Drain Tiles and Groundwater: Understanding the Relations

MINNESOTA GROUND WATER ASSOCIATION

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EXECUTIVE SUMMARY

Drainage for agricultural production over the past 150 years has been an integral component of human-driven change to Minnesota's rural landscapes.

Benefits of drainage:
Historically, poorly drained soils across much of the State would often remain saturated or flooded after spring snowmelt, preventing timely farm operations such as tilling and planting crops. Installation of agricultural drainage, both surface ditches and subsurface drainage, accelerated transport of water off farm fields and imparted producers higher crop yields. Agricultural drainage offered many other benefits such as preventing crop drown out, aerating the soil profile for improved plant growth, limiting surface runoff and soil erosion, and allowing farmers better access to croplands. Without agricultural drainage on much of Minnesota's croplands, it would have been difficult to realize high enough crop yields to remain economically viable.

Environmental concerns:
While drainage of Minnesota croplands provided the benefits mentioned above, several environmental concerns result. These include wetland loss, degradation of downstream water quality, and reduced potential for recharge.

Early agricultural drainage efforts (pre-20th century) led to the disappearance of much of Minnesota's natural wetlands. Increased focus on preventing or mitigating wetland loss over the last 50 years has helped curtail further losses, even as agricultural drainage proceeds. Prior to establishment of Minnesota statehood, wetlands accounted for more than 10 million acres in Minnesota, including prairie wetlands, peatlands, and forest wetlands that comprised approximately 19 percent of the total land area. In 2018, only half of Minnesota's pre-settlement wetlands remain, mostly in parts of the State that have not experienced widespread drainage, such as northern Minnesota.

Water-quality monitoring has shown that agricultural drainage, in particular the practice of subsurface drainage, provides a direct flow path for nutrient (nitrogen and soluble phosphorus) losses to surface water resources. The negative consequences of agricultural drainage on surface water quality are well documented. Agricultural basins with a high percentage of agricultural drainage have been implicated as part of the cause of the Gulf of Mexico hypoxia zone due to excessive nitrogen export.

The connection of hydrological effects of agricultural subsurface drainage on groundwater recharge and aquifers, on the other hand, has not been well-established. Agricultural subsurface drainage intercepts infiltrating water below croplands and directly discharges the water to nearby surface waters. However, the size of the water balance shift from drained water that would have evapotranspired or run off the land to drained water that would recharge underlying aquifers has been poorly characterized.

Drain Tiles and Groundwater:
Given the poor accounting of subsurface drainage effects on groundwater resources, the Minnesota Ground Water Association deemed it imperative that we document these effects so that groundwater resources in agricultural regions with substantial drainage can be effectively managed. This white paper documents the relations of drain tiles and groundwater resources and discusses the historical significance of agricultural drainage practices, the recognized

positive benefits and potential negative consequences of agricultural drainage practices, and the gaps in understanding of the connections between agricultural drainage and groundwater resources.

The major messages emerged from the findings of this white paper are:

- **Complex history.**

Minnesota has a long history of agricultural drainage, spanning over 150 years. Agricultural drainage, and the eventual widespread usage of subsurface drainage, can be separated into at least four distinct periods of time:

(a) early drainage to get water off the land, pre-20th century;
(b) the boom and bust era (1900-1945);
(c) postwar resurgence of subsurface drainage and early conservation efforts (1945-1960); and,
(d) emergence of the environmental movement (1960 to present).

The State's regulatory framework that both allowed for drainage and controlled its usage during these periods is complicated and has been governed by a patchwork of both State and Federal statutes.

- **Drainage Provinces.**

This white paper advances the concept of tile drainage provinces to aid in the discussion of regional differences in subsurface drainage and its overall effect on groundwater resources. Built upon the concept of groundwater provinces, three distinct tile drainage provinces were conceptualized:

1. the Southeastern Province, characterized by thin loess deposits and pre-Wisconsin tills overlying Paleozoic-age sedimentary bedrock;

2. the South-Central Province, characterized by thick Wisconsin-age glacial deposits overlying Paleozoic-age sedimentary bedrock sandstone, limestone, and dolostone aquifers; and,

3. the Western Province, characterized by clayey glacial till and lacustrine deposits overlying Cretaceous and Precambrian bedrock. The distinct geology and the soils that developed in these regions have implications for each region's subsurface drainage density and the potential implications for groundwater.

- **Knowledge gaps.**

Several critical knowledge gaps are identified in this paper, creating opportunities for further research to improve our understanding for better managed water resources:

1. Extent of drainage is unknown.

Direct estimates of the extent of subsurface drainage do not exist in Minnesota. However, several indirect methods have been utilized to estimate subsurface drainage, from the field-scale to county-level through the usage of geographic information system (GIS) analysis and aerial photography. Based on a 2012 U.S. Geological Survey estimate of subsurface drainage extent, about 21% of the land area in Minnesota has some density of subsurface drainage.

2. Effect of drainage on underlying aquifers is unknown.

A basic understanding of unconfined and confined aquifers and their recharge is necessary to connect any hydrological effects from agricultural drainage to groundwater. The basic goal of subsurface drainage to efficiently drain saturated soils clearly alters the water balance in croplands. However, its overall effect on groundwater resources has been poorly characterized, and is in large part determined by the geology below drained areas and the arrangement of underlying aquifers.

3. Water balance shifts.

An improved understanding of historical water balance shifts from pre- to post-drainage periods is necessary to understand long-term implications on net groundwater recharge. Also, more direct field-scale studies and indirect modeling studies are needed to characterize water budgets for fields with subsurface drainage.