Controlled Tile Drainage

IF-04

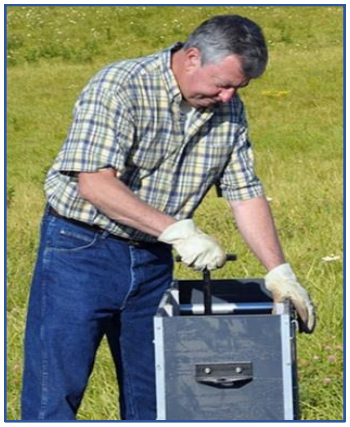

Figure 1. Operating a water control structure (USDA-NRCS).

What can controlled tile drainage accomplish?

The objectives of controlled tile drainage, also known as drainage water management, are ***Improving Water Quality*** and ***Conserving Water***. Controlled tile drainage systems make it possible to retain water in the soil profile, reducing the amount discharged from the tiles to downstream receiving waters. Crops benefit from the stored water and any nutrients contained in it during dry periods. At other times, such as seeding and harvest, excess water is allowed to flow freely from the tiles to achieve favourable field conditions.

Leading US researchers (e.g. Christianson et al., 2016) consider controlled drainage a cost-effective water management tool.

Overview of controlled tile drainage

Controlled drainage is the use of one or more flow restricting devices (such as stop logs, risers, gates, and valves) placed inline with the tile drainage pipes, allowing the water level in the field to be artificially set. Pump level controllers on lift stations located at the main outlet, can also be used to set the water level. Each control structure will influence a portion of the field called a water management zone.

Although an existing tile drainage network can be retrofitted to include controlled drainage, ideally this practice should be considered during the initial design phase. Field elevations must be mapped for the appropriate placement of the tiles, control structures and the establishment of the water management zones. Usually, one control structure is needed for every 30 to 45 cm (1 to 1.5 ft) elevation change along the main line.

The current industry standard is the inline stop log control structure (Figures 1 and 2). By manipulating the settings of the control structure, water is held back to raise the height of the water table within a water management zone. When all stop logs have been removed, the system reverts to free (conventional) tile drainage. Stop logs can be adjusted manually (Figure 1); however, automation and remote controls are also available. A controlled tile drainage system is expected to last as long as a conventional tile drainage system (>50 years).

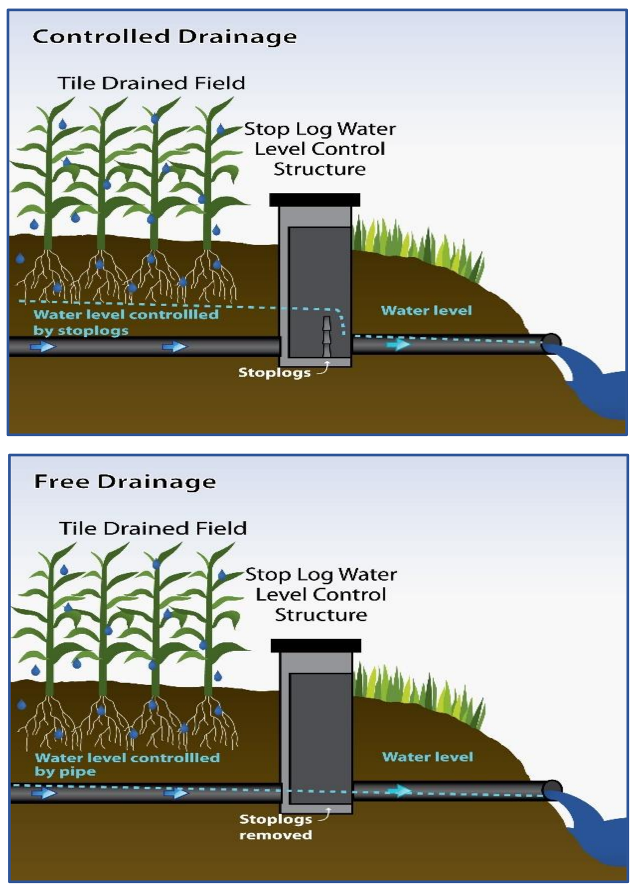

Figure 2. Controlled drainage using stop log control structures (top) and free drainage with stop logs removed (bottom).

Applicability of controlled tile drainage in Manitoba

Manitoba often has too much water when it is not needed, such as in the spring, and not enough water when it is dry. In most years, agri-Manitoba is subject to crop-water deficit during the growing season, meaning that soil moisture reserves and growing season precipitation are often inadequate to meet crop needs. Controlled drainage provides a means of storing water in the ground for crop use in dry periods.

Controlled drainage is best-suited to nearly-level land, ideally with an average slope of less than 0.5% (Christianson et al., 2016). A significant portion of agri-Manitoba meets this slope criterion; however, the suitability of this practice for any given field will depend on additional site-specific characteristics and economics.

Current research findings on controlled tile drainage

Controlled drainage has been studied extensively in the USA, especially in the upper Midwest. Crop yield and nitrate reduction benefits from various states are illustrated in Figure 3 (Christianson et al., 2016). The benefits of controlled drainage in Manitoba are expected to be different than in the upper Midwest due to differences in hydrology between the two regions. The overall drainage volume in Manitoba is lower and the overall water deficit in Manitoba is typically higher.

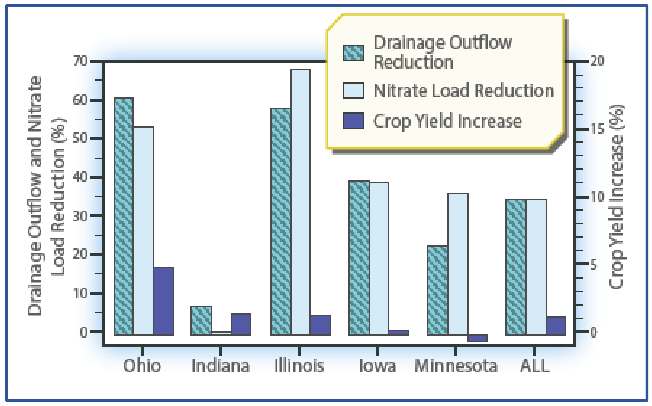

Figure 3. Drainage outflow and nitrate load reduction and crop yield increase resulting from controlled drainage vs. conventional drainage systems (Christianson et al., 2016).

Cordeiro (2013) confirmed that during short periods of water deficit, the shallow water table can meet a significant portion of crop water demand (Figure 4). Crop water demand is reflected in the measurements of hourly ETc (dashed line). Increases in hourly ETc correspond with observed drops in the water table (solid line), confirming shallow groundwater usage by the crop. As the shallow water table often contains elevated nitrate levels, holding back groundwater with controlled drainage can also supply nutrients to the crop.

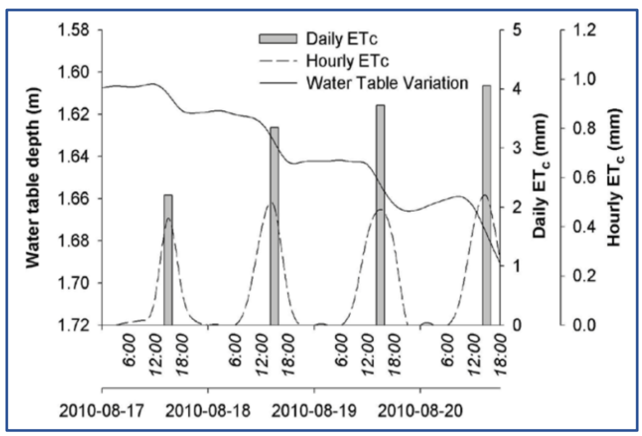

Figure 4. Contribution of shallow water table to meeting crop water demand (Daily ET_C) (Corderio, 2013).

Controlled drainage systems can be designed to include sub-irrigation, which involves feeding water back through the tile to supply the crop from below. Cordeiro (2013) and Satchithanantham (2013) studied sub-irrigation of corn and potatoes in Manitoba. While both studies confirmed the contribution of the shallow water table to crop production, they also revealed obstacles to adoption of sub-irrigation, such as lateral seepage. Several technical issues (e.g. water treatment) need to be addressed prior to adopting sub-irrigation as a BMP in Manitoba.

There is significant research in California showing shallow water tables within 1.8 m (6 ft) of the surface benefit crop yield (University of California, 2015; Ayers et al., 2006); supporting that controlled tile drainage in semi-arid regions such as Manitoba will also increase yields.

What are some design and operational considerations?

Controlled drainage can add significantly to the capital cost and operational complexity of a tile drainage system warranting *Professional Services* (see *BMP EA-01*).

Figure 5 shows the layout of a 300-acre controlled drainage system near Homewood, MB. Differences in design features of a control drainage system vs a conventional system include:

- Shorter lateral lines;
- Extra sub-mains to create water management zones;
- Multiple in-line stop log structures and buried control valves to establish and maintain water levels in each zone.

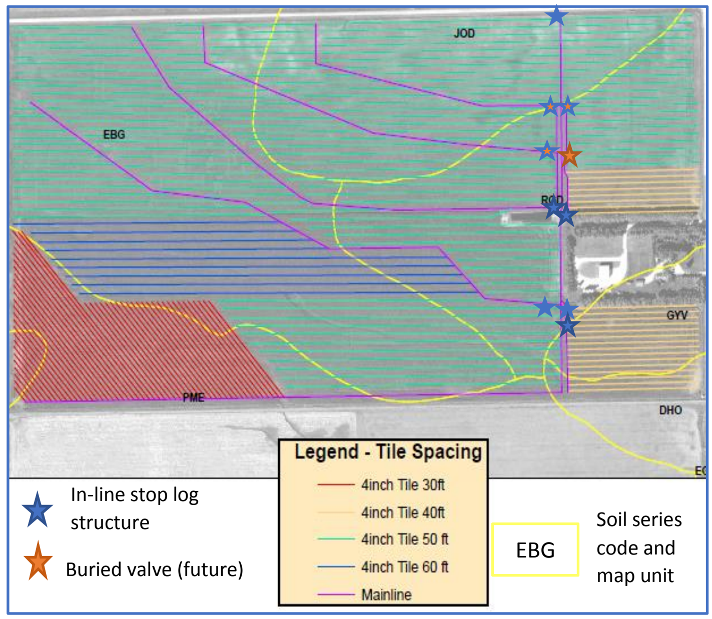

Figure 5. Typical controlled drainage design in Manitoba.

In addition to field elevations, engineering design should consider water table elevations, soil type and variability, locally-measured flow rates, drainage intensity (i.e depth/spacing tiles) and potential for lateral flow. Sub-irrigation adds further design complexity and requires a source of irrigation water.

Controlled drainage is best designed to capture a portion of the tile flow, after allowing tile water to flow freely early in the growing season. Based on a modelling exercise by Sands (2013) and the results of the Cordeiro (2013) and Satchithanantham (2013) studies, a reasonable target for Manitoba would be to save up to 25 mm (1 in) of tile drainage water for crop use, by holding back 300 mm (12 in) of water depth. Establishing a rough schedule for holding back and releasing tile water is an important component of controlled drainage. A properly managed controlled drainage system could have reduced the amount of irrigation that was otherwise required in the summer of 2011 (Figure 6).

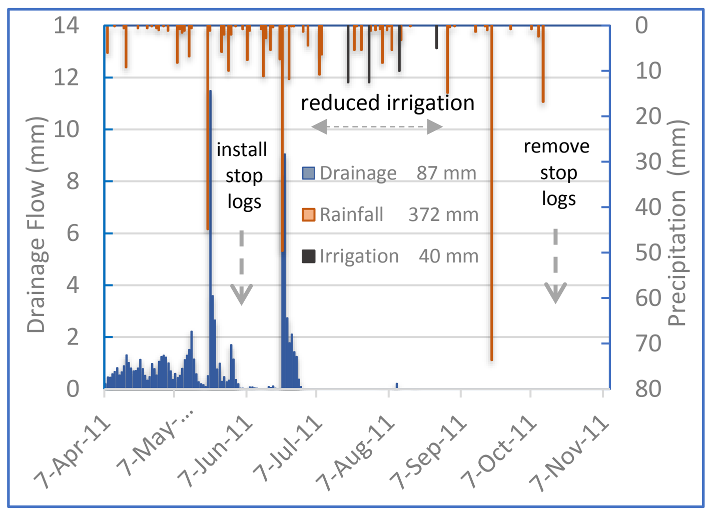

Figure 6. Illustrative free drainage flow vs. precipitation and irrigation (Cordeiro, 2013); showing potential to install stop logs at start of June to conserve water for July/August and removal of stop log in late October.

The performance of a controlled drainage system should be monitored. Crop response, soil moisture levels, and the use of piezometers to track changes in the water table can aid in optimizing performance. Guidance for the design and operation of a controlled drainage system is provided in the Drainage Water Management chapter of the Conservation Practice Standards series published by USDA–NRCS.

Outstanding questions and potential future improvements

Controlled drainage is a proven technology, with most experience gained in the Upper Midwest of the USA, Ontario and Quebec. Optimizing design and performance for Manitoba conditions requires additional research and development, including:

- Further information is required on timing of stop log adjustments relative to crop stage and/or growing season parameters (e.g. planting date, heat units), as well as water table response to evapotranspiration.
- The implications of controlled tile drainage for greenhouse gas emissions and adaptation to climate change should be studied.
- Site selection and design criteria based on soil texture and stratigraphy, hydraulic conductivity, and existing ground and groundwater gradients should be established.
- Field measurements at local research and demonstration sites, and modelling (Skaggs et al., 2012) are needed to assess:
    - the agronomic benefits of controlled drainage, particularly crop yield;
    - other potential benefits including water quality improvement;
    - performance monitoring and operation protocols.

Complementary practices

Controlled tile drainage is complementary with other BMPs that reduce nutrients in tile outflow or drainage volume:

- *IF-01 – Nutrient Management*;
- *IF-02 – Cover Crops*.

Controlled tile drainage can be supplemented by other BMPs as noted:

- *WS-01 – Tile Water Recycling*; *EF-01 – Bioreactors; EF-02 – Saturated Buffers; WS-02 – Constructed Wetlands*).

Design aids

USDA-NRCS Conservation Practice Standard Drainage Water Management Code 554. Access on USDA-NRCS website.

Additional BMP resources

ADMC and NRCS, 2013. Drainage water management; a tool that interacts with the 4Rs. Conservation Innovation Grant 68-3A75-6-116. Poster on 4R Tomorrow website.

Christianson, L.E., J. Frankenberger, C. Hay, M. J. Helmers and G. Sands, 2016. Ten ways to reduce nitrogen loads from drained cropland in the Midwest. Pub. C1400. University of Illinois Extension.

Frankenberger, J., E. Kladivko, G. Sands, D. Jaynes, N. Fausey, M. J. Helmers, R. Cooke, J. Strock, K. Nelson and L. Brown, 2006. Questions and answers about drainage water management for the Midwest. Pub. WQ-44. Purdue University Cooperative Extension Service

USDA-NRCS, 2013. Drainage water management benefits landowners (video). Access on USDA-NRCS website.

References

Ayers, J.E., E.W. Christen, R.W.O. Soppe and W.S Meyer, 2006. Resource potential of shallow groundwater for crop water use; a review. Irrigation Science: 24:147-160.

Cordeiro, M.R.C., 2013. Agronomic and environmental impacts of corn production under different water management strategies in the Canadian Prairies. Ph.D. Thesis, Dept. of Biosystems Engineering, University of Manitoba.

Sands, G., 2013. Developing optimum drainage design guidelines for the Red River Basin. University of Minnesota.

Satchithanantham, S., 2013. Water management effects on potato production and the environment. Ph.D. thesis, Dept. of Biosystems Engineering, University of Manitoba.

Skaggs, R.W., M.A. Youssef and G.M. Chescheir, 2012. DRAINMOD: Model use, calibration, and validation. Trans. of the American Society of Agricultural and Biological Engineers: 55(4): 1509-1522.

University of California, 2015. Use of shallow groundwater for crop production. Agriculture and Natural Resources Publication 8251.