar) assigned to that record to obtain the number of gallons for the individual record. Gallon totals for all records within an individual fiscal year were summed to obtain the total gallon amount for that fiscal year. This was done for all years for FY03 through FY10.

LMARS

We assigned Eco-LCA model market sectors to LMARS records in two ways:

1. By FSC and FSC description.
2. By FSC and FSC description combined with NIIN data (FSC-NIIN combination).

There are 698 FSCs in the current FSC list. FSCs allow greater detail than FSGs (current list has 80 FSGs). Almost 88 percent of the 2.1 million records were specific enough to assign to Eco-LCA model market sector data based on the FSC description only. In some other cases, the NIIN information allowed was assigned a more specific model market sector. In instances where the FSC/FSC description or the FSC/FSC descriptions coupled with NIIN data did not provide sufficient detail to identify a model market sector, we used sector 420000 (Wholesale Trade) as a default model market sector.

We quality checked this matching process by reviewing instances where different NIINs under the same FSC and with the same Item Nomenclature were assigned to different model market sectors. For example, under FSC 4710, we identified multiple NIINs with Item Nomenclature of "PIPE, PLASTIC," some of which were assigned to model market sector 326120 (Plastic pipe, fittings, and profile shapes), whereas others were assigned to model market sector 332996 (Fabricated pipe and pipe fitting manufacturing). Because this involves plastic piping, we determined model market sector 326120 to be the most appropriate and assigned it to all NIINs under FSC 4710 with Item Nomenclature of "PIPE, PLASTIC" for consistency.

LogiQuest

Almost 96 percent of the LogiQuest query from FY03 to FY10 could be assigned to Eco-LCA model market sectors using the LMARS matching method. The other four percent of the records could not be matched. Of these, 733 records were assigned to the default model market sector 420000 because of blank FSCs, blank Item Names, and inapplicable NIINs. Of the remaining records, 109 could be matched to an Eco-LCA model market sector by cross-walking them with other LMARS or LogiQuest records with the same FSC and the same or similar Item Name.

Method Comparisons and Sensitivity Analysis

Recognizing the many assumptions in this estimate, we analyzed alternative methods.

The first alternative method was to assign all line items to the default Eco-LCA model market sector 420000, Wholesale Trade (Table B-3). For LMARs, this resulted in an approximately 50 percent decrease in total gallons of water for FY10 and, on average, a decrease of approximately 53 percent for FY03 to FY09. For LogiQuest, using the default sector reduced total estimated gallons of water by 47 percent in FY10 and, on average, almost 47 percent for FY03 to FY09. We consider that this large a discrepancy likely reveals the water-intense nature of the Army's actual purchasing patterns.

Table B-3. LMARS and LogiQuest Alternative 1 Water Bootprint Summary

Fiscal year	LMARS Alternative 1 (billion gallons)	LogiQuest Alternative 1 (billion gallons)
2003	35.7	27.2
2004	39.1	14.0
2005	42.0	21.9
2006	42.2	16.7
2007	42.1	14.3
2008	40.1	14.9
2009	36.9	26.1
2010	58.2	4.4
Total	336.3	139.5

The second alternative approach was to assign all records with FSCs requiring NIIN level data in both LMARS and LogiQuest to Eco-LCA model market sector 420000, Wholesale Trade (Table B-4). The remaining records, with FSCs that were assigned to an Eco-LCA model market sector on the basis of the FSC descriptor, were assigned the same model market sector as was used in the original method.

Table B-4. LMARS and LogiQuest Alternative 2 Water Bootprint Summary

Fiscal year	LMARS Alternative 2 (billion gallons)	LogiQuest Alternative 2 (billion gallons)
2003	75.3	51.7
2004	84.7	26.8
2005	89.7	47.8
2006	87.3	26.5
2007	88.0	25.0
2008	84.0	29.3
2009	80.1	48.6
2010	116.1	8.4
Total	705.2	264.1

For LMARS, this resulted in a 1 percent decrease in the FY10 water-use estimate and, on average, a 1 percent decrease for each year from FY03 to FY09. For LogiQuest, this resulted in a 0.2 percent decrease in the FY10 water estimate and, on average, a 0.3 percent decrease from FY03 to FY09. Assigning FSCs made a large difference in the water bootprint estimate, but additional detail at the NIIN level did not significantly change the result.

In conclusion, using more granularity in the NSN to Eco-LCA model market sector matching resulted in a much larger water bootprint for the Army's supply chain than would have only the use of the default sector. There is little evidence to support using Alternative 1, as it is unlikely that the default sector is representative of the Army's actual purchasing patterns in comparison to average US consumer wholesale interactions. Alternative 2 was not significantly different than the chosen method.

Appendix C
Abbreviations

AAFES	Army and Air Force Exchange Service
AMC	US Army Materiel Command
ANL	Argonne National Laboratory
AR	Army Regulation
ASCP	Army Sustainability Campaign Plan
ASR	Army Sustainability Report
ATEC	US Army Test and Evaluation Command
B20	blend of 20 percent biodiesel and 80 percent diesel
BRAC	base realignment and closure
CERL	Construction Engineering Research Laboratory
CIDC	US Army Criminal Investigation Command
CO_2	carbon dioxide
CONUS	continental United States
CPI	consumer price index
CTR	cooperative threat reduction
CY	calendar year
DLA	Defense Logistics Agency
DoD	Department of Defense
DOE	US Department of Energy
E85	blend of 85 percent ethanol and 15 percent gasoline
Eco-LCA	Ecologically Based Life Cycle Assessment Model
eGRID	Emissions and Generation Resource Integrated Database

EIA	US Energy Information Administration
EN	Environmental Indicator
EO	Executive Order
ERDC	Engineer Research and Development Center
FMS	Foreign Military Sales
FOIA	Freedom of Information Act
FORSCOM	US Army Forces Command
FSC	Federal Supply Code
FSG	Federal Supply Group
FUSRAP	Formerly Utilized Sites Remedial Action Program
FY	fiscal year
GDP	gross domestic product
GHG	greenhouse gas
GPC	Government Purchase Card
GRI	Global Reporting Initiative
GSA	General Services Administration
IIS	Interagency and International Services
IMPAC	International Merchant Purchase Authorization Card
IMCOM	Installation Management Command
INSCOM	US Army Intelligence and Security Command
LCA	Life Cycle Assessment
LMARS	Logistics Metrics Analysis Reporting System
LPG	liquefied petroleum gas
MDEP	Management Decision Package
MDW	Military District of Washington

MEDCOM	US Army Medical Command
MILCON	military construction
MRO	maintenance, repair and operation
MWh	megawatt hour
NAICS	North American Industry Classification System
NASA	National Aeronautics and Space Administration
NETCOM	US Army Network Enterprise Technology Command/9th Signal Command
NETL	National Energy Technology Laboratory
NIIN	National Item Identification Number
NSN	National Stock Number
OASA(CW)	Assistant Secretary of the Army (Civil Works)
PET	polyethylene terephthalate
POL	petroleum, oils, and lubricants
POM	program objective memorandum
RV	recreational vehicle
TACOM	Tank-Automotive and Armaments Command
TRADOC	US Army Training and Doctrine Command
USACE	US Army Corps of Engineers
USARC	US Army Reserve Command
USGS	US Geological Survey
USMA	US Military Academy
WFN	Water Footprint Network
WMD	weapons of mass destruction
WTE	waste-to-energy

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