Water Use in Agricultural Watersheds

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Background

Concerns about water use have intensified due to factors such as the recent drought, the U.S. Supreme Court Settlements regarding the Platte and Republican River Basins, and the implementation of LB 962. To understand water use it is helpful to consider the fate of water as depicted in the **hydrologic cycle** (Figure 1). There is a constant amount of water on earth; however, the supply is continuously recycled when viewed from a global perspective. Precipitation that reaches the earth's surface either infiltrates into plant root zones, runs off to streams and rivers, or is intercepted by plants. Some of the water that infiltrates is used to supply water that evaporates from the soil or that transpires through plant leaves. When more water infiltrates the soil than plant root zones can store, the excess infiltration flows through the unsaturated zone toward the groundwater aquifer. Water that reaches the groundwater is usually called **recharge**. Recharge causes the local groundwater level to rise which creates a gradient that causes groundwater to flow away from the recharge area. Groundwater may flow toward streams, lakes and rivers if groundwater aquifers are connected to the stream. In other cases the elevation of the stream may be higher than the groundwater surface and water may flow from the stream to the groundwater. Water also reaches streams and lakes by direct overland runoff. Thus, water in streams and lakes can come from either runoff or groundwater. The contribution of flow due to groundwater is frequently called **base flow**. Energy from the sun and dry winds causes water in streams, lakes and the ocean to evaporate, and water to evaporate from the soil and or transpire through plants. The return of water to the atmosphere as water vapor is referred to as **evapotranspiration** and is abbreviated as **ET**. Water vapor in the atmosphere condenses as it cools and returns to the earth as precipitation, and the hydrologic cycle is complete.

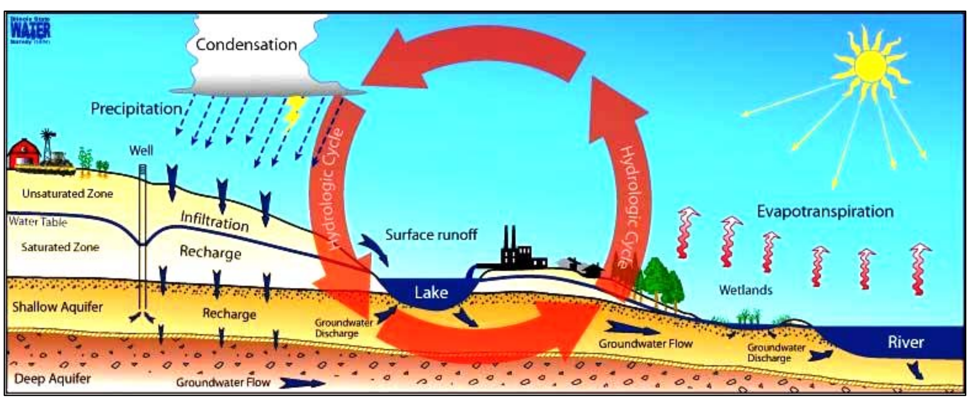

Figure 1. Diagram of the hydrologic cycle (source www.sws.uiuc.edu/docs/watercycle).

Watersheds

We are generally concerned with **watersheds** at the local scale. A watershed is the land whose runoff drains into a particular stream (Figure 2). All land uses in the watershed affect its water balance. Many processes included in the hydrologic cycle also apply to the watershed. The primary difference is that water vapor as evapotranspiration generally does not return to the same watershed where the ET occurred. Thus evapotranspiration represents a loss for the watershed. In the Great Plains the jet stream transports air from more arid regions into the area and the evapotranspiration that occurs is often transported toward more humid regions.

Precipitation is the primary source of renewable water supplies for most watersheds in the Great Plains. Some watersheds benefit from inflow from surface water in streams and rivers from upstream regions. Groundwater may also flow into the watershed area. Precipitation and inflow to the watershed produces outflow (streamflow or groundwater discharge) or evapotranspiration within the watershed. Some water is also temporarily stored within the watershed as water in reservoirs or groundwater aquifers. Water is also stored in the unsaturated soil (i.e. the root zone and the vadose zone) above the groundwater aquifer. Water in storage can increase or decrease over time depending on the balance between inflow, outflow and evapotranspiration.

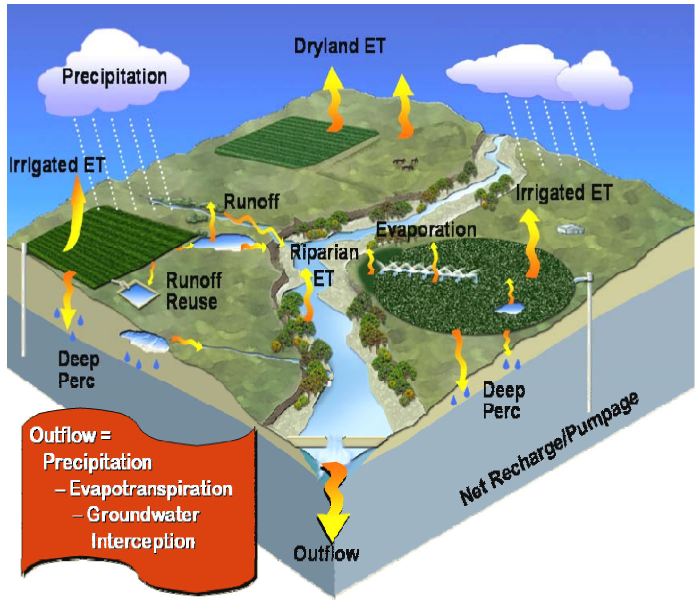

Figure 2. Diagram of an agricultural watershed.

Man can affect the hydrologic cycle and the water balance of a watershed by diverting surface water in lakes or streams and pumping groundwater. Some applications, such as irrigating crops, increase evapotranspiration. The increase in evapotranspiration due to irrigation is the called the **consumptive use of irrigation water** and represents a conversion of liquid water to water vapor that ultimately leaves the watershed. Some of the water diverted from streams or pumped from groundwater for irrigation may percolate through root zones of irrigated fields or seep from water delivery systems. Seepage and drainage usually recharge the groundwater aquifer. Some water may run off irrigated fields or may be spilled from delivery systems. If the runoff and/or spills flow to a stream or lake, the water is usually referred to as **return flow** because it becomes available downstream.

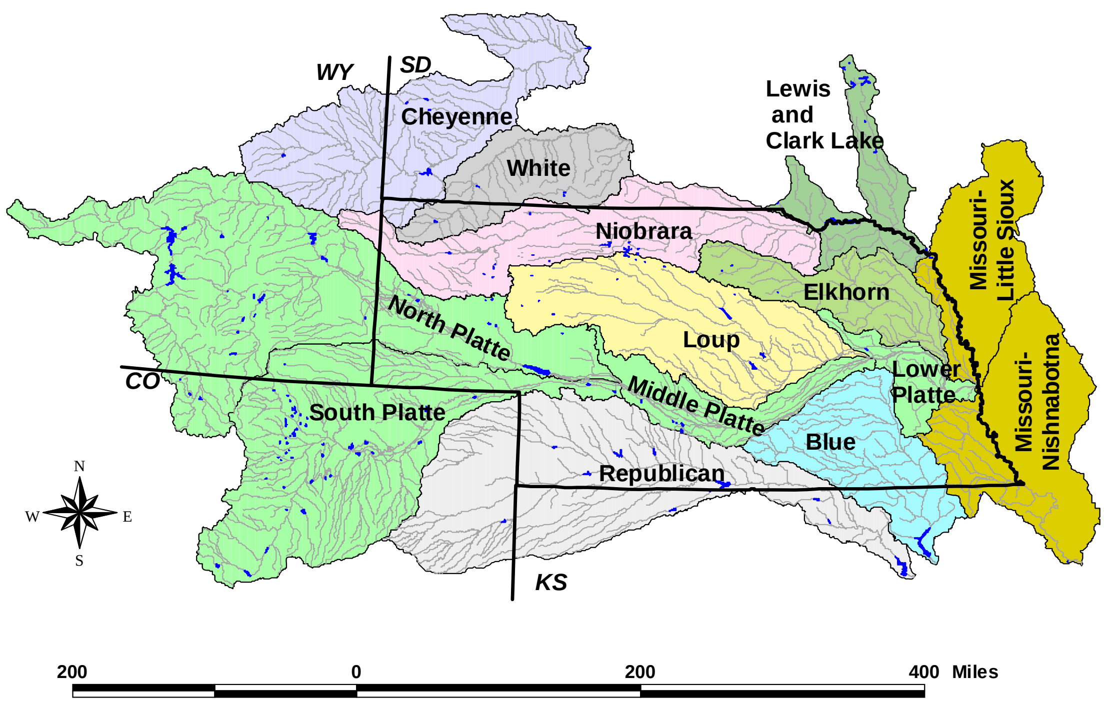

Figure 3. Major watersheds in Nebraska.

Nebraska shares most of her major watersheds with neighboring states (Figure 3.) Only the Loup and the Elkhorn are wholly contained in Nebraska. Managing shared watersheds has proven to be challenging all across the Western U.S. as the components in the upper reaches of the watershed affect the water balance at the state boundary or other political subdivision.

Water Use

Use can be defined as the act of utilizing something for a particular purpose. For water we generally think of diverting water from streams or reservoirs, or pumping from groundwater, to supply an intentional use. Evapotranspiration that occurs due to natural activities is not generally considered to be a "use". Thus, evapotranspiration from native range or evaporation of natural lakes would not normally be referred to as a use. The act of moving water from its original location to a different location or time ("i.e., using the water") has an intended purpose. For example we irrigate to cool crops and to reduce water stress during dry periods to sustain crop yields. We might also use streamflow or groundwater to cool electrical power generation systems or to produce ethanol. When we "use" water we generally increase evapotranspiration.

Not all of the water "used" is consumed (*i.e., converted from a liquid to water vapor*). For example, consider the sprinkler and surface irrigation examples shown in Figure 2. Water supplied to the irrigated field as either rain or irrigation can be used for crop evapotranspiration, but may also result in runoff which may return to the streams of the watershed or may percolate through the crop root zone and recharge the groundwater aquifer. Thus, the amount of water pumped for irrigation is not all consumptively used. Data from the USGS (2005) lists the relative consumptive use of water by major sectors in Nebraska. The data show that up to 90% of the water consumed in the state is for irrigation. Cooling of power plants represents approximately 8% of the total consumptive use in the state. These data show that little water is consumed for domesticate or municipal uses.

Consumptive Use

A term this being widely used today is **consumptive use**. The meaning of consumptive use is often different between individuals, especially those that are new to hydrology. Various scientific and engineering organizations have developed definitions for consumptive use that vary slightly but that usually have a consistent message. The Glossary of Meteorology defines consumptive use as "*The total amount of water taken up by vegetation for transpiration or building of plant tissue, plus the unavoidable evaporation of soil moisture, snow, and intercepted precipitation (interception) associated with the vegetal growth. Consumptive use is primarily applied to a single type of vegetation in a given area and does not include evaporation from water surfaces in or adjacent to the area; thus, it is not as general in scope as evapotranspiration or duty of water.*" The United States Geological Survey defines consumptive use as "*that 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.*" The United States Bureau of Reclamation adds that "*water whose state, chemical, or biological characteristics are altered sufficiently to render it useless to further beneficial uses*" is also referred to as water consumption. The Irrigation Association lists definitions of use that are partially based on terminology from the American Society of Civil Engineers and the American Society of Agricultural and Biological Engineers as:

- <u>*Consumptive*</u>*: Total amount of water taken up by vegetation for transpiration or building of plant tissue, plus the unavoidable evaporation of soil moisture, snow, and intercepted precipitation associated with vegetal growth.*
- <u>*Nonconsumptive*</u>*: Water that leaves the selected region and not considered consumptive. Examples are runoff, deep percolation, and canal spills.*
- <u>*Beneficial Use*</u>*: Beneficial use of water supports the production of crops: food, fiber, oil, landscape, turf, ornamentals, or forage.*

- *Nonbeneficial Use: Water utilized in plant growth which cannot be attributed as beneficial*.
- *Reasonable Use: In the context of irrigation performance, all beneficial uses are considered to be reasonable uses. Non-beneficial uses are considered to be reasonable if they are justified under the particular conditions at a particular time and place.*
- *Unreasonable Use: Unreasonable uses are non-beneficial uses that, furthermore, are not reasonable; that is, they are without economic, practical, or other justification.*

The State of Utah considers consumptive use to be the "*portion of water withdrawn from a surface or groundwater source that is consumed by particular use(s) and does not return to a natural water source or another body of water*."

The common theme within these definitions is that water which is converted from liquid to water vapor by evapotranspiration is consumptive use since it represents a loss from the watershed and is not available to downstream users in the watershed or neighboring watershed. There is a subtle difference in the definitions regarding how water is made available for consumptive use. Some include all water and other organizations focus on water that is withdrawn from the source for a use. The latter definition seems to be more appropriate for managing watersheds.

Consumptive use is more subtle if we alter evapotranspiration due to changes in land use and/or agricultural production practices. Consider expanded use of conservation tillage in agriculture. It is widely recognized that reduced tillage contributes to higher infiltration rates that supply water for crop evapotranspiration and groundwater recharge. The increased evapotranspiration diminishes the amount of runoff that contributes to streamflow leaving the watershed. So, as one compares to earlier times the changes in farming practices could be considered an increase in consumptive use. However, the individual producer did not intentionally move water from one location to another in this process, so in that sense it may not be an increase in consumptive use even though it results in an increase in evapotranspiration.

Some consumptive use may be beneficial in that they increase crop yields and profitability, allow for production of electrical energy or provide for increased recreation at lakes, or provide for some other purpose. In other cases consumptive use may be nonbeneficial. Examples of nonbeneficial uses would be evapotranspiration from weeds in road ditches that are wetted due to uncontrolled runoff from irrigated lands, evapotranspiration from artificially wetted areas adjacent to canals, or evaporation of water applied to streets and pavements in urban areas. The fate of an irrigation water withdrawal relative to these considerations is illustrated in Figure 4. Identification and reduction of nonbeneficial uses of water offers potential to enhance water supplies with little loss of economic or environmental impact.

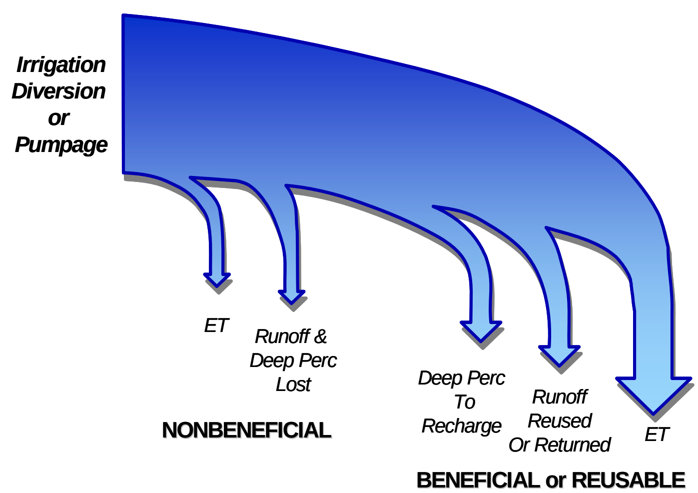

Figure 4. Schematic diagram of the possible fate of water.

Farm Scale

Water use at the farm or field scale differs slightly from considerations for the hydrologic cycle and/or at the watershed scale. The fate of water for an irrigated field located in a watershed is illustrated in Figure 5. The rectangular dashed line represents the water balance for an irrigator. Additions to the field water balance include rainfall, and irrigation water from ground or surface water sources. Losses of water from the field represent runoff, deep percolation from the field and evapotranspiration from the field and evaporation from on-farm storage or conveyance systems. Farmers profit by increasing efficiency to obtain as much evapotranspiration by irrigated crops as is profitable. Thus, runoff, deep percolation and evaporation from storage are seen as losses of water. Water that percolates from the field or that runs off and returns to the stream would not be seen as a loss at the watershed scale as they are still in the system for use elsewhere.

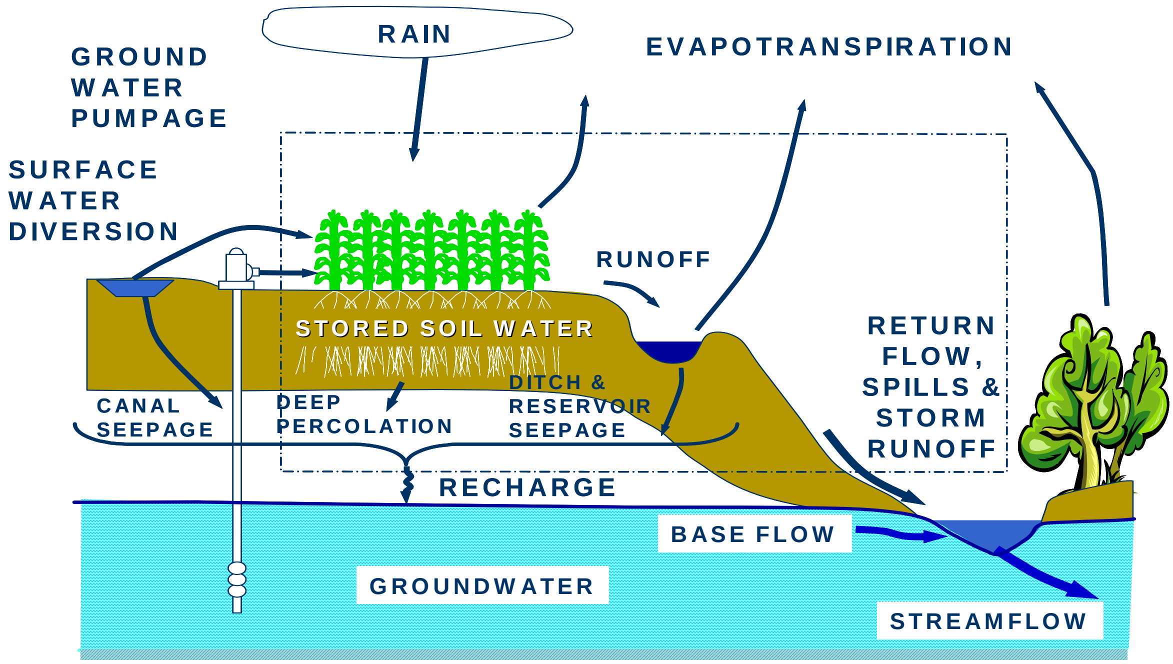

Figure 5. Diagram of water balance for an irrigated field supplied with ground and surface water for irrigation.

Summary

Water use can be viewed at several scales and each perspective offers a different conclusion regarding water balances and the impact of man’s activity. It is essential to consider these perspectives in managing water and to clearly define the perspective to avoid misunderstanding and false expectations.