

Water Management and Stewardship in Midstream, Downstream, and Delivery Operations in the Oil and Gas Industry

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Executive Summary

The oil and gas industry has significant connections to the water environment. Water is beneficially used, consumed, generated, reused, recycled, and disposed of over the life cycle of an oil and gas resource. The degree and impact of these connections vary with the nature and location of the resource and the methods of extracting and converting that resource into valuable end products.

This report uses the oil and gas (petroleum) life cycle represented in Figure ES.1 as an organizing framework for explanation and discussion. As depicted in Figure ES.1, the scope of this study is focused on the midstream, downstream, and delivery components of the oil and gas life cycle. Upstream components of the life cycle will be addressed in a future report.

This study describes water use, management, and stewardship practices, the existing regulatory framework, quantitative water footprint information, and comparison of water use to other industry and societal uses.

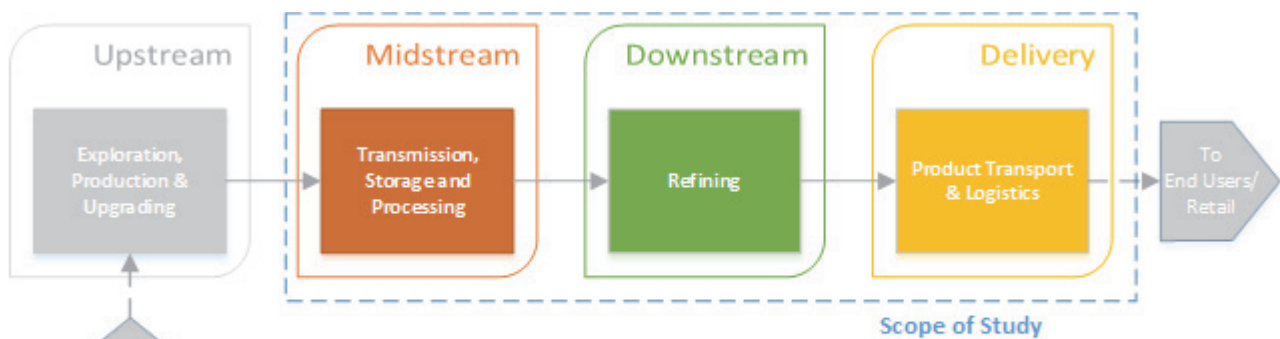


Figure ES.1—Petroleum Life Cycle and Scope of Study

Water Use

Water is used throughout the midstream, downstream, and delivery phases of the oil and gas life cycle. The most significant of these uses, however, is for oil refining. The raw material of the petroleum refining industry is petroleum material such as crude oil. Petroleum refineries process this raw material into a wide variety of petroleum products, including gasoline, fuel oil, jet fuel, heating oils and gases, and petrochemicals. Petroleum refining includes a wide range of physical separation and chemical reaction processes.

Water use in gas processing, oil and gas transmission (midstream) and oil and gas delivery phases is negligible compared to the amount of water required for oil refining. Therefore, this section focuses on water use in oil refining.

In petroleum refineries, water is vital for many applications including crude desalting, scrubbing, cooling, steam production, utility water, fire protection, and more. Refineries depend on uninterrupted and sustainable water supplies to maintain production and safety.

Refineries also generate wastewaters which are typically reused or discharged to the environment (mainly fresh and marine water bodies) after the appropriate level of treatment to meet regulated discharge limits. These limits vary from one location to another. In ecologically sensitive areas, a higher degree of effluent treatment may be required to allow discharge into the environment.

Figure ES.2 illustrates the water use and management in a typical refinery. Water inputs to a refinery come from a variety of sources including fresh, saline, and brackish surface water, groundwater, public water supplies, rainwater, and water contained within the crude oil. Much of the water used within a refinery can be reused, sometimes with and sometimes without treatment. Water outputs from the refinery process include losses to atmosphere, clean stormwater, utility blowdown, discharge of treated first flush stormwater and wastewaters, and water treatment residuals.

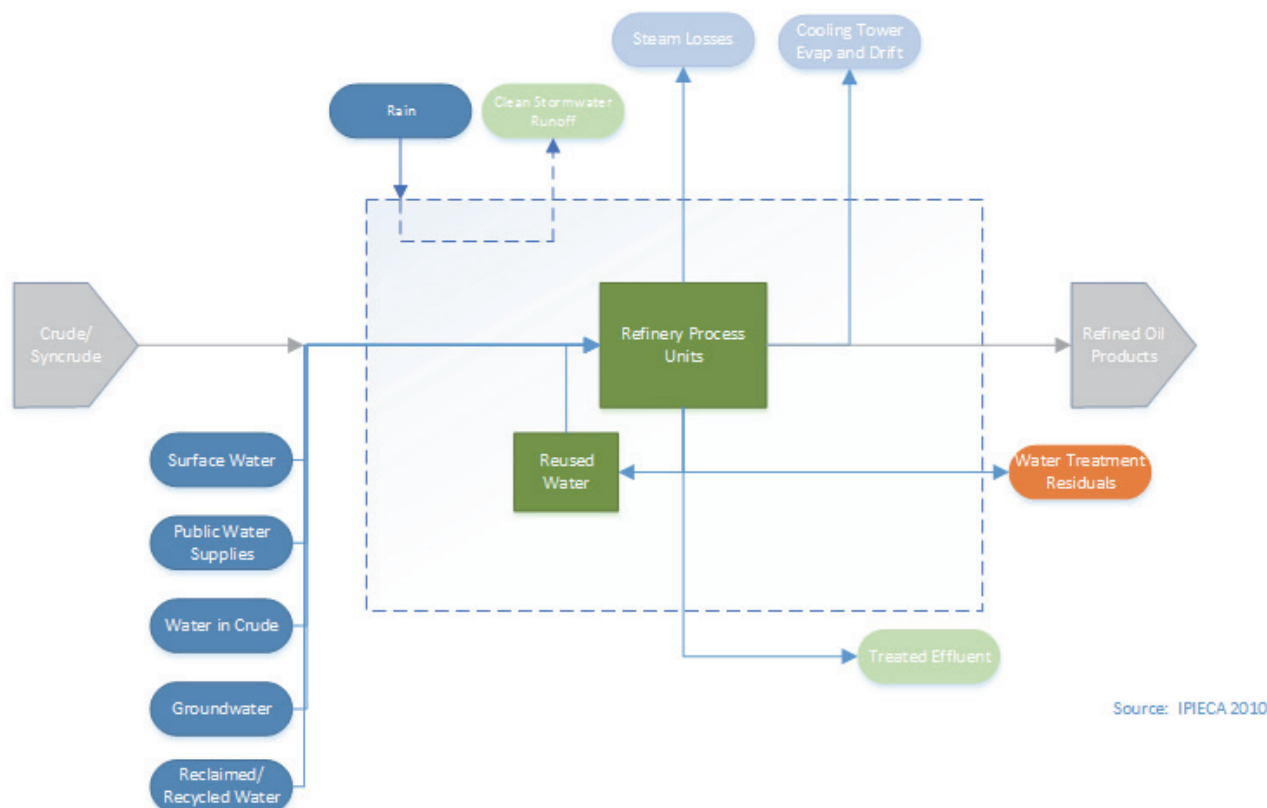


Figure ES.2—Water Use and Management Simplified Schematic in a Typical Refinery (with Closed Circuit Cooling) Water System

Losses to atmosphere are considered “consumptive” losses in that they represent a net loss of water within the refinery. However, losses to atmosphere allow for the reincorporation of that water into the hydrologic cycle where it will ultimately be available for reuse.

Water is used throughout the refinery for many different purposes and each purpose has its own set of water quality requirements. For some uses (such as cooling water, fire water, and utility water), lower quality brackish and saline sources, and reused refinery or municipal treatment plant effluent can be used, thereby reducing the overall fresh water demand for the facility. Other uses require a higher water quality. Table ES.1 provides a summary of the types of water uses within a refinery, the typical water sources for those uses, and specific water quality needs.

Regulatory Framework

Many different federal, state, and local regulations pertain to water use in oil refining, although the regulation with the most direct and significant impact on water management is the Clean Water Act (CWA), including the CWA's National Pollutant Discharge Elimination System (NPDES) program. In many states, the U.S. Environmental Protection Agency (USEPA) has delegated authority for implementation of the NPDES program. The NPDES permitting program encompasses all discharges from a facility, including both wastewater and stormwater. One key regulation

pertaining to water management in oil refining is USEPA's Effluent Limitation Guidelines (ELGs) for the petroleum refining industry. In addition, the regulatory framework for water discharges from refineries includes water quality-based effluent limits (WQBELs) that allow flexibility for local regulators to set customized permit limits based on the characteristics and uses of the receiving stream. The more stringent requirement of technology-based effluent limits and WQBELs will be used in determining the permit limits for oil refineries.

Industry-led Water Stewardship Activities

Through industry-leading organizations and stakeholder partnerships, the oil and gas industry has been taking action to improve water stewardship and sustainability practices, including in the area of oil refining which is most relevant to this report. Key organizations leading these efforts include the American Petroleum Institute (API), the International Petroleum Industry Environmental Conservation Association (IPIECA), the Petroleum Environmental Research Forum (PERF), and the World Business Council for Sustainable Development (WBCSD). Examples of activities conducted through these organizations include development of guidance on sustainability reporting and water management for oil and gas activities, and documentation of best practices and strategies for water use minimization in refineries.

Water Footprint

As noted above, the water footprint for oil refining dominates all other water uses for oil and gas within the midstream, downstream and delivery phases of the life cycle. Water consumed in the refining process is the water lost to atmosphere through evaporation from steam heating and evaporative cooling processes. Through evaporation, this water is returned to the hydrologic cycle. The remainder of the water used is treated and reused or discharged to surface water, thereby also returning to the hydrologic cycle. The estimated consumptive water use for oil refining is between 5 and 9 gallons per million British thermal units of energy generated by combustion of the refined oil product (gal/MMBtus). Consumptive water use for all other activities in midstream, downstream (such as gas processing), and delivery phases of the oil and gas life cycle is 1 gal/MMBtu or less.

Comparison of Oil and Gas Industry Water Use

Conventional petroleum-based fuels historically have had a relatively minor impact on the overall water resources of the United States. According to King and Webber (King and Webber 2008), conventional petroleum gasoline consumes between 7 and 14 gallons of water per 100 miles driven, and conventional petroleum diesel consumes between 5 and 11 gallons of water per 100 miles. King and Webber (King and Webber 2008) stated that, "In general, fuels more directly derived from fossil fuels are less water intensive than those derived either indirectly from fossil fuels, or directly from biomass."

The latest nationwide water use estimation by the U.S. Geological Survey (USGS, 2009) presented 2005 water withdrawals in the United States for eight categories of use: public supply, domestic, irrigation, livestock, aquaculture, industrial, mining, and thermoelectric power generation. Thermoelectric power was the largest category of water use, followed by irrigation and public supply. The remaining categories of self-supplied industrial, mining, self-supplied domestic, aquaculture, and livestock water uses together accounted for less than 10 % of total water withdrawals. Notable withdrawal statistics include the following:

- Thermoelectric-power withdrawals account for 49 % of total water use, 41 % of total freshwater withdrawals, and 53 % of fresh surface water withdrawals for all categories.
- Irrigation withdrawals represented 37 % of total freshwater withdrawals and 62 % of total freshwater withdrawals for all categories excluding thermoelectric power.
- Public supply represented about 13 % of total freshwater withdrawals, and 21 % of all withdrawals, excluding thermoelectric power.

Industrial withdrawals represented about 4 % of total withdrawals and about 9 % of total withdrawals for all categories excluding thermoelectric power. Petroleum refining was included in the industrial category. Compared with other water use sectors, the oil and gas industry uses less water than the thermo-electric power industry, agricultural irrigation, biofuels for energy production, and public water supply.

The industry's beneficial use, management and stewardship of its water resources results in significant societal benefits. The oil and gas industry provides good jobs for many Americans and contributes significantly to the Gross Domestic Product (GDP) of the United States. Each direct job in the oil and natural gas industry supported approximately 2.8 jobs elsewhere in the U.S. economy in 2011. Counting direct, indirect, and induced impacts, the industry's total impact on labor income was \$598 billion, or 6.3 % of national total in 2011. The industry's total impact on the U.S. GDP was \$1.2 trillion, accounting for 8.0 % of the national total in 2011 (PricewaterhouseCoopers, 2013).

Key Take-aways

- Water is an increasingly important global environmental and social issue. Stewardship of this key resource in the transport, refining, and delivery of refined fuels to consumers, like all commercial and industrial enterprises, is gaining new focus. Water is essential for the safe operation of fuels production and transport; it plays a key role in protecting employees and assets.
- The oil and gas industry is using its practical and technological expertise to explore ways to decrease demands on scarce freshwater supplies and encourage procedures to conserve, recycle and reuse water. In some cases, the industry has found ways to use reclaimed wastewater or low quality water in the industrial process - utilizing less fresh water ((WBMWD) n.d.).
- Water withdrawal and discharge in oil refining operations is regulated by numerous federal, state, and local regulations, the most prominent of which are the CWA and associated permitting program and the national discharge standards for all oil refineries. In addition, regulators have the ability to establish water quality based effluent limits in permits that can be customized to specific conditions to protect the local receiving stream.
- Stormwater management and stormwater runoff water quality from oil and gas operations are also highly regulated as is the proactive prevention and protection from spills that could impact surface water and groundwater quality. The industry is also reducing its impact by monitoring and reporting discharges. Through continually improving the storage, handling and transportation of all products our operations are further reducing the possibility of marine or groundwater contamination (IPIECA 2010).
- In midstream, downstream, and delivery phases of the oil and gas life cycle, water use in oil refining dominates all other activities with respect to quantity of water used. Oil refining requires the consumptive use of water in the range of 5 to 9 gal/MMBtu. This consumed water is the water that is lost to atmosphere through evaporation and will ultimately rejoin the hydrologic cycle for future use. The remainder of the water used in oil refining is treated and discharged consistent with regulatory and water quality obligations.
- The latest nationwide water use estimation by USGS (Maupin 2014) estimated water withdrawals in the United States for 2010 for eight categories of use: public supply, domestic, irrigation, livestock, aquaculture, industrial, mining, and thermoelectric-power generation. Thermoelectric power was the largest category of water use, followed by irrigation and public supply. The remaining categories of self-supplied industrial, mining, self-supplied domestic, aquaculture, and livestock water uses together accounted for less than 10 % of total water withdrawals. Industrial withdrawals represented about 4 % of total withdrawals. Petroleum refining was included in the industrial category. Compared to other water use sectors, the oil and gas industry uses less water than the thermo-electric power industry, agricultural irrigation, biofuels for energy production, and public water supply.
- The oil and gas industry has actively participated in establishing global standards for measuring and reporting water stewardship performance for all industries and routinely and voluntarily reports individual company

performance through such avenues as annual stockholder and corporate responsibility reports and industry organization data collection and reporting efforts (such as IPIECA water use reports).

- With further sharing and implementation of best practices and increased use of alternative water sources for refinery water demands (such as reusing treated municipal wastewater for cooling and other operational purposes), the industry trend of declining water requirements for refining is expected to continue. The industry continues to make significant capital investments in equipment and each day operates significant assets to treat wastewater, maintain water quality, and protect the environment.
- Several key industry organizations, including API, IPIECA, PERF, and WBCSD have been and continue to be instrumental in providing leadership and sharing best practices across the industry to improve water use and sustainability.

Water Management and Stewardship in Midstream, Downstream, and Delivery Operations in the Oil and Gas Industry

1 Scope and Objectives

The oil and gas industry has significant connections to the water environment. Water is beneficially used, consumed, generated, reused, recycled, and disposed of over the life cycle of an oil and gas resource. The degree and impact of these connections vary with the nature and location of the resource and the methods of extracting and converting that resource into valuable end products.

This report uses the oil and gas (petroleum) life cycle represented in Figure 1 as an organizing framework for explanation and discussion. As depicted in Figure 1, the scope of this study is focused on the midstream, downstream, and delivery components of the oil and gas life cycle. Upstream components of the life cycle will be addressed in a future report.

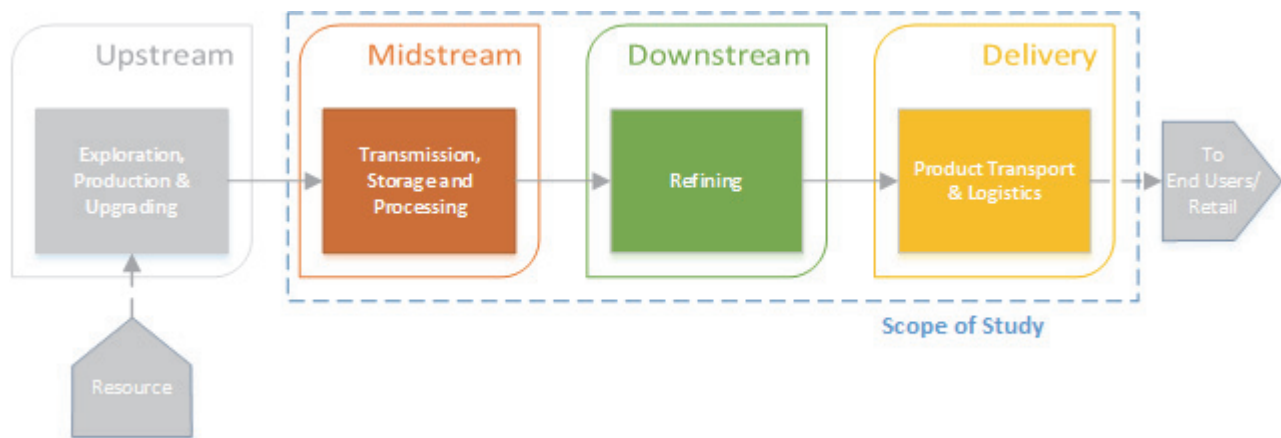


Figure 1—Petroleum Life Cycle and Scope of Study

This study is intended to inform stakeholders about how the oil and gas industry uses water in the petroleum life cycle (midstream, downstream, and delivery phases) and the different industry-led and regulatory practices employed to conserve and protect water resources. Specifically, within its scope, the study:

- describes water use in each life cycle stage;
- describes water management and stewardship practices employed by the industry, including when these practices may and may not be feasible;
- describes the existing regulatory framework governing the oil and gas industry and its use, management, and protection of water resources and the environment;
- provides a quantitative summary of the water footprint for typical operations;
- illustrates oil and gas industry water use in context with other industry and societal uses.

This study provides stakeholders with a more thorough understanding of oil and gas industry water management and stewardship in midstream, downstream, and delivery operations. The study does not endeavor to address other media such as air emissions or residual streams.

2 Abbreviations and Acronyms

API	American Petroleum Institute
bgd	billion gallons per day
CAA	Clean Air Act
CDP	Formerly known as the Carbon Disclosure Project; in 2013, CDP rebranded its name to the abbreviation only
COGCC	Colorado Oil and Gas Conservation Commission
CWA	Clean Water Act
CZMA	Coastal Zone Management Act
DOT	U.S. Department of Transportation
EA	environmental assessment
EIS	environmental impact statement
ELG	Effluent Limitation Guideline
ESA	Endangered Species Act
gal/MMBtu	gallons per million British thermal units
GAO	U.S. Government Accountability Office
GCD	groundwater conservation district
GDP	Gross Domestic Product
GEMI	Global Environmental Management Initiative
GTL	gas-to-liquids
GWPC	Ground Water Protection Council
H ₂ S	hydrogen sulfide
HCA	high-consequence area
IAOGP	International Association of Oil and Gas Professionals
IPIECA	International Petroleum Industry Environmental Conservation Association
MACT	maximum achievable control technology
NEPA	National Environmental Policy Act of 1969
NETL	National Energy Technology Laboratory
NGL	natural gas liquids
NPDES	National Pollutant Discharge Elimination System
OPA	Oil Pollution Act
PERF	Petroleum Environmental Research Forum
POTW	publicly owned treatment works
SDWA	Safe Drinking Water Act
SPCC	spill prevention, control, and countermeasures
SPE	Society of Petroleum Engineers
TDS	total dissolved solids
TMDL	total maximum daily load
TSS	total suspended solids
TWDB	Texas Water Development Board

UIC	Underground Injection Control
USDOE	U.S. Department of Energy
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WBCSD	World Business Council for Sustainable Development
WQBEL	water quality-based effluent limit

3 Water Use

3.1 General

This section expands on the simplified representation in Figure 1 to describe how water management varies through midstream, downstream, and delivery phases, and depending on the type of resource. A composite diagram comparing activities for each resource is included in Appendix A.

Water stewardship is an ethic embodying responsible planning and management of water resources. Industry water stewardship practices related to specific water use, and when these practices may or may not be feasible, are described in this section. For the purpose of this report, the following definitions are used.

- **Use.** Refers to water that is withdrawn for a specific purpose (in this case, midstream, downstream, and delivery operations within the oil and gas industry). Water use includes both self-supplied withdrawals and deliveries from public supply. More broadly, water use pertains to the interaction of humans with and influence on the hydrologic cycle (Kenny et al. 2009).
- **Consumptive Use.** Consumptive use precludes the subsequent withdrawal for another use, at least temporarily, because it represents that fraction of water that is removed from availability due to evaporation, transpiration, or incorporation into products or crop, or consumed by livestock or humans (Maupin 2014).
- **Generate.** A small amount of water is contained within the extracted oil and gas and is separated from the oil and gas during midstream and downstream processing. This is the water that is referred to as being “generated” during oil and gas processing.
- **Reuse or Recycle.** Water from an industrial or commercial process that is not disposed of, but beneficially used again in the same or another process (IPIECA, API, and OGP 2010). For the purposes of this report, the terms reuse and recycle are synonymous and will be used interchangeably.
- **Disposal.** Final discharge or placement, on site or off site, of wastewater under proper process and authority with no intention to retrieve (IPIECA, API, and OGP 2010).
- **Management.** Sustainable water management can be defined as water resource management that meets the needs of present and future generations (USEPA 2012).

3.2 Midstream

Midstream activities vary between oil, whether from regular crude or synthetic crude, and gas. Midstream generally comprises the following operations:

- terminals;
- transmission (can include pipeline construction and expansion; hydrostatic testing of new and existing lines for both oil and gas; and transportation via truck, rail, and tanker);
- processing.

Asset ownership and custody transfer of the resource often govern what specific midstream activities are involved. Subcategories of midstream oil and gas activities are depicted in Figure 2.

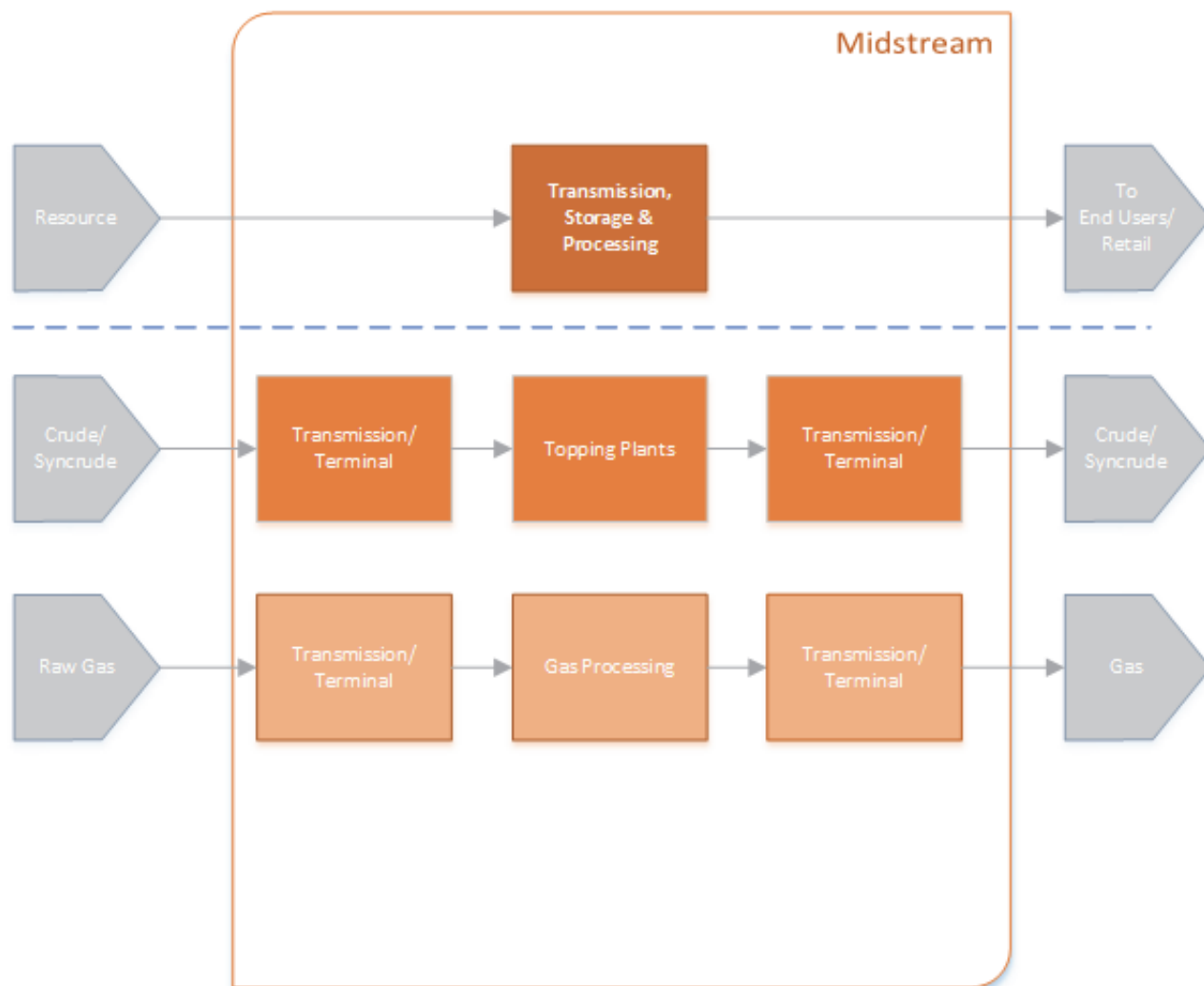


Figure 2—Midstream Activities by Petroleum Resource Type

3.2.1 Oil

Conventional, unconventional, and heavy oil/oil sands are all handled similarly in midstream, downstream, and delivery phases of the life cycle. Midstream oil activities primarily consist of transmission pipelines. The pipelines are used to convey crude oil from the source to oil refineries for processing. Some water is used in the construction of pipelines, although a relatively small amount. Once pipelines are constructed, hydrostatic testing is conducted to check for leaks in the system. To conduct this testing, pipelines must be completely filled with water. When hydrostatic testing is complete, the water is stored and tested to assess water quality. The test water is typically of sufficient quality for discharge to sewer or for direct land application. Test water of lower quality is managed through treatment or disposal.

Midstream oil activities can also include midstream oil terminals designed to reduce the water content of the crude prior to transmission to the refinery. These terminals are sometimes located at a midstream location and sometimes located within the refinery limits as part of downstream activities. In midstream terminals, oil is pumped into tanks where the oil and water phases can separate into distinct layers. The water is then bled off the tanks and the crude is transferred to conveyance pipelines for transmission to the refinery. This process is a net producer of oily water, which can be treated and reused or returned to the hydrologic cycle.

Figure 3 depicts the typical water balance within a midstream oil terminal.

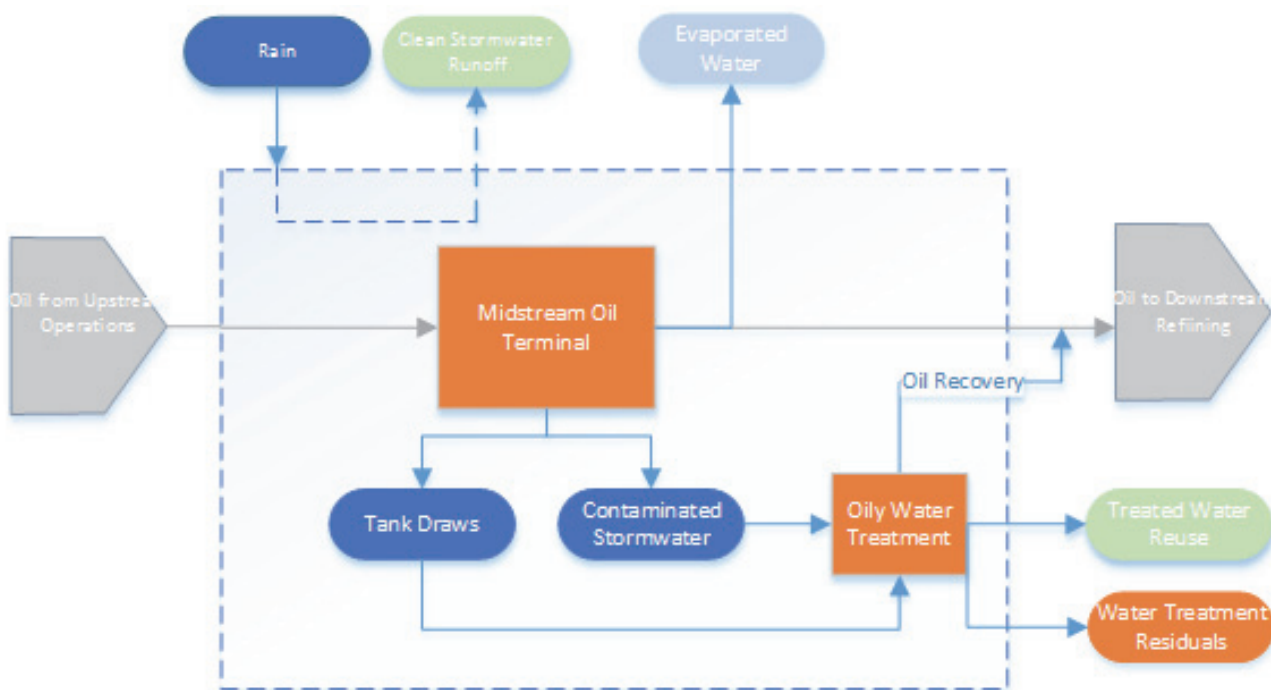


Figure 3—Typical Water Use and Management in Midstream Oil Terminal Operations

Topping plants, sometimes referred to as topping refineries, are also considered a midstream activity. Topping plants are simple refineries that include atmospheric distillation towers, but do not include more complex refining processes such as reforming, catalytic cracking, and coking. They are generally small in size. Topping plants separate the crude oil into its major constituents, which include liquefied petroleum gases, gasoline blending stocks, and distillate fuels (jet and diesel fuels and heating oils). These products from the topping plants can then be conveyed to and further refined in more complex refineries. Water is used in topping plants as cooling water and in water-cooled heat exchangers.

Industry water management and stewardship activities applied to midstream oil terminals include the treatment and reuse of oily water and recovery of oil from oily water streams.

3.2.2 Natural Gas

By the midstream point in the natural gas life cycle, gas from conventional, unconventional, offshore, and onshore sources are handled similarly. The processing of natural gas for sale to end users is an activity that, depending on location and proximity of gas processing facilities to the well field, is sometimes classified as an upstream activity and sometimes classified as a midstream activity. A minimal level of processing to remove water and corrosive agents (hydrogen sulfide and carbon dioxide) is always part of the upstream process, but it is the removal of additional impurities and separation of the natural gas liquids (NGLs) that can be either an upstream or midstream process. Regardless of the point within the gas life cycle gas processing occurs, the process is the same, as is the water balance around the process.

Gas processing includes removal of additional impurities such as trace metals and metalloids, and separation of NGLs, which include propane, butane, ethane, among others, for recovery and sale. Little water is used in gas processing and the process is a net water producer, meaning that more water comes out of the process than is put in due to the inherent water content of the gas. Typical water use in natural gas processing is illustrated in Figure 4.

Industry water management and stewardship activities applied to gas processing include the reuse of condensed water within gas processing facilities.

Aside from processing, the other key element of midstream natural gas activities is transmission. The transmission of gas from one region to another is accomplished through a complex system of low pressure, small diameter gathering pipelines that convey produced gas to the gas plant (gathering lines), the interstate pipeline system, and the distribution system. The interstate pipelines are high pressure lines, typically operating at pressures of between 200 and 1,500 pounds per square inch (psi). This high pressure reduces the volume of the natural gas being transported and also propels natural gas through the pipeline (naturalgas.org n.d.). Compressor stations are located periodically along the interstate pipelines to ensure that the gas remains at the desired pressure. At the compressor station, the gas is compressed either by a turbine, motor, or engine. The compressor stations also include systems to capture any liquids or other unwanted particles from the natural gas in the pipeline.

Very little water is used in midstream natural gas activities and gas processing is a net water generator.

3.3 Downstream

Downstream activities vary between oil, whether from regular crude or synthetic crude, and gas. Downstream generally comprises following activities.

- Oil Refining
- Gas Refining
- Ethane Separation and Ethane Cracking
- Gas-to-liquids (GTL)
- Liquefied Natural Gas (LNG)

Subcategories of downstream oil and gas activities are depicted in Figure 5. Downstream activities for all oil resources (onshore, offshore, unconventional, oil sands, heavy oil) consist of oil refining processes. Oil refining processes will vary based on the specific type of oil to be refined, products to be produced, anticipated throughput, and other factors; however, the general uses of water throughout the process are the same. The raw material of the petroleum refining industry is petroleum material such as crude oil. Petroleum refineries process this raw material into

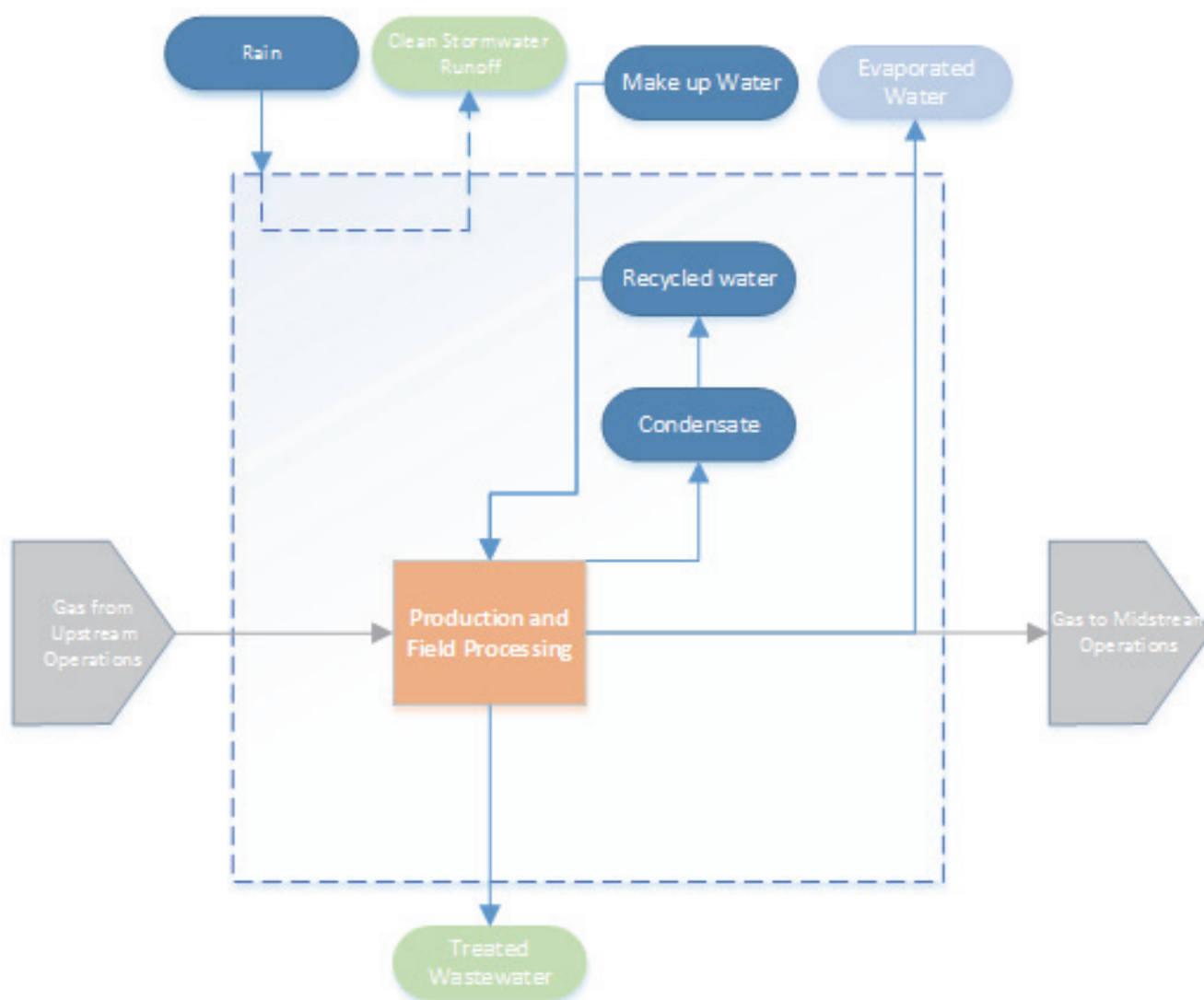


Figure 4—Typical Water Use and Management in Midstream Gas Processing Operations

a wide variety of petroleum products, including gasoline, fuel oil, jet fuel, heating oils and gases, and petrochemicals. Petroleum refining includes a wide variety of physical separation and chemical reaction processes.

Downstream activities for gas resources can consist of one of three options, depending on the end use for the resource. Extracted and purified gas can be either directly conveyed to the point of sale, liquefied (LNG process) to reduce volume prior to transportation, or refined to separate ethane for ethane cracking or to produce liquid petroleum products, such as gasoline (GTL process). Each of these downstream activities is further described in the subsections below.

3.3.1 Oil Refining

In petroleum refineries, water is vital for many applications including crude washing; cooling; steam production for various contact and non-contact processes, including pre-heating, steam stripping, vacuum generation, and other processes; fire protection; and more. Dependence on uninterrupted and sustainable water supplies is therefore critical to maintaining production and safety.