Drainage Records Modernization Guidelines

Prepared by:

Minnesota Board of Water and Soil Resources

In partnership with:

Water Resources Center
Minnesota State University, Mankato

September 2008

Table of Contents

Section		Page
1.	Introduction	3
2.	Purposes and Funding for Drainage Records Modernization Guidelines	4
3.	Lead Organizations and Staff for Guidelines Development	4
4.	Pertinent Definitions	4
5.	Interviews of Drainage Authorities with Modernized Records	6
6.	Benefits of Drainage Records Modernization	7
6.1	Drainage Records Preservation	7
6.2	Improved Access to Drainage System Records	8
6.3	Enhanced Drainage System Management Capability	8
7.	Recommendations from Drainage Authorities Experienced in Records Modernization	9
8.	Funding and Collaboration	11
9.	Gathering and Preserving Historical Records	12
9.1	Levels of Scanning for Drainage Records Modernization	13
9.2	Scanning of Historical Records	17
9.2.1	Scanning Hardware	18
9.2.2	Scanned Document Types	19
9.2.3	Scanned Document Naming Convention	20
9.2.4	Document Index	21
9.2.5	Metadata	21
10.	Mapping	23
10.1	Mapping and GIS Development	24
10.1.1	Aerial Photography	25
10.1.2	Township, Section and Quarter Lines	25
10.1.3	USGS Topographic Maps	25
10.2	GIS / Mapping Software and Hardware	26
10.3	Digitizing/Mapping Methods	27
10.3.1	Manual Digitizing	27
10.3.2	Heads-Up Digitizing	28
10.3.3	Coordinate Geometry	28
10.4	GIS / Mapping Line Work Recommendations	29
10.5	Georeferencing	30
10.6	GIS / Mapping Attributes	30
10.7	Level 2 Mapping and GIS Development	32
10.7.1	Field Surveys	32
10.7.2	Side Inlets / Outlets / Surface Risers	32
10.7.3	Private Tile and Ditch Alignments	33
10.7.4	Riparian Buffers / Buffer Strip Inventory	34
10.7.5	Culvert and Bridge Inventory	34
10.7.6	Benefited Acres	35
11.	Public Accessibility to Modern Drainage Records	36

List of Figures

Figure **Page**

1: Location / Plan Maps 14
2: Drainage System Profiles....14
3: Other Legal Documents 14
4: Orders for improvements, redeterminations of benefits, repairs 15
5: Typical Design Sections and Details 15
6: Cross-Section Drawings....16
7: Benefited Acres Documents 16
8: Private Ditch and Tile Information 16
9: Drawing Legend indicating plans corrected to show ditch as constructed....18
10: Drawing Legend indicating plans as of the preliminary design stage 18
11: 42” Large Format Scanner on Base (Contex) 19
12: File scanned with dark areas and then converted to an inverse 20
13: McLeod County example of a Master Document Index....21
14: Example GIS Data Layers, Map Generation and Spatial Analysis 23
15: Example Map with Multiple Data Layers....25
16: Open Ditch Aerial Photography....25
17: Example Digitizing Table 26
18: Manual Digitizing of a Map on a Digitizing Table....28
19: Example Digitized Drainage System Locations 29
20: Tile Outlet into Drainage Ditch and Perforated Tile Riser Inlet....33
21: Public and Private Drainage System Components 33
22: Example Map showing Ditch Buffer Data....34
23: Example of Todd County Culvert and Bridge Inventory....35
24: Example Map of Benefited Parcels and Acres 36
25: Example County Web Page for Drainage System Information 37

1. Introduction

Minnesota Statutes Chapter 103E. Drainage is also referred to as Minnesota public drainage law. Chapter 103E and Chapter 103D. Watershed Districts, vest authority and responsibility for administration of Chapter 103E drainage systems, including open ditch and subsurface tile systems, in Minnesota counties and watershed districts. These public drainage authorities are responsible for all aspects of administration of Chapter 103E drainage systems, which are principally financed by the assessed, benefited landowners. The responsibilities of Chapter 103E drainage authorities include maintenance of all associated drainage system records, in accordance with the requirements of Section 103E.101 Drainage Proceeding and Construction Records.

A survey of Chapter 103E drainage authorities conducted for the Public Drainage Ditch Buffer Study, February 2006 (http://www.bwsr.state.mn.us/aboutbwsr/publications/bufferstudyweb.pdf) indicated that approximately 80 counties and 21 watershed districts had Chapter 103E drainage systems under their jurisdiction at that time. Based on Geographic Information System (GIS) analysis of a Minnesota Surface Hydrology data layer that identifies channelized streams and ditches (source: Department of Natural Resources Data Deli), it is estimated that there are more than 21,000 miles of publicly administered surface drainage ditches in Minnesota. The total miles of publicly administered subsurface tile in Minnesota is unknown, but is expected to also involve many thousands of miles of tile.

With the increasing availability of computer power, electronic scanning equipment, as well as database, GIS and other computer software, new methods have emerged to create, store, use and otherwise manage drainage system records. Implementation of one or more of these methods is considered “drainage records modernization”. These methods also serve the purpose of drainage records preservation, which is increasingly important as drainage system records continue to age. Some drainage system records are more than 100 years old. Most drainage system records were created on materials such as commonly available paper and mylar, using methods such as typewriters with carbon paper and blue line processes that are subject to deterioration over time, even when documents are carefully stored.

In the mid 1990s, the Board of Water and Soil Resources (BWSR) began to provide state cost-share for drainage system inventories and drainage records modernization through what is currently called the Local Water Management Challenge Grant Program. The objective was and is to support Comprehensive Local Water Management Plan priorities for improved management of water quantity and quality through enhanced management of Chapter 103E drainage systems. Through fiscal year 2006, 24 drainage authorities received these challenge grants and an additional 9 drainage authorities had pursued drainage records modernization without state cost-share. These drainage authorities are identified on page 17 of the Public Drainage Ditch Buffer Study. The cost-share provided ranged from $5,000 to $55,000, with an average of approximately $24,000 per drainage authority. These cost-share grants require a minimum 1:1 local match via cash and/or in-kind work on the grant project. Because the number and length of Chapter 103E drainage systems within the jurisdiction of a county or watershed district can vary substantially, so too can the scope and cost of associated drainage records modernization.

The survey of Chapter 103E drainage authorities conducted for the Public Drainage Ditch Buffer Study included questions about drainage system records. Responses indicated that the majority of drainage authorities had only paper and other hard copy records of drainage systems within their jurisdiction. For those drainage authorities with modernized drainage records, the survey indicated significant variability in the level of detail of the records. The stakeholder advisory group for the study proposed development of recommended methods for drainage records modernization, based on the experience of drainage authorities that have already developed modern drainage system records.

2. Purposes and Funding for Drainage Records Modernization Guidelines

In 2006, the stakeholder Drainage Work Group, which was an outgrowth of the advisory group for the Public Drainage Ditch Buffer Study, clarified the purposes for drainage records modernization guidelines, including:

a) Consolidate, document and share the experience of drainage authorities that have modernized their Chapter 103E drainage system records, to increase the efficiency and reduce the costs for drainage records modernization by other drainage authorities.
b) Promote drainage records preservation through modernization.
c) Promote more consistent drainage records modernization statewide.
d) Enable more efficient and effective administration of Chapter 103E drainage systems for enhanced management of water quantity and quality.

In response to a consensus recommendation of the Drainage Work Group to develop drainage records modernization guidelines, the 2007 Minnesota Legislature appropriated funding to the Board of Water and Soil Resources for development of these guidelines.

3. Lead Organizations and Staff for Guidelines Development

The BWSR contracted with the Minnesota State University, Mankato, Water Resources Center (WRC) to conduct interviews of drainage authorities that have modernized their Chapter 103E drainage records and to draft these guidelines. The Water Resources Center had conducted the survey of Chapter 103E drainage authorities for the Public Drainage Ditch Buffer Study. Mr. Richard J. Moore, GIS Analyst, WRC, who was assigned to this project, also had prior direct involvement in drainage records modernization efforts. The BWSR provided editing and layout assistance for these guidelines (Al Kean, Chief Engineer; Jon Fure, Communications Director). The Drainage Work Group provided advice, based on periodic updates and coordination during the development process, as well as review and discussion of a final draft of this document.

4. Pertinent Definitions

Attributes – Information about a spatial feature or data. This information describes the characteristics of the feature or data, such as dimensions, location, etc. The attribute information can describe anything about the spatial feature or data. This information can then be used in a database to query specific characteristics and to display similar features and data.

Data Layers and Data Overlays – Data layers and data overlays are created from available data and are used in conjunction with other data layers to display correlations between data. By overlaying data, users can see patterns or find features that inhabit the same space. Data layers pertinent to drainage typically are a specific subset, such as soils, open ditches, subsurface tile, roadways or parcels. The attributes of these data are stored in associated tables and are used to query out data associated with the real world features.

Drainage System Segments – Those segments of drainage systems that have a particular attribute associated with them, such as a certain tile size, grade, or a certain branch of a system. By breaking down a larger drainage system into smaller segments and attaching attribute data to those specific segments, the user can easily query the data associated with those segments.

Drainage Records Modernization – In the context of this document, drainage records modernization is the process of taking drainage system records, such as hard copy plans, profiles, drainage authority orders, and other drainage system documents and data and creating digital versions usable via computers. Modernization involves scanning, digitizing, database creation and otherwise organizing electronic versions of these drainage system records. These digital versions can then be used with database and mapping software to map, query and analyze data for various drainage system administration purposes.

Geographic Information System (GIS) – A geographic information system (GIS) integrates hardware, software, and data for capturing, managing, analyzing and displaying all forms of geographically referenced information. In the strictest sense, it is any information system capable of integrating, storing, editing, analyzing, sharing, and displaying geographically referenced information. In a more generic sense, GIS applications include tools that allow users to create interactive queries (user created searches), analyze spatial information, edit data and maps, and present the results of these operations.

Georeferencing – The process of aligning spatial data (shape files: points, polygons, etc.) to an image file such as an historical map, satellite image, or aerial photograph. To georeference an image, one first needs to choose the coordinate system and other projection parameters, establish control points, input the known geographic coordinates of those control points, and then minimize residuals. Georeferencing eliminates the need for a digitizing table, when maps have already been scanned into a digital format. In this case, the process of digitizing occurs on the computer screen and not on the digitizing table.

Global Positioning System (GPS) – A satellite-based navigation and surveying system that enables 3-dimensional location of points and objects. GPS satellites circle the earth twice a day in a very precise orbit and transmit signal information to earth. GPS receivers use these satellite signals and triangulation to calculate an exact location. Applicable vertical and horizontal control data enable definition of locations relative to a given coordinate system.

Mapping – In the context of this document, mapping is the process of taking a scanned digital image and converting it into a format that can be stored, manipulated and displayed in a Geographic Information System (GIS). The process can involve the georeferencing of the image to its real world location to assist in the digitizing of features on the map into points, lines and

polygons within the GIS and overlaying other data layers for various purposes. Attributes can and should be attached to digitized features to enable queries and displays of various information included in/on the maps.

Metadata – Data about data. Metadata describes the attributes and contents of an original document or work, and can relieve potential data users of having to have full advance knowledge of the existence and characteristics of a data set, in order to appropriately use data.

Scanning and Digitizing – Scanning is the process of taking a hard copy version of a document and sending it through a scanner that will take an image and save it into a format that can be read on a computer, normally as a picture (e.g. JPG or PDF format). Digitizing is the process of converting a map or other document into points, lines or polygons in a format that can be used electronically, including creation of data layers. These electronic documents can then be manipulated further into other image formats, including formats that can be read by mapping software.

5. Interviews of Drainage Authorities with Modernized Records

The drainage authorities that were interviewed regarding their experience with drainage records modernization involved both counties and a watershed district. The experience of these drainage authorities was a key basis for these guidelines. Their contributions in this regard are gratefully acknowledged.

The drainage authorities and points of contact interviewed include:

Blue Earth County – Craig Austinson
Chippewa County – Jon Clauson
Douglas County – Tom Anderson
Lincoln County – Robert Olsen
Martin County – Deb Mosloski
McLeod County – Renee Rosenow and Christy Christensen
Meeker County – Barb Loch and Ron Mortenson
Mower County – Rick Morrison
Pope County – Allan Kuseske
Renville County – Larry Zupke
Swift County – Mike Johnson
Todd County – Gloria Stevenson
Yellow Medicine County – John Kolhei
North Fork Crow River Watershed District – Allan Kuseske

The interviews with county and watershed district staff followed a defined format of questions and discussion. A list of questions was created by the WRC and BWSR staff focusing on the different components of the process of drainage records modernization and related experience. A goal was to identify methods and equipment used and products developed, what did and didn't work well, as well as the uses and benefits of drainage records modernization. Because the drainage authorities interviewed had been involved in drainage records modernization projects

over the span of about 10 years, the equipment and methods used has evolved somewhat. This reality was considered in the development of these guidelines.

Interviews started by inquiring about the catalyst(s) that prompted the drainage authority to undertake a drainage records modernization project. Funding was a second topic of discussion. Because the process of modernizing and preserving hard copy drainage records typically involves scanning of documents early in the process, this was the focus of the next set of questions. These questions addressed the types of scanners used, the settings used for scanning documents, as well as the logistics of how the work was organized and accomplished. This included discussion of techniques used to scan fragile and deteriorating documents. Organization of electronic documents was a related topic.

A number of interview questions addressed mapping and associated digitization and georeferencing for data use in GIS and associated software. These questions helped identify equipment, methods and logistics for this important component of drainage records modernization projects. This included investigation of the ways drainage systems were defined and organized on maps and in databases, and the associated attributes and metadata. This included definition of reasons for different methods of organizing data, and lessons learned.

Collaboration within and amongst drainage authorities and their partners was explored to better define collaboration to date for drainage records modernization. This included investigation of associated motivations, partnerships and cost savings.

The use of modernized drainage records was another focus of interview questions. These questions and associated discussion helped define what and how modern drainage records are being used and how this is affecting drainage authority operations. This included definition of benefits of drainage records modernization, as well as further definition of lessons learned about the methods used, changes made during the process and advice for other drainage authorities.

6. Benefits of Drainage Records Modernization

Through the interviews of drainage authorities that have undertaken the task of modernizing their drainage records and consultation with the Drainage Work Group, the following benefits were identified as outcomes of drainage records modernization.

6.1 Drainage Records Preservation

- The conversion of paper, mylar and other types of hard copy documents and maps to digital format greatly reduces the need for handling of the originals, and potentially the need to retain them.
- The digitization of drainage records provides an archived copy of all original documents and maps, preventing the loss of these historical legal documents (with proper electronic backup).

6.2 Improved Access to Drainage System Records

- The ability to share greater amounts of information more readily and efficiently with landowners, auditors, engineers, viewers and others involved in drainage system administration.
- With electronic document availability, staff time needed to handle landowner inquiries can be substantially reduced, as well as the associated "counter time" of landowners seeking drainage system information.
- The accessibility and ease of printing of electronic documents enables more efficient information sharing among the county and/or watershed district staff involved in drainage system administration.
- Enhanced ability to compare and standardize digitized drainage system information across county and/or watershed district boundaries.
- Digitized drainage system information can increase the accuracy and reduce the time and costs for redetermination of benefits for drainage systems.
- Readily available digital records and maps can reduce engineering costs for drainage system repair or improvement projects by quickly providing available information about the drainage system. Drainage system maps with information about the locations of all public and private feeder drainage systems, including surface and subsurface side inlets, can enhance the value of these records. Old maps do not always match aerial photographs of ditch locations and some drainage systems are missing a map of the system. These issues are often addressed during drainage records modernization using all available information.

6.3 Enhanced Drainage System Management Capability

- When paper drainage system map information is converted to digital format, other types of data layers can be overlaid electronically, substantially improving drainage management potential.
- Topographic data overlaid on drainage system maps can help define drainage management options, which can help manage water quantity and quality issues within a drainage system, subwatershed and associated watershed.
- Digital maps and overlays can be used as a tool to educate the public about water resource issues dealing with drainage needs and drainage management.
- Drainage authorities and partners have used digital drainage system maps and overlays to determine buffer areas, feedlot setbacks and locations for temporary or permanent detention areas to control water quantity and quality.
- Modern drainage records can be an important resource for drainage system improvement, land use management, and planning and zoning decisions related to water quantity and quality.
- Modern drainage records combined with digital elevation model data can be used to evaluate and address highly erosive areas along drainage ditch systems, for example by implementing side inlet pipes and drop structures, or strategic buffer strips.

7. Recommendations from Drainage Authorities Experienced in Records Modernization

- **Start Small – Complete a Test Set**
  - The drainage system administration staff interviewed frequently suggested that it is best to start small and gradually work up to full records modernization.
  - Those that tried to do too much too fast, often became overwhelmed and frustrated when they needed to go back and make changes to their modernization procedure.

- **Consider Data Format and Compatibility**
  - Before starting a modernization effort, make sure that the digitized data to be produced will be in formats that allow linkage with other county data, watershed district data, and available GIS layers. For example, creating data that can be interfaced with an existing drainage assessment list allows the landowner list, benefits list and assessments to be interfaced with GIS, parcel information and scanned data to efficiently generate mailing lists, send notices, and review benefits associated with drainage projects.

- **Scanning and Digitizing Drainage System Records**
  - Nearly all of those interviewed noted that scanning and digitizing drainage system records is an important early step in the modernization process.
  - For some drainage system administrators, scanning was not a high priority. For these administrators, digitized data for the locations of drainage systems entered into Microsoft Access or Excel was workable and sufficient. However, others argued that this adds an extra step that can be very time consuming, if there are many records. This approach might be workable for jurisdictions with few drainage systems.

- **Georeferencing Scanned Drainage System Maps**
  - A strongly desired step in the mapping process is to georeference the digital layers so the maps will fall onto real-world locations that are compatible with other GIS data layers.
  - Once completed, ditch and tile locations and other points of interest (e.g., side inlets to ditches, or tile inlets) can be on-screen digitized and added to GIS databases.

- **Drainage System Location and Benefited Area**
  - Many drainage authority staff indicated a need for easy and fast access to drainage system locations and the benefited or assessed areas.
  - Modernized records with these two basic data components facilitate accurate and consistent assessment discussions and reviews.
  - Data that can be readily summarized also assists discussions about redetermination of benefits and avoids confusion and mistrust in this regard.

- **Digital Drainage System Segment Identification**
  - The general minimum suggested GIS layer for use in modernized records included the ditch and/or tile line segments with a few key minimum attributes, such as dimensions, elevations, grade, tile size and tile material type (if known).
  - Field verification should be done on all line segments to later confirm locations.

- Facilitates the later addition of drainage system features using GPS when these systems are inspected.

➢ **Maintenance and Land Use Information**
- Once all drainage system segments are digitized, many of those interviewed identified various associated data linked to each segment. These data layers included:
  - maintenance history,
  - addition of culverts and bridges, potentially with size and elevation information, side inlets, etc…
  - Section 103E.021 required buffer strip locations,
  - parcels and ownership,
  - soils, and
  - conservation program lands (CRP, RIM, CREP, WRP, etc...).

➢ **Consider a Team Approach to Modernization**
- To save money and staff time, team up with neighboring county(ies) or watershed district(s) and work together to modernize records.
- Several modernization projects have utilized a joint contract with engineering firms that can at a minimum provide expertise on the proper conversion protocol to follow, or potentially perform the entire conversion process.
- Some jurisdictions have modernized records "in-house" as time, funding, and staffing allow. However, many drainage authorities lack sufficient expertise or priority for this kind of effort and it can take years to complete.

➢ **Make Modern Records Mobile**
- Digitized layers can readily be loaded onto laptops or handheld GPS equipment with mapping capability, and taken into the field.
- With mobile data that incorporates GIS, updates or proposed changes can be shown and rapidly overlaid with other pertinent information.
- This application may require significant training, but can greatly facilitate landowner discussions and drainage system maintenance.

➢ **Consider Public Access to Records**
- Although it did not appear that any of the jurisdictions interviewed have made drainage system records available online for public viewing, some associated data has been made available via web sites. Several drainage authority staff suggested that digitizing should/could be used to allow for greater public access to data.
- Staff of several jurisdictions indicated they are working towards a website format where drainage records will be available to the public.
- Public access to records could be a valuable tool for benefits discussions, government transparency, public relations and accountability.

8. Funding and Collaboration

Many of the drainage authorities interviewed identified various sources of funding for their records modernization project. The most common source came from Local Water Planning/Management Challenge Grants administered by the BWSR to assist drainage authorities in modernizing their records, together with the required 1:1 matching contributions of cash or in-kind services. The matching contributions came from various sources within counties and watershed districts.

Drainage system repair funds were also used by some drainage authorities to fund, or help fund, drainage records modernization. Some of these funds were used as match for a challenge grant. A general assessment across all drainage systems to spread the cost of the project to all the benefited landowners was a method of funding used by some drainage authorities. There was a general opinion that preservation and modernization of drainage records benefits the whole system, thus reducing costs in the future and justifying the use of drainage system funds to help pay for records modernization. When a whole system was assessed, the cost to each landowner typically was small.

The potential for clarifying benefited lands and parcels through mapping of systems and assessment lists was also an incentive to modernize drainage records for some drainage authorities. After pilot projects on several drainage systems, some drainage authorities concluded that the modernization process, when conducted together with redetermination of benefits, increased the number of parcels currently benefited and thus increased the assessment base for each system and lowered the incremental costs to benefited landowners for drainage records modernization.

To reduce the incremental cost of a records modernization project, many counties chose to work with watershed district(s) and/or other local government units that encompassed parts or all of the county. Some counties also spread the cost and/or in-kind services amongst different county departments that are required to support Chapter 103E drainage system administration, thus reducing the cost to any single department. The following is a list of potential collaborators identified through interviews of drainage authorities.

- County Environmental Services
- County Recorder / Auditor / Assessor
- County Highway Department
- Municipalities (where appropriate)
- Soil and Water Conservation Districts
- Regional Development Commissions
- Public Works Department
- Watershed Districts / Projects

Efforts to integrate various county and watershed district staff into the process reportedly helped expand the scope of drainage records modernization and increased the utility of such efforts for everyone involved.

9. Gathering and Preserving Historical Records

In Minnesota, land information is collected and maintained locally by a variety of county offices, including the Recorder (formerly Registrar of Deeds), Registrar of Titles, Auditor, Treasurer, Assessor, Surveyor, Land Management, Planning and Zoning, Engineer, Public Works, and GIS Departments, as well as by watershed districts. The process of gathering and preserving land information, specifically drainage system records, is important for every county and watershed district. While some drainage authorities utilize significant digital technology, others rely solely on paper records. The need to gather and modernize these records is important in order to preserve these historical legal documents and enable more efficient drainage system administration.

As many drainage authorities indicated during the interviews, some drainage system maps are more than 100 years old and are falling apart. The material they were printed on ranges from regular paper to mylar, which can crack and break after many years of being rolled up and stored. The need to convert these paper and mylar maps to a digital format is the first step in an important process of preserving these documents and making them easily accessible. Once in digital form, these documents can be easily shared and transferred between departments and governmental units. They can also be converted into digital data for use in mapping and analysis.

Prior to starting the preservation process, a thorough review of historical records for each of the drainage systems should be undertaken to determine establishment, repair, and improvement dates. This will help with organization of the documents and maps to be scanned.

When gathering drainage system history, it is important to look at each system separately and determine all the key components and actions that define the drainage system, such as when it was established, when there were improvements to the system, if/when a system was divided to create separate systems, and when repairs and other maintenance were completed. The associated engineering and administrative documents are key records. Many drainage system inspectors or other drainage authority staff may have much of this information available in notes or reports that they have submitted to the county commissioners or watershed district managers for a regular or periodic update on the system. If this process has not been undertaken to date, it can prove very valuable to the drainage authority, because it generates a comprehensive history of each of the drainage systems under its jurisdiction. This historical fact finding mission may identify potential areas that need to be researched more, but can benefit the drainage authority and drainage systems in the long run.

Funding and collaboration should be addressed by all the stakeholders involved in administering the drainage systems. The work of gathering drainage system history can sometimes be divided amongst the various stakeholders involved in drainage system administration to correlate data collection to those with the most knowledge of individual aspects of drainage systems. Interns can also be hired to go through drainage records, with appropriate direction.

Following are the suggested attributes to be collected for the history of each drainage system.

- Drainage system number
- Location – such as township(s), range(s) and section(s), flow direction, and watershed ID

- Length of system, including miles of open ditch and/or tile
- Dates and types of key proceedings, such as petitions and orders for establishment, improvement, redetermination of benefits, and repairs
- Engineering – engineer of record, as well as estimated and final costs for various proceedings and projects
- Engineering drawings, including plans, profiles and dimensions of drainage systems
- Benefits – Viewer appointments, dollar value of benefits and distribution of assessments
- Ongoing observations/comments from Drainage Inspectors concerning the system
- Maintenance history
- Additions of culverts, bridges, side inlets
- Buffer strip locations and dimensions
- Oral history can fill in some gaps where there are no maps or other key documents available

9.1 Levels of Scanning for Drainage Records Modernization

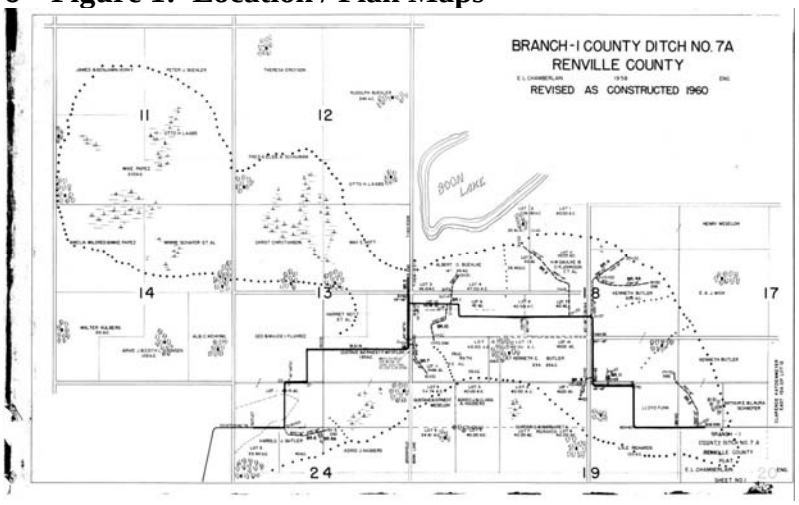
In modernizing drainage system records, a key goal typically should be to preserve all records pertaining to each system. Because there can be many documents that pertain to each system, priorities for scanning are important, as are methods to organize and consolidate information. In order to establish a good base of historical documents for records modernization projects, the following information breaks down the types of documents to scan into two levels.

Level 1 documents (Figures 1 - 6) include the key establishment, improvement and repair documents that describe the what, where and when about drainage systems, including both open ditches and subsurface tile. Preservation of these documents is fundamental for future reference and understanding to assist good decision making.

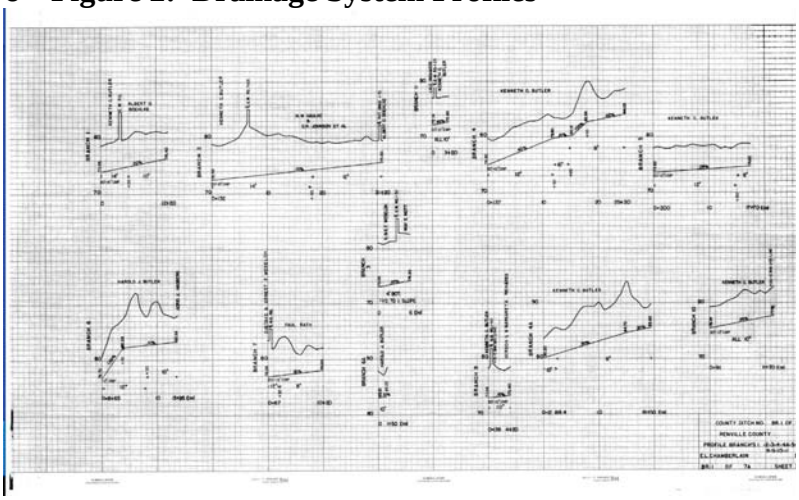
Level 2 documents (Figures 7 & 8) enable the drainage authority to better track and map the benefited acres for each system, as well as to track private ditches and tile that outlet into Chapter 103E drainage systems.

The following list of examples reflects the primary documents recommended for scanning. The benefit of scanning these documents in groups is that many of the documents are already stored together within the courthouse record system. Since each document will be scanned separately and named separately, working with them by type will not be detrimental to organization of records by drainage system, or inefficient in terms of time.

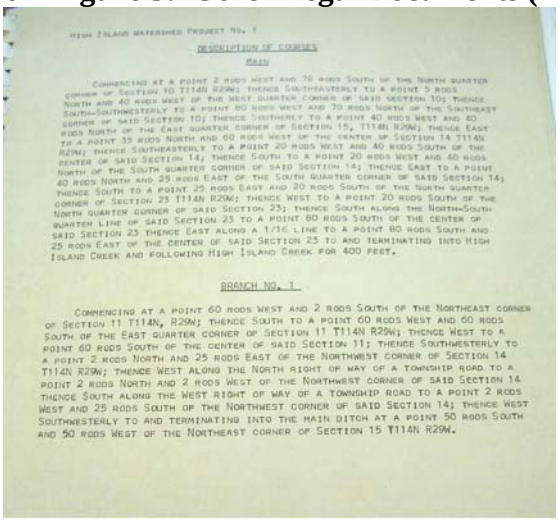
- **Level 1:**
  - **Figure 1: Location / Plan Maps**



  - **Figure 2: Drainage System Profiles**



  - **Figure 3: Other Legal Documents (Photograph when can't scan)**



HIGH ISLAND WATERSHED PROJECT No. 1

DESCRIPTION OF COURSES

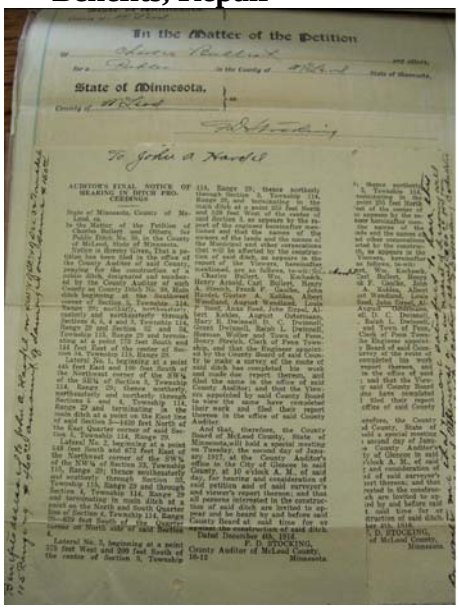
Main

COMMENCING AT A POINT 2 RODS WEST AND 70 RODS SOUTH OF THE NORTH QUARTER CORNER OF SECTION 10 T114N R29W; THENCE SOUTHEASTERLY TO A POINT 5 RODS NORTH AND 40 RODS WEST OF THE WEST QUARTER CORNER OF SAID SECTION 10; THENCE SOUTH-SOUTHWESTERLY TO A POINT 80 RODS WEST AND 70 RODS NORTH OF THE SOUTHEAST CORNER OF SAID SECTION 10; THENCE SOUTHERLY TO A POINT 40 RODS WEST AND 60 RODS NORTH OF THE EAST QUARTER CORNER OF SECTION 15, T114N R29W; THENCE EAST TO A POINT 35 RODS NORTH AND 60 RODS WEST OF THE CENTER OF SECTION 14 T114N R29W; THENCE SOUTHEASTERLY TO A POINT 20 RODS WEST AND 40 RODS SOUTH OF THE CENTER OF SAID SECTION 14; THENCE SOUTH TO A POINT 20 RODS WEST AND 40 RODS NORTH OF THE SOUTH QUARTER CORNER OF SAID SECTION 14; THENCE EAST TO A POINT 40 RODS NORTH AND 25 RODS EAST OF THE SOUTH QUARTER CORNER OF SAID SECTION 14; THENCE SOUTH TO A POINT 25 RODS EAST AND 20 RODS SOUTH OF THE NORTH QUARTER CORNER OF SECTION 23 T114N R29W; THENCE WEST TO A POINT 20 RODS SOUTH OF THE NORTH QUARTER CORNER OF SAID SECTION 23; THENCE SOUTH ALONG THE NORTH-SOUTH QUARTER LINE OF SAID SECTION 23 TO A POINT 80 RODS SOUTH OF THE CENTER OF SAID SECTION 23 THENCE EAST ALONG A 1/16 LINE TO A POINT 80 RODS SOUTH AND 25 RODS EAST OF THE CENTER OF SAID SECTION 23 TO AND TERMINATING INTO HIGH ISLAND CREEK AND FOLLOWING HIGH ISLAND CREEK FOR 400 FEET.

BRANCH NO. 1

COMMENCING AT A POINT 60 RODS WEST AND 2 RODS SOUTH OF THE NORTHEAST CORNER OF SECTION 11 T114N, R29W; THENCE SOUTH TO A POINT 60 RODS WEST AND 60 RODS SOUTH OF THE EAST QUARTER CORNER OF SECTION 11 T114N R29W; THENCE WEST TO A POINT 60 RODS SOUTH OF THE CENTER OF SAID SECTION 11; THENCE SOUTHWESTERLY TO A POINT 2 RODS NORTH AND 25 RODS EAST OF THE NORTHWEST CORNER OF SECTION 14 T114N R29W; THENCE WEST ALONG THE NORTH RIGHT OF WAY OF A TOWNSHIP ROAD TO A POINT 2 RODS NORTH AND 2 RODS WEST OF THE NORTHWEST CORNER OF SAID SECTION 14 THENCE SOUTH ALONG THE WEST RIGHT OF WAY OF A TOWNSHIP ROAD TO A POINT 2 RODS WEST AND 25 RODS SOUTH OF THE NORTHWEST CORNER OF SAID SECTION 14; THENCE WEST SOUTHWESTERLY TO AND TERMINATING INTO THE MAIN DITCH AT A POINT 50 RODS SOUTH AND 50 RODS WEST OF THE NORTHEAST CORNER OF SECTION 15 T114N R29W.

- **Figure 4: Orders for Establishment, Improvement, Redetermination of Benefits, Repair**



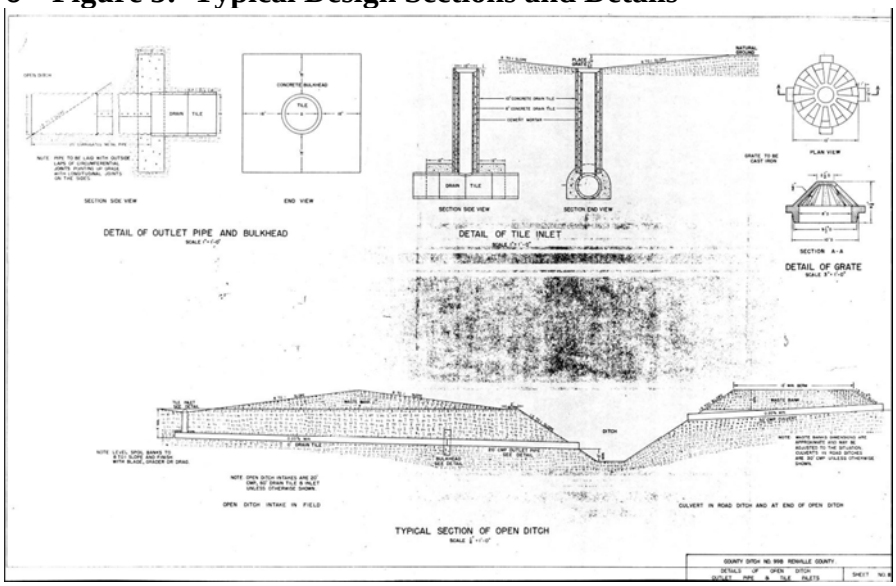
In the Matter of the Petition

State of Minnesota,

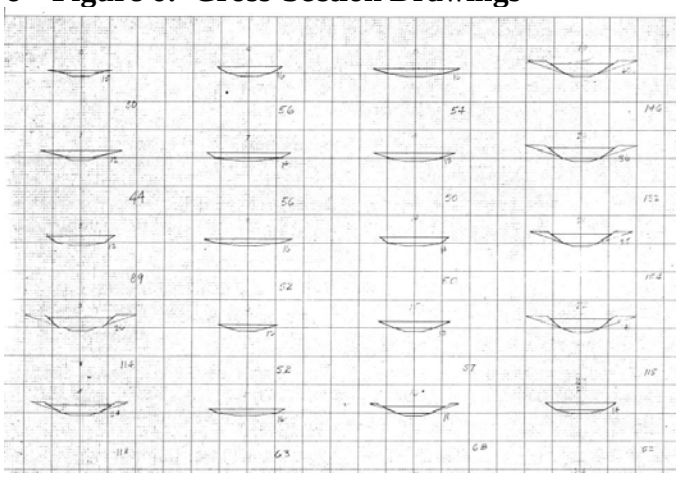
To John A Nardell

AUDITOR'S FINAL NOTICE OF HEARING IN DITCH PROCEEDINGS

- **Figure 5: Typical Design Sections and Details**



- **Figure 6: Cross-Section Drawings**



- **Level 2**
  - **Figure 7: Benefited Acres Documents (including tabulations and maps)**

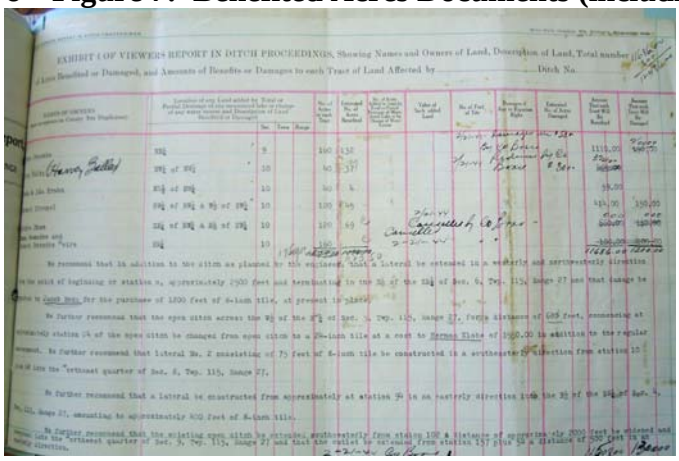


EXHIBIT I OF VIEWERS REPORT IN DITCH PROCEEDINGS, Showing Names and Owners of Land, Description of Land, Total number of Acres Benefited or Damaged, and Amounts of Benefits or Damages to each Tract of Land Affected by ..... Ditch No.

  - **Figure 8: Private Ditch and Tile Information (particularly digitized and georeferenced maps)**

9.2 Scanning of Historical Records

One of the most important components of drainage records modernization is scanning of the historical drainage system records. Scanning and digitizing these records protects them from loss due to deterioration and enables many efficiencies of drainage system management.

The first step, which will be addressed in more detail in section 9.2.1, is the purchase or rental of a large format scanner. Scanners can range in price from $5,000 – $20,000, but these costs can often be spread out across multiple departments and/or partners to make the purchase more economically feasible.

Many suggestions from counties and watershed district(s) that have completed this process are presented for consideration. These will help to minimize dead ends or road blocks in the process of scanning.

- When scanning deteriorating documents, use large pieces of clear plastic and sandwich the document between them. Then feed the sandwiched document through the scanner. The scanner will read the information on the map or document through the clear plastic. Another suggestion is to tape the document to an existing large sheet of paper. This will add tape to the already deteriorating document, but the sheet can become a permanent backing to the old document. Documents can also be laminated to preserve the document for later use and handling.

- Maps that are wider than the scanner can be folded in half, run through the scanner and then flipped over and run through the scanner again. This will create two images along a seam that can be mosaiced together using photo processing software.

- The drainage authority should do a backup of the scans to ensure there is redundancy in the electronic documents. One of the counties surveyed backed up each drainage system on 1 or 2 CDs depending on the file size. This method allows for quick reference of a backup. Where backup of servers are standard practice, this method may not be needed, but is suggested for a permanent record that can be stored off site.

- Many of the drainage authorities interviewed chose to do the scanning in-house for quality control purposes. They felt they had more control over the end product and could devote staff time to the project. Other respondents hired interns to do some of the work, but were cautious about hiring well qualified, responsible persons and providing adequate supervision.

- Another suggestion is focused on the types of drawings that are being stored. Not all updated versions of an engineer's drawings have made it back to the drainage authority. Drawings can be "As-Built" (or "As-Constructed"), or might include later notations of changes. Major repairs and improvements that modify the drainage system may have been implemented, so check the legend of each drawing for this type of information. See Figures 9 and 10 for examples. When preparing the documents for scanning, be aware of this and reflect it in the naming of the documents, as discussed in section 9.2.3.

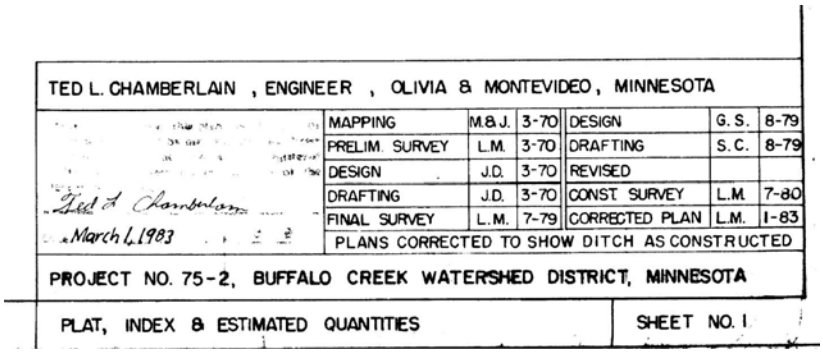


Figure 9: Drawing Legend indicating plans corrected to show ditch as-constructed

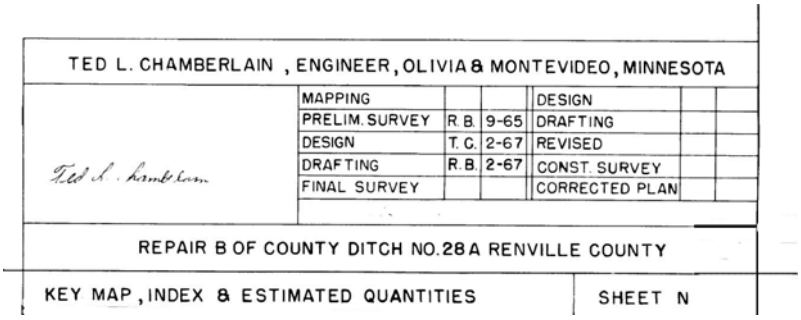


Figure 10: Drawing Legend indicating plans as of the preliminary design stage

9.2.1 Scanning Hardware – Choosing a large format scanner that is right for drainage records modernization involves weighing and evaluating several different factors. It's critical to understand what you want the scanner to do for the end product and how it will add value to your county or watershed district. It is also important to consider drainage authority priorities, such as speed, productivity, quality, flexibility and whether you need to scan in color, monochrome, grayscale or all three. Determine which considerations are most important and then compare the products and decision factors against your requirements and applications. Consider how the scanner addresses total cost of ownership and how it will help you achieve your goals. The decision concerning purchasing a scanner can be shared within a county, because other departments may have a use for a large format scanner. For example, the highway department, planning and zoning department, or recorder's office might also use the scanner to preserve the large format documents that are maintained in their departments.

Through interviews with drainage authorities who have undertaken this process, they all suggest using a large format rolling scanner (36" or larger) similar to the one shown in Figure 11. This type of scanner is the easiest to use, because it feeds the document through from the front to the back of the scanner. The documents can be sent through and either received by another staff member or flow out onto a table.

Figure 11: 42” Large Format Scanner on Base © Contex

A scanner can be a large purchase. If a drainage authority chooses not to purchase a scanner, it has two other options. Some counties and regional development commissions have purchased scanners and are willing to rent out use of the scanner to others. This approach may be beneficial to both the owner and the renter, because the owner receives a fee that reduces the effective purchase cost and the renter does not incur the large purchase cost. The other option is to hire an engineering or scanning firm to scan all the documents needed for the project. Respondents from those interviewed did not suggest this approach for several reasons. The documents may need to be sent out to be scanned thus increasing the chance that something will happen to them. Also, the respondents felt they had the local knowledge concerning the ditches and thus can name and make changes to the documents scanned, as appropriate.

Some of the brands used by the interviewed drainage authorities were scanners by Contex and the Ideal FSC 8010 Color Scanner. When choosing a scanner, compression is important and thus should be looked at when the purchase is made. Image compression is minimizing the size in bytes of a graphics file without degrading the quality of the image to an unaccceptable level. The reduction in file size allows more images to be stored in a given amount of disk or memory space. It also reduces the time required for images to be sent over the Internet or downloaded from Web pages.

9.2.2 Scanned Document Types – The types of documents that a scanner produces can vary greatly depending on which scanner is purchased. However, all scanners can produce a Tagged Image File Format (TIFF) and this is the format suggested by those interviewed. TIFF is a file format for storing images, including photographs and line art. TIFF format is standard in document imaging and document management systems. In this environment, it is normally used with CCITT Group IV 2D compression, which supports black-and-white (also called bitonal or monochrome) images. In high-volume environments, documents are typically scanned in black and white (rather than color or grayscale) to conserve storage capacity. An average A4 size scan produces 30 kilobytes (KB) of data at 200 pixels per inch (PPI) resolution and 50 KB of data at 300 PPI. However, a resolution of 300 PPI is far more common than 200 PPI, for clarity.

It is suggested by those interviewed to scan documents at 400 dots per inch (DPI). Images and files sizes can always be reduced by decreasing resolution, but can never be increased. For this reason, scanning the document at a higher resolution will retain more data, because this is the only time these documents will be scanned. Storage space is becoming increasingly less costly

and thus can accommodate the larger file sizes. If your documents are in color, it is best to scan them using a color profile. Again, documents can always be turned to black and white, but the same cannot be said of turning a black and white document into color. When documents are dark background with white lines, scan them in and then do inverse to make white background and black lines as shown in Figure 12. The software that accompanies these scanners will normally have this feature available. Otherwise, this can be achieved in any photo processing software.

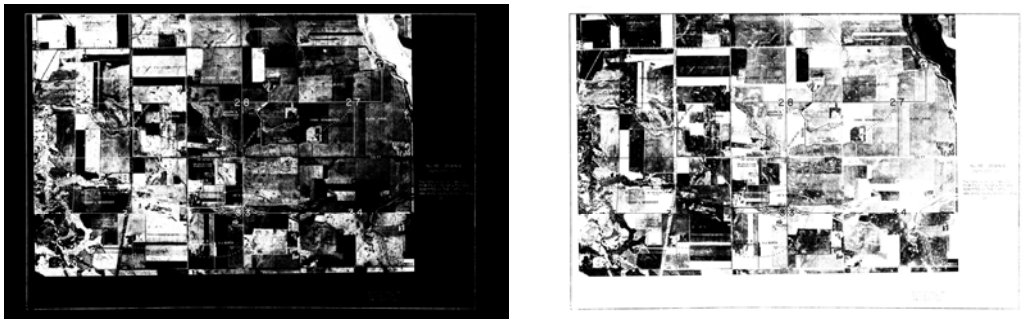


Figure 12: File scanned with dark areas and then converted to an inverse.

TIFFs can easily be converted to many different formats after they are created. A popular format, PDF, can be easily created from TIFFs at a later date for ease of use. PDFs are very portable and work well in web creation. It is suggested that PDFs be created from the TIFFs at a separate time. Certain types of document imaging systems can do the conversion directly from the program when needed.

9.2.3 Scanned Document Naming Convention – After scanning each document, the scanning system will ask the user to name the document. As suggested before, scan each page in separately. The reason for this is each page of a ditch map series contains important information and looking through a folder with just a Sheet1 name does not improve the efficiency of data use. Taking the time to name the document correctly will improve the efficiency of locating a document, as well as incorporate it into an index of all the documents.

The recommended **Naming Convention** for scanned documents is as follows:

- DD_##_MT_TYPE_YYYY_PN_PT

- An example of this: CD_01_PL_ORIG_1948_1_5

The following data description shows each component of the filename. For the ## or ### component, determine if your drainage authority drainage system numbers include greater than 100 or less than 100 and then use the appropriate format. This will aid in sorting of the drainage systems in a file tree. If you have 132 drainage systems, then system 78 should be as 078. Any system below 10 should be written with a 0 in front so that the names wills sort correctly.

- DD = Drainage System Type
  - CD = County Ditch or Tile
  - JD = Judicial or Joint Ditch or Tile
  - PD = Public Ditch or Tile

- ## - 2 Digit Drainage System Number – If numbers are less than 100.
- ### - 3 Digit Drainage System Number – If numbers are greater than 100.
- MT – Map Type
    - PL – Plan
    - PR – Profile
    - EN – Engineer's Drawings (other than plan and profile)
- TYPE – Type of Drawings
    - ORIG – Original drainage system construction
    - IMP – Improvement
    - REP – Repair
- YYYY – Year the document was published or completed
- PN – Page Number of
- PT – Page Total

9.2.4 Document Index – A recommendation from many of the drainage authorities interviewed is to create a master document index. Figure 13 is an example from McLeod County. This helps locate many of the documents needed by referencing the list, looking at the date of the document, and then determining what data is contained within that document from the description field.

COUNTY DITCH 28			
FILENAME	*DATE*	*TITLE / DESCRIPTION*	*REF. NO.*
CD28Mc002	July, 1916	Exhibit 1, Map of, CD 28, McLeod Co, Minn	145.
CD28Mc010	Mar, 1953	CD 28, Install 12" Drain Tile on Br 9, ** *Dismissed 1963-4 improvement maps call this Br 1***	--
CD28Mc011	Nov, 1963	Sheet 1, Plans, Improvement of, CD 28, McLeod Co, MN, Index	152.
CD28Mc015	1969	Sheet 2, CD 28, McLeod Co, Profile of Main, BRs 2, 2A, 3, 4, 5, 6 and 7	–
CD28Mc016	1971	Dwg 1, CD 28, Mc, Improvement, RECORD DRAWINGS, CONSTRUCTED 1970	–
CD28Mc402	Nov, 1916	"Sale of Ditch Jobs", Description by stake number	
CD28Mc404	Mar, 1921	Pages 1of3, Order to construct (Br 8 ~ Sta 0 to 51+3)	
CD28Mc410	Apr, 1953	Proposal that was approved	
CD28Mc417	Oct, 1964	Notice of final hearing, Improvement of CD 28	
CD28Mc424	Jun, 1986	Letter to replace segment of tile to a different size	
	Geo-referenced Map(s)		
BOLD	Legal description used in determining linework.		

Figure 13: McLeod County Example of a Master Document Index

9.2.5 Metadata – Metadata is sometimes called "data about data". It describes the content, quality, condition, availability and other characteristics of data, which is particularly important for digital, geospatial data. It is through the evaluation of metadata that a user can determine if the data meets the user's needs. Metadata describe different aspects of data, including:

- Identification – What is the name of the data set? Who developed the data set? What geographic area does it cover? What themes of information does it include? How current are the data? Do restrictions exist for accessing or using the data?
- Data Quality – How good are the data? Is information available that allows a user to decide if the data are suitable for his or her purpose? What is the positional and attribute accuracy? Are the data complete? Was the consistency of the data verified?

- Spatial Reference and Organization Information – How is the data referenced to the real world (coordinate systems, datums)? How is the data organized (data models, topology)?
- Entity and Attribute Information – What geographic information (roads, houses, elevation, temperature, etc.) is included? How is the information encoded? Were codes used? If so, what do the codes mean?
- Distribution – From whom can I obtain the data? What formats are available? What media are available? Are the data available online? What is the price of the data?"

Metadata makes spatial information more useful to all types of users by making it easier to document and locate data sets. The growing availability of data of all kinds from many different sources has helped GIS technology become more useful and widely adopted. With metadata support, data producers can publish information about data, and data consumers can search for the data they need. Because spatial data is the fuel of a GIS, it is important to know if the data will meet user needs. Data users need metadata to locate appropriate data sets. Metadata provides information about the data available within an organization or from catalog services, clearinghouses, or other external sources. Metadata not only helps find data, but once data has been found, it also informs how to interpret and use data. Publishing metadata facilitates data sharing. Sharing data between organizations stimulates cooperation and a coordinated, integrated approach to spatial data policy issues. From a data management perspective, metadata is important for maintaining an organization's investment in spatial data. Metadata benefits an organization in the following ways:

- Provides an inventory of data assets
- Helps determine and maintain the value of data
- Helps you determine the reliability and currency of data
- Supports decision making
- Documents legal issues
- Helps keep data accurate and helps verify accuracy to support good decision making and cost savings
- Helps determine budgets because it provides a clearer understanding of when or if data needs to be updated or repurchased

Both data and time are costly. A GIS development plan that takes metadata into account from the beginning will save time and money later. Data expense continues to be the largest part of most GIS budgets, usually more than staff costs. If metadata is part of standard operating procedures, along with creating the data, creating metadata is easiest and costs very little. Time and effort related to metadata should be entered into the budget or project plan of every GIS operation. For example, because GIS technology can provide detailed visual data presentations, it is an indispensable resource. Metadata is the key to providing timely information that can be easily accessed and shared across multi-jurisdictional boundaries at all levels of government.

There are different programs that will help you document your data. Minnesota uses a program called Datalogr that was created in Michigan. It can be accessed through the Land Management Information Center website (http://www.lmic.state.mn.us/chouse/datalogr.html). ESRI ArcMap also has a function built into its ArcCatalog program that can help with the creation of metadata for the data sets you create.

10. Mapping / GIS

The mapping of drainage systems is a process that can involve different levels of detail and different data layers. Through the interviews conducted with counties and watershed districts that have modernized their drainage records, two levels of mapping and GIS development have been defined.

Level 1 mapping and GIS development enables fundamental use of drainage system records in electronic format for administration of Chapter 103E drainage systems.

Level 2 mapping and GIS development enhances the accuracy of electronic drainage system maps and records through field surveys and creates additional data layers for different components of public and private drainage systems to enable enhanced management of Chapter 103E drainage systems.

The mapping of drainage system data involves creating a Geographic Information System (GIS) upon which the user can layer different types of data to see relationships, patterns and trends through spatial analysis that enhance the management and administration of drainage systems. Figure 14 shows a visual of a GIS with pertinent data layers, as well as examples of spatial analysis that can be conducted with various data layers.

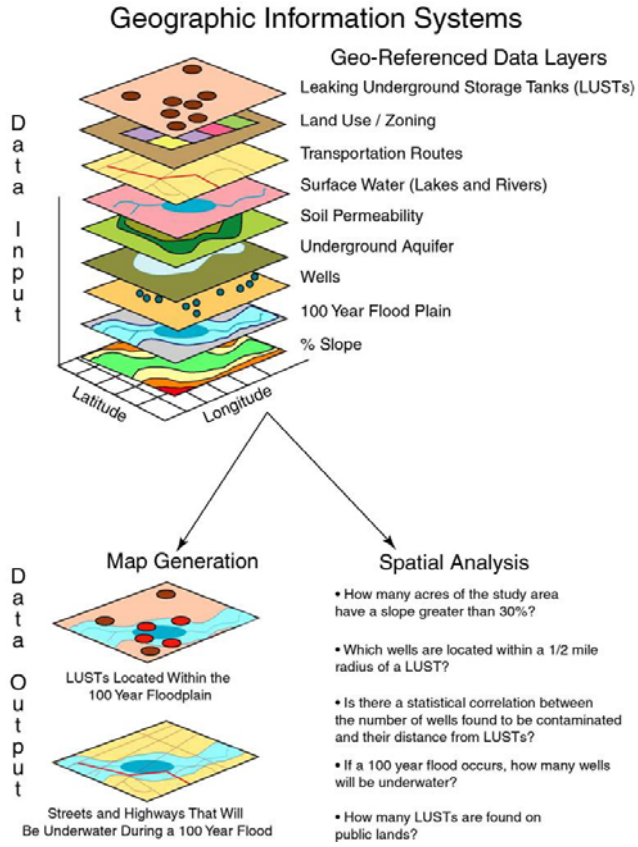


Figure 14: Example GIS Data Layers, Map Generation and Spatial Analysis

10.1 Mapping and GIS Development – Available Data Layers

The process of mapping drainage system records involves the creation of the line work associated with these drainage systems. When using one of the digitizing methods described in section 10.3, reference layers will be needed for the digitizing of points, lines or polygons. The following list is not all-inclusive, but identifies data layers available and recommended for reference when used in a mapping example shown in Figure 15. A description of each layer and its corresponding use for the digitizing process is presented below.

- Aerial Photography (FSA – 1939, 1950, 1991, 2003, 2006, 2008)
- Township polygons or lines (DNR)
- Section polygons or lines (DNR)
- Quarter-Quarter Lines (DNR)
- USGS Topographic Maps
- Railroads (DNR)
- Road Network (DNR)
- Minor Watersheds (DNR)
- Major Watersheds (DNR)
- Protected waters and waterways (DNR)

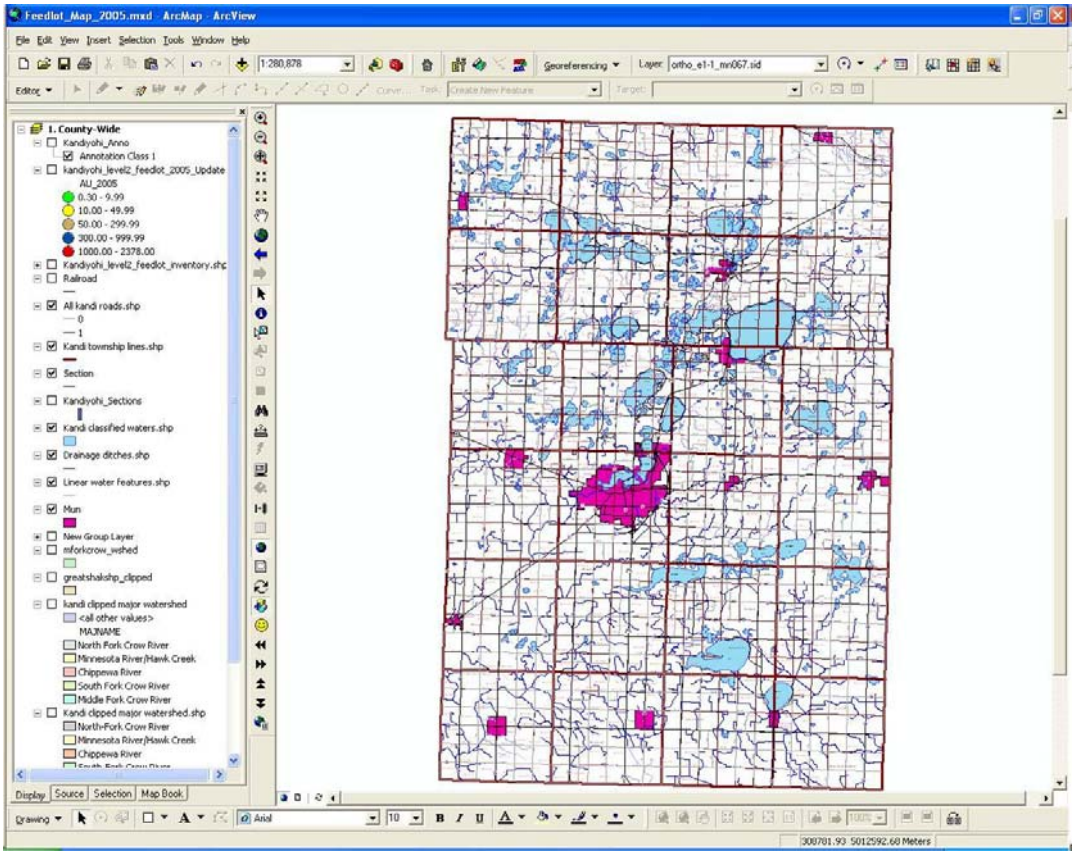


Figure 15: Example Map with Multiple Data Layers

10.1.1 Aerial Photography – The use of aerial photography in mapping is complementary to the task of digitizing the line features of the drainage system. Depending on the digitizing process used, a user can digitize the open ditch system directly off an aerial photograph such as the one in Figure 16, knowing where the beginning and ending point of that stretch of ditch is located.

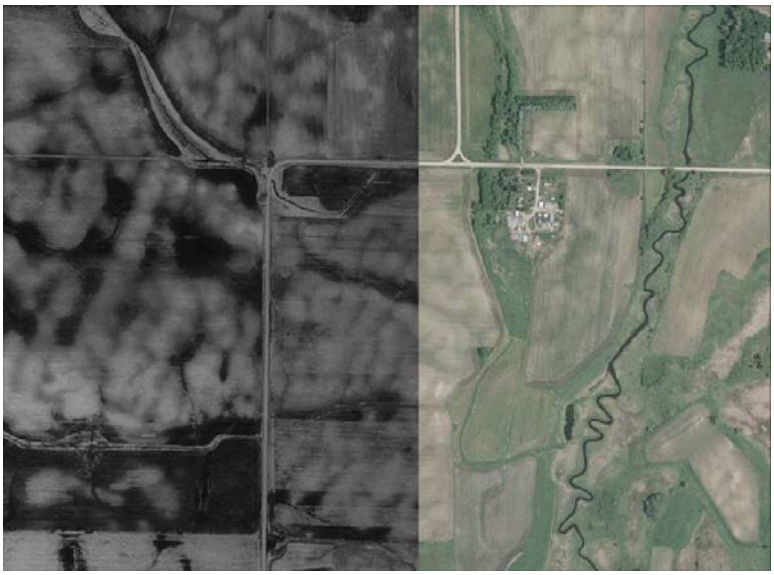


Figure 16: Open Ditch Aerial Photography – 1991 (Left) and 2004 (Right)

10.1.2 Township, Section and Quarter Lines – When digitizing using coordinate geometry, the legal descriptions of the ditches typically are based on section corners and half section corners. If coordinate geometry is the preferred method of digitizing, an issue concerning the use of section corners needs to be addressed. The township and section data are derived primarily from Section corner locations captured from paper USGS seven and one-half minute quadrangle maps. This data source can generally be considered accurate to approximately 50 feet. Some areas of less accurate data (as much as 200 feet off) are known to exist in the vicinity of the Mesabi and Vermillion Iron Ranges.

10.1.3 USGS Topographic Maps – The use of USGS maps can aid in adding in features that are not directly under the county or watershed district jurisdiction. Connecting waterways, lake connectors and other stream descriptions can be gleaned from the USGS map and used to create a comprehensive hydrology network with the boundaries of the county and/or watershed. The availability of the elevation data on the USGS map can also aid in determining flow direction in areas that are questionable.

The remaining layers will aid in orienting the user to locations within the work area. The boundaries of watersheds will also aid in showing where a whole drainage system encompasses a certain land area.

The GIS layers described above can all be downloaded through the Minnesota DNR Data Deli at http://deli.dnr.state.mn.us .

10.2 GIS / Mapping Software and Hardware

The primary software recommended for mapping is ESRI ArcMap 9.2. This software is the industry leader and has gone through a transformation from ArcView 3.1 to ArcMap 9.2. The process of digitizing the linework can be completed in either of these versions of the software, but the enhanced tools in ArcMap 9.2 add topology and connectivity to the data.

The following list of software is suggested to be used for drainage records modernization.

- ESRI ArcMap 9.2
- ESRI ArcView 3.3
- Photo Manipulation Software (Photoshop or Microsoft Document Imaging)
- Microsoft Office Suite 2000, 2003 or 2007 Professional version (suggested components are Word, Excel, and Access)

The following list of hardware is suggested to be used for drainage records modernization.

- Computer
- Printer
- Scanner
- Digitizing Table – This will only be used if the chosen digitizing process is manual digitizing directly from paper maps. An example of the table is shown in Figure 17.

Figure 17: Example Digitizing Table

- System Requirements for ArcMap 9.2 and photo software
  - Platform – PC
  - Operating System – Windows XP or Windows Vista
  - Memory – 1 GB RAM

- Processor – 1.6 GHz

- System Requirements for ArcView 3.3
  - Windows 98 or greater
  - 24 MB of RAM.

The following list of hardware is suggested if you are choosing to expand your modernization to the next level of field surveying and inventory of ditch features.

- GPS enabled PDA or handheld GPS Unit

- Digital Camera
- Laptop Computer

- Large memory storage card for more permanent storage of data on the PDA
- All terrain vehicle or truck for use in field data gathering

10.3 Digitizing / Mapping Methods

Digitizing refers to the process whereby an analog (paper) map is converted into digital format to create electronic maps. This data conversion process is also known as geocoding. Digitizing is one of the key ways in which data can be input and stored in a GIS. Points, linear features and areas (polygons) can all be input by digitizing. All features have real world geographic coordinates associated with them, as well as topological data that are input as part of the digitizing process.

Two primary methods for digitizing have been used by drainage authorities for drainage records modernization, including manual digitizing and heads-up digitizing. The method of choice had to do with many variables such as existing software and hardware and their experience in GIS/Mapping. Following are descriptions of these methods.

10.3.1 Manual Digitizing – This is the most basic method of digitizing traditional paper maps. Manual digitizing is done by placing a paper map on a digitizing board and entering elements of

the map into a database using a digitizing puck. An operator enters data by placing the digitizing pointer (puck) over the points on the map attached to the digitizing board and pressing different buttons on the puck to indicate the type of each point as shown in Figure 18. A point can be either an individual element, or a part of a larger element such as a line or a polygon. Lines and polygons are defined by a set of points entered by an operator and connected by lines (vectors). Therefore, the accuracy of the data depends on the accuracy of the source map and skill of the digitizing puck user. For lines and polygons, the more points entered the smoother the curves of the lines will appear. The spatial accuracy level the human hand can resolve is about 40 DPI (dots per inch), but can decrease significantly with user fatigue. This method can be both time consuming and can introduce significant error via the digitizing process. Only a few counties have followed this process using the services of an outside firm.

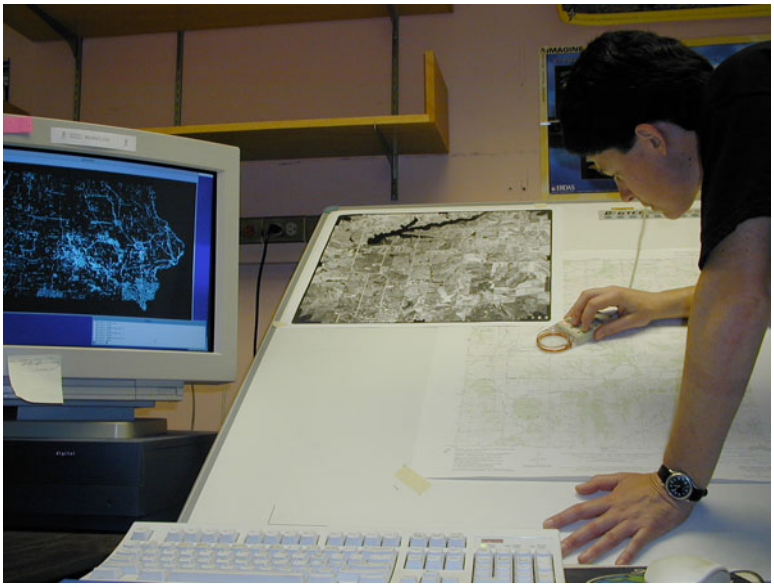


Figure 18: Manual Digitizing of a Map on a Digitizing Table

10.3.2 Heads-Up Digitizing – Heads-up digitizing is similar to manual digitizing in the way the lines are traced by hand, but it works directly on the computer screen using the scanned raster image as the backdrop (i.e. vectorizing raster data). This method of geocoding is commonly called "heads-up" digitizing because the attention of the user is focused up on the screen, and not on a digitizing tablet. While lines are still manually traced, the accuracy level is higher than using a digitizing tablet, because the raster images can be scanned at high resolution (normally from 200 DPI to 1600 DPI). With the help of display tools, such as zoom in and out, the operator can work at the resolution of the raster data and, therefore, digitize at a higher level of accuracy. However, the accuracy level is still not guaranteed, because it is highly dependent on the operator. This method is also time-consuming and takes about the same amount of time as the manual digitizing method. An example of “heads-up” digitizing with a georeferenced image behind it is shown in Figure 19.

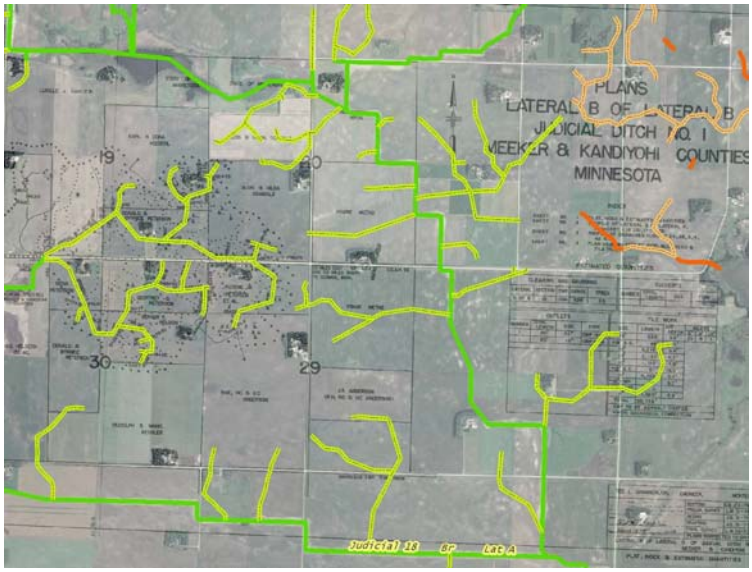


Figure 19: Example Digitized Drainage System Locations

10.3.3 Coordinate Geometry (COGO) – A third method for the input of ditch map data involves the calculation and entry of coordinates using coordinate geometry (COGO) procedures. This involves entering, from survey data, the explicit coordinates of features from some known monument or point. Although this input method is very labor intensive, it is useful for creating very precise cartographic definitions of property, such as for land records management. Two counties chose to use this method to create the tile component of drainage system networks. While the open ditch systems could be mapped from aerial photography, these counties decided that the tile systems could be mapped using the legal descriptions of construction.

10.4 GIS / Mapping Line Work Recommendations

When creating the GIS / mapping line work for drainage systems, several factors should be considered.

- If GIS expertise is available within the drainage authority, the drainage authority can do mapping in-house. If no GIS staff is available, the drainage authority could contract with a Regional Development Commission (RDC), private firm with GIS expertise, another local government unit with GIS staff, or certain college technical departments with GIS expertise, such as the WRC at Minnesota State University, Mankato. Drainage Inspectors experienced in GIS can digitize the line work in the off season, but this approach will extend the timeline of the project.
- Greater accuracy of the “As-Planned” line work often can be derived from the legal description of the drainage system and property boundaries (as opposed to using historical maps). Better “As-Constructed” accuracy for open ditch drainage systems (and sometimes subsurface tile) often can be obtained from aerial photography. Where open ditch systems could not be digitized by aerial photography, scanned georeferenced images have been used.

- Digitize in County Coordinates to minimize error and distortion. County Coordinate projections can be converted to another projection later, such as UTM or State Plane. Previous ditch layers created by various agencies can be used for reference in determining locations of ditch features. However, adjusting a previously created ditch layer may take more time than creating a new one.
- Digitize the line work in the direction of flow, or where applicable, use a flip line so that it shows direction of flow. This will benefit future uses of this dataset such as a network analysis. Also, create a new feature for the line work at any change in attributes such as drainage system segment, tile or ditch size, or gradient change. At a minimum, a new feature should be created for differences in drainage system segment number, channel dimension or tile size. If private ditches or tiles are drawn on the map, be sure to digitize them and label them as such. The added information may be beneficial to future users of the data.
- Multiple layers can be constructed to differentiate between different versions of the same drainage system, such as as-planned, as-constructed, or as-modified.
- The information contained in these data layers can be added to additional layers with minimal time. Some drainage authorities have created these extra layers while they were working on the georeferenced images. The additional layers were “viewersheds”, abandoned tiles, and a questions layer that can be easily called up for areas that need more review.

10.5 Georeferencing

Georeferencing is the process of aligning spatial data (layers that are shape files: points, lines, polygons) to an image file such as an historical map, satellite image, or aerial photograph. To georeference an image, one first needs to establish control points, input the known geographic coordinates of these control points, define the coordinate system and other projection parameters and then minimize residuals. Residuals are the difference between the actual coordinates of the control points and the coordinates predicted by the geographic model created using the control points on the GIS map. Residuals provide a method of determining the level of accuracy of the georeferencing process.

Georeferenced drainage system maps enable effective overlaying of other available GIS data layers and associated spatial analysis, based on a variety of variables. This can provide substantial enhancement of drainage management and drainage system administration.

10.6 GIS / Mapping Attributes

When constructing a GIS database of drainage system networks, the attribute data is just as important as the spatial data. The attributes of a feature describe or characterize the feature. The ability to query data, analyze the data and produce detailed maps is what makes GIS such a powerful tool. The counties and watershed districts interviewed for these guidelines had a wide range of attributes that they collected, but many attributes were common to most or all of these drainage authorities. Below is a list of GIS mapping data attributes developed by McLeod County.

SHAPE: Polyline shape file – ArcMap will create this field for the user
LENGTH: The length calculated in feet.
FNAME: The name of each drainage system.
DITCH_NO: The number of each drainage system.
TAX_NUM: Tax number associated with this drainage system in the Tax System
MAPDATE: Most current source used in determining line work.
HYDRO TYPE: Classification scheme used for labeling the ditches and waterways.

[Ditch] County and Judicial Ditches and Tiles, including Branches and Laterals
[Lake Connector] Line of ditch extending through a water body.
[Major Stream] Major streams flowing through the drainage authority jurisdiction.
[Minor Ditch] Ditch or tile drawn on map and/or visible on Aerial Photo (AP).
[Minor Stream] Streams identified on USGS Quadrangle sheets not identified as County or Judicial Ditch.
[Private Ditch] Private ditches or tiles, as documented.

LATBR: Displays the line segment as part of the Main, or the Lateral or Branch Number
TILE DIM: Displays if ditch is open or the tile dimension.
TILE AGE: Displays the age of when the tile was installed
TILE MATERIAL: Contains the attribute for the material type of the tile
CLASS: Contains the attribute code for each of the different waterway classes. The classes were coded because there were 5 different sources for the data.

[1] Major Stream
[2] Minor Stream on USGS Quadrangle Maps
[4] County or Judicial Ditch
[4T] County or Judicial Ditch, Tile
[5] Private Ditch
[5T] Private Ditch, Tile
[6] Lake Connector
[7] Minor Ditch as seen on Aerial Photos (AP)
[7T] Minor Ditch Tile as seen on Aerial Photos (AP)
[8] Minor Ditch on Map, but Not Labeled
[8T] Minor Ditch on Map as Tile, but Not Labeled

SOURCE: County Ditch Maps, legal descriptions and aerial photos used in determining line work. A key is provided for each ditch, which lists each scanned document referenced in the Attribute Source and a brief description of the document's contents. The documents are coded as follows:

JD04	McR	460
Ditch	Counties	Document Number

DNR_PW: DNR Protected Waterways in County
COMMENTS: Supporting notation for line segment placement.
CLASS TYPE: Ditch classification scheme used for labeling the ditches.

[CD and JD] "4" - County and Judicial Ditches, including Branches and Laterals.
[CD and JD Tile] "4T" - County and Judicial Tiled Ditches, including Branches and Laterals.
[Lake Connector] "6" - Line of ditch extending through a water body.
[Major Stream] "1" - Major streams flowing through County.
[Minor Ditch] "7" - Ditch visible on Aerial Photo (AP).

[Minor Stream USGS] “2” - Ditch drawn on USGS Quadrangle Map and visible on Aerial Photo (AP).
[Minor Ditch Tile] “7T” - Tiled ditch visible on Aerial Photo (AP).
[On Ditch Map, but Not Labeled] “8” Open ditch, not a County or Judicial Ditch.
[Private Ditch] *“5”* - Private ditch as documented.
[Private Tile] *“5T”* - Private tiled ditch as documented.
[Tile on Ditch Map, but Not Labeled] “8T” - Tile ditch, not labeled.

WATERSHED: The watershed in which the ditch is located
DITCH_BOTTOM: Width of the ditch at bottom if known
SLOPE: Slope of the sides of the ditch when constructed
OUTLETTO: Ditch segment that this ditch line outlets into
NAMELVL1: Used to Label the ditch system when segment has multiple labels
NAMELVL2: Used to Label the ditch system when segment has multiple labels
NAMELVL3: Used to Label the ditch system when segment has multiple labels

10.7 Level 2 Mapping and GIS Development

Level 2 mapping and GIS development includes a number of enhancements of the breadth and level of detail of drainage records modernization. These additional components complement Level 1 mapping and GIS development. The drainage authorities that have undertaken these components felt it was important to collect this information while they were in the field inspecting or otherwise managing Chapter 103E drainage systems, they may have collected the information in conjunction with another project, or simply wanted to expand their capability to use GIS to help manage the drainage systems under their jurisdiction.

10.7.1 Field Surveys – Field Surveying is collecting information about each system in the field which can increase the accuracy and data collected for these systems. Improving the locations of inlets, outlets and such will help in the overall modernizing of the ditch records. The most common method of field survey is using a GPS Unit to locate structures. To be more advanced, use a GPS enabled PDA with ArcPad installed. ArcPad is ESRI software which can be loaded on a GPS enabled PDA for mobile GIS.

ArcPad combines GPS collection within a GIS mapping environment and uses familiar GIS maps with positional tools. This increases field data accuracy because you can see where you are and where you’re going next which is needed to track buried tile and collect their ditch attributes to create a usable system generated in real time. ArcMap looks similar to ArcView or ArcGIS on a PDA. With a GPS enabled PDA, maps can be downloaded and used in the field. The attributes of existing drainage systems can be downloaded to the PDA for quicker and standardized data entry.

A digital camera can be used to take pictures of sites and included in the GIS database. To reference an image, take a photo of the GPS unit with the location coordinates and then a photo of the landscape. This will allow the photograph to be referenced to its real world location back in the office.

10.7.2 Side Inlets / Outlets and Tile Inlets – Determining the locations of all side inlets of surface drainageways into ditch systems and tile outlets into ditch systems will aid in the creation of the digital drainage system maps and enable enhanced management of drainage systems. Locations of side inlets and tile outlets will help in the mapping process by verifying or improving the locations of these features. This information component can also help determine and track which inlets/outlets are part of the public drainage system and which are private, including tracking of permitting for an outlet into a public system. It is recommended that the location, size (and elevation, if possible) of side inlets/outlets be acquired, if this Level 2 component is pursued. Examples of side inlets and surface risers are shown in Figure 20.

Figure 20: Tile Outlet into Drainage Ditch and Perforated Tile Riser Inlet

10.7.3 Private Tile and Ditch Alignments – Private ditches and private tile are components of many drainage systems. Some of the drainage authorities interviewed have pursued the mapping of private drainage systems that contribute to public Chapter 103E systems, in order to distinguish private from public and to better manage the public systems, including approval for outlets into public drainage systems. Collecting information on the private systems allows the drainage authority to incorporate this information into the GIS database and to communicate more effectively with landowners about drainage system administration. In Figure 21 below, Lateral HH is part of the public drainage system, while the dashed lines connecting to it are private tile. It is recommended that a separate GIS data layer be created for this data.

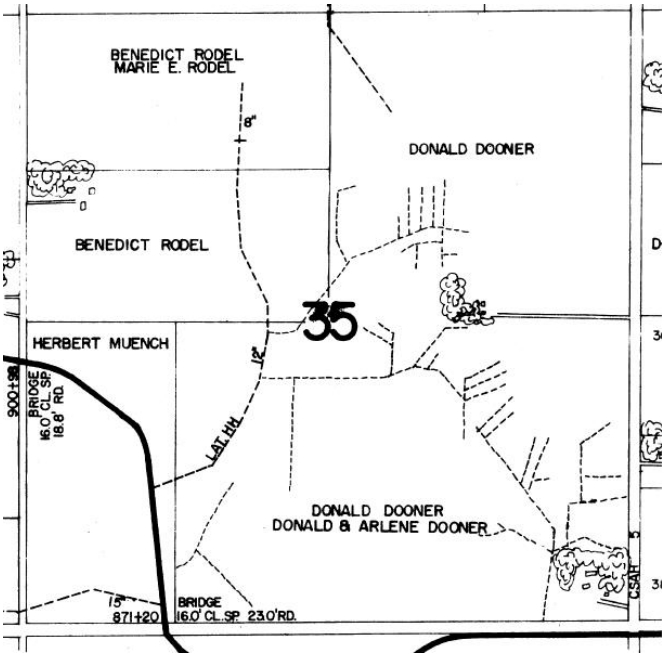


Figure 21: Public and Private Drainage System Components

10.7.4 Riparian Buffers / Buffer Strip Inventory – The requirement for grass strips along certain public drainage ditches is contained in Minnesota Statutes, Section 103E.021 Ditches Must be Planted with Permanent Grass. Drainage proceedings that necessitate the appointment of viewers, which triggers the buffer strip requirement, include establishment, improvement, certain major repairs, and redetermination of benefits. In 2007, the Legislature added Section 103E.067 Ditch Buffer Strip Annual Reporting. Riparian buffers are also implemented along drainage ditches via federal, state and local conservation programs. A separate GIS data layer similar to the one shown in Figure 22 can be created to define the locations and dimensions of these buffers, as well as a method to track the inspection and maintenance actions taken for required buffer strips that organizes data for the Section 103E.067 reporting requirements.

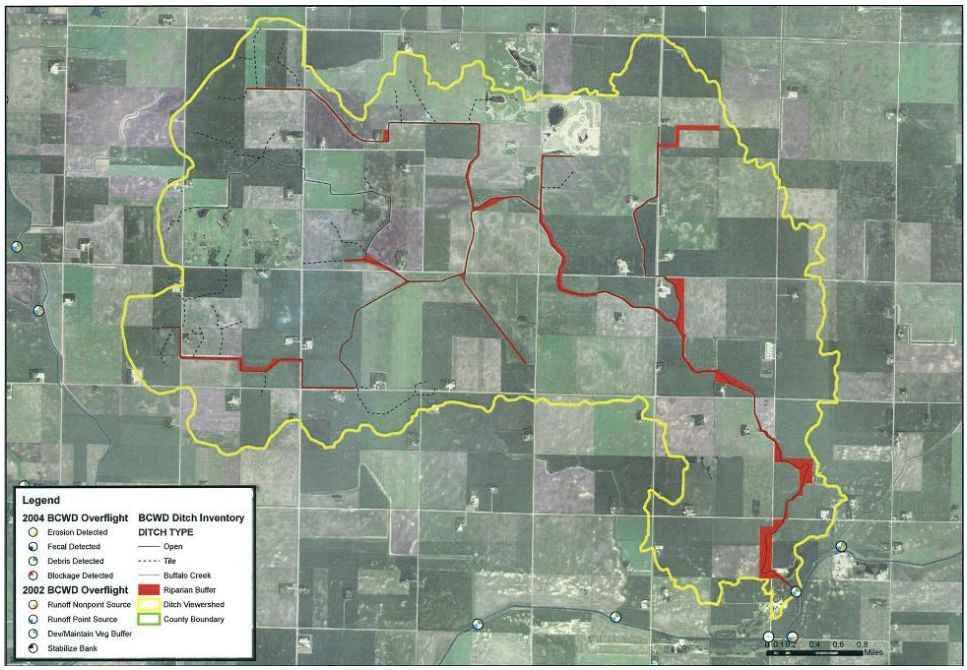


Figure 22: Example Map Showing Ditch Buffer Data

10.7.5 Culvert and Bridge Inventory – An inventory of culverts and bridges on drainage systems within the jurisdiction of the drainage authority can complement the GIS database. One county interviewed for this document chose to inventory all the culverts and bridges on the drainage systems under its jurisdiction to determine locations, dimensions, elevations, type and condition of these hydraulic structures, for which drainage system records were incomplete. This information was used to determine locations where water could pond within Chapter 103E drainage ditches, due to the bottom elevation of the culvert or bridge being higher than the established elevation of the drainage ditch bottom. The associated surveys included GPS for location and roadway elevations. This project was a collaboration of the Todd County Public Works Department, GIS and Land Services Department and Soil and Water Conservation District. Figure 23 shows an example of the data collected and included in a GIS database.

DITCH SYSTEM: CD 29

Crossing Number: 167

Cooperative project between Todd County Soil and Water Conservation, Todd County Public Works, and Todd County GIS and Land Services.

Minnesota County Coordinate System
Todd County
NAD 83(1996 adj.)
NAVD 88

Existing Culvert Cross Section Data

DATEGPS	TWP	RANGE	SEC	TYPE	SIZE	GROUP	DESCRIPTION	DIR	NORTHING	EASTING	ELEV
1/8/2007	T131N	R34W	36	CMP	48	SINGLE	Invert of Pipe	SOUTH	226861.34	498340.03	1301.86
1/8/2007	T131N	R34W	36	CMP	48	SINGLE	Top of Pipe		226861.67	498339.85	1305.96
1/8/2007	T131N	R34W	36	CMP	48	SINGLE	Shoulder		226874.35	498338.98	1312.18
1/8/2007	T131N	R34W	36	CMP	48	SINGLE	Centerline1		226889.17	498340.82	1312.87
1/8/2007	T131N	R34W	25	CMP	48	SINGLE	Shoulder		226904.11	498341.20	1312.15
1/8/2007	T131N	R34W	25	CMP	48	SINGLE	Top of Pipe		226916.71	498339.84	1306.45
1/8/2007	T131N	R34W	25	CMP	48	SINGLE	Invert of Pipe	NORTH	226917.27	498339.81	1302.17

Figure 23: Example of Todd County Culvert and Bridge Inventory

10.7.6 Benefited Acres – Many of the counties interviewed either map the benefited acres of Chapter 103E drainage systems or create an excel spreadsheet of the benefited acres so that assessments for projects can be easily calculated based on the most current determination. The counties that map the benefited acres used a data layer that was a division of the sections into 40-acre blocks as shown in Figure 24. The following attributes were contained in this layer to accept the information from the benefited acres document. This data can also be input into a Microsoft Excel spreadsheet and calculations can easily be updated, as appropriate.

Benefited acres attributes for Shapefile table or Excel spreadsheet table:

- Town – Township Number
- Rang – Range Number
- Sect – Section Number
- Fort – Forty Code Number
- Trctacre – number of acres in each tract
- Benacre – number of acres in each tract benefited
- Percent – percent of benefited acres within tract
- Name – ditch name
- Amtorig – amount that each owner is liable for
- Costorig – total cost of original ditch project
- Descript – legal description of tract

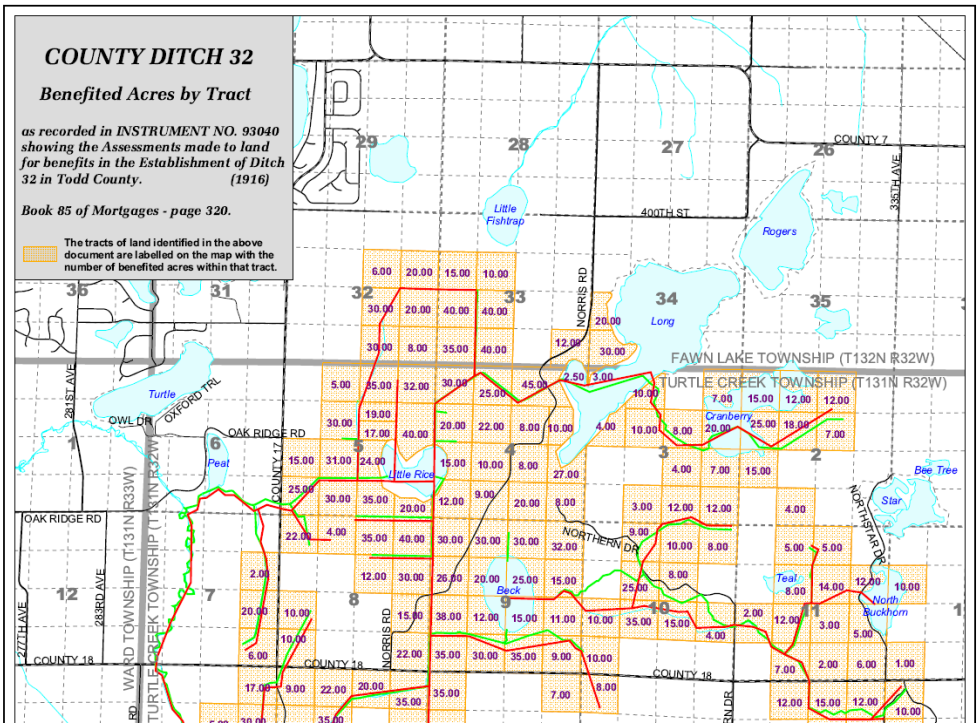


Figure 24: Example Map of Benefited Parcels and Acres

11. Public Accessibility to Modern Drainage Records

Some counties have chosen to make their drainage ditch records available to other departments within their county, as well as to the public. The counties that have internally shared their documents normally make the documents available as a PDF that can be shared on a central server. This minimizes the maintenance needed to update the information and allows for a centralized collection point for all documents associated with drainage.

The centralized storage of the drainage ditch records allows staff to easily pull a document up for drainage system administration or reference purposes, including discussions with landowners in a drainage system. This will reduce staff time to locate the document and the document can be printed directly from a computer.

Some counties have also made the documents available online. The method of presenting this information can be as simple as a webpage with links to each document. The knowledge needed to perform this is minimal and can usually be provided by an IT staff or webmaster. Other counties have more advanced database systems that integrate into a webpage. The user searches for a certain ditch system and all documents associated with that ditch system are returned. This is why an index of the documents is an important part of the process of drainage records modernization. The index serves two purposes and saves the county time if they choose to make the information available online. Figure 25 is an example of Todd County's web page for county and judicial ditch information.

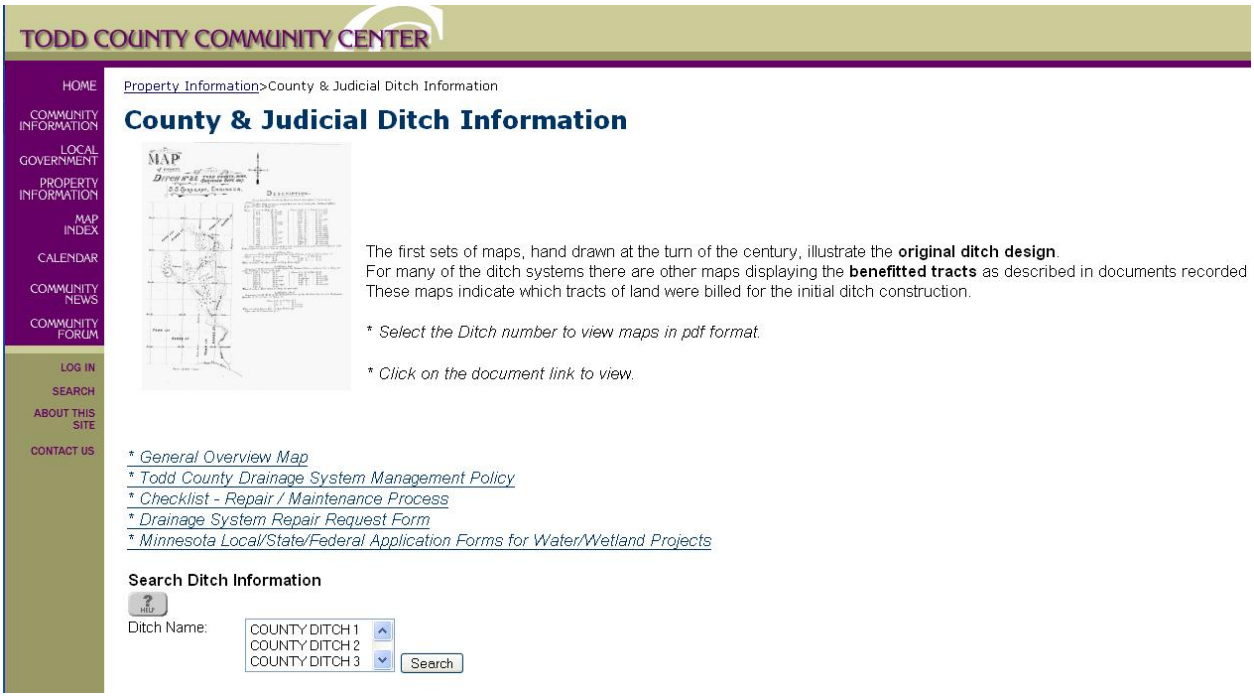


Figure 25: Example County Web Page for Drainage System Information

GIS information is also an important tool and end product of this process. GIS helps the drainage authority translate the technical information of drainage systems into a language that can be more easily understood by various stakeholders. Staff members can use GIS data in drainage authority meetings and public meetings to visually show this information. GIS can help inform public officials and landowners about drainage systems and drainage issues using a visual display. The ability to overlay soils data or elevation data can speak volumes to officials and landowners who are making decisions based on this information, as well as inform and educate others in an efficient manner.